Chapter 4: Flight Instruments

Introduction

Flight instruments provide information regarding the glider's direction, altitude, airspeed, and performance. Instruments can consist of a basic set typically found in training aircraft or a more advanced set in a high-performance glider used for cross-country or competition flying. Refer to the Pilot's Handbook of Aeronautical Knowledge (FAA-H-8083-25) for detailed descriptions of different instruments.

Instruments displaying airspeed, altitude, and vertical speed are part of the pitot-static system. Heading instruments display magnetic direction by sensing the earth's magnetic field. Performance instruments, using gyroscopic principles, display the aircraft's attitude, heading, and rate of turn. Electronic instruments using computer and global positioning system (GPS) satellite technology provide pilots with moving map displays, electronic airspeed and altitude, air mass conditions, and other functions relative to flight management. Examples of self-contained instruments and indicators that are useful to the pilot include the yaw string, inclinometer, and outside air temperature (OAT) gauge.

This chapter describes basic glider instruments and systems. Pilots flying gliders with advanced electronic instruments should consult the manufacturer's documentation for a complete description of operation and seek instruction as needed.

Pitot-Static Instruments

The pitot-static system uses two different air pressure measurements:

1. Static ports transport ambient atmospheric pressure to instruments through tubing.
2. The pitot tube transports ambient air pressure plus any ram air pressure resulting from forward motion to instruments through tubing.

Impact & Static Pressure Lines

Impact or ram-air pressure from the forward motion of the glider increases air pressure in the pitot tube, which mounts on either the nose or vertical stabilizer to allow uninterrupted exposure to the oncoming airflow. Glider static ports often mount either on the vertical stabilizer or the side of the fuselage. [*Figure 4-1*]

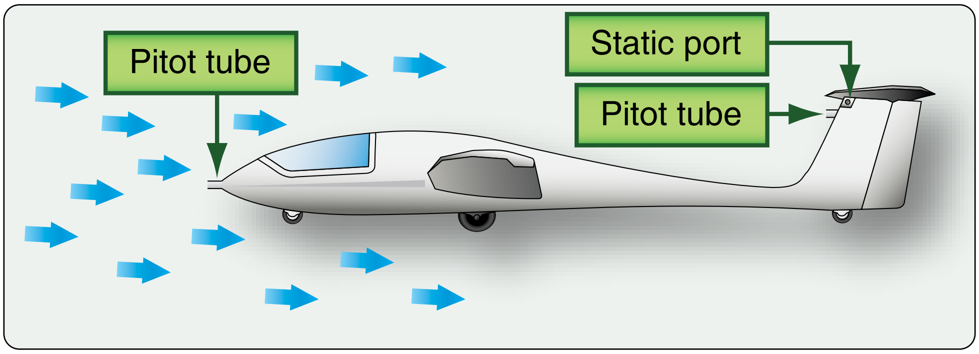


Figure 4-1. *A pitot tube often mounts in the glider's nose or the vertical fin, with the forward-facing open end exposed directly to the oncoming airflow.*

As airspeed increases, pressure builds in the pitot tube and in the connected expandable diaphragm. The pressure rises in the pitot tube and diaphragm until it reaches a state of equilibrium preventing any further rise in pressure. Conversely, pressure in the system decreases as airspeed decreases since air can also flow out of the system. [*Figure 4-2*]

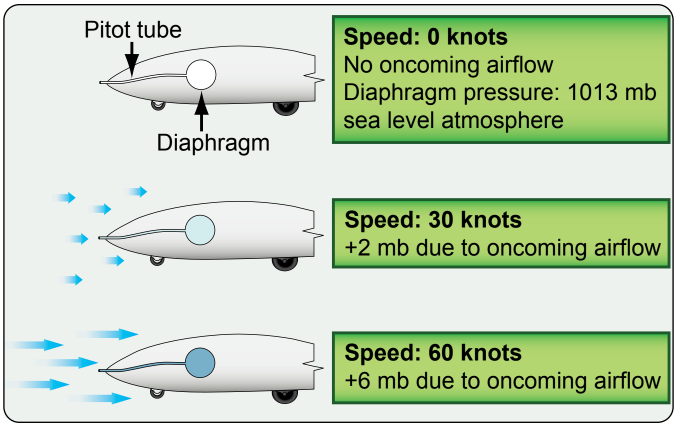


Figure 4-2. *Pressure inside the diaphragm as a function of airspeed.*

The static pressure (pressure of the still air) comes from the movement of air in and out of the static ports and tubing. Gliders using flush mounted static sources often have two vents, one on each side of the fuselage. This compensates for variation of static pressure due to changes in glider attitude and air turbulence.

Pilots check the openings of both the pitot tube and the static port(s) during the preflight inspection to ensure obstructions do not block the free flow of air. A certificated mechanic should clean any blockage. Blowing into these openings could damage flight instruments.

Airspeed Indicator

The airspeed indicator measures the difference between the pitot pressure and static pressure, and displays this difference as the indicated airspeed (IAS) of the glider. [*Figure 4-3*] Color-coded arcs depict airspeed ranges for different phases of flight. The upper and lower limits of the arcs correspond to defined airspeeds. *Figure 4-4* shows the internal structure of an airspeed indicator.

Figure 4-3. *Airspeed indicator.*

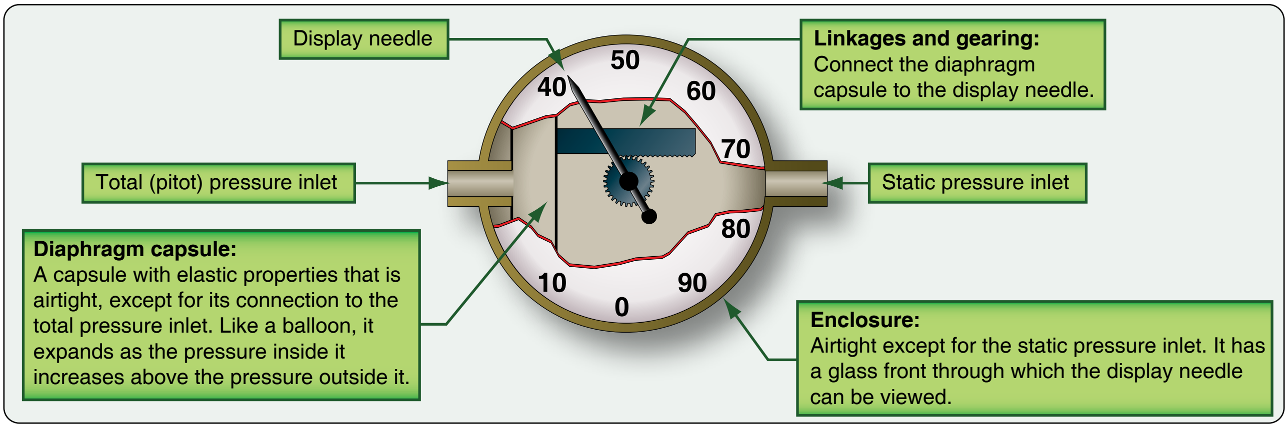


Figure 4-4. *Anatomy of the airspeed indicator.*

As shown in *Figure 4-4* above, the airspeed indicator contains a diaphragm that expands or contracts in response to the difference between pitot and static pressure. This diaphragm movement drives the needle (airspeed needle pointer) on the face of the instrument. When pitot pressure equals static pressure, the indicator reads zero. As pitot pressure becomes progressively greater than static pressure, the needle moves and points to the corresponding airspeed. [*Figure 4-5*]

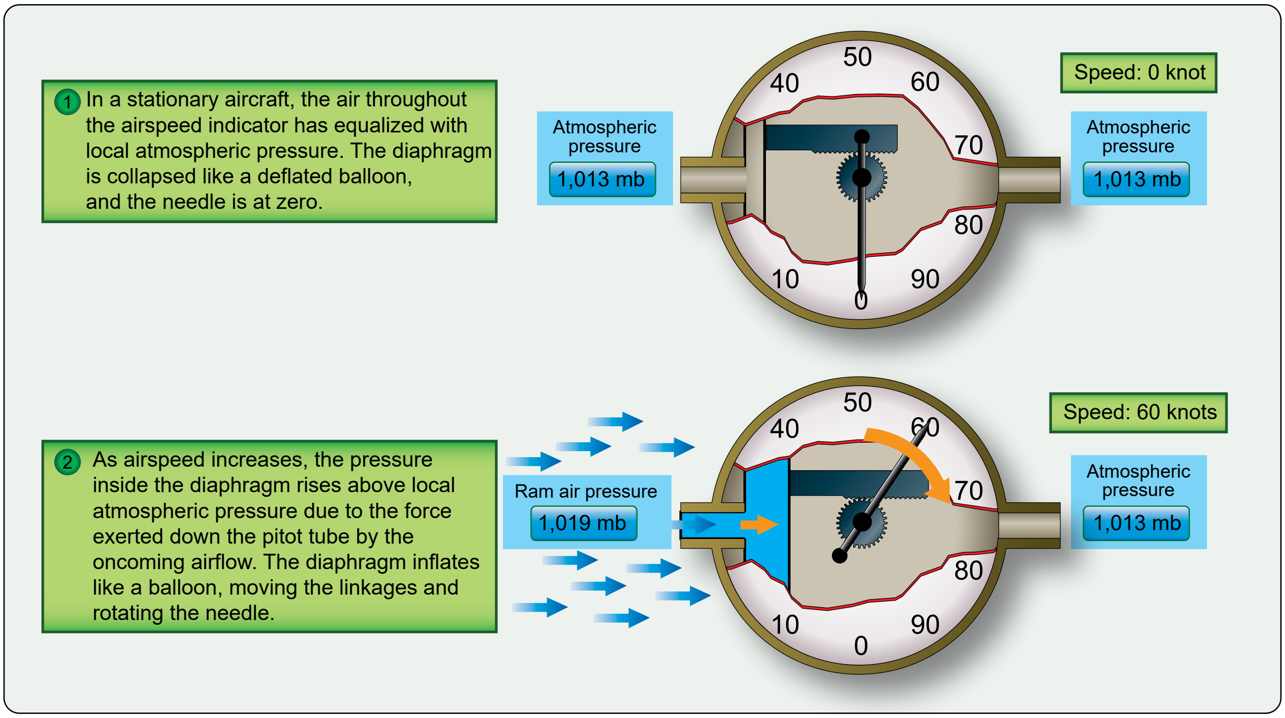


Figure 4-5. *Airspeed indicator operation.*

The Effects of Altitude on the Airspeed Indicator

The airspeed indicator displays dynamic pressure (pitot pressure minus static pressure) calibrated to an airspeed at standard sea-level pressure. Due to lower air density as altitude increases, the buildup of pressure in the diaphragm decreases and the indication becomes lower than at sea level. The error becomes greater as altitude increases. [*Figure 4-6*]

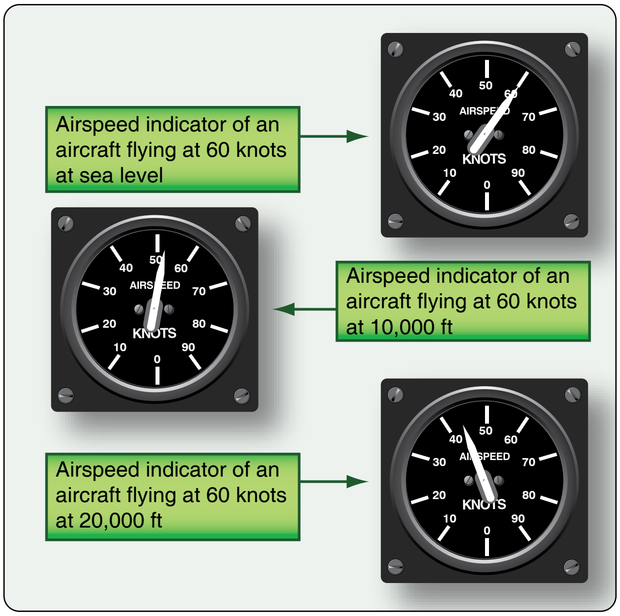
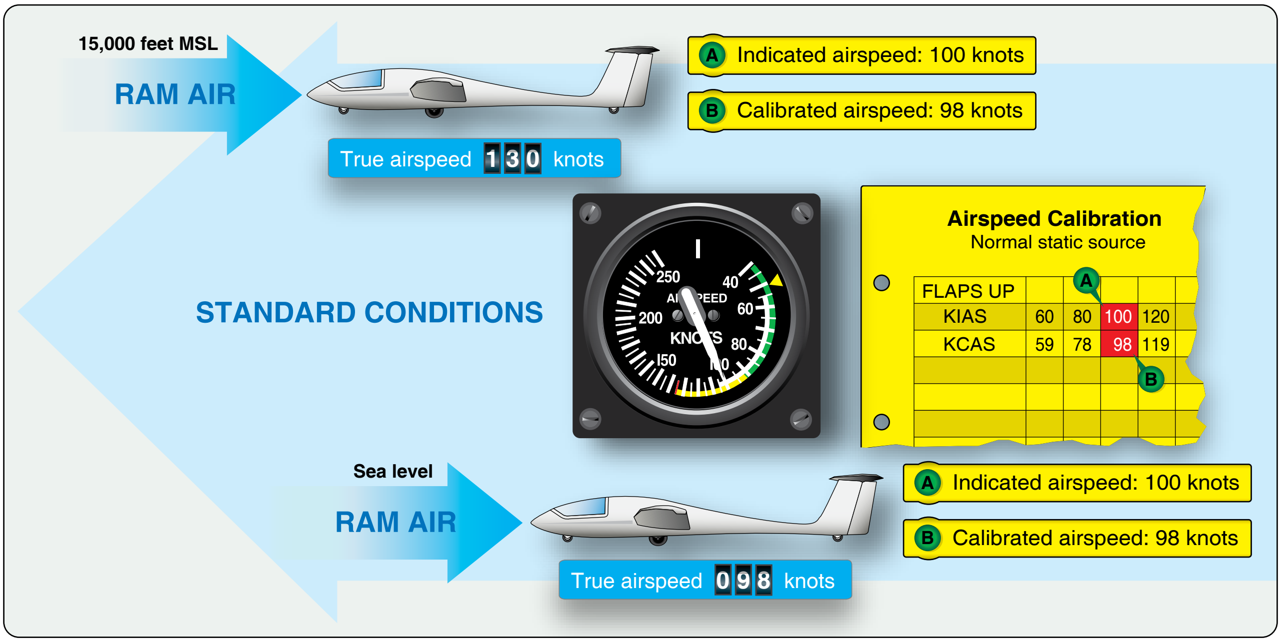


Figure 4-6. *Effects of altitude on the airspeed indicator.*

Types of Airspeed

Pilots work with various airspeed numbers including indicated airspeed (IAS), calibrated airspeed (CAS), and true airspeed (TAS). [*Figure 4-7*]



Airspeed Calibration
Normal static source

FLAPS UP			A	
KIAS	60	80	100	120
KCAS	59	78	98	119
			B	

Figure 4-7. *Three types of airspeed.*

Indicated Airspeed (IAS)

The pilot reads the IAS directly from the airspeed indicator, uncorrected for installation error or instrument error. Although air density affects indicated airspeed, a particular glider in steady wings-level flight at a fixed weight stalls at a specific dynamic pressure (indicated airspeed) regardless of the air density. [*Figure 4-8*]

Altitude center vertically	IAS at which stall occurs in steady wings-level flight	True airspeed (TAS)
1,000 feet	40 knots	41 knots
10,000 feet	40 knots	48 knots
20,000 feet	40 knots	56 knots
30,000 feet	40 knots	64 knots
40,000 feet	40 knots	72 knots

Figure 4-8. *Indicated stall airspeeds and true airspeeds at various altitudes.*

Calibrated Airspeed (CAS)

CAS corrects IAS for installation and instrument errors. Significant errors may occur at low airspeeds. At cruising and higher airspeed ranges, IAS and CAS differences become small.

Pilots should refer to the airspeed calibration chart to correct for possible airspeed errors because airspeeds, such as those found on the color-coded face of the airspeed indicator, on placards, or in the Glider Flight Manual or Pilot's Operating Handbook (GFM/POH), usually reflect CAS. Some manufacturers use IAS rather than CAS to denote the airspeeds.

Dirt, dust, ice, or snow collecting at the pitot tube opening may obstruct air passage and prevent correct indications. Degradation due to age and vibration may also affect the sensitivity of the diaphragm. Therefore, airspeed indicators should undergo periodic calibration.

True Airspeed (TAS)

TAS is the actual speed at which the aircraft moves through the air. In still air, TAS equals the actual speed over the ground. However, the airspeed indicator only indicates TAS under standard atmospheric conditions at sea level (29.92 inches of mercury ("Hg) and 15°C). At a constant IAS, TAS increases as the glider climbs because air density decreases with an increase of altitude.

The airspeed indicator provides a convenient means to manage most flight parameters since it indicates dynamic pressure. If the airspeed indicator did display TAS, the pilot would need to use a quick reference card to look up the stall speed, best L/D speed, and minimum sink speed for the current altitude while trying to fly. Fortunately, the pilot only needs to remember one set of numbers for most parameters. For example, *Figure 4-8* illustrates that for each glider, the pilot need only remember one stall speed for all altitudes.

A pilot can determine TAS by two methods. The first and more accurate method involves using a flight computer. In this method, the pilot corrects the CAS for temperature and pressure variation using the airspeed correction scale on the computer. The second method approximates TAS by increasing the current IAS by 2 percent for every 1,000 feet above sea level.

Airspeed Indicator Markings

Gliders manufactured after 1945 have airspeed indicators that conform to a standard color-coded marking system. [*Figure 4-3*] This system enables the pilot to determine important airspeed information quickly. For example, the green arc represents the normal operating range, while the yellow arc represents the caution range. A pilot who notes an airspeed needle in the yellow arc and rapidly approaching the red line while maneuvering should immediately take corrective action to reduce the airspeed. In this case, the pilot should use smooth control pressure at high airspeeds to avoid unsafe stress on the glider structure.

A description of the standard markings on an airspeed indicator follows:

- The white arc—flap operating range.

- The lower limit of the white arc—stalling speed in the landing configuration.

- The top of the white arc—maximum speed for use of full flaps. If flaps are operated at higher airspeeds, severe strain or structural failure could result.

- The lower limit of the green arc—stalling speed with the wing flaps and landing gear retracted.

- The upper limit of the green arc—maximum structural cruising speed. This is the maximum speed for normal operations.

- The yellow arc—caution range. The pilot should avoid speeds within this area unless in smooth air.

- The red line—never-exceed speed. This is the maximum speed at which the glider can be operated in smooth air. This pilot should never intentionally exceed this speed.

Effect of Altitude on V_{NE}

The never-exceed speed (V_{NE}) decreases with increased altitude due to the possibility of flutter at higher true airspeeds. At high altitudes maintaining a speed at or below the red line may exceed actual V_{NE}. Since the decrease in V_{NE} varies by model, the flight manual may include a table, such as the one shown in *Figure 4-9*, that documents the decrease in V_{NE} with altitude. At high true airspeeds during a rapid descent, the glider structure could suddenly flutter and break apart. Glider manufacturers test for flutter and adherence to V_{NE} speeds published in the flight manual for the specific make and model should prevent it.

Altitude (in feet)	V_{NE} (IAS in knots)
Up to 6,500	135
10,000	128
13,000	121
16,500	115

Figure 4-9. *IAS corresponding to V_{NE} decreases with altitude.*

Other Airspeed Limitations

Placards in the view of the pilot may display other important airspeed limitations not marked on the face of the airspeed indicator. [Figure 4-10]

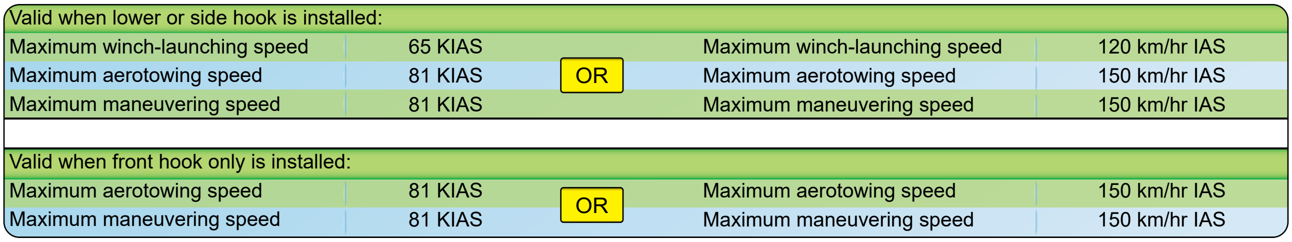
- Maneuvering speed (V~A)—— a structural design
- airspeed used in determining the strength requirements for the glider and its control surfaces. The structural design requirements do not cover multiple inputs in one axis or control inputs in more than one axis at a time at any speed, even below V~A. If encountering rough air or severe turbulence during flight, the pilot should reduce airspeed to maneuvering speed or less to prevent exceeding structural limits. Maneuvering speed varies with the weight of the glider and does not appear as a specific airspeed on the airspeed indicator. For gliders with a published rough airspeed limitation (V~B), the pilot should keep below that speed in rough air to accommodate maximum gust intensity.

- Landing gear operating speed (V~LO)—maximum speed for extending or retracting the landing gear if using a glider equipped with retractable landing gear.

- Minimum sink speed—airspeed that results in the least amount of altitude loss over a given time, or
- which maximizes the altitude gain when taking advantage of rising air.

- Best glide speed—airspeed that results in the least amount of altitude loss over a given distance, not considering the effects of wind.

- Maximum aerotow or ground launch speed—maximum airspeed for tow without exceeding design specifications.



Valid when lower or side hook is installed:				
Maximum winch-launching speed	65 KIAS	OR	Maximum winch-launching speed	120 km/hr IAS
Maximum aerotowing speed	81 KIAS		Maximum aerotowing speed	150 km/hr IAS
Maximum maneuvering speed	81 KIAS		Maximum maneuvering speed	150 km/hr IAS

Valid when front hook only is installed:				
Maximum aerotowing speed	81 KIAS	OR	Maximum aerotowing speed	150 km/hr IAS
Maximum maneuvering speed	81 KIAS		Maximum maneuvering speed	150 km/hr IAS

Figure 4-10. *Sample speed limitation placards placed in a glider and in view of the pilot.*

Altimeter

The altimeter measures the static air pressure of the surrounding air. Tubing connects the altimeter static pressure inlet to the static port holes located on the side of the glider. [*Figure 4-11*]

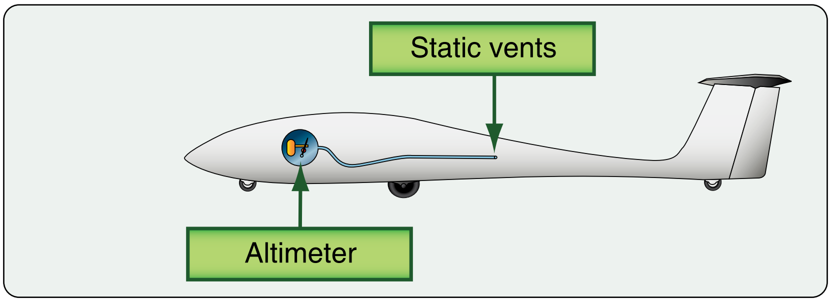
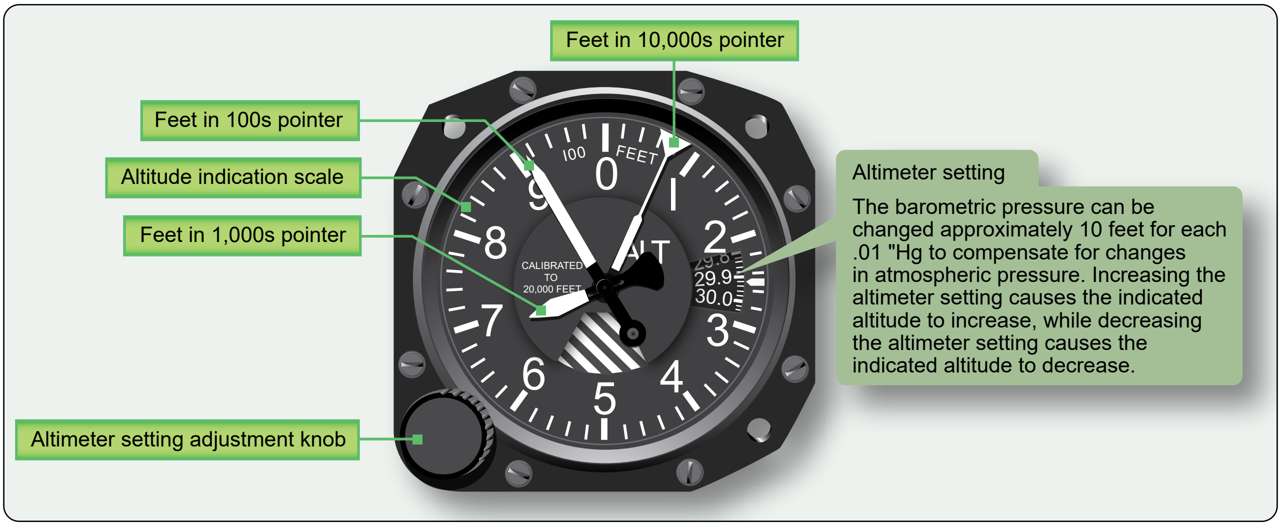


Figure 4-11. *Static vents and altimeter plumbing.*

If using the local altimeter setting (the local pressure corrected to sea level), the altimeter indicates the glider's current height above mean sea level (MSL). [*Figure 4-12*] Subtracting the ground elevation from current MSL altitude gives the height above ground.



The barometric pressure can be changed approximately 10 feet for each .01 "Hg to compensate for changes in atmospheric pressure. Increasing the altimeter setting causes the indicated altitude to increase, while decreasing the altimeter setting causes the indicated altitude to decrease.

Figure 4-12. *Altimeter.*

The weight of a column of air above a given location creates atmospheric pressure. At sea level, an overlying column of air exerts a force equivalent to 14.7 pounds per square inch, 1013.2 mb, or 29.92 inches of mercury under standard conditions. At a higher altitude, the shorter overlying column of air weighs less and exerts less pressure. Therefore, atmospheric pressure decreases with altitude. At 18,000 feet, atmospheric pressure drops to approximately half that at sea level. [*Figure 4-13*]

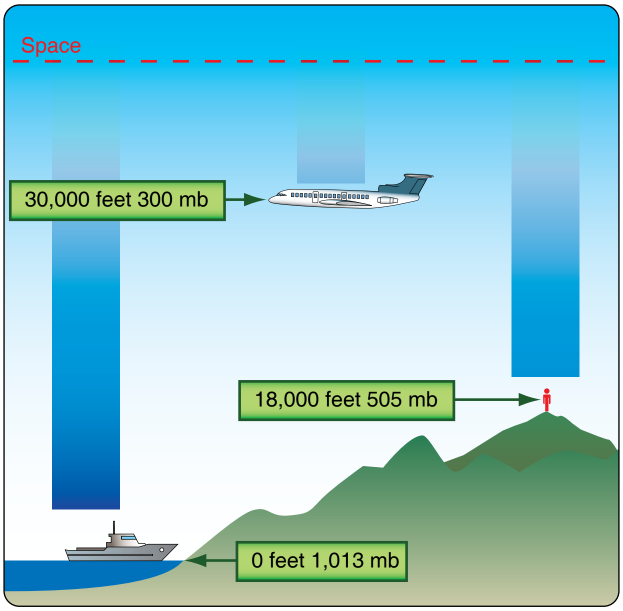
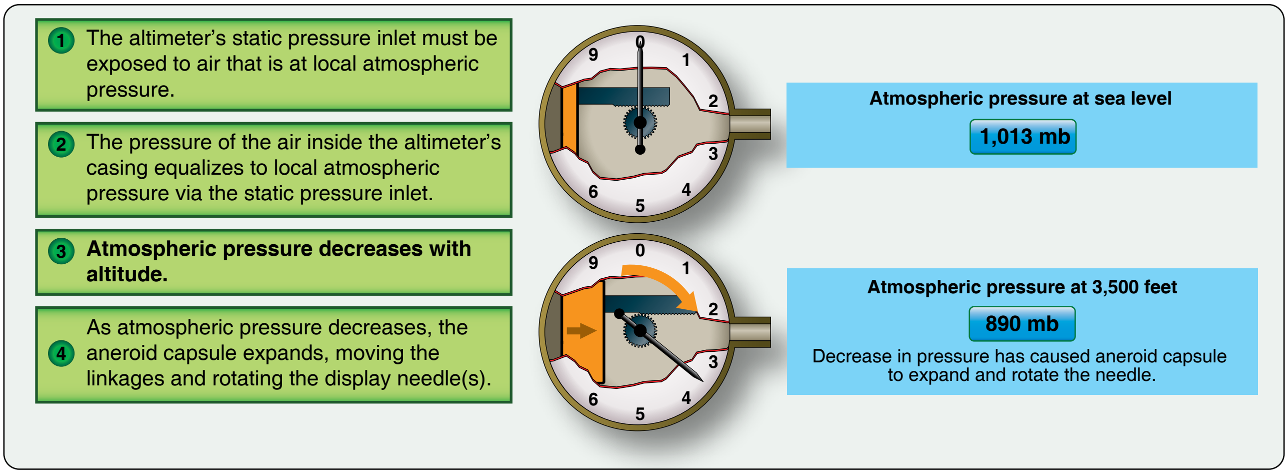


Figure 4-13. *Atmospheric pressure and altitude.*

Principles of Operation

The altimeter works like an aneroid barometer that measures atmospheric pressure at the current elevation except that the altimeter indicates pressure in feet. The altimeter indicates changes in altitude during a climb or descent as atmospheric pressure changes. *Figure 4-14* and *Figure 4-15* illustrate how the altimeter functions. Some altimeters have one pointer while others have more.



① The altimeter's static pressure inlet must be exposed to air that is at local atmospheric pressure.

② The pressure of the air inside the altimeter's casing equalizes to local atmospheric pressure via the static pressure inlet.

③ **Atmospheric pressure decreases with altitude.**

④ As atmospheric pressure decreases, the aneroid capsule expands, moving the linkages and rotating the display needle(s).

Atmospheric pressure at sea level

1,013 mb

Atmospheric pressure at 3,500 feet

890 mb

Decrease in pressure has caused aneroid capsule to expand and rotate the needle.

Figure 4-14. *How the altimeter functions.*

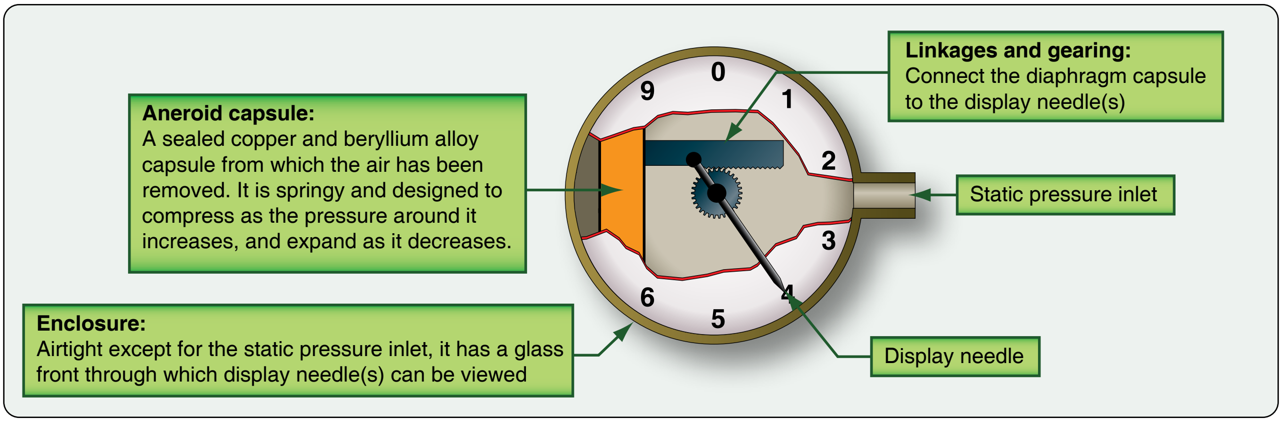


Figure 4-15. *Inside the altimeter.*

The markings on the dial of a typical altimeter include numerals arranged clockwise from 0 to 9 inclusive, as shown in *Figure 4-12*. When the surrounding pressure changes, the expansion or contraction of the aneroid element moves the hands through a gear train. The hands sweep the calibrated dial to indicate altitude. In the altimeter with three hands shown in *Figure 4-12*, the thinnest hand with an end shaped like a triangle indicates altitude in tens of thousands of feet; the shortest pointed hand indicates thousands of feet; and the long pointed hand indicates hundreds of feet, subdivided into 20-foot increments.

Types of Altitude

Altitude corresponds to a vertical distance above some point or level used as a reference. Altitude measured from different reference levels serves different purposes. [*Figure 4-16*]

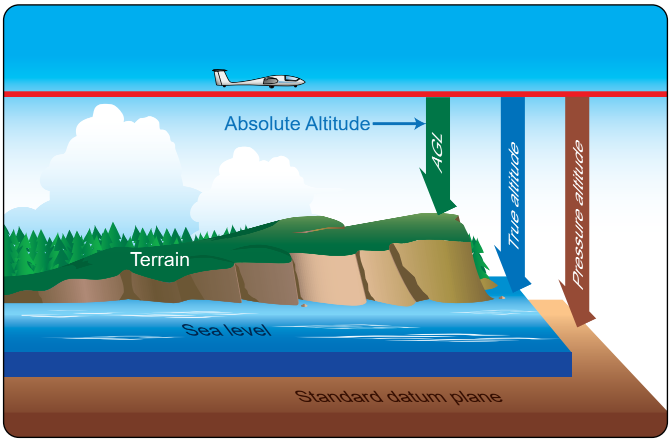


Figure 4-16. *Types of altitude.*

Glider pilots should understand the following altitudes:

- Indicated altitude—altitude read directly from the altimeter. During preflight, the pilot should set the altimeter to the current local altimeter setting. If the indicated altitude deviates from the known field elevation by ±75 feet or more, the pilot should not fly and refer the altimeter to an appropriately rated repair station for evaluation and correction. The pilot can use indicated altitude for terrain and obstacle clearance. However, true altitude and indicated altitude may differ depending on pressure and temperature conditions.

- True altitude—the vertical distance of the glider above sea level in standard atmospheric conditions (known as MSL often expressed in this manner: 10,900 feet MSL, 5,280 feet MSL, or 940 feet MSL). Airport, terrain, and obstacle elevations found on aeronautical charts are expressed as MSL (true altitudes).

- Pressure altitude—altitude indicated with the altimeter setting adjusted to 29.92. The pressure altitude corresponds to the height above the standard datum plane, a theoretical plane where air pressure equals 29.92 inHg. Pilots use pressure altitude for computer solutions to determine density altitude, true altitude, and TAS, etc. When flying in class A airspace, pilots set the altimeter to 29.92.

- Density altitude —pressure altitude corrected for nonstandard temperature variations. In standard conditions, pressure altitude equals density altitude. In temperatures above standard, the density exceeds pressure altitude. With temperatures below standard, the density altitude is less than pressure altitude. The density altitude determines the glider's performance and affects the power output of a tow plane or self-launching glider.

- Absolute altitude—vertical distance above the terrain, above ground level (AGL). The pilot can use absolute altitude to estimate gliding distance over terrain without benefit of lift.

Effect of Nonstandard Pressure

On a flight made from a high-pressure area to a low-pressure area without adjusting the altimeter, the glider descends if the pilot maintains a given indicated altitude. When flying from a low-pressure area to a high-pressure area without adjusting the altimeter, the glider climbs if the pilot maintains a given indicated altitude. The pilot adjusts for this phenomenon by setting the altimeter. A correctly set altimeter provides an appropriate amount of vertical separation between aircraft at different cruising altitudes and can help prevent mid-air collisions. It also allows a more accurate absolute altitude computation, which gives a glider pilot the ability to determine gliding distance more precisely.

Setting the Altimeter

To adjust the altimeter for nonstandard pressure, the pilot sets the pressure scale in the altimeter window (Kollsman window) to the given local altimeter setting or to the field elevation. Altimeter settings correspond to station pressure reduced to sea level, expressed in inches of mercury.

A reporting station takes an hourly measurement of the atmospheric pressure and corrects this value to sea-level pressure. These altimeter settings reflect height above sea level only near the reporting station. When flying below 18,000 feet MSL, the pilot should re-adjust the altimeter as the flight progresses from one station to the next. When flying at or above 18,000 feet MSL, the pilot sets the altimeter to 29.92.

When flying over high mountainous terrain, certain atmospheric conditions can cause the altimeter to indicate an altitude of 1,000 feet or more above the true altitude. For this reason, the pilot should fly with a margin of increased altitude—not only for possible altimeter error, but also for downdrafts, which may occur if encountering high winds.

A cross-country flight from TSA Gliderport, Midlothian, Texas, to Winston Airport, Snyder, Texas, via Stephens County Airport, Breckenridge, Texas, illustrates the use of altimeter settings. Before launch from TSA Gliderport, the pilot receives the current local altimeter setting of 29.85 and adjusts the altimeter to this value. The indication varies slightly from the known airport elevation of 660 feet due to a slight altimeter calibration error.

When over Stephens County Airport, the pilot receives a current area altimeter setting of 29.94 and applies this setting to the altimeter. Before entering the traffic pattern at Winston Airport, the pilot receives a new altimeter setting of 29.69 from the Automated Weather Observing System (AWOS). If the pilot desires to enter the traffic pattern at approximately 1,000 feet above the terrain, and if the field elevation of Winston Airport is 2,430 feet MSL, the pilot should use an indicated altitude of 3,400 feet.

2,430 feet + 1,000 feet = 3,430 feet, rounded to 3,400 feet

For illustration, assume a distraction caused the pilot to neglect the adjustment for the Winston Airport altimeter setting and to continue using the Stephens County Airport setting of 29.94. The pattern entry would occur approximately 250 feet below the Winston Airport's traffic pattern altitude of 3,400 feet and the altimeter would indicate approximately 2,680 feet upon landing or 250 feet higher than the field elevation.

Actual altimeter setting = 29.94

Correct altimeter setting = 29.69

Difference = .25

One inch of pressure is equal to approximately 1,000 feet of altitude.

.25 × 1,000 feet = 250 feet

In this scenario, the pilot, although low, might fly a successful visual approach angle to the landing zone. The pilot should adjust the visual angle to the landing zone to compensate for the lower altitude. However, risk of an accident increases due to the incorrect pattern entry altitude. For example, the glider might strike an obstacle in the flight path if not seen by the pilot. If the pilot does not reset the altimeter, the following memory aid illustrates what can happen "From a high to a low—look out below."

Effect of Nonstandard Temperature

Variations in air temperature also affect the altimeter. On a warm day, air weighs less per unit volume than on a cold day. For example, the pressure level at which the altimeter indicates 10,000 feet occurs at a higher altitude on a warm day than under standard conditions. On a cold day, the 10,000-foot indication moves lower. The adjustment made by the pilot to compensate for nonstandard pressure does not compensate for nonstandard temperature. If considering terrain or obstacle clearance during the selection of a cruising true altitude, particularly at higher altitudes, the pilot should consider this effect. Colder than standard temperature places the glider closer to the ground for a given true altitude, and the pilot should use a higher altitude to provide adequate terrain clearance. [*Figure 4-17*]

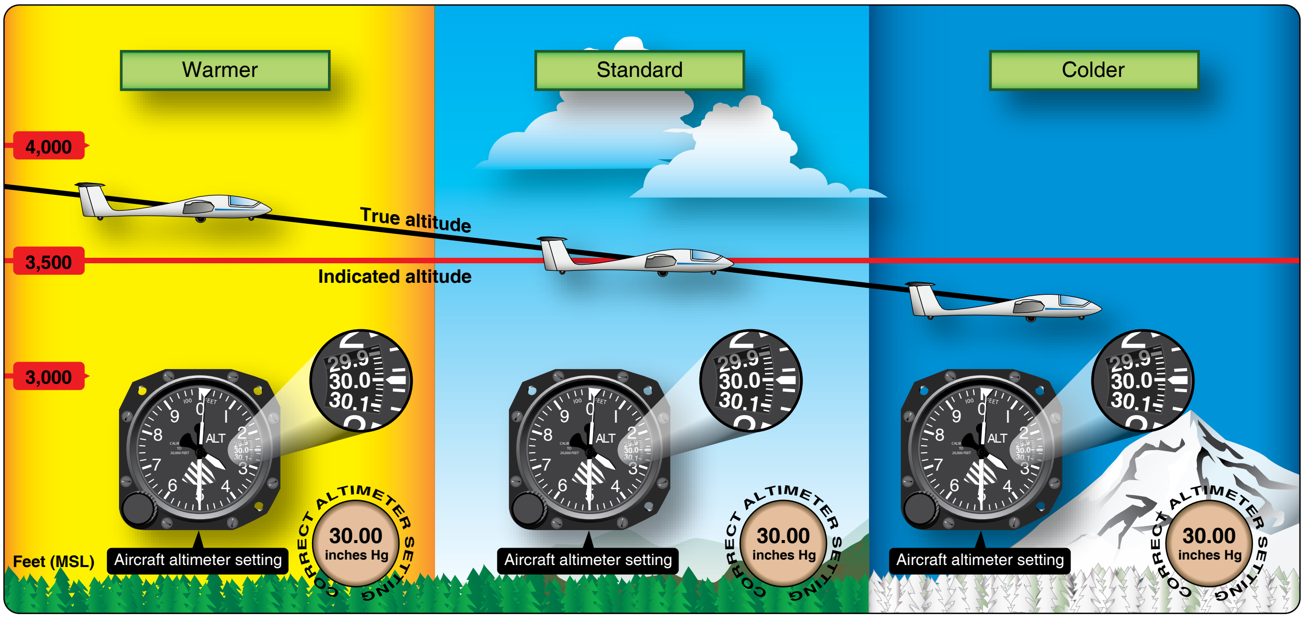


Figure 4-17. *Nonstandard pressure and temperature.*

Variometer

Variometer instruments measure the vertical ascent or descent of the local air mass and glider combined and display that information as vertical speed. The variometer can be considered a simple flow meter measuring air flowing between an outside reference (static or total energy port) and an internal reference flask. The variometer depends upon the pressure lapse rate in the atmosphere to derive information about rate of climb or rate of descent. A non-electric variometer uses a separate insulated tank (thermos or capacity flask) as a reference chamber to increase sensitivity and accuracy of the instrument. The tubing runs from the reference chamber through the variometer instrument to an outside static port in an uncompensated variometer. [*Figure 4-18* and *4-19*]

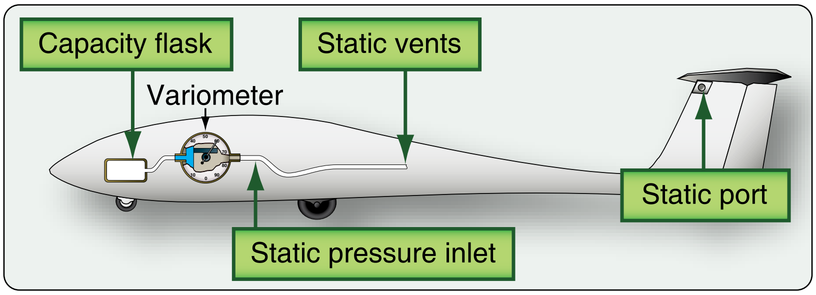


Figure 4-18. *Uncompensated variometer plumbing.*

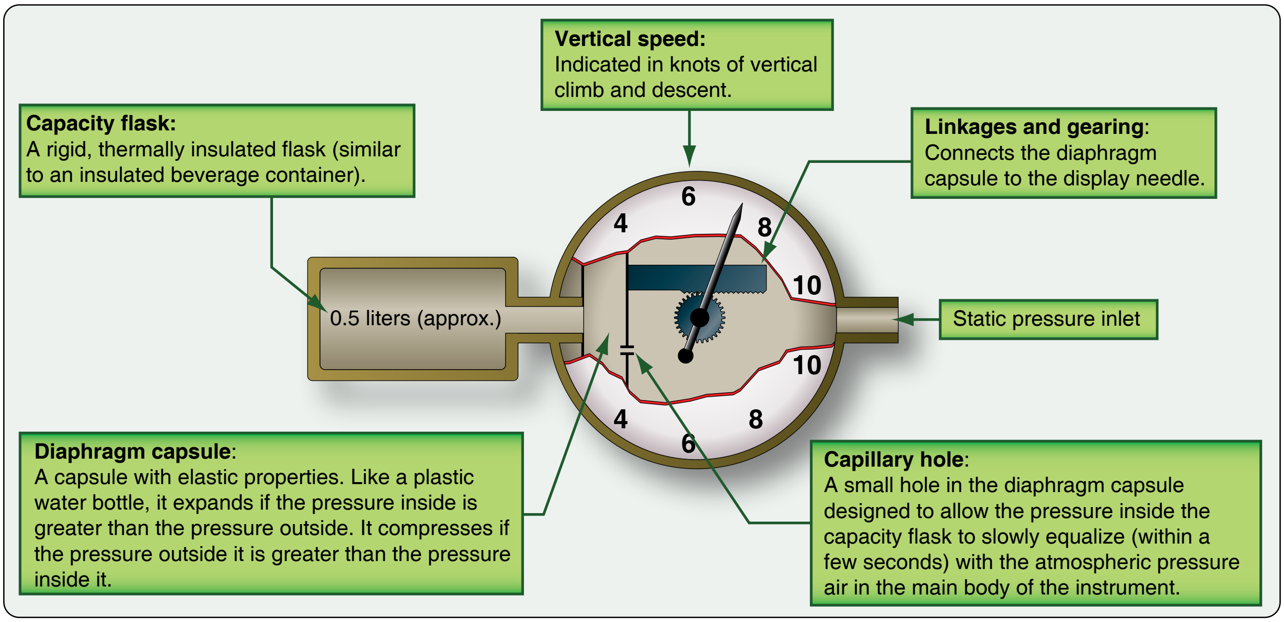
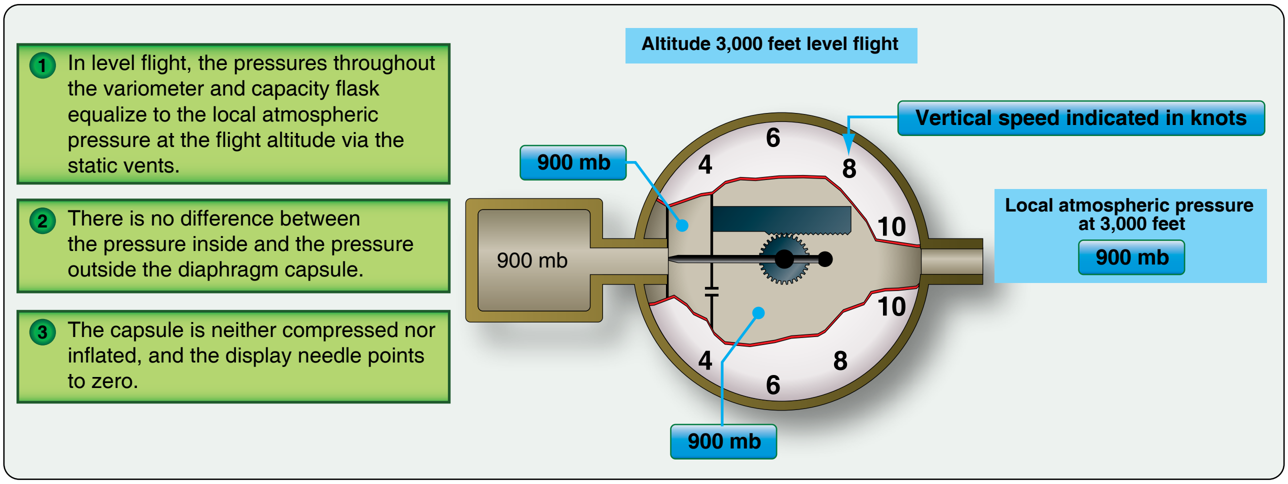


Figure 4-19. *A variometer diaphragm anatomy.*

Pressure differences between the air inside the variometer/reference chamber system and the air outside of the system tend to equalize as air flows from high-pressure areas to low-pressure areas. When pressure inside the reference chamber exceeds the pressure outside, air flows out of the reference chamber through the mechanical variometer to the outside environment, and the variometer indicates a climb. When air pressure outside the reference chamber exceeds the pressure inside, air flows through the variometer and into the reference chamber until pressure equalizes. In this case, the variometer needle indicates conditions that force the glider to lose height, *Figures 4-20* and *4-21* illustrate how the variometer works in level flight and while the glider ascends. In addition, *Figure 4-22* illustrates certain flight maneuvers that cause the variometer to display changes in altitude.

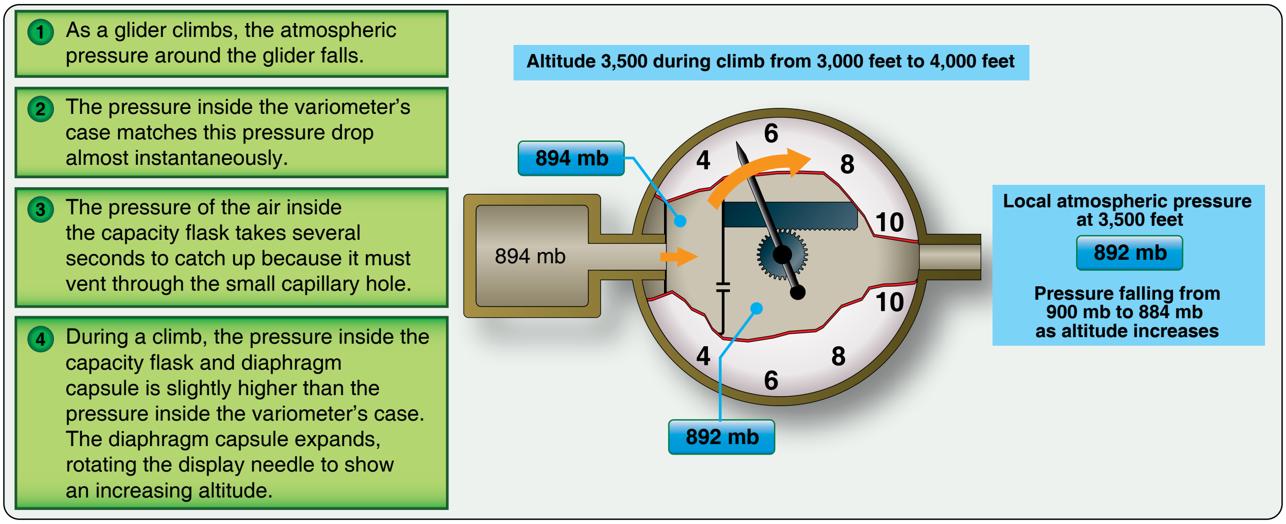


① In level flight, the pressures throughout the variometer and capacity flask equalize to the local atmospheric pressure at the flight altitude via the static vents.

② There is no difference between the pressure inside and the pressure outside the diaphragm capsule.

③ The capsule is neither compressed nor inflated, and the display needle points to zero.

Figure 4-20. *Uncompensated variometer in level flight.*



① As a glider climbs, the atmospheric pressure around the glider falls.

② The pressure inside the variometer's case matches this pressure drop almost instantaneously.

③ The pressure of the air inside the capacity flask takes several seconds to catch up because it must vent through the small capillary hole.

④ During a climb, the pressure inside the capacity flask and diaphragm capsule is slightly higher than the pressure inside the variometer's case. The diaphragm capsule expands, rotating the display needle to show an increasing altitude.

Figure 4-21. *Uncompensated variometer in a climb.*

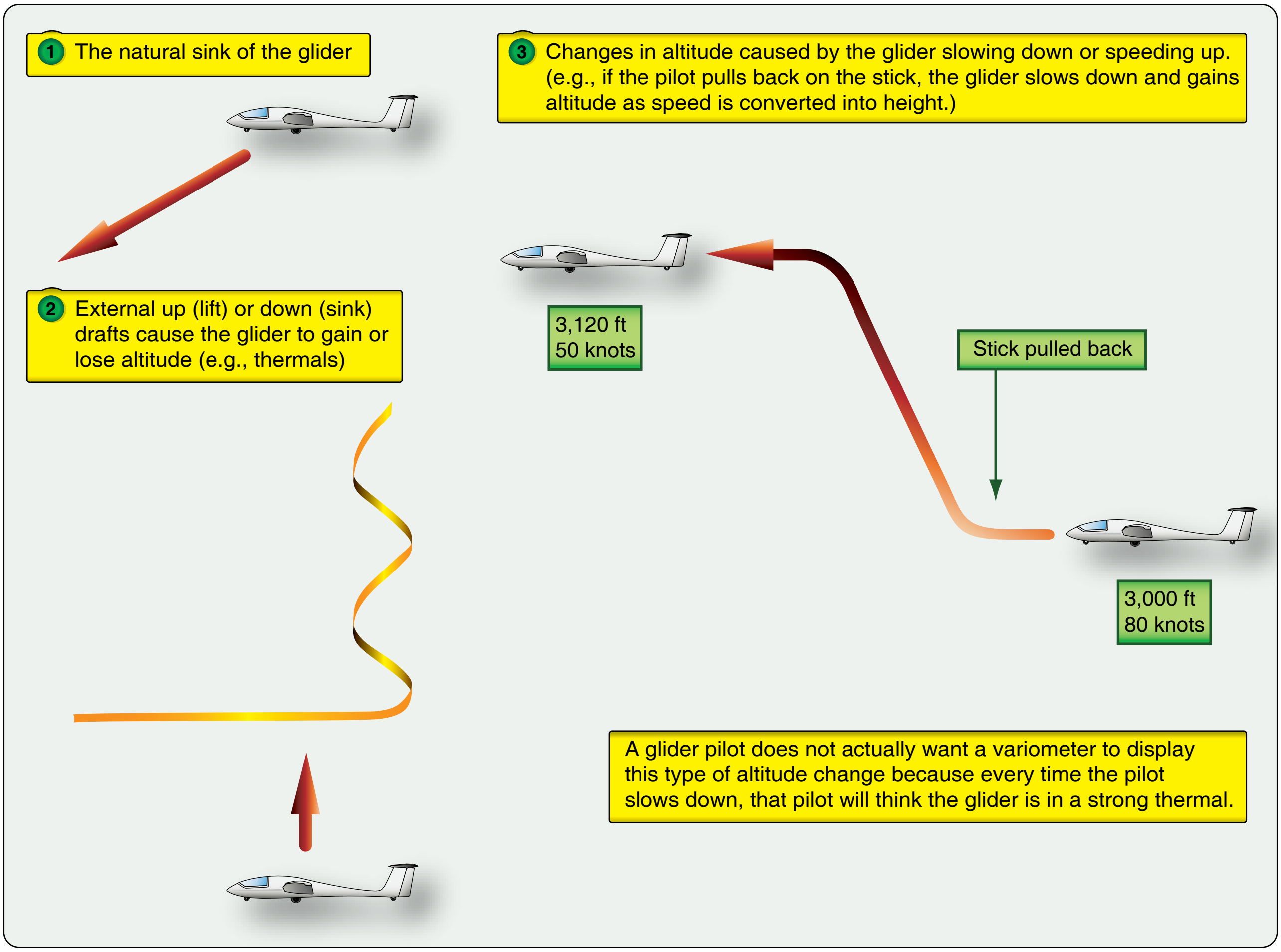


Figure 4-22. *Flight maneuvers that display altitude changes on an uncompensated variometer.*

Electric-powered variometers offer several advantages over the non-electric variety. These advantages include more rapid response rates and separate audible signals for climb and descent.

Some electric variometers use special sensors. As air flows into or out of the reference chamber, it cools sensors in a circuit and alters the electrical resistance measured by the system. The resulting change in resistance corresponds to the rate of climb or descent. The system displays that information on the variometer.

Many electric variometers provide audible tones, or beeps, that indicate the rate of climb or rate of descent of the glider. Pilots using an audio variometer can listen for the rate of climb or descent, which allows more time to focus attention outside the aircraft. [*Figure 4-23*]

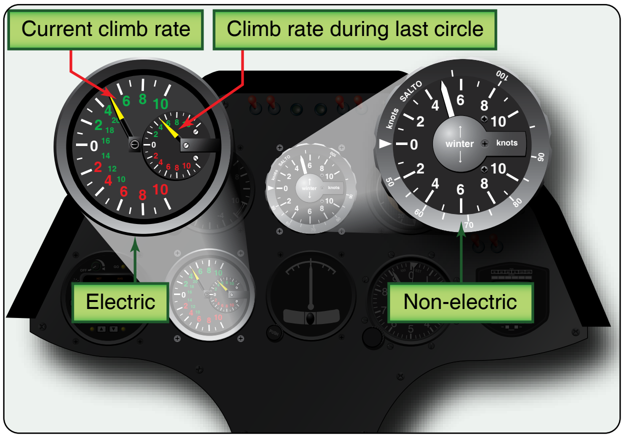


Figure 4-23. *When an electric variometer is mounted to the glider, installation of a non-electric variometer can provide a backup.*

In the past, some variometers had a rotatable rim speed scale called a MacCready ring. This scale indicates the optimum airspeed to fly when traveling between thermals for maximum cross-country performance. During the glide between thermals, the pilot sets the index arrow to the rate of climb expected in the next thermal. On the speed ring, the variometer needle points to the optimum speed to fly between thermals. If the pilot expects a low rate of climb, the instrument selects a lower optimum speed between thermals. When the pilot expects strong lift at the next thermal, the instrument suggests a faster optimum cruise airspeed. [*Figure 4-24*] A MacCready ring has single pilot values, values with a passenger, and may also adjust for ballast since more weight results in higher gliding speeds. Electronic instrument displays have become more common than Macready rings.

Figure 4-24. *The MacCready ring.*

Pilot induced climbs and dives result in changes in airspeed and affect an uncompensated variometer by causing changes in pressure altitude. In still air, when the pilot initiates a dive, the variometer indicates a descent. When the glider pilot pulls out of the dive and initiates a rapid climb, the variometer indicates an ascent. A glider with an uncompensated variometer gives an accurate indication of rising and descending air only if the pilot maintains a constant airspeed.

Total Energy System

A variometer with a total energy system senses changes in airspeed and tends to cancel out the resulting climb and dive indications (stick thermals). This gives a glider pilot an indication of rising or descending air despite changes in airspeed.

A popular type of total energy system consists of a small venturi, a pair of holes, or simply a slot on the back side of a small vertical tube mounted in the air stream and connected to the static outlet of the variometer. When airspeed increases during a dive, more suction from the venturi offsets the increased pressure at the static outlet of the variometer. Similarly, when airspeed decreases during a climb, reduced suction from the venturi offsets the pressure reduction at the static outlet of the variometer. The net effect reduces climb and dive indications caused by airspeed changes. To maximize the precision of this compensation effect, the system can use a total energy probe, which sits in undisturbed airflow ahead of the aircraft nose or tail fin. [*Figure 4-25*]

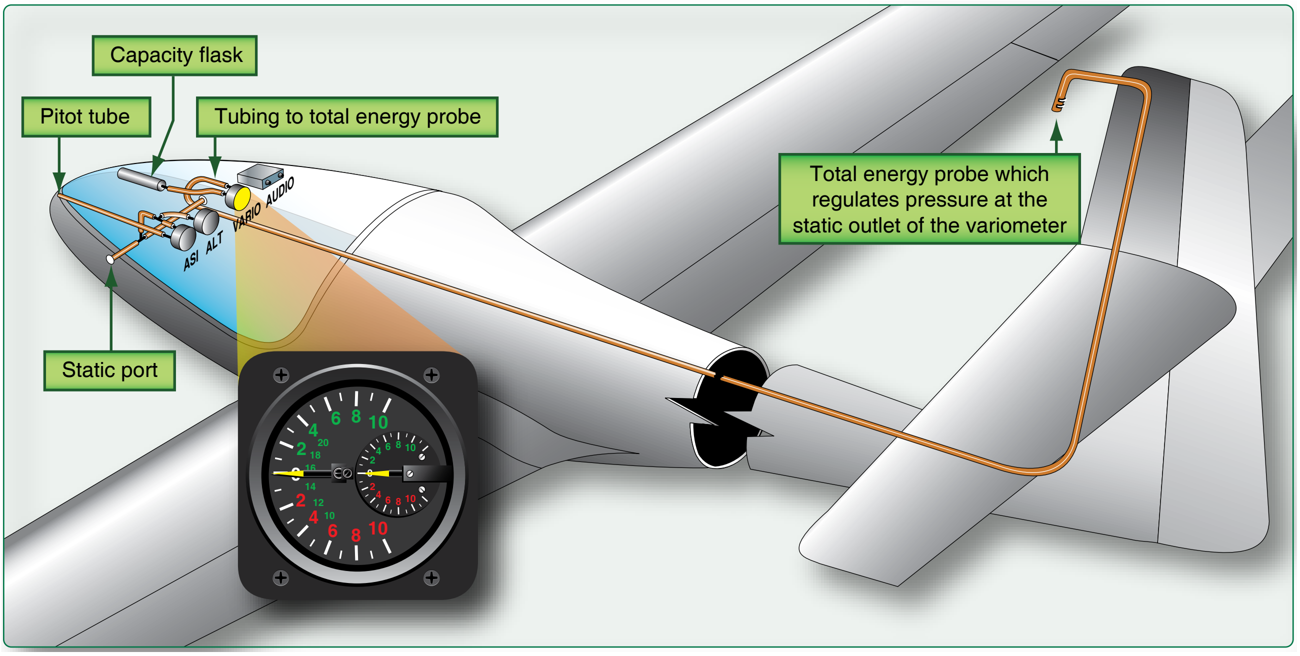


Figure 4-25. *A total energy variometer system.*

Another type of total energy system design uses a diaphragm-type compensator placed in line from the pitot tube to the line coming from the reference chamber (thermos or capacity flask). Deflection of the diaphragm offsets the effect the airspeed change has on pitot pressure. In effect, the diaphragm modulates pressure changes in the capacity flask and masks stick thermals.

Netto

A Netto variometer indicates the vertical movement of the air mass, regardless of the glider's climb or descent rate. Some Netto variometer systems employ a calibrated capillary tube that functions as a tiny valve. Pitot pressure pushes minute quantities of air through the valve and into the reference chamber tubing. This removes the glider's known sink rate at various airspeeds from the variometer indication. [*Figure 4-26*]

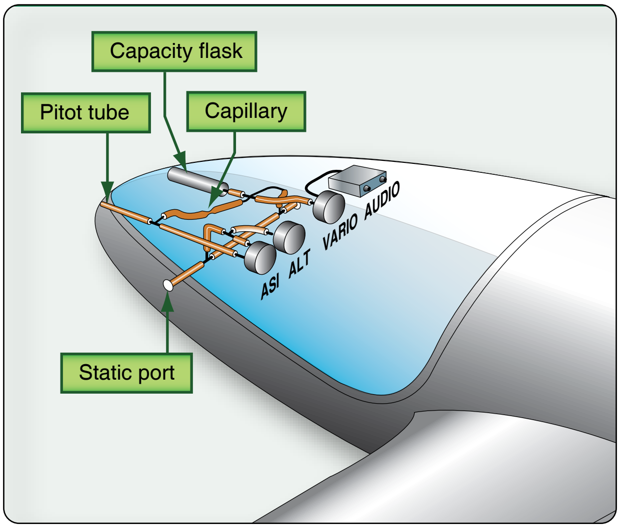


Figure 4-26. *An example of a Netto variometer system.*

Computerized (electronic) Netto variometers employ a different method to remove the glider sink rate. In this type of system, sensors for both pitot pressure and static pressure provide airspeed information to the computer. The computer stores the known sink rate of the glider at every airspeed. At any given airspeed, the computer removes the sink rate of the glider, and the variometer displays the rate of ascent or descent of the air mass itself.

Electronic Flight Computers

Since nonpowered gliders lack a generator or alternator, electrical components, such as the flight computer, if installed, draw power from the glider's rechargeable battery or batteries. Some gliders use solar cells arrayed behind the pilot, or on top of the instrument panel cover, to supply additional power to the electrical system during flight in sunny conditions.

The primary components of most flight computer systems include an electric variometer, a coupled GPS receiver, and a microprocessor. The variometer measures rate of climb and descent. The GPS provides position information. The microprocessor interprets altitude, speed, and position information. The microprocessor output aids the pilot in cross-country decision-making by suggesting a speed to fly. *Figure 4-27* shows a glider flight computer.

Figure 4-27. *Glider flight computer display.*

The GPS-coupled flight computer can provide the following information:

- Current position
- Previous position
- Speed and time to destination
- Distance to planned destination
- Height needed to glide to destination
- Current climb or descent rate
- The optimum airspeed to fly to the next thermal
- The optimum airspeed to fly to a location on the ground, such as the finish line in a race or the airport of intended landing at the end of a cross-country flight

The primary benefits of the flight computer divide into two areas: navigation assistance and performance (speed) enhancement.

Flight computers utilize the concept of a waypoint, which includes latitude, longitude, and altitude. Glider races and cross-country glider flights frequently involve flight around a series of waypoints called turnpoints. The course may be an out-and-return course, polygon shape, or just a series of waypoints. The glider pilot navigates from point to point, using available lift sources to climb periodically so that flight can continue to the intended goal. The GPS-enabled flight computer aids in navigation, summarizing flight progress, and logging completion of tasks or flight goals. When encountering strong lift, for example, the pilot can use the flight computer to mark the location of the thermal. If rounding a nearby turnpoint, the glider pilot might use the flight computer to return to the marked thermal for a rapid climb before continuing.

During the climb portion of the flight, the flight computer's variometer constantly updates the achieved rate of climb. During cruise, the GPS-coupled flight computer aids in navigating accurately to the next turnpoint. The flight computer also suggests the optimum cruise airspeed for the glider to fly, based on the expected rate of climb in the next thermal. During final glide to a goal, the flight computer can display glider altitude, altitude required to reach the goal, distance to the goal, the strength of the headwind or tailwind component, and optimum airspeed to fly.

When the flight computer detects rapid climbs, it suggests higher cruise airspeeds to enhance performance. When the computer detects a low rate of climb, it compensates for the weaker conditions by suggesting lower airspeeds. The flight computer frees the pilot to look for other air traffic, look for sources of lift, watch the weather ahead, and plot a strategy for the remaining portion of the flight.

As explained in the next chapter, water ballast increases the optimal speed to fly. The flight computer compensates for water ballast carried, adjusting speed-to-fly computations according to the weight and performance of the glider. Some flight computers require the pilot to enter data regarding the ballast load of the glider. Other flight computers automatically compensate for the effect of water ballast by constantly measuring the performance of the glider and deducing the operating weight of the glider from these measurements. If the wings of the glider become contaminated with bugs, glider performance declines. The flight computer can be adjusted to account for the resulting performance degradation.

Magnetic Compass

Most gliders do not come under regulation for powered aircraft as referenced in Title 14 of the Code of Federal Regulations (14 CFR) part 91, section 91.205, and only need to comply with regulations for "civil aircraft." For this reason, some gliders do not have a compass unless required per the aircraft's Type Certificate Data Sheets (TCDS).

Slip/Skid Indicators

Yaw String

A piece of yarn mounted in the free airstream and easily visible to the pilot, provides an effective slip/skid indicator. [*Figure 4-28*] During coordinated flight, the yarn points straight back. During a slipping turn, the tail (unattached end) of the yaw string offsets toward the outside of the turn. During a skidding turn, the tail of the yaw string offsets toward the inside of the turn. A pilot having difficulty sensing and correcting uncoordinated flight can apply pressure to the rudder pedal not aligned with the yaw string tail.

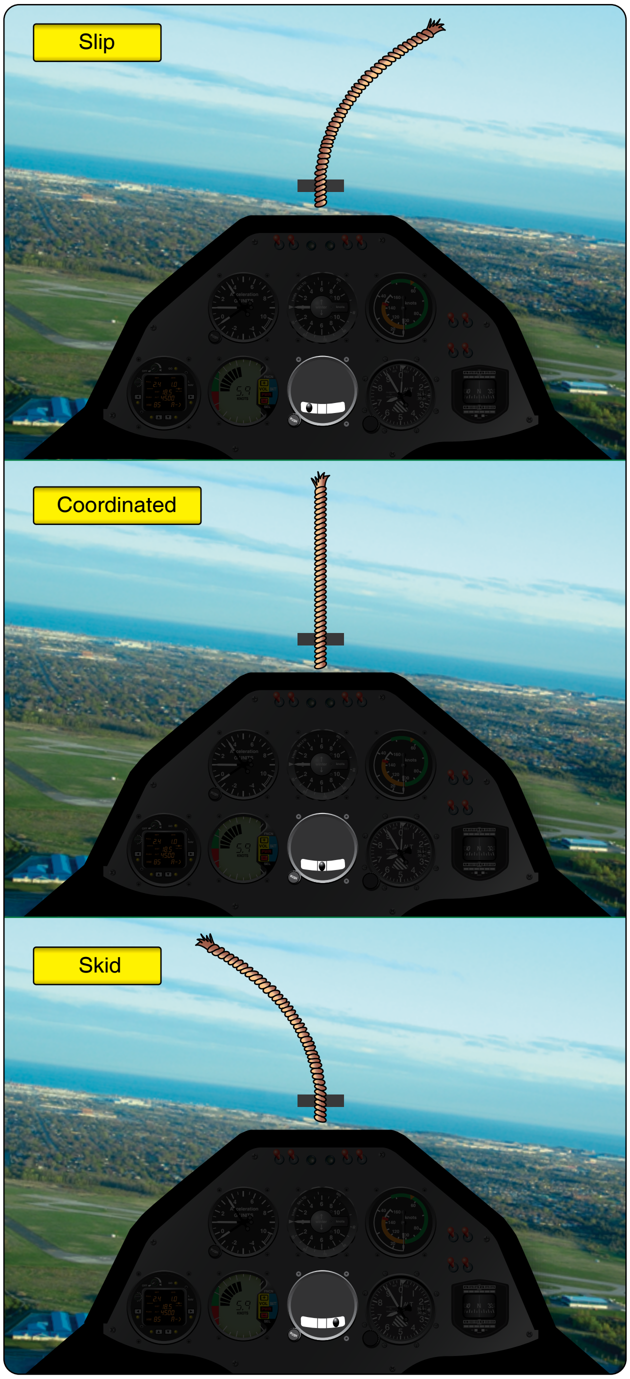


Figure 4-28. *Left turn condition indications of a yaw string and inclinometer.*

Inclinometer

An inclinometer also provides slip/skid indication. The inclinometer responds to centrifugal force and gravity. The inclinometer consists of a metal ball in an oil-filled, curved glass tube. When the glider flies in coordinated fashion, the ball remains centered at the bottom of the glass tube. The inclinometer differs from the yaw string during uncoordinated flight. The ball moves to the inside of the turn to indicate a slip and to the outside of the turn to indicate a skid. [*Figure 4-28*] The phrase, "step on the ball" explains how a pilot should respond to restore coordinated flight. During a spin, the inclinometer does not provide direction of rotation information, and pilots should not use the inclinometer for guidance.

Gyroscopic Instruments

Unpowered gliders do not usually have gyroscopic instruments, while self-launching gliders often have one or more gyroscopic instruments on the panel. Common gyroscopic instruments include the attitude indicator, heading indicator, and turn coordinator.

G-Meter

A panel-mounted G-meter registers positive G forces from climbs and turns, as well as negative G forces when diving down or pushing over from a climb. During straight, unaccelerated flight in calm air, the G-meter registers a load factor of 1 G (1.0 times the force of gravity). During flight in turbulent air, the glider and pilot experience G-loads greater than or less than 1 G when encountering updrafts or downdrafts.

Each glider type can withstand a specified maximum positive G-load and a specified maximum negative G-load. The operating limitations, as described in the GFM/POH or on placards, are the definitive source for this information. Exceeding the allowable limit loads may result in deformation of the glider structure. In extreme cases, exceeding permissible limit loads may cause structural failure of the glider. The G-meter allows the pilot to monitor G-loads from moment to moment during aerobatic flight and during flight in rough air. Most G-meters also record and display the maximum positive G-load and the maximum negative G-load encountered during flight. The recorded maximum positive and negative G-loads can be reset by adjusting the control knob of the G- meter. [*Figure 4-29*]

Figure 4-29. *The G-meter.*

FLARM Collision Avoidance System

A mid-air collision presents a risk to all pilots, and glider pilots have additional mid-air scenarios to consider when thermaling, cloud street flying, or ridge running. Periodically, mid-air collisions or near misses occur in club flying, during competitions, and between gliders and towplanes after release.

FLARM systems (the name being inspired from “flight alarm”) can warn pilots of impending collisions with other FLARM-equipped gliders and give the location of non-threatening nearby FLARM-equipped gliders. *Figure 4-30* shows the interior of an ASW 19 glider with a FLARM unit on top of the instrument panel. FLARM transmits and receives information, models the unique flight characteristics of gliders, and stays quiet unless it detects a real threat. However, it can only provide information about other gliders with an operating FLARM system.

Figure 4-30. *FLARM unit on top of the instrument panel.*

FLARM obtains its position from an internal global positioning system (GPS) and a barometric sensor and then broadcasts this data with forecast data about the future 3D flight track. Its receiver receives signals from other FLARM devices typically within 3-5 kilometers and processes the information received. Motion-prediction algorithms predict potential conflicts for up to 50 other signals and warn the pilot using sound and visual means. FLARM can also store information about static aerial obstacles, such as cables, into a database.

Why use FLARM in a glider? Conventional Airborne Collision Avoidance Systems (ACAS) would provide continuous and unnecessary warnings about all aircraft in the vicinity. FLARM only gives selective alerts to aircraft posing a collision risk. It consumes much less power than a transponder or ADS-B and is relatively inexpensive to buy and install. While versions exist for use in light aircraft and helicopters, as well as gliders, the short range of the signal makes FLARM unsuitable for avoiding collisions with fast aircraft.

While gliders are exempt from carrying transponders and ADS-B out transmitters in most, but not all airspace, the Soaring Society of America strongly encourages pilots to install this equipment when operating near high density airspace. This increases their visibility to other users of the National Airspace System (NAS).

Transponder Code

The Federal Aviation Administration (FAA) assigned transponder code 1202 for use by gliders not in contact with air traffic control (ATC) as of March 7, 2012. Effective November 1, 2021 (JO 7110.66G), the FAA amended this practice to include gliders in contact with ATC. Glider pilots operating in areas with an agreement with local ATC to use a different code should contact the agreement sponsor for guidance.

Definitions

- SQUAWK CODE: The 4-digit code set in the transponder, such as 1202.
- IDENT or SQUAWK IDENT: A controller may direct a pilot to "ident" or "squawk ident" to verify the aircraft's location on the radar screen. When directed, the pilot pushes the button on the transponder marked IDENT. This

causes the target on the controller's radar screen to change for several seconds. The pilot should not push the ident button without direction from ATC.

- Tow planes normally squawk 1200 unless otherwise instructed by ATC.

Outside Air Temperature (OAT) Gauge

The outside air temperature gauge (OAT) mounts with the sensing element in contact with the outside air. OAT gauges display degrees Celsius, degrees Fahrenheit, or both, and provide the glider pilot with information about freezing temperatures which could affect water ballast or flight controls. [*Figure 4-31*]

Figure 4-31. *Outside air temperature (OAT) gauge.*

When flying a glider loaded with water ballast, knowledge of the height of the freezing level can affect safety of flight. Extended operation of a glider loaded with water ballast in below-freezing temperatures may result in frozen drain valves, ruptured ballast tanks, and structural damage to the glider.

Chapter Summary

This chapter introduced the pitot-static system and its associated instruments including the airspeed indicator, the altimeter, and the variometer. A glider has various V-speeds and some of these speeds correspond to specific markings on the airspeed indicator regardless of altitude. The chapter also explains what a pilot should know about setting an altimeter, nonstandard pressure and temperature effects on indicated altitude, and different kinds of altitude. Variometers normally indicate the sum of the descent rate of the glider added to the lift or sink of the surrounding air mass. A compensated variometer removes indications that result from changes in airspeed (stick thermals). A netto removes the sink rate of the glider and provides the vertical speed of the surrounding air mass. Flight computers can integrate information from different sources, including from memory, and provide a wealth of information to the glider pilot. Other instruments described in this chapter include a magnetic compass, yaw string, inclinometer, gyroscopes, G-meter, and outside temperature gauge (OAT). Pilots can use FLARM systems for short range collision avoidance, however the system can only detect other aircraft that use the FLARM system. A transponder-equipped glider automatically reports position and altitude to ATC.