

Chapter 5

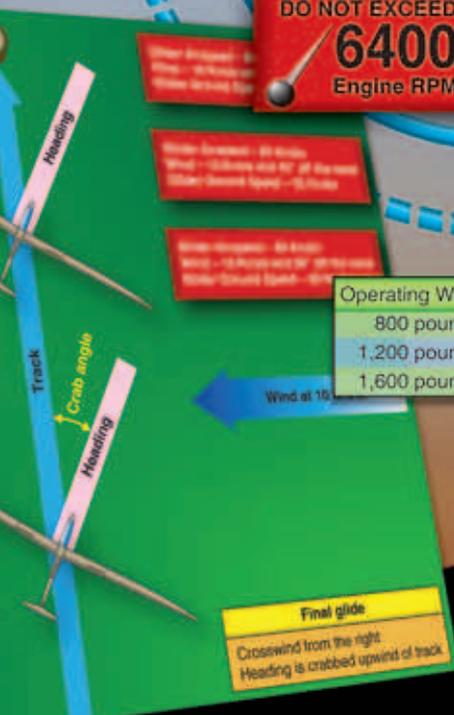
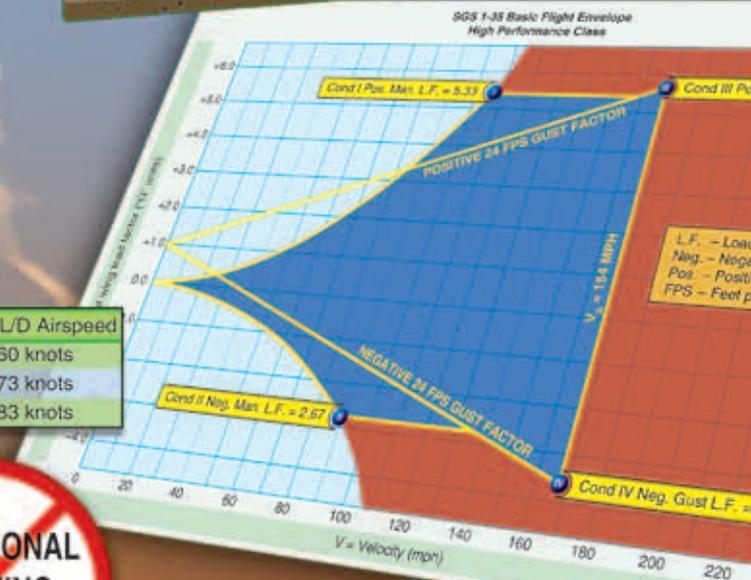
Glider Performance

Introduction

Glider performance during launch phase, landing, and free flight phase depends on many factors: design, weather, wind, and other atmospheric phenomena.



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



Factors Affecting Performance

Glider performance during launch depends on the power output of the launch mechanism and on the aerodynamic efficiency of the glider itself. The four major factors that affect performance are density altitude, weight, design, and wind.

High and Low Density Altitude Conditions

Every pilot must understand the terms “high density altitude” and “low density altitude.” In general, high density altitude refers to thin air, while low density altitude refers to dense air. Those conditions that result in a high density altitude (thin air) are high elevations, low atmospheric pressure, high temperatures, high humidity, or some combination thereof. Lower elevations, high atmospheric pressure, low temperatures, and low humidity are more indicative of low density altitude (dense air). However, high density altitudes may be present at lower elevations on hot days, so it is important to calculate the density altitude and determine performance before a flight.

One way to determine density altitude is to use charts designed for that purpose. [Figure 5-1] For example, you plan to depart an airport where the field elevation is 1,600 feet MSL. If the altimeter setting is 29.80, and the temperature is 85 °F, what is the density altitude? First, correct for nonstandard pressure (29.8 "Hg) by referring to the right side of the chart and adding 112 feet to the field elevation. The result is a pressure altitude of 1,712 feet. Then, enter the chart at the bottom, just above the temperature of 85 °F (29.4 °C). Proceed up the chart vertically until intercepting the diagonal 1,712-foot pressure altitude line, then move horizontally to the left and read the density altitude of approximately 3,500 feet. This means a self-launching glider or towplane will perform as if it were at 3,500 feet MSL on a standard day.

Most performance charts do not require a pilot to compute density altitude. Instead, the computation is built into the performance chart itself. A pilot needs only the correct pressure altitude and the temperature. Some charts, however, may require computing density altitude before entering them. Density altitude may be computed using a density altitude chart or by using a flight computer.

Atmospheric Pressure

Due to changing weather conditions, atmospheric pressure at a given location changes from day to day. The following is the METAR report for Love Field observed on the 23rd at 21:53Z (GMT) which indicates a local pressure of A2953, or altimeter setting of 29.53 "Hg. When barometric pressure drops, air density decreases. The reduced density of the air results in an increase in density altitude and decreased glider performance. This reduces takeoff and climb performance and increases the length of runway needed for landing.

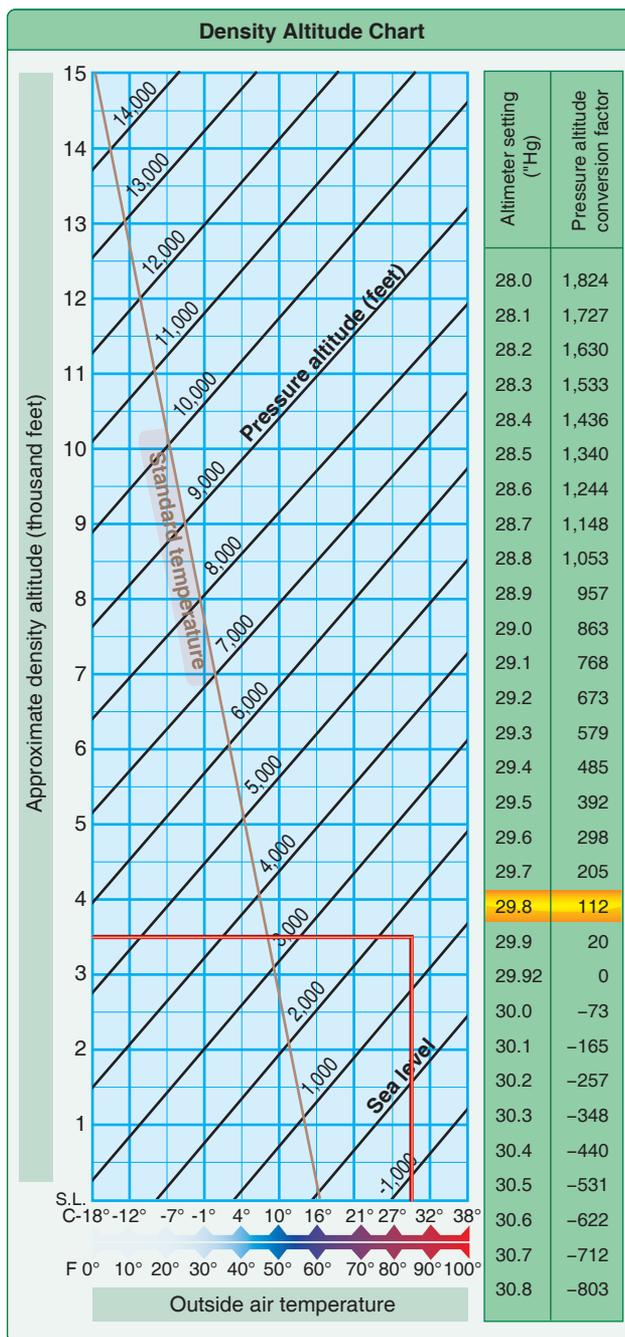


Figure 5-1. Density altitude chart.

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

The 12/11 notation of this report indicates the reported temperature and dewpoint for Love Field.

When barometric pressure rises, air density increases. The greater density of the air results in lower density altitude. Thus, takeoff and climb performance improves, and the length of runway needed for landing decreases.

Altitude

As altitude increases, air density decreases. At altitude, the atmospheric pressure that acts on a given volume of air is less, allowing the air molecules to space themselves further apart. The result is that a given volume of air at high altitude contains fewer air molecules than the same volume of air at lower altitude. As altitude increases, density altitude increases, and glider takeoff and climb performance is reduced.

Temperature

Temperature changes have a large effect on density altitude. When air is heated, it expands—the molecules move farther apart, making the air less dense. Takeoff and climb performance is reduced, while the length of runway required for landing is increased.

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—almost twice the density altitude increase compared to the increase for Love Field. The effects of altitude and temperature are significant, a fact pilots must consider when computing aircraft performance.

Wind

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

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, on the other hand, 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.

Crosswinds during cruising flight cause glider heading (the direction in which the glider nose is pointed) and glider track (the path of the glider over the ground) to diverge. In a glider, it must be remembered that crosswinds have some head or tailwind component that results in a lower or higher true groundspeed. When planning the landing, the wind effects must be factored into the landing pattern sight picture

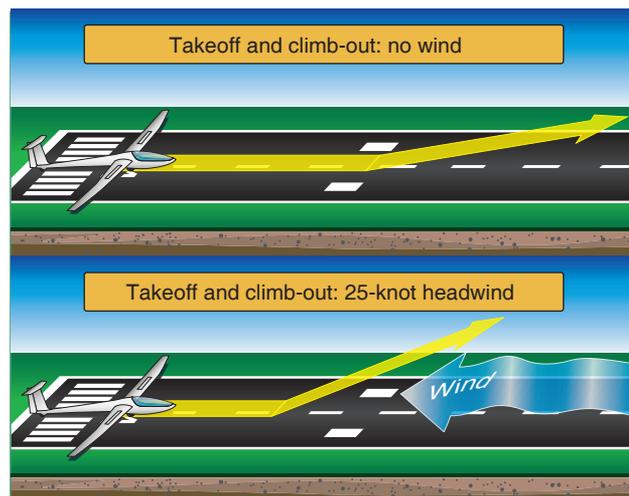


Figure 5-2. Apparent wind effect on takeoff distance and climb-out angle.

and allowances must be made for the winds, indicated or expected. It is a lot easier to lose altitude than it is to make up altitude when the glider is down low. When gliding toward an object on the ground in the presence of crosswind, such as on final glide at the end of a cross-country flight, the glider pilot should keep the nose of the glider pointed somewhat upwind of the target on the ground. For instance, if the crosswind is from the right during final glide, the nose of the glider is pointed a bit to the right of the target on the ground. The glider's heading is upwind (to the right, in this case) of the target, but if the angle of crab is correct, the glider's track is straight toward the target on the ground. [Figure 5-3]

Headwind during landing results in a shortened ground roll, and tailwind results in a longer ground roll. Crosswind landings require the pilot to compensate for drift with the proper flight control input, such as a sideslip or a crab. Glider pilots must be aware of the apparent angle versus the rate of descent. The glider descends at a constant rate, but the different groundspeeds will result in different approach angles. These different approach angles require specific techniques to ensure safe touchdowns in the landing zone. For example, if landing in a strong headwind, the glider pilot should plan for a closer base leg to allow for the apparent steeper approach due to the slower ground speed. Another technique would be the delayed extension of spoilers or drag brakes and accepting the 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 drag brake extension or slipping or a combination as allowed by the GFM to touchdown in the landing zone. In any condition, the glider pilot must make allowances for the current conditions of wind and density altitude to ensure a safe landing in the landing area. A glider pilot must respond to the current conditions and amend the traffic pattern and/or modify their procedures to compensate

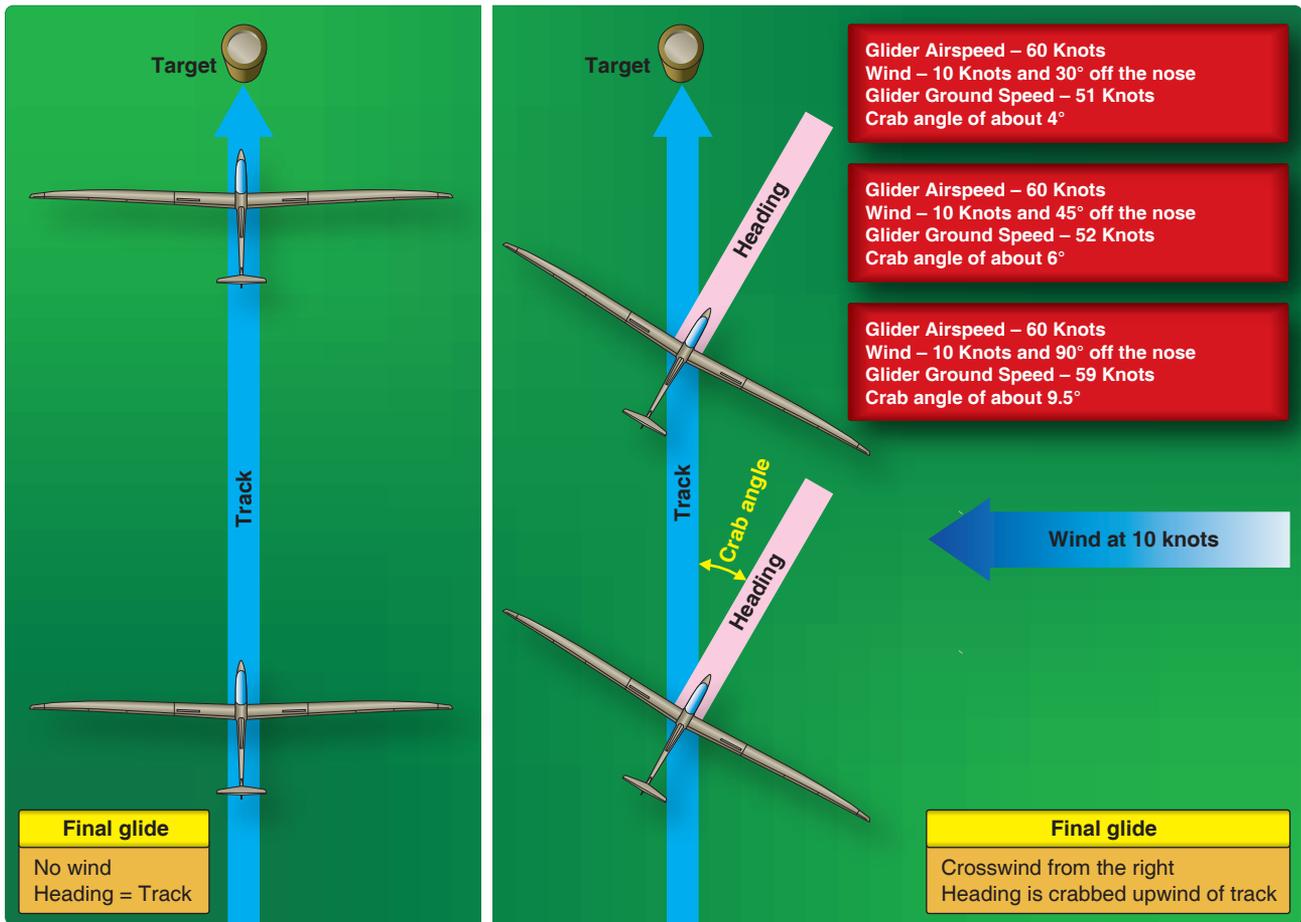


Figure 5-3. Crosswind effect on final glide.

for the conditions and land safely. The different groundspeeds also result in different touchdown points unless the pilot takes some kind of action. In any case, the pilot should aim for the touchdown zone markers and not for the end of the runway. [Figure 5-4]

During landing in windy/gusty conditions, there is a tendency to lose airspeed (flying speed) and increase sink. The friction between the ground and the air mass reduces the wind strength. The glider may be flying into a strong headwind at one moment; a few seconds later, the windspeed diminishes to nearly zero. The pilot landing into a headwind can usually expect to lose some of that headwind while approaching the surface due to surface friction slowing the wind. When the change is abrupt, the pilot experiences a loss of airspeed because it requires some small time and loss of altitude to accelerate the inertia of the glider up to the airspeed previously displayed when into the stronger headwind. This takes on the appearance of having to dive at the ground to maintain flying speed. Fly a faster approach to ensure staying above stalling speed. Depending on the wind change, a longer ground roll may be the result. If this occurs near the ground, the glider loses speed, and there may be insufficient altitude to recover the lost speed. This is called “wind gradient.” Consideration

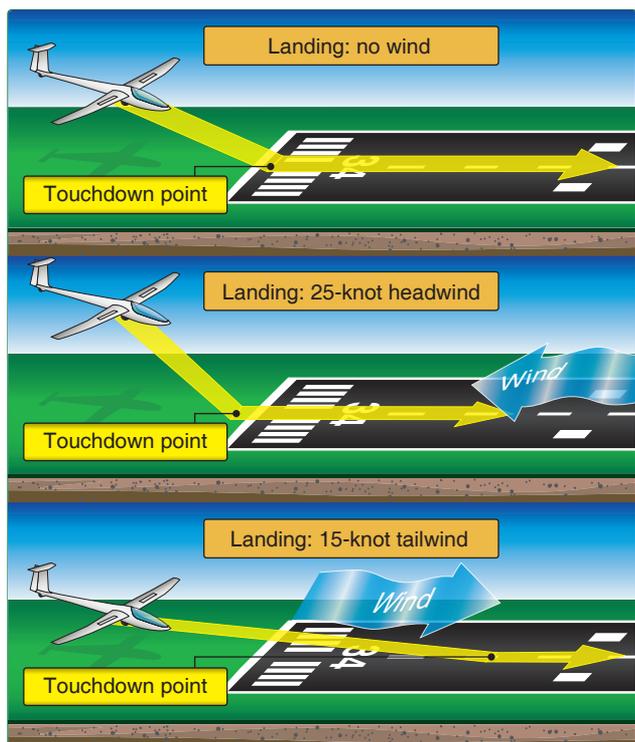


Figure 5-4. Wind effect on final approach and landing distance.

of wind gradient during a ground launch is important, as a sudden increase in windspeed could result in exceeding the designed launch speed. [Figure 5-5]

The pilot landing with a tail wind has a higher groundspeed for an indicated airspeed. As the surface friction slows the winds, the pilot may see an increase in airspeed before the higher inertia-induced airspeed is dissipated, which may increase the ground roll distance to touchdown. This may be experienced with a downdraft in the vicinity of obstructions upwind of the runway as the winds curl down and wrap under the obstructions. This effect can lead to major undershoots of the approach path and landing short if the winds are strong enough. Local pilots can be a rich source of information about local wind currents and hazards.

Glider pilots must understand that wind near the ground behaves differently higher up. Atmospheric conditions, such as thermal formation, turbulence, and gust and lulls, change the in-flight behavior of the glider significantly. As the wind flows over the ground, ground obstructions, such as buildings, trees, hills, and irregular formations along the ground, interfere with the flow of the wind, decreasing its velocity and breaking up its smooth flow as occurs in wave and ridge flying.

Wind gradient affects a pilot turning too steeply on final approach at a very low airspeed and at low altitudes near to the surface. There is less wind across the lower wing than across the higher wing. The rolling force created by the wind gradient affects the entire wing area. This can prevent the pilot from controlling the bank with the ailerons and may roll the glider past a vertical bank. [Figure 5-6] Be cautious with any bank angle and at any airspeed while close to the ground when transitioning a wind gradient.

When approaching to land during windy and gusty conditions, add half of the wind velocity to the approach speed to ensure adequate speed for a possible encounter with a wind gradient. During landing under these conditions, it is acceptable to allow the glider to touch down a little faster than normal instead of holding the glider off the ground for a low kinetic energy landing. Upon touchdown during these landings, extending the air brakes fully prevents the glider from becoming airborne through a wind gust during the landing roll.

Some self-launching gliders are designed for extended periods of powered cruising flight. For these self-launching gliders, maximum range (distance) for powered flight and maximum duration (elapsed time aloft) for powered flight are primarily limited by the self-launching glider's fuel capacity. 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.

Weight

Glider lift, drag, and glide ratio characteristics are governed solely by its design and construction, and are predetermined at takeoff. The only characteristic the pilot controls is the weight of the glider. In some cases, pilots may control glider configurations, as some high-performance gliders may have a wing extension option not available on other models. Increased weight decreases takeoff and climb performance, but increases high-speed cruise performance. During launch, a heavy glider takes longer to accelerate to flying speed. The heavy glider has more inertia, making it more difficult to accelerate the mass of the glider to flying speed. After takeoff, the heavier glider takes longer to climb out because

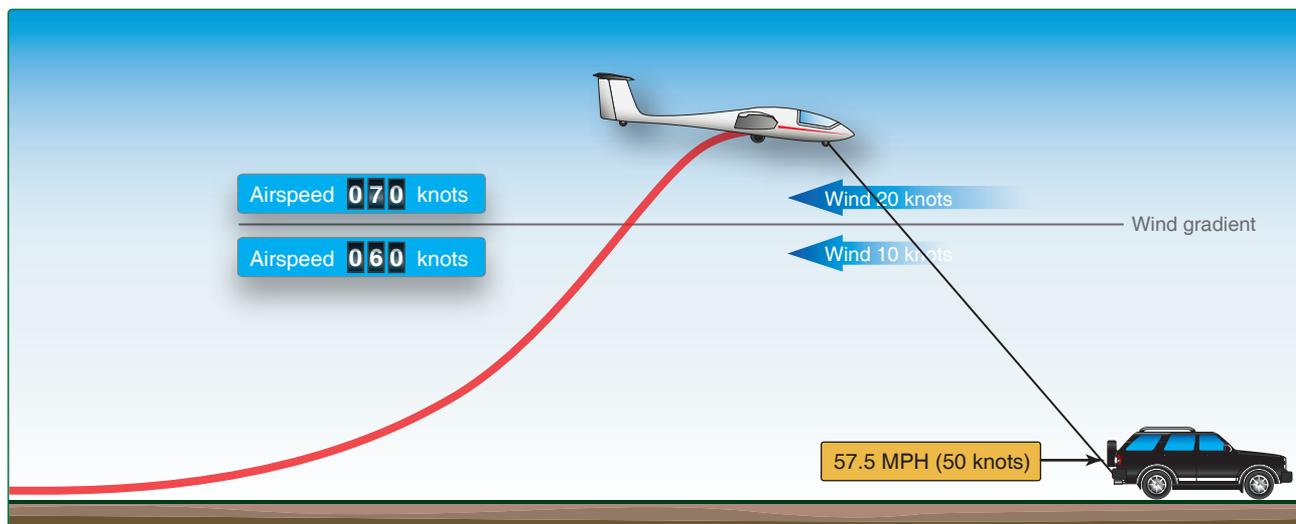


Figure 5-5. During gusting conditions, the pilot must monitor the pitch during the tow.

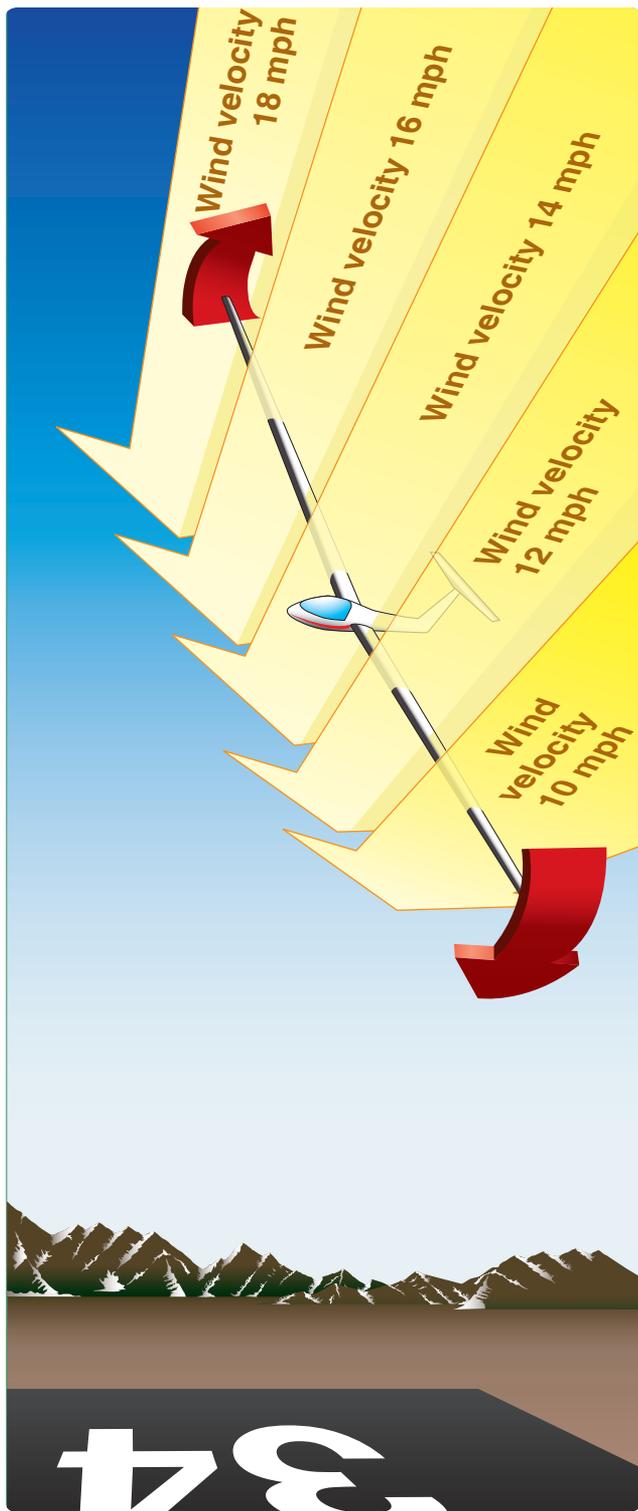


Figure 5-6. Effect of wind velocity gradient on a glider turning into the wind. Stronger airflow over higher wing causes bank to steepen when close to the surface where surface friction slows winds.

the heavier glider has more mass to lift to altitude than does the lighter glider (whether ground launch, aerotow launch, or self-launch). [Figure 5-7]

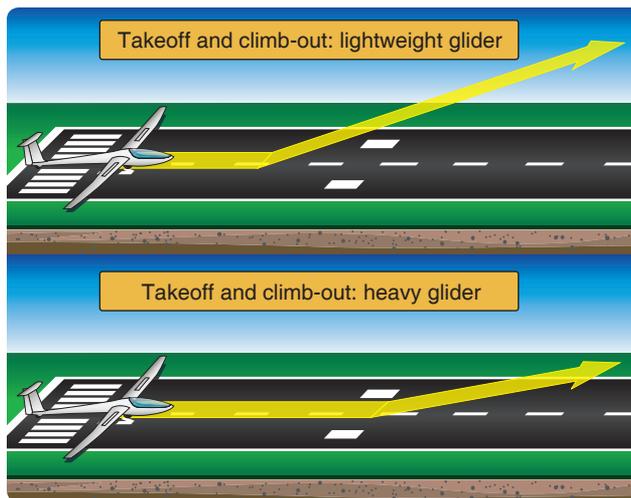


Figure 5-7. Effect of weight on takeoff distance and climb-out rate and angle.

The heavy glider has a higher stall speed and a higher minimum controllable airspeed than an otherwise identical, but lighter, glider. The stall speed of a glider increases with the square root of the increase in weight. If the weight of the glider is doubled (multiplied by 2.0), then the stall speed increases by more than 40 percent (1.41 is the approximate square root of 2; 1.41 times the old stall speed results in the new stall speed at the heavier weight). For example, a 540-pound glider has a stalling speed of 40 knots. The pilot adds 300 pounds of water ballast making the new weight 840 pounds. The new stalling speed is approximately 57 knots (square root of $\sqrt{300 + 40} = 57$).

When circling in thermals to climb, the heavy glider is at a disadvantage relative to the light glider. The increased weight of the heavy glider means stall airspeed and minimum sink airspeed are greater than they would be if the glider were operating at a light weight. At any given bank angle, the heavy glider's higher airspeeds mean the pilot must fly larger diameter thermalling circles than the pilot of the light glider. Since the best lift in thermals is often found in a narrow cylinder near the core of the thermal, larger diameter circles generally mean the heavy glider is unable to exploit the strong lift of the thermal core, as well as the slower, lightweight glider. This results in the heavy glider's inability to climb as fast in a thermal as the light glider. [Figure 5-8]

The heavy glider can fly faster than the light glider while maintaining the same glide ratio as the light glider. The advantage of the heavier weight becomes apparent during cruising flight. The heavy glider can fly faster than the light glider and still retain the same lift-to-drag (L/D) ratio.

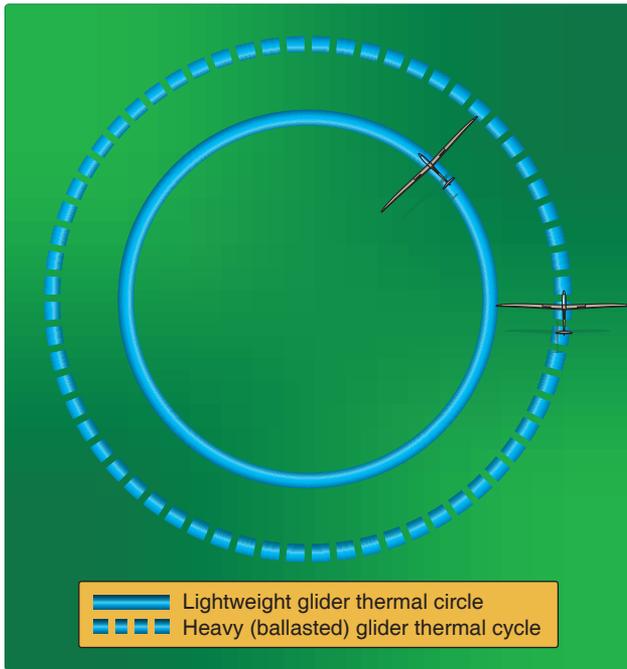


Figure 5-8. Effect of added weight on thermaling turn radius.

If the operating weight of a given glider is increased, the stall airspeed, minimum controllable airspeed, minimum sink airspeed, and the best L/D airspeed are increased by a factor equal to the square root of the increase in weight. [Figure 5-9] Glide ratio is not affected by weight because, while a heavier glider sinks faster, it does so at a greater airspeed. The glider descends faster, but covers 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.

To help gliders fly faster, some gliders have tanks that can hold up to 80 gallons of water. Higher speeds are desirable for cross-country flying and racing. The disadvantages of these ballasted gliders include reduced climb rates in thermals and the possibility that suitable lift cannot be located after tow release. To prevent this, the water ballast can be jettisoned at any time through dump valves, allowing the pilot to reduce the weight of the glider to aid in increased climb rates.

The addition of ballast to increase weight allows the glider to fly at increased airspeeds while maintaining its L/D ratio. Figure 5-9 shows that adding 400 pounds of water ballast increases the best L/D airspeed from 60 knots to 73 knots. The heavy glider has more difficulty climbing in thermals than the light glider, but if lift is strong enough for the heavy

glider to climb reasonably well, the heavy glider’s advantage during the cruising portion of flight outweighs the heavy glider’s disadvantage during climbs.

Water is often used as ballast to increase the weight of the glider. However, the increased weight requires a higher airspeed during the approach and a longer landing roll. Once the cross-country phase is completed, the water ballast serves no further purpose. The pilot should jettison the water ballast prior to entering the traffic pattern. Reducing the weight of the glider prior to landing allows the pilot to make a normal approach and landing. The lighter landing weight also reduces the loads that the landing gear of the glider must support.

With the glide ratio data available to the pilot, provided by the charts/graphs located in the GFM/POH for the glider, the pilot can review or plot any specific combination of airspeed and glide ratio/lift to drag ratio (L/D). The resulting plot of L/D with airspeed (angle of attack) shows that glide ratio increases to some maximum at the lowest airspeed. Maximum lift-to-drag ratio (L/D_{MAX})/glide ratio, occurs at one specific airspeed (angle of attack and lift coefficient). If the glider is operated in a steady flight condition, total drag is at a minimum. This is solely based on airspeed. Any airspeed (angle of attack lower or higher) than that for L/D_{MAX} /glide ratio reduces the L/D_{MAX} /glide ratio and consequently increases the total drag for a given glider’s lift.

Note that a change in gross weight would require a change in airspeed to support the new weight at the same lift coefficient and angle of attack. This is why the glider GFM/POH has different speeds for flying with or without ballast. The configuration of a glider during flight has a great effect on the L/D. One of the most important of which is the glider’s best L/D/glides ratio.

Rate of Climb

Rate of climb for the ground-launched glider primarily depends on the strength of the ground-launching equipment. When ground launching, rates of climb generally are quite rapid, and can exceed 2,000 feet per minute (fpm) if the winch or tow vehicle is very powerful. When aerotowing, rate of climb is determined by the power of the towplane. It is important when selecting a towplane to ensure that it is capable of towing the glider, considering the existing conditions and glider weight.

Self-launching glider rate of climb is determined by design, powerplant output, and 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 in others. The pilot should consult the GFM/POH to determine rate of climb under the existing conditions.

Flight Manuals and 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
- Weight and balance data
- Description of glider systems
- Glider performance
- Operating limitations

Placards

Cockpit placards provide the pilot with readily available information that is essential for the safe operation of the glider. All required placards are located in the GFM/POH.

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

Performance Information

The GFM/POH is the source provided by the manufacturer for glider performance information. In the GFM/POH, glider performance is presented in terms of specific airspeed, such as stall speed, minimum sinking airspeed, best L/D airspeed, maneuvering speed, rough air speed, and the never exceed speed (V_{NE}). Some performance airspeeds apply only to

particular types of gliders. Gliders with wing flaps, for instance, have a maximum permitted flaps 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

In addition, the manufacturer provides information about the rate of sink in terms of airspeed, which is summarized in a graph called a polar curve, or simply a polar. [Figures 5-11]

The vertical axis of the polar shows the sink rate in knots (increasing sink downwards), while the horizontal axis shows airspeed in knots. Every type of glider has a characteristic polar derived either from theoretical calculations by the designer or by actual in-flight 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 amount of 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 final glide tools that will be discussed in Chapter 11, Cross-Country Soaring.

Minimum sink rate is determined from the polar by extending a horizontal line from the top of the polar to the vertical axis. [Figure 5-12] 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 polar). The best glide speed (best L/D) is found by drawing a tangent to the polar from the origin. The best L/D speed is 50 knots with a sink speed of 2.1 knots. The glide ratio at best

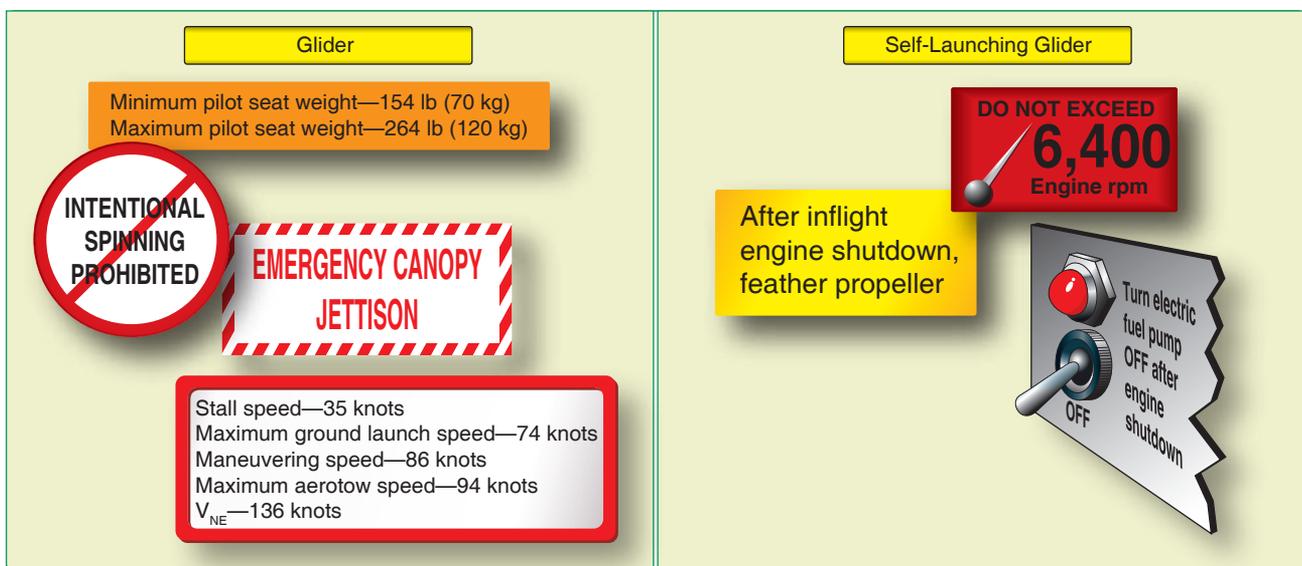


Figure 5-10. Typical placards for nonmotorized and self-launching gliders.



Figure 5-11. Dual and solo polar performance curves for a two-seat glider.

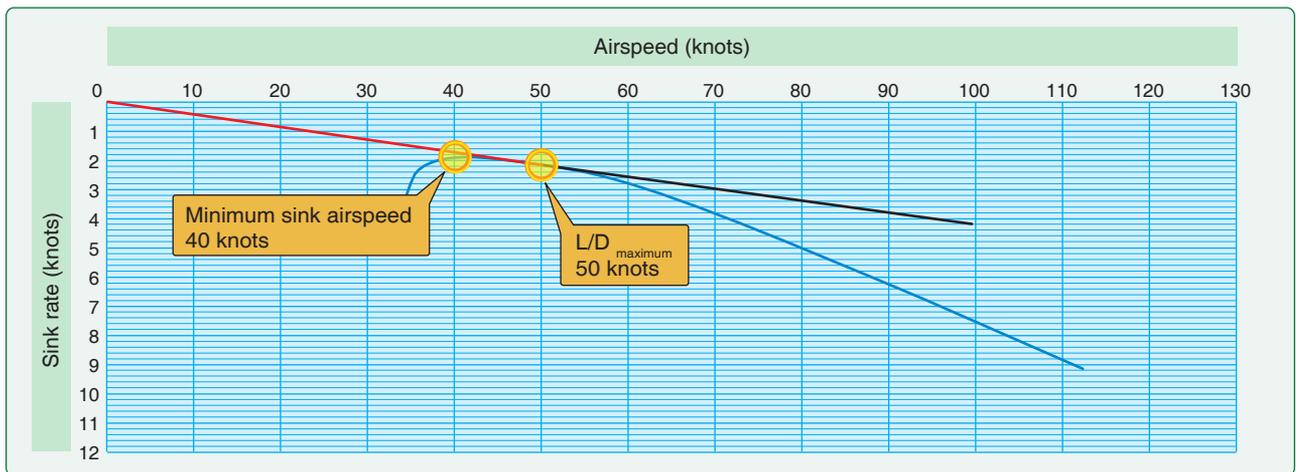


Figure 5-12. Minimum sink airspeed and maximum L/D speed.

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. 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.

The best speed to fly for distance in a headwind is easily determined from the polar. To do this, 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.

From the new tangent point, read the best speed to fly. An example for a 20-knot headwind is shown in Figure 5-13. The speed to fly in a 20-knot headwind is found to be 60 knots. By repeating the procedure for different headwinds, it is apparent that flying a faster airspeed as the headwind increases results in the greatest distance over the ground. If this is done for the polar curves from many gliders, a general rule of thumb is found: add half the headwind component to the best L/D for the maximum distance. For tailwinds, shift the origin to the left of the zero mark on the horizontal axis.

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

Sinking air usually exists between thermals, and it is most efficient to fly faster than best L/D in order to spend less time in sinking air. How much faster to fly can be determined by the glider polar, as illustrated in Figure 5-14 for an air mass that is sinking at 3 knots. The polar graph in this figure has its vertical axis extended upwards. Shift the origin vertically by 3 knots and draw a new tangent to the polar. Then, draw a line vertically to read the best speed to fly. For this glider, the best speed to fly is found to be 60 knots. Note, the variometer shows the total sink of 5 knots (3 knots for sink and 2 knots for the aircraft) as illustrated in the figure.

If the glider is equipped with water ballast, wing flaps, or wingtip extensions, the performance characteristics of the glider is depicted in multiple configurations. [Figures 5-15, 5-16, and 5-17] Comparing the polar with and without ballast, it is evident that the minimum sink is higher

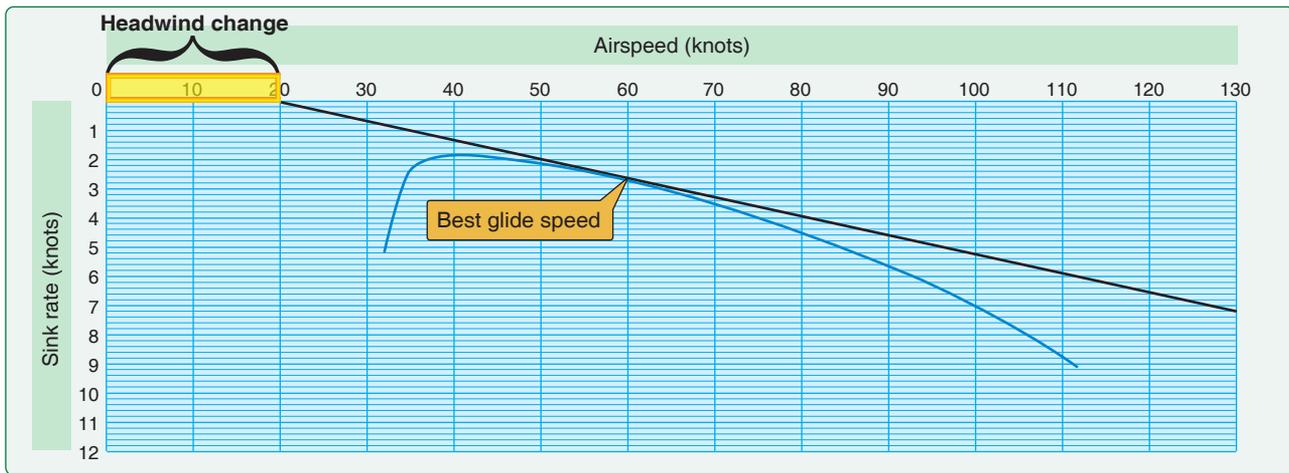


Figure 5-13. Best speed to fly in a 20-knot headwind.

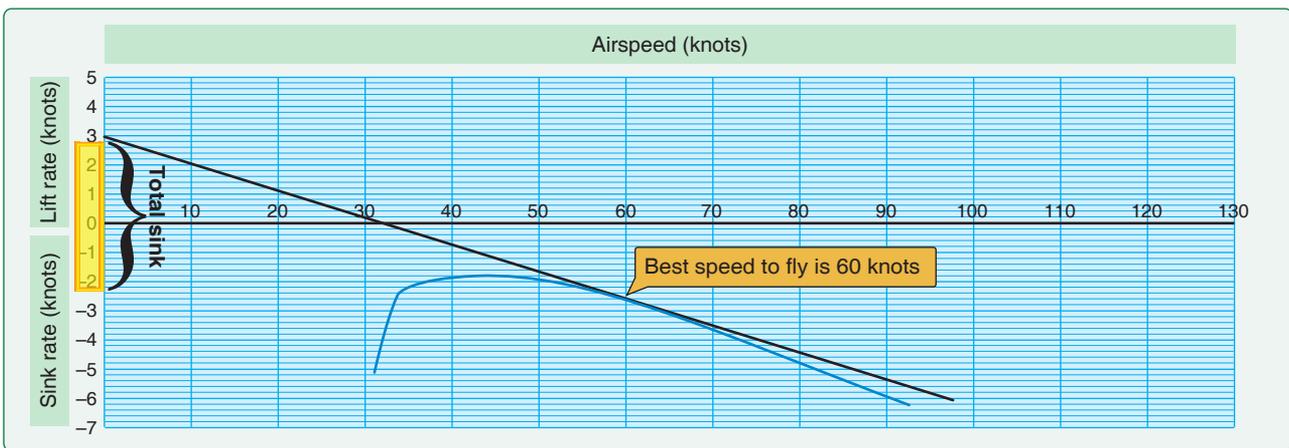


Figure 5-14. Best speed to fly in sink.

and occurs at a higher speed. [Figure 5-15] With ballast, it would be more difficult to work small, weak thermals. The best glide ratio is the same, but it occurs at a higher speed. In addition, the sink rate at higher speeds is lower with ballast. From the polar, then, ballast should be used under stronger thermal conditions for better speed between thermals. Note that the stall speed is higher with ballast as well.

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 5-16] Therefore, when cruising at or above 70 knots, a -8° flap setting would be advantageous for this glider. 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.

Wingtip extensions also alter the polar, as shown in Figure 5-17. The illustration shows that the additional 3 meters of wingspan is advantageous at all speeds. In some gliders, the low-speed performance is better with the tip extensions, while high-speed performance is slightly diminished by comparison.

Weight and Balance Information

The GFM/POH provides information about the weight and balance of the glider. This information is correct when the glider is new as delivered from the factory. Subsequent maintenance and modifications can alter weight and balance considerably. Changes to the glider that affect weight and balance should be noted in the airframe logbook and on appropriate cockpit placards that might list, for example, “Maximum Fuselage Weight: 460 pounds.”

Weight is a major factor in glider construction and operation; it demands respect from all pilots. The pilot should always be aware of proper weight management and the consequences of overloading the glider.

Limitations

Whether the glider is very simple or very complex, designers and manufacturers provide operating limitations to ensure the safety of flight. The VG diagram provides the pilot with information on the design limitations of the glider, such as limiting airspeeds and load factors (L.F. in Figure 5-18).

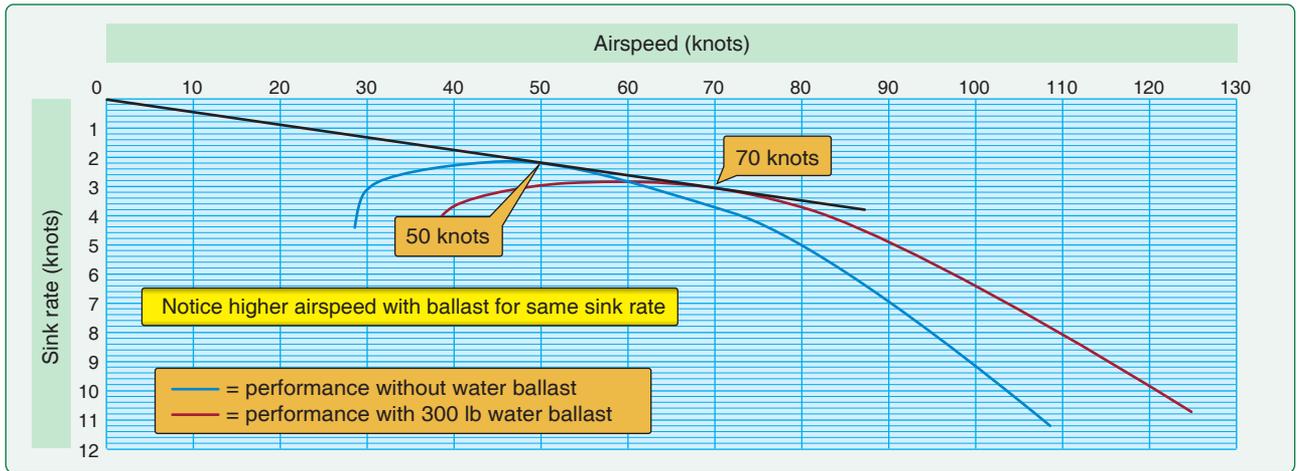


Figure 5-15. Effect of water ballast on performance polar.

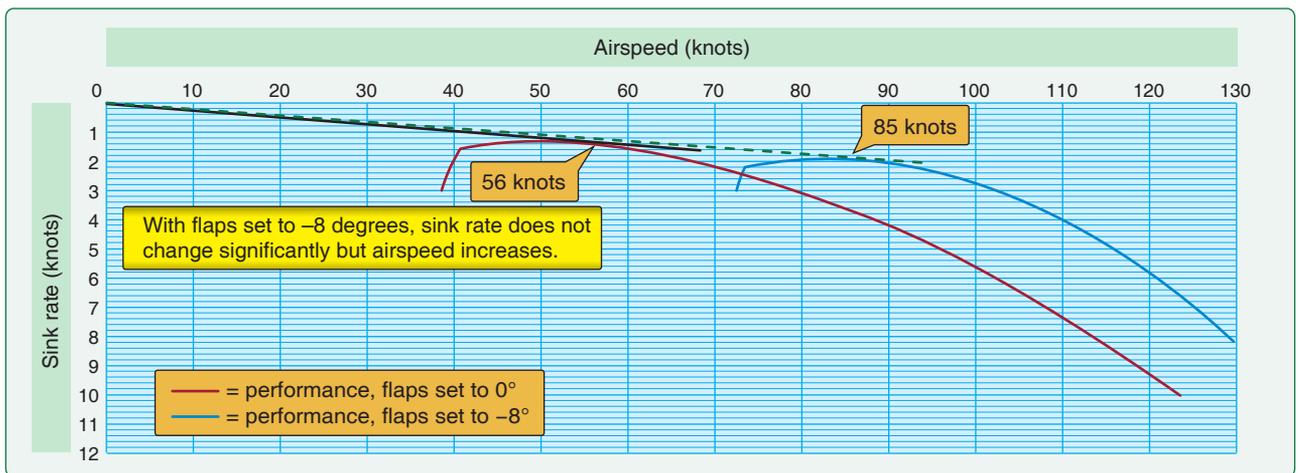


Figure 5-16. Performance polar with flaps at 0° and -8°.

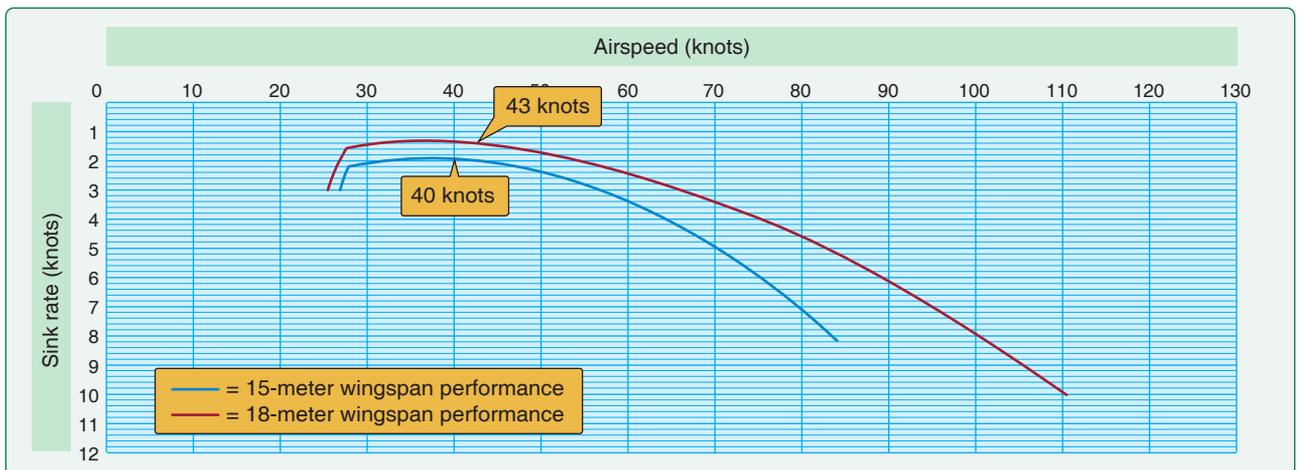


Figure 5-17. Performance polar with 15-meter and 18-meter wingspan configurations.

Pilots should become familiar with all the operating limitations of each glider being flown. *Figure 5-18* shows four different possible conditions and the basic flight envelope for a high performance glider.

Weight and Balance

Center of Gravity

Longitudinal balance affects the stability of the longitudinal axis of the glider. To achieve satisfactory pitch attitude handling in a glider, the CG of the properly loaded glider is forward of the center of pressure (CP). When a glider is produced, the manufacturer provides glider CG limitations, which require compliance. These limitations are generally found in the GFM/POH and may also be found in the glider airframe logbook. Addition or removal of equipment, such as radios, batteries, or flight instruments, or airframe repairs can have an effect on the CG position. Aviation maintenance technicians (AMTs) must record any changes in the weight and balance data in the GFM/POH or glider airframe logbook. Weight and balance placards in the cockpit must also be updated.

Problems Associated With CG Forward of Forward Limit

If the CG is within limits, pitch attitude control stays within acceptable limits. However, if the glider is loaded so the CG is forward of the forward limit, handling is compromised. The glider is said to be nose heavy. Nose heaviness makes it difficult to raise the nose on takeoff and considerable back pressure on the control stick is required to control the pitch attitude. Tail stalls occur at airspeeds higher than normal and are followed by a rapid nose-down pitch tendency. Restoring a normal flight attitude during stall recoveries takes longer. The landing flare is more difficult than normal, or perhaps even impossible, due to nose heaviness. Inability to flare could result in a hard nose-first landing.

The following are the most common reasons for CG forward of forward limit:

- Pilot weight exceeds the maximum permitted pilot weight.
- Seat or nose ballast weights are installed but are not required due to the weight of the pilot.

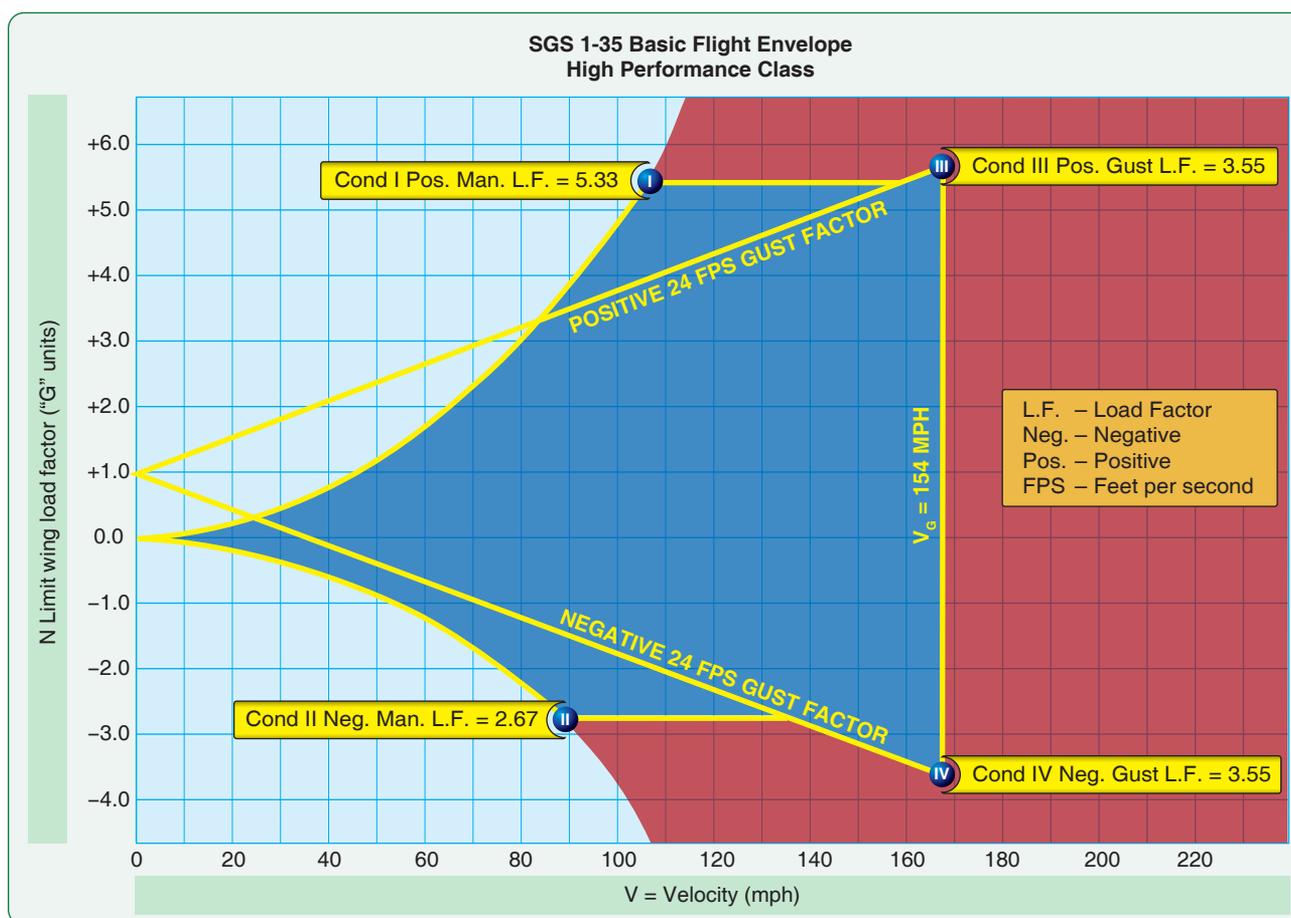


Figure 5-18. Typical example of basic flight envelope for a high-performance glider.

Problems Associated With CG Aft of Aft Limit

If the glider is loaded so the CG location is behind the aft limit, handling is compromised. The glider is said to be tail heavy. Tail heaviness can make pitch control of the glider difficult or even impossible.

The fundamental problem with a CG aft of the aft limit is the designed function of the horizontal stabilizer and elevator. Fixed wing aircraft are generally designed so that the horizontal stabilizer and elevator provide a down force to counter the slightly nose forward CG such that the aircraft tend to resume a level pitch attitude after an upset about the lateral axis. As the airspeed changes, the pilot changes the trim or trims the aircraft so the down force exactly balances the forward CG within limits. Should the aircraft be upset and the nose pitches upward, the resultant slower airspeed results in less down force produced by the horizontal stabilizer and elevator. This decreased down force lets the nose lower so the airspeed retains to the pre-upset value. This is called positive stability. Conversely, if the upset places the aircraft in a nose down attitude, the increased airspeed will increase the down force and raise the nose to the pre-upset balanced condition. However, if the control surface is in a stalled condition, this stabilizing action will not begin until the control surface regains un-stalled airflow and begins producing down force again.

The following are the most common reasons for flight with CG located behind permissible limits:

- Pilot weight is less than the specified minimum pilot seat weight and trim ballast weights necessary for the lightweight pilot are not installed in the glider prior to flight.
- Tailwheel dolly is still attached, far aft on the tailboom of the glider.
- Foreign matter or debris (water, ice, mud, sand, and nests) has accumulated in the aft fuselage of the glider and was not discovered and removed prior to flight.
- A heavy, non-approved tailwheel or tail skid was installed on the aft tail boom of the glider.

Sample Weight and 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 limitations.

In *Figure 5-19*, the chart indicates that the minimum weight for the front seat pilot is 125 pounds, and that the maximum is 250 pounds. It also indicates that the maximum rear seat pilot weight is 225 pounds. If each pilot weighs 150 pounds, the intersection of pilot weights falls within the envelope;

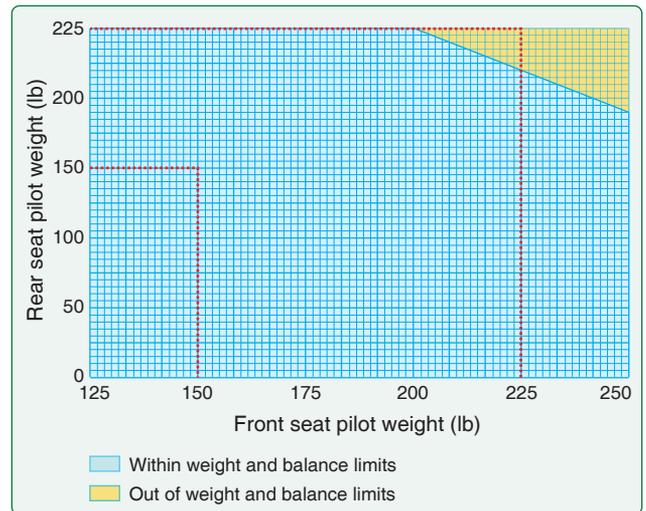


Figure 5-19. Weight and balance envelope.

the glider load is within the envelope and is safe for flight. If each pilot weighs 225 pounds, the rear seat maximum load is exceeded, and the glider load is outside the envelope and unsafe for flight.

The CG position can also be determined by calculation using the following formulas:

- $\text{Weight} \times \text{Arm} = \text{Moment}$
- $\text{Total Moment} \div \text{Total Weight} = \text{CG Position (in inches aft of the reference datum)}$

The computational method involves the application of basic math functions. The following is an example of the computational method.

Given:

Maximum gross weight.....	1,100 lb
Empty weight.....	600 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, $\text{weight} \times \text{arm} = \text{moment}$. To simplify calculations, the moments may be divided by 100.
3. Total the weight and moments.
4. To determine the CG, divide the moments by the weight.

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 5-20]

Item	Weight (pounds)	Arm (inches)	Moment (inch-pounds)
Empty weight	600	+20	12,000
Front seat pilot	180	+30	+5,400
Rear seat pilot	200	-5	-1,000
980 total weight		+16.73	+16,400 total moment

Figure 5-20. Weight and balance: front and rear seat pilot weights and moments.

In Figure 5-20, the weight of each pilot has been entered into the correct block in the table. For the front seat pilot, multiplying 180 pounds by +30 inches yields a moment of +5,400 inch-pounds. For the rear seat pilot, multiplying 200 pounds by -5 inches yields a moment of -1,000 inch-pounds. The next step is to find the sum of all weights (980 pounds) and record it. Then, find the sum of all moments (+16,400 inch-pounds) and record it. Now, find the arm (the CG position) of the loaded glider. Divide the total moment by the total weight to discover the CG of the loaded aircraft glider in inches from the datum:

$$+16,400 \text{ inch-pounds} \div 980 \text{ pounds} = +16.73 \text{ inches}$$

The final step is to determine whether total weight and CG location values are within acceptable limits. The GFM/POH lists the maximum gross weight as 1,100 pounds. The operating weight of 980 pounds is less than the 1,100 pounds maximum gross weight. The GFM/POH lists the approved CG range as between +14.80 inches and +18.60 inches from the datum. The operating CG is +16.73 inches from the datum and is within these limits. The weight and balance are within operating limits.

Ballast

Ballast is nonstructural weight that is added to a glider. In soaring, ballast weight is used for two purposes. Trim ballast is used to adjust the location of the CG of the glider so handling characteristics remain within acceptable limits. Performance ballast is loaded into the glider to improve high-speed cruise performance.

Removable trim ballast weights are usually made of metal and are bolted into a ballast receptacle incorporated in the glider structure. The manufacturer generally provides an attachment point well forward in the glider cabin for trim ballast weights. These weights are designed to compensate for a front seat pilot who weighs less than the minimum permissible front seat pilot weight. The ballast weight mounted well forward in the glider cabin helps place the CG within permissible limits, which allows the maximum shift in CG with the minimum addition of weight.

Some trim ballast weights are in the form of seat cushions, with sand or lead shot sewn into the unit to provide additional weight. This type of ballast, which is installed under the pilot's seat cushion, is inferior to bolted-in ballast because seat cushions tend to shift position. Seat cushion ballast should never be used during acrobatic or inverted flight.

Sometimes trim ballast is water placed in a tail tank in the vertical fin of the fuselage. The purpose of the fin trim ballast tank is to adjust CG location after water is added to, or drained from, the main wing ballast tanks. Unless the main wing ballast tanks are precisely centered on the CG of the loaded aircraft glider, CG location shifts when water is added to the main ballast tanks. CG location shifts again when water is dumped from the main ballast tanks. Adjusting the amount of water in the fin tank compensates for CG shifts resulting from changes in the amount of water ballast carried in the main wing ballast tanks. Water weighs 8.35 pounds per gallon. Because the tail tank is located far aft, it does not take much water to have a considerable effect on CG location. For this reason, tail tanks do not need to contain a large volume of water. Tail tank maximum water capacity is generally less than two gallons of water.

Although some older gliders employed bags of sand or bolted-in lead weights as performance ballast, water is used most commonly to enhance high-speed performance in modern sailplanes. Increasing the operating weight of the glider increases the optimum speed to fly during wings-level cruising flight. The resulting higher groundspeed provides a very desirable advantage in cross-country soaring and in sailplane racing.

Water ballast tanks are located in the main wing panels. Clean water is added through fill ports in the top of each wing. In most gliders, the water tanks or bags can be partially or completely filled, depending on the pilot's choice of operating weight. After water is added, the filler caps are replaced to prevent water from sloshing out of the filler holes.

Drain valves are fitted to the bottom of each tank. The valves are controlled from inside the cockpit. The tanks can be fully or partially drained while the glider is on the ground to reduce the weight of the glider prior to launch, if the pilot so desires. The ballast tanks also can be partially or completely drained in flight—a process called dumping ballast. The long streaks of white spray behind a speeding airborne glider are dramatic evidence that the glider pilot is dumping water ballast, most likely to lighten the glider prior to landing. The filler caps are vented to allow air to enter the tanks to replace the volume of water draining from the tanks. It is important to ensure that the vents are working properly to prevent wing damage when water ballast is drained or jettisoned. [Figures 5-21 and 5-22]



Figure 5-21. *Water ballast tank vented filler cap.*

It is important to 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 in-flight handling, as well as landings, more difficult. If the wing-heavy condition is extreme, it is possible the pilot will lose control of the glider.

Ballast drains should also be checked to ensure that water ballast drains properly into the airstream, rather than leaking into the fuselage and pooling in the bottom of the fuselage. Water that is trapped in the fuselage may flow through or over bulkheads, causing dislocation of the CG of the glider. This CG dislocation can lead to loss of control of the glider.

The flight manual provides guidance regarding the length of time it takes for the ballast tanks to drain completely. For modern gliders, it takes about 3 to 5 minutes to drain a full tank. When landing is imminent, dump ballast early enough to give the ballast drains sufficient time to empty the tanks.

Use of water ballast when ambient temperatures are low can result in water freezing the drain valve. If the drain valve

freezes, dumping ballast is difficult or impossible. If water in the wings is allowed to freeze, serious wing damage is likely to occur. Damage occurs because the volume of water expands during the freezing process. The resulting increased volume can deform ribs and other wing structures or cause glue bonds to delaminate. When weather or flight conditions are very cold, do not use water ballast unless antifreeze has been added to the water. Prior to using an antifreeze solution, consult the GFM to ensure that antifreeze compounds are 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.

Water ballast is routinely dumped 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.

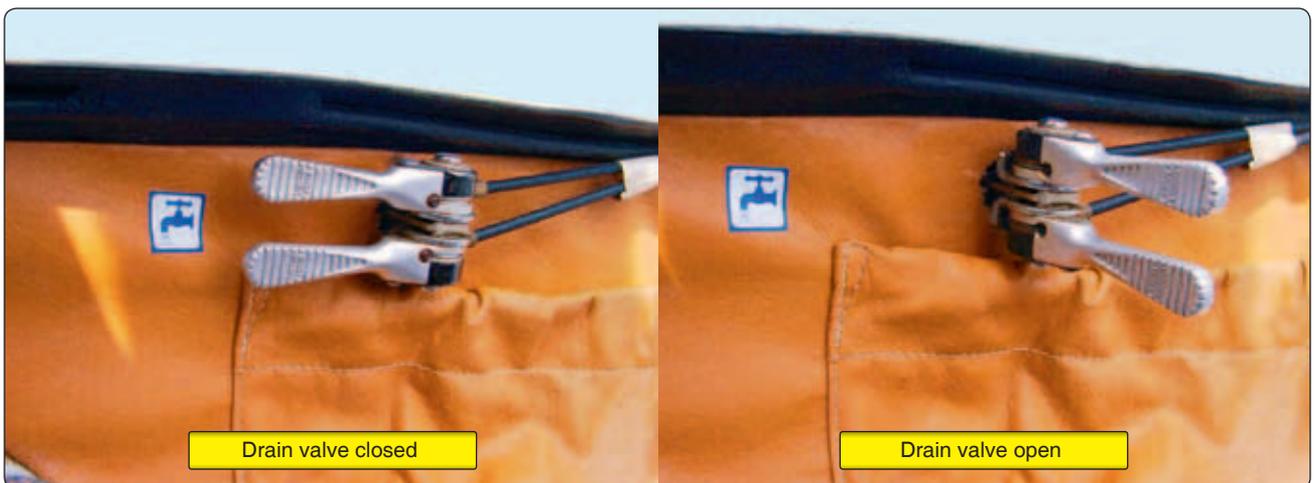


Figure 5-22. *Water ballast drain valve handles.*

- Reduces the load that glider structures must support during landing and rollout.

The performance advantage of water ballast during strong soaring conditions is considerable. However, there is a downside. The pilot should be aware that water 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 that safety of flight is not compromised.