Chapter 5: Glider Performance

Introduction

Glider performance depends on design, weather, wind, and other atmospheric phenomena. While the design of the glider affects performance to a great degree, design remains fixed and known to the pilot. Other factors change and affect launch, cruise, and landing.

Variable Performance Factors

For a specific glider flight, some factors that affect performance include density altitude, wind, and weight.

Density Altitude

In general, an increase in density altitude refers to thinner air, while a decrease in density altitude refers to thicker air. Conditions that result in high-density altitude include high elevation, low atmospheric pressure, high temperature, high humidity, or some combination of these factors. Lower elevation, high atmospheric pressure, low temperature, and low humidity reduce density altitude. Since high density altitudes may exist at lower elevations on hot days, pilots should consider density altitude based on actual conditions before a flight.

A chart provides one way to determine density altitude. [*Figure 5-1*] For example, knowing field elevation of 1,600 feet MSL with a current altimeter setting of 29.80 "Hg and temperature of 85 °F, what is the density altitude? The right side of the chart provides an adjustment for nonstandard pressure (29.80 "Hg) and suggests adding 112 feet to the field elevation. This step provides a current pressure altitude of 1,712 feet. The next step involves tracing a line vertically from the bottom of the chart from the temperature of 85 °F (29.4 °C) that intercepts the diagonal 1,712-foot pressure altitude line. The final step involves tracing a line horizontally to the left from the interception point and reading the density altitude of approximately 3,500 feet. Under these conditions, a self-launching glider or towplane will perform as if at 3,500 feet MSL on a standard day.

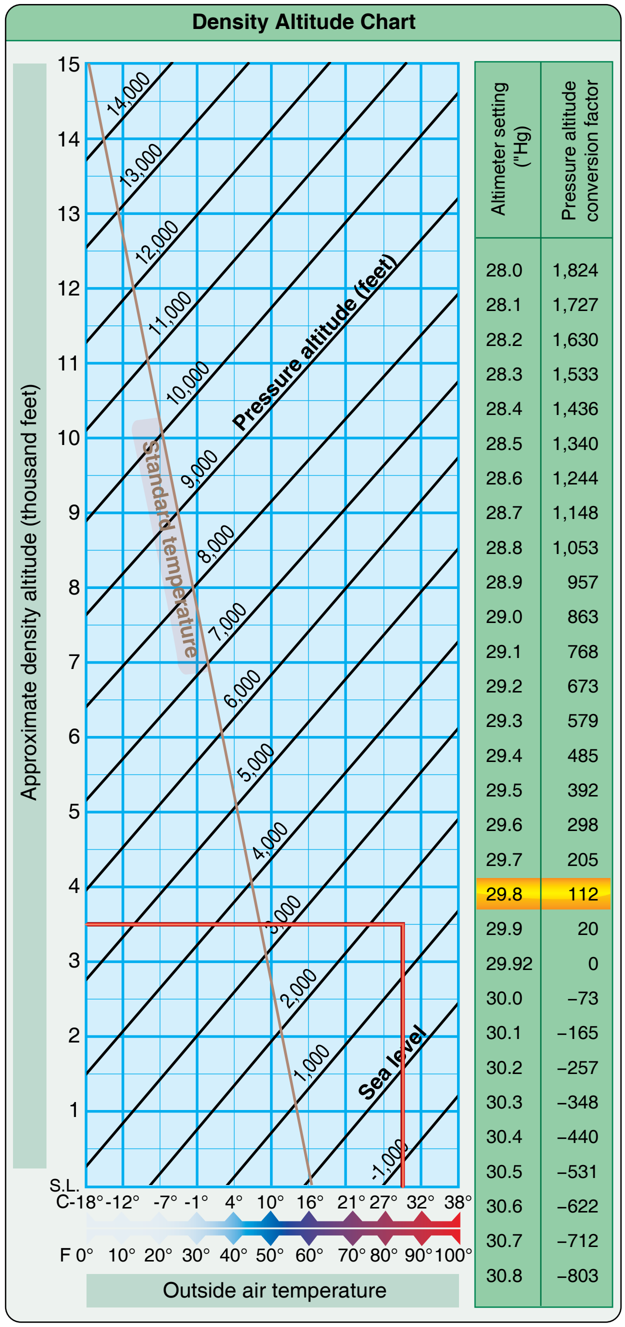

Figure 5-1. *Density altitude chart.*

Many performance charts use pressure altitude and temperature inputs without requiring the pilot to calculate density altitude. However, if the pilot wants to know the density altitude, a density altitude chart or a flight computer can supply that information.

Atmospheric Pressure

Atmospheric pressure at a given location changes from day to day. The following sample Meteorological Aerodrome Report (METAR) indicates a local pressure of A2953, or altimeter setting of 29.53 inHg. When considering barometric pressure only, the lower than normal pressure reading results in a higher density altitude that decreases aircraft performance. This reduction affects takeoff and climb performance and increases the length of runway needed during landing for both the glider and towplane. On the other hand, if barometric pressure rises, the lower density altitude improves takeoff and climb performance, and the length of runway needed for landing decreases.

KDAL 232153Z 21006KT 7SM -RA BKN025 BKN060 OVC110 12/11 A2953 RMK AO2 PRESFR SLP995 P0005 T01220106

Temperature

Temperature changes have a significant effect on density altitude. Heated air expands—the molecules move farther apart, making the air less dense. Higher density altitude reduces glider and towplane takeoff and climb performance and increases the length of runway required for landing.

Consider the following METAR for two airports with same altimeter setting, temperature, and dewpoint. Love Field (KDAL) airport elevation of 487 feet versus Denver International (KDEN) at 5,431 feet.

KDAL 240453Z 21007KT 10SM CLR 25/15 A3010 RMK AO2…

KDEN 240453Z 24006KT 10SM FEW120 SCT200 25/15 A3010 RMK AO2…

The computed density altitude for Love Field is 1,774 feet; for Denver, 7,837 feet—Denver experiences almost twice the amount of increase compared to Love Field. The effects of altitude and temperature can surprise a pilot who does not consider the related performance issues.

Wind

Wind also affects glider performance. Headwind during launch or landing results in a shorter ground roll, while tailwind causes a longer ground roll. [*Figure 5-2*] Crosswinds during launch or landing require proper crosswind procedures or control input to track along the runway.

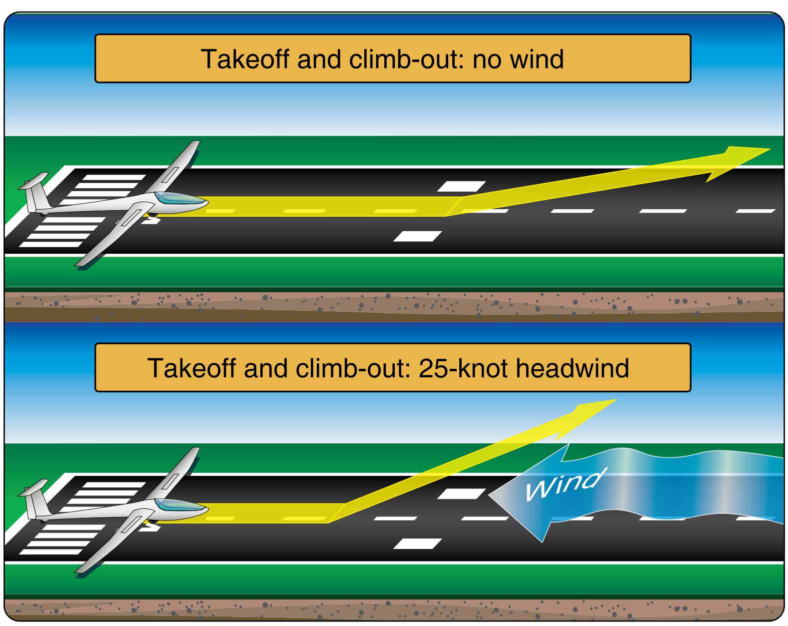

Figure 5-2. *Apparent wind effect on takeoff distance and climb-out angle.*

Due to diminishing ground friction between the wind and the ground, wind speed often increases with altitude. This "wind gradient" during a ground launch could result in an exceedance of the maximum launch speed. [*Figure 5-3*]

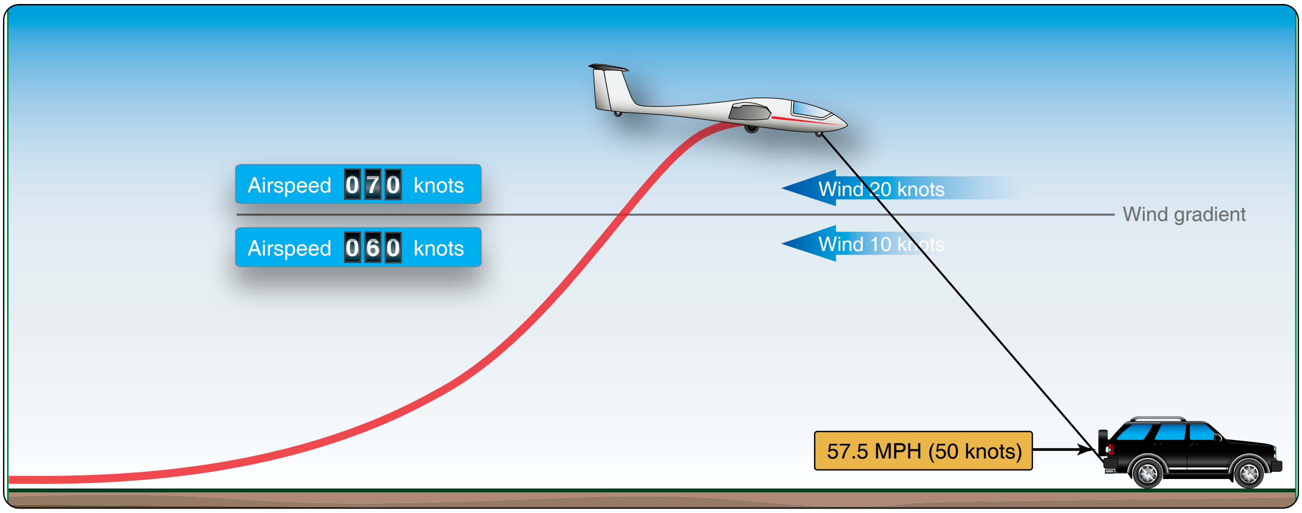

Figure 5-3. *A wind gradient may affect airspeed during a ground tow.*

During cruising flight, headwinds reduce the groundspeed of the glider. A glider flying at 60 knots true airspeed into a headwind of 25 knots has a groundspeed of only 35 knots. Tailwinds increase the groundspeed of the glider. A glider flying at 60 knots true airspeed with a tailwind of 25 knots has a groundspeed of 85 knots.

Some self-launching gliders can cruise for extended periods using the engine. The self-launching glider's fuel capacity normally limits maximum range and duration with the engine running. Wind has no effect on flight duration but does have a significant effect on range. During powered cruising flight, a headwind reduces range, and a tailwind increases range. The Glider Flight Manual/Pilot's Operating Handbook (GFM/POH) provides recommended airspeeds and power settings to maximize range when flying in no wind, headwind, or tailwind conditions.

When flying straight and level and following a selected ground track, the pilot can point the glider into the prevailing wind as the preferred method to correct for wind drift. The wind speed, the angle between the wind direction and the glider's longitudinal axis, and the airspeed of the glider determine the required wind correction angle. [*Figure 5-4*] Crosswinds may also have a head or tailwind component that results in a lower or higher groundspeed.

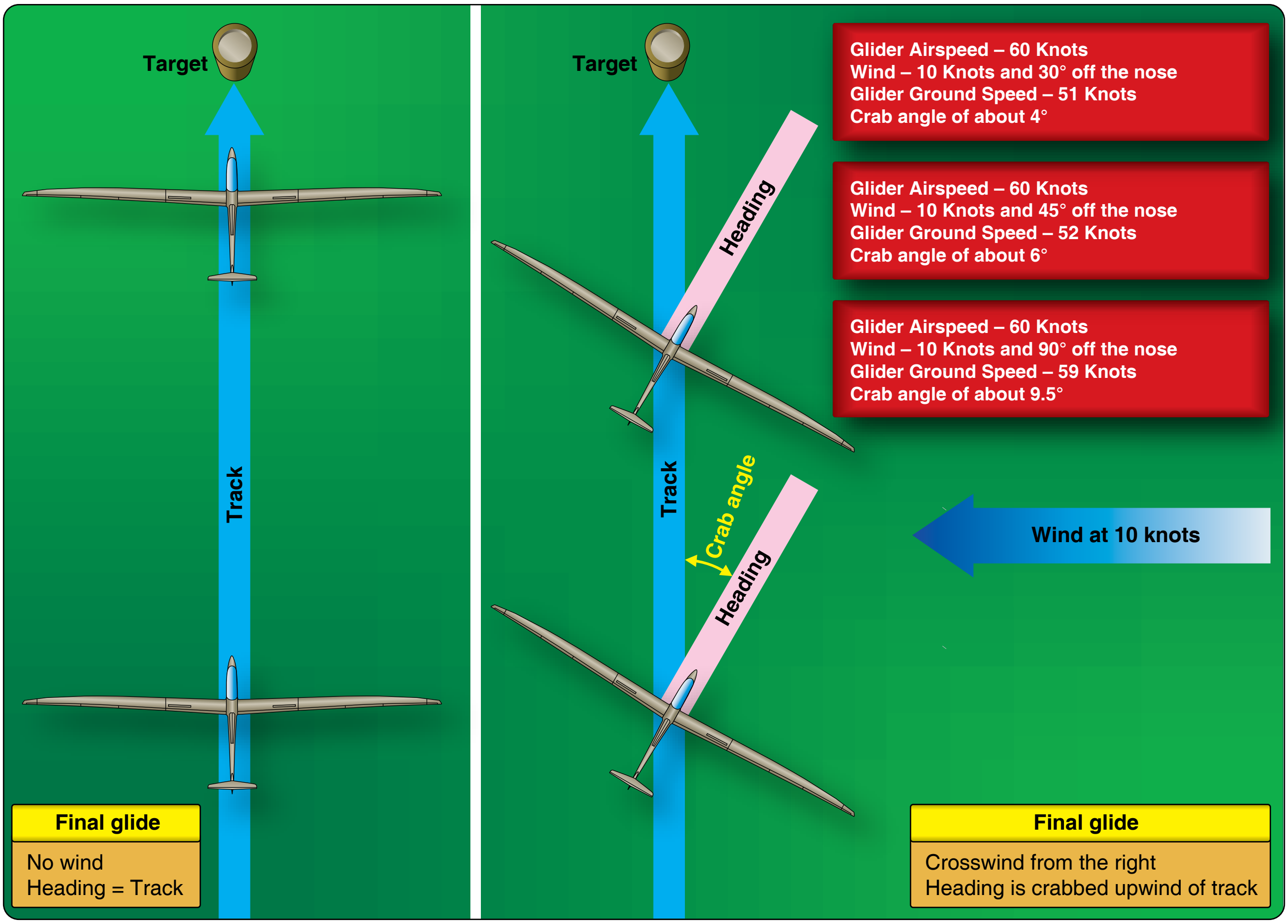

Figure 5-4. *Crosswind effect on final glide.*

A headwind during an approach results in greater altitude loss per distance traveled. The glider descends at a constant rate, but a lower groundspeed increases the observed approach angle. Pilots use various techniques to ensure safe touchdowns in different wind conditions. For example, if landing in a strong headwind, the glider pilot should plan for a base leg closer to the landing zone to allow for the steeper approach. Another technique uses delayed extension of spoilers or dive brakes with a faster airspeed to counter the headwind component. In the case of a tailwind and an apparent lower angle of approach, the glider pilot can use more spoiler or dive brake extension, slip, or use a combination of the two if allowed by the GFM. In any case, the pilot generally aims for a spot past the threshold of the runway to provide a safety factor that accounts for the effects of the wind gradient or other factors that may cause the approach to be shorter than expected. [*Figure 5-5*]

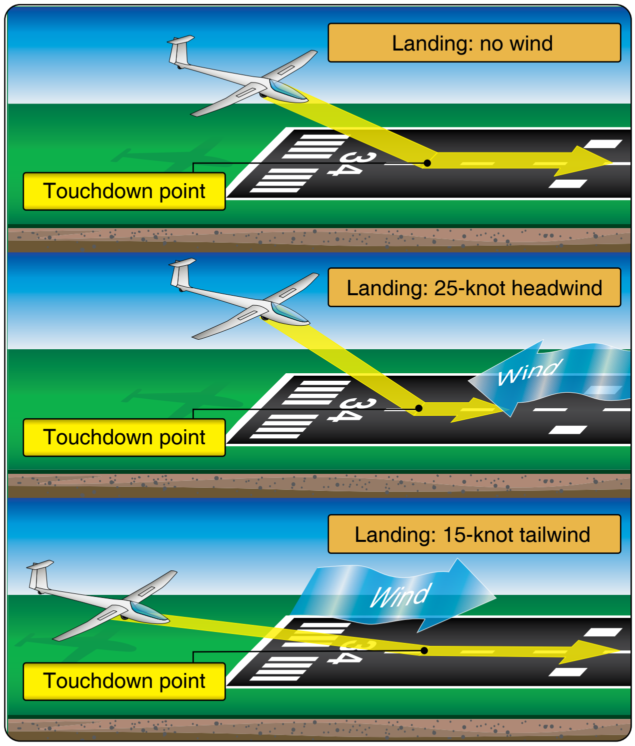

Figure 5-5. *The effect of wind on final approach and landing distance.*

When approaching to land during windy and gusty conditions, a pilot normally adds half of the difference between the steady wind and gusts to the approach speed to mitigate any variations in airspeed. Instead of holding the glider off the ground for a low kinetic energy landing during these conditions, the pilot can land a little faster than normal. Upon touchdown, extending the air brakes prevents the glider from becoming airborne from a gust during the landing roll.

The pilot usually expects any headwind to diminish during descent to a landing. This is called the wind gradient. If the wind gradient is abrupt, the pilot may experience a sudden airspeed loss. After the pilot lowers the nose to compensate, it takes a finite time interval to overcome the inertia of the glider and regain airspeed. A significant speed loss near the ground may preclude recovering any or all the lost speed. A wind gradient on final approach may cause the glider to land short of the point of intended touchdown therefore, a closer approach may be necessary.

The pilot landing with a tailwind has a higher groundspeed and should expect a longer landing roll. As the surface friction slows the winds, the pilot may observe an increase in airspeed.

A strong windshear gradient can affect a glider during a steep turn on a low altitude final approach at a low airspeed. The gradient can create different lift on the low wing and the raised wing. [*Figure 5-6*] The rolling force created by the gradient can overcome the ailerons, cause a loss of control, and explains why the pilot should limit bank angle while close to the ground and transitioning a strong wind gradient.

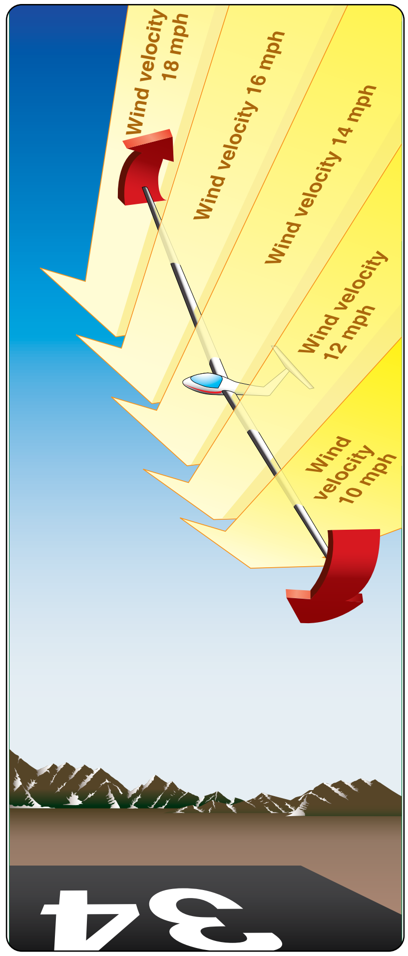

Figure 5-6. *Effect of wind velocity gradient on a glider. Stronger airflow over higher wing may cause bank to steepen.*

Weight

The weight of a glider affects acceleration during launch. A glider at maximum takeoff weight takes longer to attain flying speed. After takeoff, a tow plane with a heavy glider will climb more slowly. Increasing the weight of a powered glider causes it to accelerate more slowly and climb more slowly. [*Figure 5-7*]

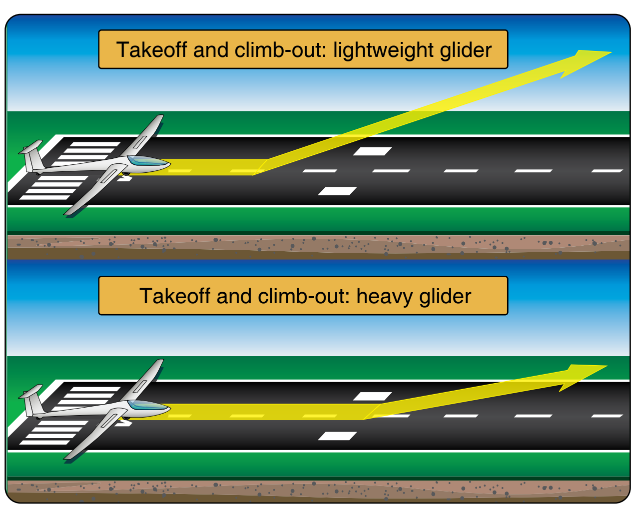

Figure 5-7. *Effect of weight on takeoff distance and climb-out rate and angle.*

The stall speed increases with the square root of any load on the glider. For example, if the weight or load factor on the glider doubles, the stall speed increases by the square root of 2 or 1.41. If a 540-pound glider has a stalling speed of 40 knots and the pilot adds 300 pounds of water ballast increasing the total weight to 840 pounds, the stall speed increases to approximately 50 knots (40 x $\sqrt{(840/540)}$).

The speed that results in the lowest altitude loss over time, the minimum sink airspeed, also increases with weight. At any given bank angle, a heavier glider uses higher airspeeds for efficiency, which result in larger diameter circles. The best lift in thermals often occurs in a narrow cylinder near the core, and large diameter circles generally reduce the glider's capability to exploit the strongest lift. [*Figure 5-8*]

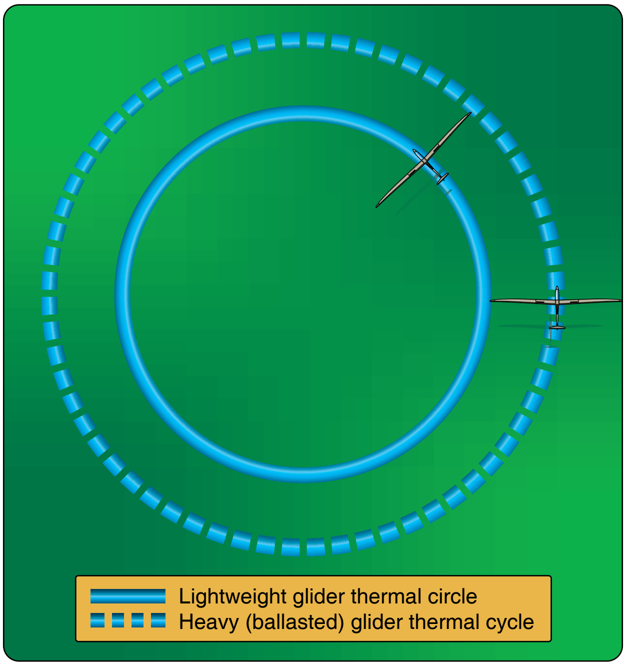

Figure 5-8. *Effect of added weight on thermaling turn radius.*

Increasing the operating weight of a given glider not only increases the stall airspeed and minimum sink airspeed, it also increases the best L/D airspeed [*Figure 5-9*]. Although a heavier glider sinks faster, it glides the same horizontal distance (at a higher speed) as a lighter glider with the same glide ratio and starting altitude.

Operating Weight	Stall Airspeed	Minimum Sink	Best L/D Airspeed
800 pounds	36 knots	48 knots	60 knots
1,200 pounds	44 knots	58 knots	73 knots
1,600 pounds	50 knots	68 knots	83 knots

Figure 5-9. *Effect of added weight on performance airspeeds.*

Figure 5-9 above shows that increasing weight from 800 to 1,200 pounds increases the best L/D airspeed from 60 knots to 73 knots. A glider with more weight can fly faster while maintaining the same lift-to-drag (L/D) ratio (glide ratio). The advantage of the heavier weight becomes apparent during faster flight between thermals in sink. In strong lift the heavy glider can climb reasonably well, and the advantage during the cruising portion of flight may outweigh the disadvantage during climbs.

To fly faster with efficiency, some gliders have water tanks that allow the pilot to add weight as ballast. The pilot normally jettisons the water ballast before entering the traffic pattern or earlier if conditions necessitate a higher climb rate. Reducing the weight of the glider before landing allows the pilot to make a normal approach, normal landing, and reduces load on the landing gear.

Rate of Climb

Rate of climb for a ground-launched glider depends on the power of the ground-launch equipment. With a powerful winch or tow vehicle, rate of climb can exceed 2,000 feet per minute (fpm). For an aerotow, the rate of climb depends on the power of the towplane. The towplane should have sufficient power to tow the glider safely, considering the existing conditions, which include glider weight.

The rate of climb of self-launching gliders may vary from as low as 200 fpm to as much as 800 fpm or more. The pilot should consult the GFM/POH to determine rate of climb under the existing conditions.

Flight Manuals & Placards

The GFM/POH provides the pilot with the necessary performance information to operate the glider safely. A GFM/POH may include the following information:

- Description of glider primary components
- Glider assembly instructions
- Weight and balance data
- Description of glider systems
- Glider performance data
- Operating limitations

Placards

Placards attached to the glider provide the pilot with essential information for safe operation. The GFM/POH lists all the required placards.

The amount of information that placards convey to the pilot increases as the complexity of the glider increases. High-performance gliders may have wing flaps, retractable landing gear, a water ballast system, drogue chute for use in the landing approach, and other features to enhance performance. [*Figure 5-10*]

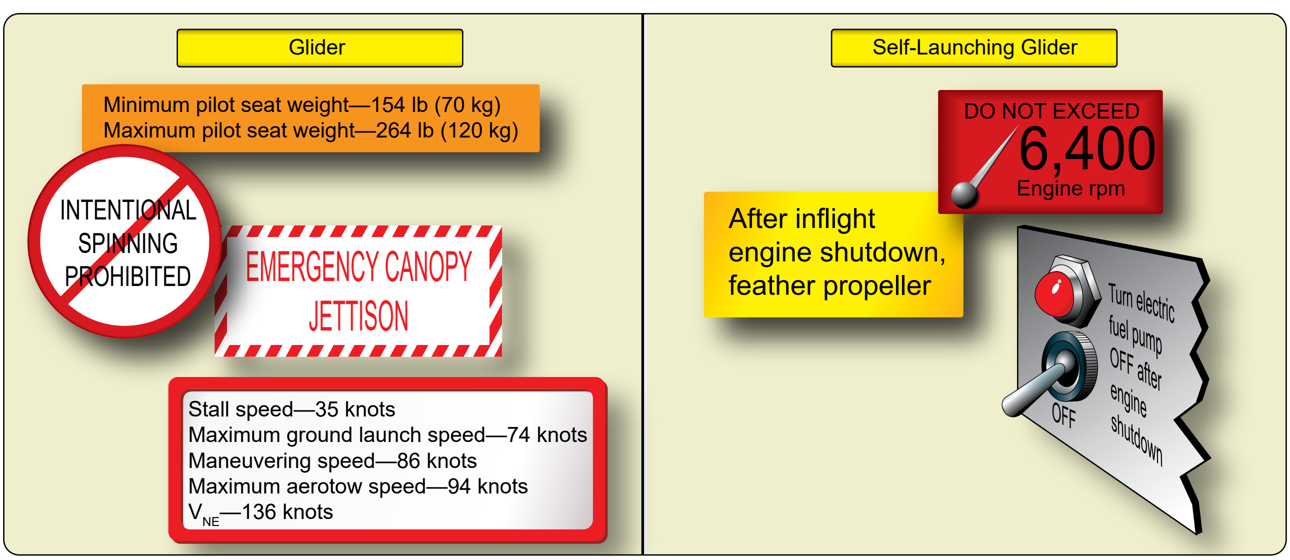

Figure 5-10. *Typical placards for gliders.*

Performance Information

The GFM/POH provided by the manufacturer contains glider performance information. The GFM/POH lists specific airspeeds such as stall speed, minimum sink airspeed, best L/D airspeed, maneuvering speed, rough airspeed, maximum aerotow speed, maximum ground launch speed, and the never exceed speed (V_{NE}). Some performance airspeeds apply only to gliders with certain equipment. For instance, gliders with wing flaps have a maximum permitted flap extended airspeed (V_{FE}).

Manuals for self-launching gliders include performance information about powered operations. These include rate of climb, engine and propeller limitations, fuel consumption, endurance, and cruise.

Glider Polars

The manufacturer provides information about the rate of sink in terms of airspeed summarized in a graph called a polar curve, or simply a polar.

The vertical axis of a polar shows the sink rate (increasing sink downwards), while the horizontal axis shows airspeed in the same units (knots). Every type of glider has a characteristic polar derived either from theoretical calculations or by actual inflight measurement of the sink rate at different speeds. The polar of each individual glider varies (even from other gliders of the same type) by a few percent depending on relative smoothness of the wing surface, the sealing around control surfaces, and even the number of bugs on the wing's leading edge. The polar forms the basis for speed to fly and strategies discussed in Chapter 11, Cross-Country Soaring.

The peak of the blue sink rate curve determines minimum sink rate. [*Figure 5-11*] In this example, a minimum sink of 1.9 knots occurs at 40 knots. Note that the sink rate increases between minimum sink speed and the stall speed (the left end point of the blue curve). A tangent from the origin to the polar indicates the best glide speed (best L/D). The best L/D speed is 50 knots with a sink speed of 2.1 knots. The glide ratio at best L/D speed is determined by dividing the best L/D speed by the sink rate at that speed, or 50/2.1, which is approximately 24 in this example. Thus, this glider has a best glide ratio in calm air (no lift or sink and no headwind or tailwind) of 24:1 at 50 knots.

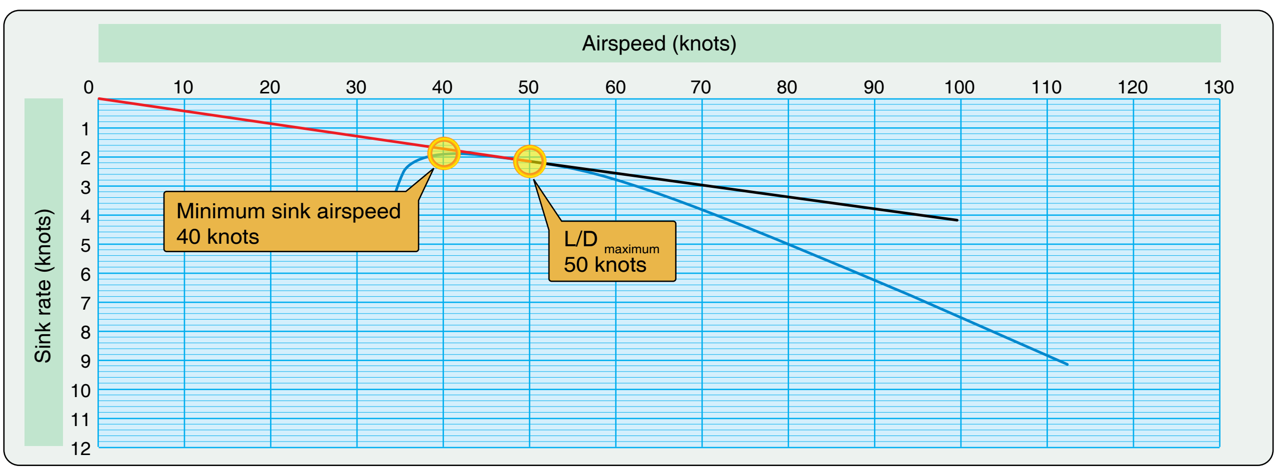

Figure 5-11. *Minimum sink airspeed and maximum L/D speed.*

To determine the best speed to fly for distance over the ground in a headwind, the pilot can shift the origin to the right along the horizontal axis by the speed of the headwind and draw a new tangent line to the polar. For tailwinds, the pilot shifts the origin to the left of the zero mark on the horizontal axis.

Figure 5-12 shows an example for a 20-knot headwind. The new tangent indicates 60 knots as the best glide speed. By repeating the procedure for different headwinds, the data show that flying faster as headwinds increase results in a greater distance traveled over the ground. Analysis of the data from many gliders leads to the following general rule: the pilot can add half the headwind component to the zero wind L/D to obtain maximum distance.

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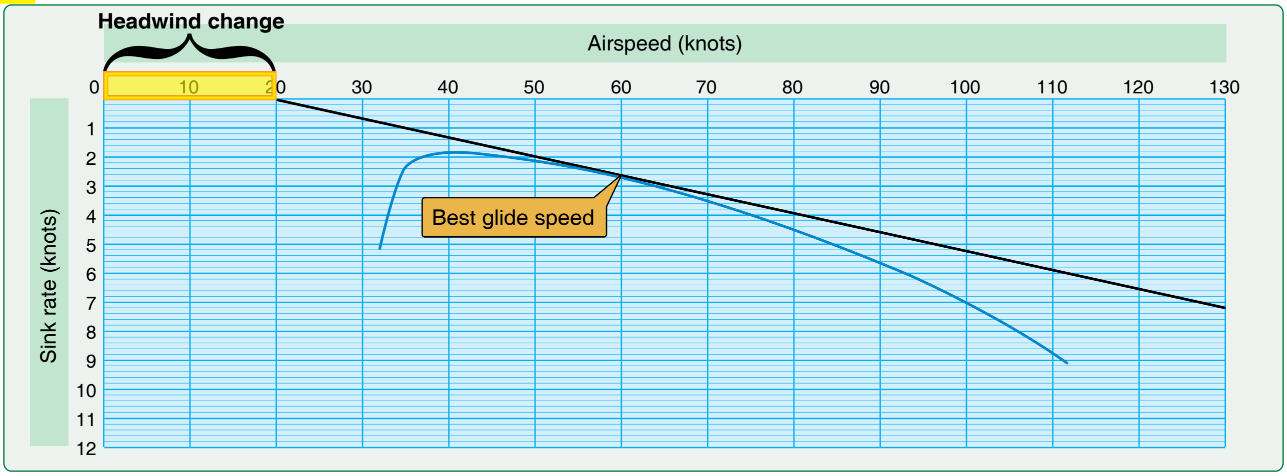

Figure 5-12. *Best speed to fly in a 20-knot headwind.*

The speed to fly in a tailwind lies between minimum sink and best L/D, but never lower than minimum sink speed.

Sinking air often exists between thermals and flying faster than best L/D can result in less time in sinking air and an increase in efficiency. The pilot can determine how much faster to fly using the glider polar, as illustrated in *Figure 5-13* for an airmass sinking at 3 knots between thermals. In this case, the pilot draws a tangent line to the polar that begins 3 knots above the origin to read the best speed to fly, 60 knots in this case. Note, that in this situation, the variometer would show a total sink of 5 knots (3 knots from sinking air and 2 knots for the constant aircraft descent) as highlighted in the figure.

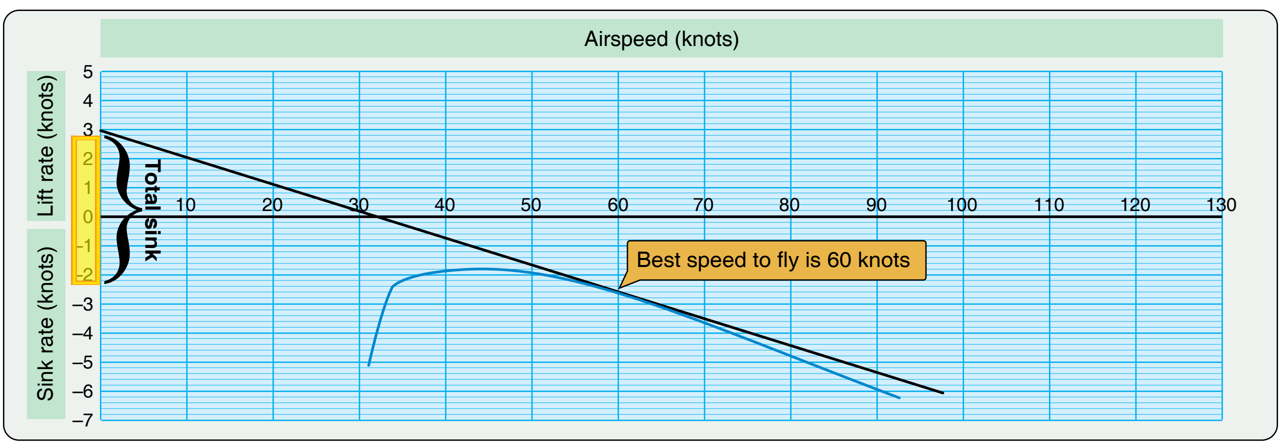

Figure 5-13. *Best speed to fly in sinking air.*

If the glider has water ballast, wing flaps, or wingtip extensions, the polar depicts the performance characteristics of the glider in those configurations. [*Figure 5-14*, *Figure 5-15*, and *Figure 5-16*] Comparing the polar with and without ballast shows that the minimum sink increases and occurs at a higher speed after adding weight. As a result, working weak thermals becomes more challenging with ballast. In addition, ballast lowers the sink rate at higher speeds. [*Figure 5-14*] The best glide ratio remains the same, but it occurs at a higher speed. Note that as expected, the stall speed increases with added ballast.

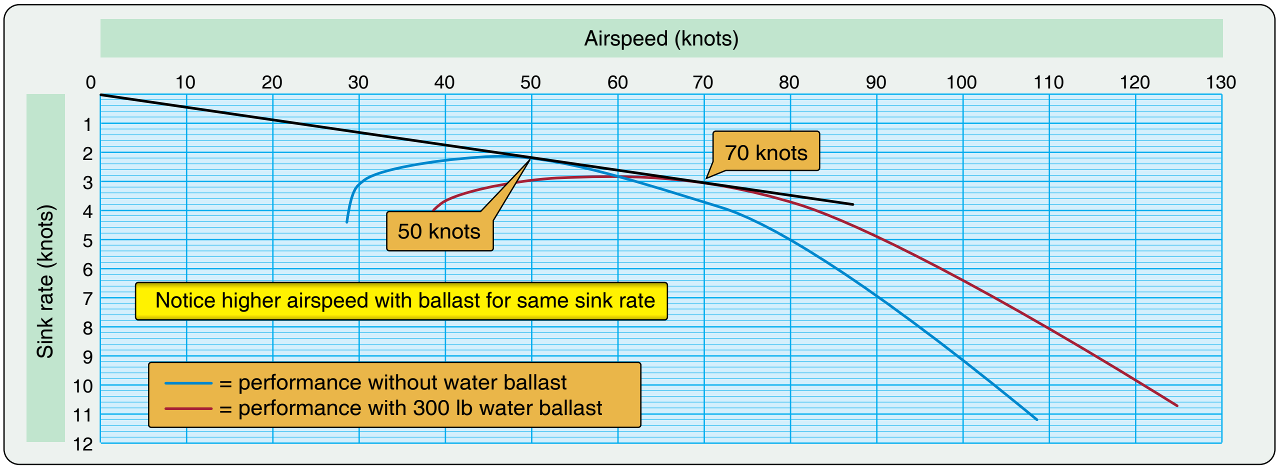

Figure 5-14. *Effect of water ballast on performance polar.*

Flaps with a negative setting as opposed to a 0-degree setting during cruise also reduce the sink rate at higher speeds, as shown in the polar. [*Figure 5-15*] Therefore, when cruising at or above 70 knots, setting the flaps to -8° would provide an advantage. The polar with flaps set at -8° does not extend to speeds lower than 70 knots since the negative flap setting loses its advantage there.

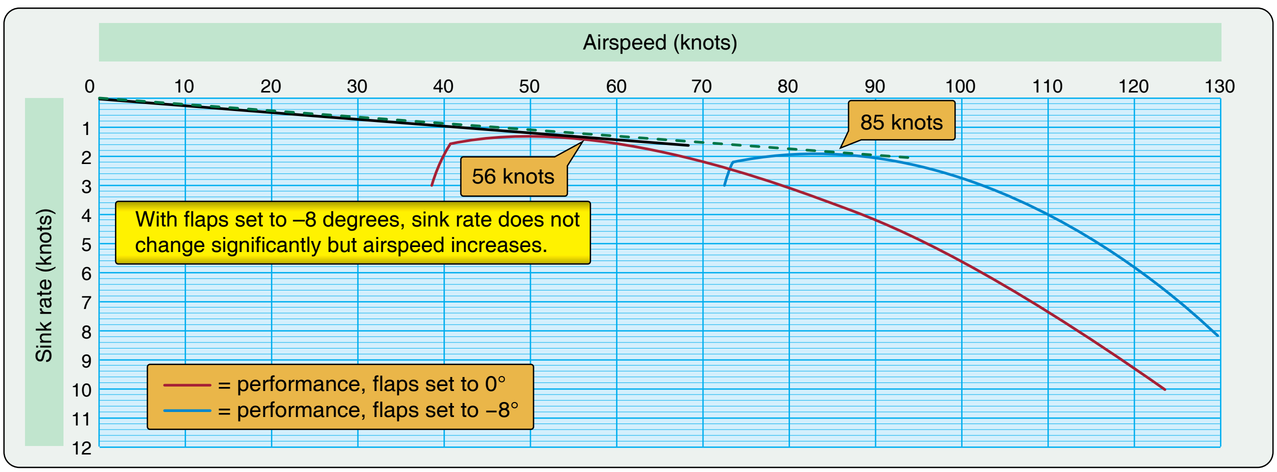

Figure 5-15. *Performance polar with flaps at 0° and –8°.*

Wingtip extensions also alter the polar data, as shown in *Figure 5-16*. The illustration shows that the additional 3 meters of wingspan creates an advantage at all speeds. In some gliders, the low-speed performance improves with the tip extensions, while high-speed performance diminishes slightly.

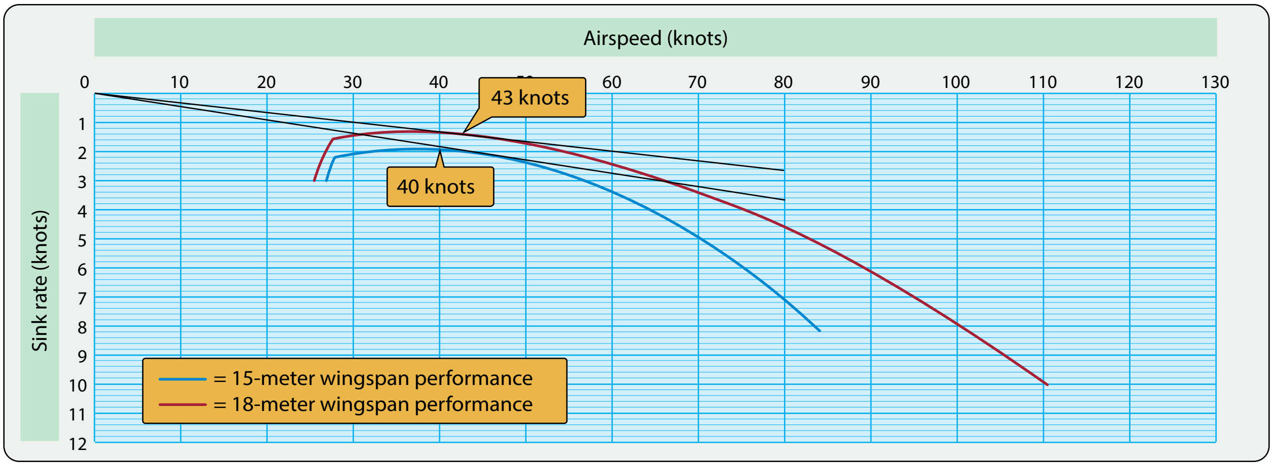

Figure 5-16. *Performance polar with 15-meter and 18-meter wingspan configurations. (Matt please add tangent lines to intersect the curves at the 43 and 40 knot annotated points.)*

Limitations

Regardless of glider complexity, designers and manufacturers provide operating limitations to ensure the safety of flight. The glider VG diagram provides the pilot with information on the design limitations, such as limiting airspeeds and load factors (L.F. in *Figure 5-17*). Pilots should become familiar with all the operating limitations of each glider flown and should not operate outside the limits. *Figure 5-17* shows different possible limiting conditions and the basic flight envelope for a high-performance glider.

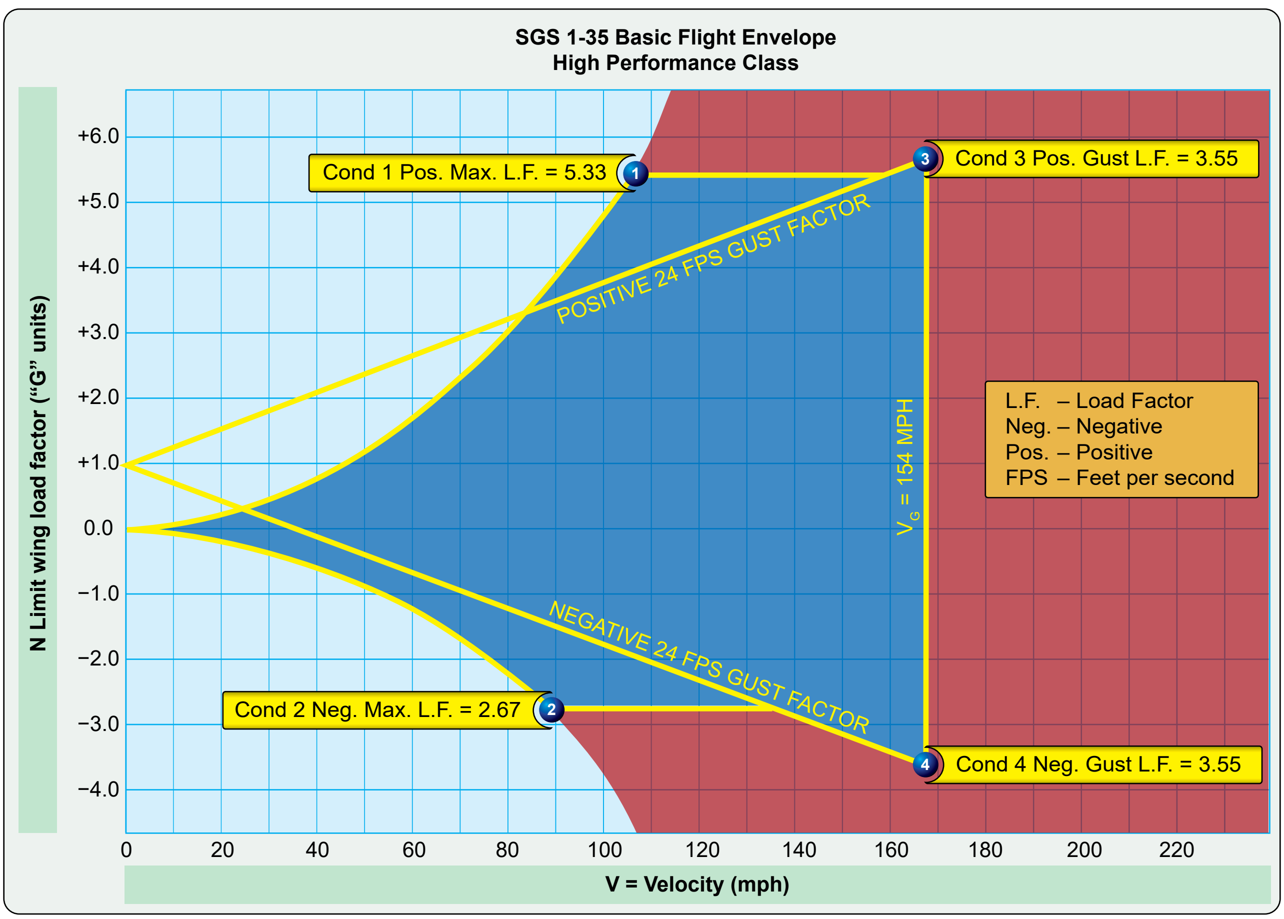

Figure 5-17. *Sample glider flight envelope.*

The curved yellow lines represent the maximum lift that the glider can generate at different airspeeds as Gs.

Condition 1 identifies the maximum speed at which the pilot can use full elevator up authority without damaging the glider. Up to this point along the curve and to the left at lower speeds, the glider would stall before the pilot exceeds the design load limit shown on the diagram. At higher speeds (to the right of condition 1), lift can exceed the maximum design load factor before a stall occurs. Such operation may impose damaging loads to the structure.

Condition 2 represents the speed at which the pilot can use full down elevator authority and not create a negative load that damages the glider. Above this speed the pilot can impose damaging loads to the structure.

Vertical Gusts During High-Speed Cruise

In high-speed cruise pilots should pay attention to load factor limitations. An encounter with an abrupt updraft during wings-level high-speed cruise increases the angle of attack, bends the wings upward, briefly increases the G-load, and stores elastic energy in the wing spars. As the wings release this energy, the wing spars spring downward and loft the fuselage higher. As the fuselage reaches the top of this motion, the wing spars, now bent downward, move upward again to release the stored energy. Since a negative G-load can occur as the fuselage drops downward, the seat belt and shoulder harness can prevent the pilot's head from banging against the top of the canopy.

During these excursions, the weight of the pilot’s hand and arm may inadvertently move the control stick forward or aft. Positive G-loading and the increased apparent weight of the pilot’s arm tend to move the control stick aft and further increase the angle of attack and G-load. Negative G-loading and the decreased apparent weight of the pilot’s arm tend to move the control stick forward and further decrease the angle of attack and G-load.

To minimize the intensification of vertical gusts and avoid high-speed pilot induced oscillations (PIOs), the pilot should reduce speed when cruising through turbulent air. The pilot may also brace both arms and use both hands on the control stick to prevent unwanted input. Some glider designs incorporate a parallelogram control stick linkage to reduce the likelihood of PIOs during high-speed cruise.

Weight & Balance

The pilot should understand proper weight and balance management and the consequences of overloading or improperly loading the glider.

Weight & Balance Information

The GFM/POH provided by the manufacturer gives information about the weight and balance of the glider. Since addition or removal of equipment, such as radios, batteries, flight instruments, or airframe repairs affect the CG position, aviation maintenance technicians (AMTs) record changes to the weight and balance data in the GFM/POH and glider airframe logbook. They also update weight and balance placards.

Center of Gravity

Longitudinal balance affects stability around the lateral axis of a glider. To achieve satisfactory pitch attitude handling, manufacturers position the center of gravity (CG) of a properly loaded glider forward of the center of lift (CL) and publish the glider CG limits in the GFM/POH.

On most gliders, the horizontal stabilizer and elevator provide a down force to balance the CG and center of lift arrangement. As the airspeed changes the pilot adjusts the trim, and the tail-down force exactly balances the forward CG. A glider in this configuration tends to resume its previous pitch attitude after an upset about the lateral axis. Should an upset occur that pitches the nose upward, the resultant slower airspeed and decrease in tail-down force lowers the nose and allows the airspeed to return toward its pre-upset value. Conversely, if the upset places the aircraft in a nose-down attitude, the increase in airspeed increases tail-down force and raises the nose toward the pre-upset condition. This arrangement creates positive stability. However, if the tail stalls, this stabilizing action will not begin until the tail begins producing down force.

Problems Associated with CG forward of the Published Limit

Loading the glider with the CG forward of the limit makes it difficult to raise the nose on takeoff and requires considerable back pressure on the controls to regulate pitch attitude. At low airspeeds the tail may stall or not provide sufficient down force. Any tail stall results in a sudden nose-down pitch change and potential for a slow recovery. The pilot may not have sufficient elevator authority to perform the landing flare due to nose heaviness. Inability to flare could result in a nose-first hard landing.

A CG forward of the limit might occur for these reasons:

- The pilot weight exceeds the maximum permitted.
- Installed ballast weights added to the weight of the pilot exceed the maximum permitted.

Problems Associated with CG forward of the Published Limit

Loading a glider with the CG location behind the aft limit creates a tail-heavy condition. Tail heaviness can make pitch control of the glider difficult or impossible.

A CG aft of the limit might occur for these reasons:

- The pilot weighs less than the specified minimum pilot seat weight without necessary ballast installed in the glider.
- Tailwheel dolly not removed prior to flight.
- A heavy, non-approved tailwheel or tail skid installed on the aft tail boom of the glider.
- Foreign matter or debris (water, ice, mud, sand, or nests) accumulation in the aft fuselage.

Sample Weight & Balance Problems

Some glider manufacturers provide weight and balance information in a graphic presentation. A well-designed graph provides a convenient way to determine whether the glider is within weight and balance limits.

Sample *figure 5-18* indicates that the minimum weight for the front seat pilot is 125 pounds (the lowest number on the x-axis) to a maximum of 250 pounds (the highest number on the x-axis). It also indicates a maximum rear seat pilot weight of 225 pounds (the highest number on the y-axis). If each pilot weighs 150 pounds, the intersection of pilot weights falls within the envelope. Therefore, the glider load falls within the envelope for safe flight. If each pilot weighs 225 pounds, the intersecting lines intersect in the yellow portion of the graph and indicate a load outside of weight and balance limits.

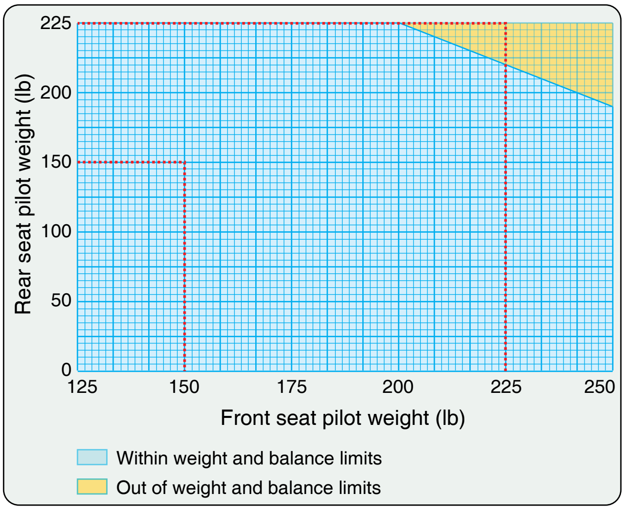

Figure 5-18. *Sample weight and balance envelope.*

Weight along the longitudinal axis of the glider affects the CG location. Pilots calculate the CG using of the arm or distance of known weights from a specific point (datum) on the longitudinal axis. The GFM/POH supplies the arm from the datum for the empty glider, each occupant seat, and for any cargo storage.

The pilot can determine the CG position using the following formulas:

- Weight × Arm = Moment.
- Total Moment ÷ Total Weight = CG Position (in relation to the datum).

The computational method involves the application of basic math functions as follows:

Given:

Maximum gross weight: 1,040 lb

Empty weight: 669 lb

CG range: 14.8–18.6 in

Front seat occupant: 180 lb

Rear seat occupant: 200 lb

To determine the loaded weight and CG, follow these steps:

1. List the empty weight of the glider and the weight of the occupants.
2. Enter the moment for each item listed. Remember, weight × arm = moment.
3. Total the weight and moments.
4. To determine the CG, divide the total moments by the total weight. [*Figure 5-19*]

Note: *The weight and balance records for a particular glider provide the empty weight and moment, as well as the information on the arm distance. [Figure 5-19]*

Item	Weight (pounds)	Arm (inches)	Moment (inch·pounds)
Empty weight	669	+93.7	+62,685
Front seat pilot	180	+43.8	+7,884
Rear seat pilot	190	+74.7	+14,193
	1,039 total weight	+81.58	+84,762 total moment

Figure 5-19. *Sample weight and balance: front and rear seat pilot weights and moments.*

In *Figure 5-19* above, the weight of each pilot appears in the appropriate block in the table. For the front seat pilot, multiplying 180 pounds by 43.8 inches yields a moment of 7,884 inch-pounds. For the rear seat pilot, multiplying 190 pounds by 74.7 inches yields a moment of 14,193 inch-pounds. The next step is to find the sum of all weights (980 pounds) including the empty weight of the glider. Then, find the sum of all moments (+84,762 inch-pounds). To determine the CG position of the loaded glider, divide the total moment by the total weight to in inches from the datum: 84,762 inch-pounds ÷ 1039 pounds = 81.58 aft of the datum.

For the final step the pilot determines whether total weight and CG location values are within acceptable limits. The GFM/POH lists the maximum gross weight as 1,040 pounds. The operating weight of 1039 pounds does not exceed the 1,040 pounds maximum gross weight. The GFM/POH lists the approved CG range as between 78.2 inches and 86.1 inches from the datum. The operating CG of 81.58 inches from the datum falls within these limits. Therefore, the calculation shows the glider within operating limits if loaded as planned.

Ballast

Ballast includes nonstructural weight added to a glider. In soaring, ballast weight serves two purposes. Trim ballast adjusts the location of the CG of the glider to remain within acceptable limits. Performance ballast improves high-speed cruise performance.

Trim Ballast

Removable trim ballast weights, often made of metal, attach to a ballast receptacle incorporated in the glider structure. These weights compensate for a front seat pilot who weighs less than needed to maintain the CG within acceptable operating limits. The ballast weight mounted well forward in the glider cabin can move the CG within permissible limits with the minimum addition of weight.

Whenever an approved POH or Glider Flight Manual limitation section includes specific instructions on the use of trim ballast, pilots must follow the approved method stated in the GFM/POH for placement of that ballast. For gliders without limitations or placards regarding placement of trim ballast, pilots may consider using a seat cushion with sand or lead shot sewn into the unit to provide additional weight. Since this type of ballast may shift position during maneuvering, pilots should not rely on seat cushion ballast during acrobatic or inverted flight. The pilot should develop a means to verify the presence, absence, weight, and appropriateness of any trim ballast before a flight.

Trim ballast may also include water in a tail tank in the vertical fin. Water weighs 8.35 pounds per gallon. Because of its far-aft location, the pilot can use a small amount of water in the tail tank to offset the moment of any main wing tank performance ballast. Even though a tail tank generally holds less than two gallons of water, a calculation error leading to excess water in the tail could result in flight with a CG aft of the limit.

Performance Ballast

Adding weight enhances high-speed performance in gliders. Increasing the operating weight of the glider increases the optimum speed to fly during wings-level cruising flight. The resulting higher ground speed provides an advantage in cross-country soaring and in glider racing.

Manufacturers commonly install water tanks in the main wing panels. That water acts as performance ballast. Personnel add clean water through fill ports in the top of each wing. The amount of water introduced depends on the pilot's choice of operating weight. After adding water, replacement of the filler caps prevents water from sloshing out of the filler holes. Vents in the filler caps allow air to enter the tanks to replace the volume of water drained from the tanks. [*Figure 5-20*] Pilots should ensure that the vents work properly to prevent wing damage when draining water ballast.

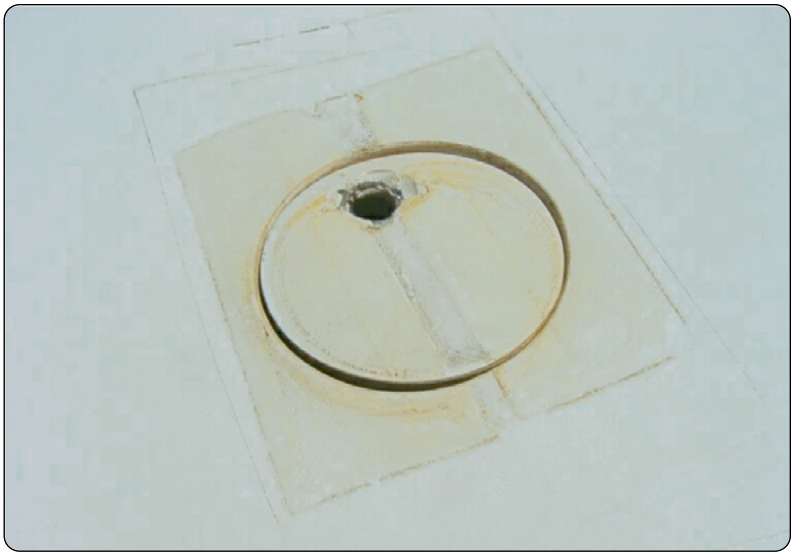

Figure 5-20. *Water ballast tank vented filler cap.*

Drain valves fit to the bottom of each tank, and the pilot controls the valves from inside the glider. [*Figure 5-21*] The pilot can fully or partially drain the tanks with the glider on the ground to reduce weight prior to launch. The pilot can also manipulate the valves to drain the ballast tanks partially or completely in flight—a process called dumping ballast, which normally occurs prior to landing. The long streaks of white spray behind an airborne glider indicate water draining in the air.

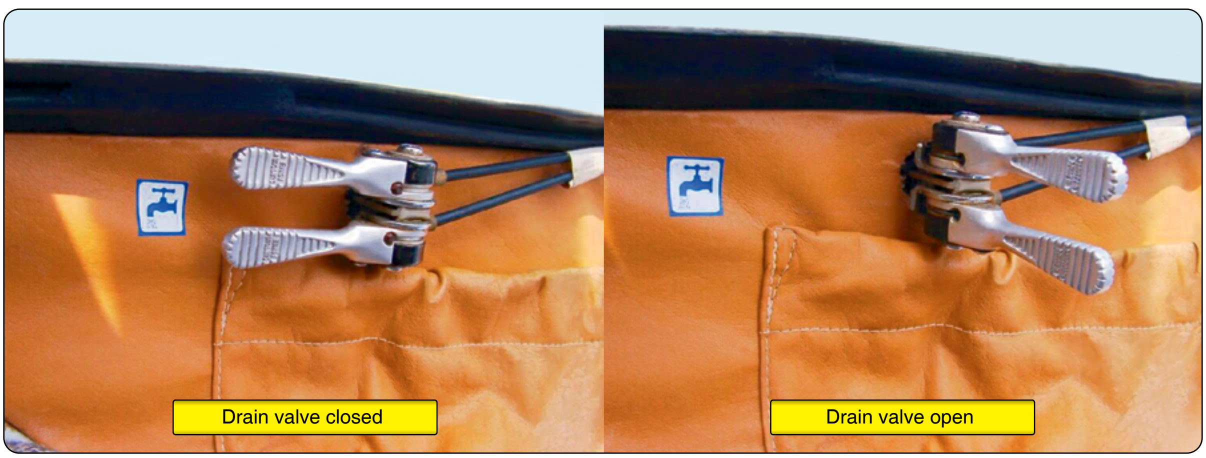

Figure 5-21. *Water ballast drain valve handles.*

Pilots should check the drain valves for correct operation prior to flight. Water ballast should drain from each wing tank at the same rate. Unequal draining leads to a wing-heavy condition that makes inflight handling, as well as landings, more difficult. If the wing-heavy condition becomes extreme, the pilot may lose control of the glider.

Water ballast should drain into the air outside the glider rather than leak into the fuselage. Water trapped in the fuselage may flow through or over bulkheads, causing unmanaged changes to the glider CG. Sufficient CG movement could lead to control difficulty or even total loss of control.

The flight manual provides guidance regarding the length of time it takes for the ballast tanks to drain completely. When preparing for landing, the pilot should dump ballast early enough to give the ballast drains sufficient time to empty the tanks.

Use of water ballast in low ambient temperatures can result in water freezing the drain valve, making dumping ballast difficult or impossible. If only one valve freezes, uneven dumping may occur as discussed above. If water in the wings freezes, serious wing damage may occur because water expands while freezing. The resulting increased volume can deform ribs and other wing structures or delaminate glued bonds. In cold weather or when expecting cold flight conditions, pilots should not use water ballast unless adding antifreeze to the water. The GFM has information on antifreeze compounds approved for use in the glider.

A glider carrying large amounts of water ballast has noticeably different handling characteristics than the same glider without water ballast. Water ballast:

- Reduces the rate of acceleration of the glider at the beginning of the launch due to the increased glider weight.
- Increases the length of ground roll prior to glider liftoff.
- Increases stall speed.
- Reduces aileron control during the takeoff roll, increasing the chance of uncontrolled wing drop and resultant ground loop.
- Reduces rate of climb during climb-out.
- Reduces aileron response during free flight. The addition of large amounts of water increases lateral stability substantially. This makes quick banking maneuvers difficult or impossible to perform.

The pilot routinely dumps water ballast before landing to reduce the weight of the glider. Dumping ballast:

- Decreases stall speed.
- Decreases the optimum airspeed for the landing approach.
- Shortens landing roll.
- Reduces the load that glider structures must support during landing and rollout.

While performance advantages from ballast occur during strong soaring conditions, pilots should consider that ballast degrades takeoff performance, climb rate, and low-speed handling. Before committing to a launch with water ballast aboard, the pilot should review operating limitations to ensure safety of flight.

Chapter Summary

Factors that affect all glider flights include temperature, atmospheric pressure, humidity, wind, and operating weight. Pilots should consider the design of the glider and its operating characteristics and know the expected performance before flight. Pilots should only fly when weight and balance conditions remain within limits since these conditions affect stability and control. Glider polars indicate the performance speeds that pilots can expect at different weights and under different wind conditions and can assist in maximizing performance. Glider pilots flying models that use water ballast should understand how to verify proper system operation before flight and know when to drain any water when necessary or before landing.