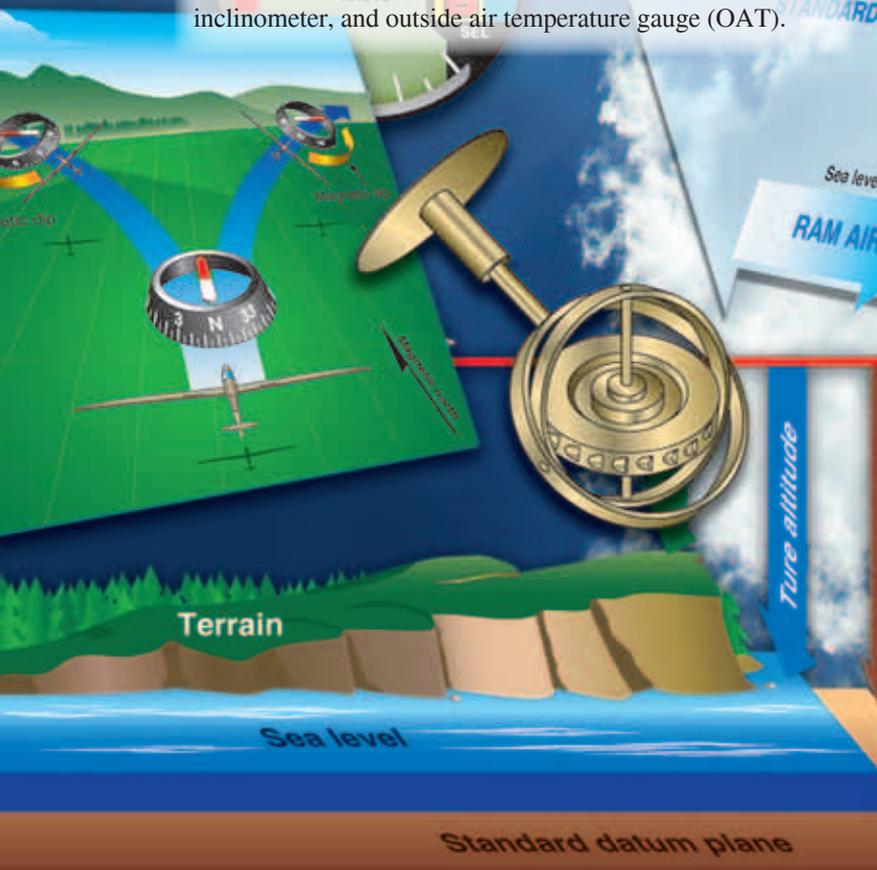


Flight Instruments

Introduction

Flight instruments in the glider cockpit provide information regarding the glider's direction, altitude, airspeed, and performance. The categories include pitot-static, magnetic, gyroscopic, electrical, electronic, and self-contained. This categorization includes instruments that are sensitive to gravity (G-loading) and centrifugal forces. Instruments can be a basic set used typically in training aircraft or a more advanced set used in the high performance sailplane for cross-country and competition flying. To obtain basic introductory information about common aircraft instruments, please refer to the Pilot's Handbook of Aeronautical Knowledge (FAA-H-8083-25).

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 attitude, heading, and rates of turn. Unique to the glider cockpit is the variometer, which is part of the pitot-static system. Electronic instruments using computer and global positioning system (GPS) 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 gauge (OAT).



Standard Conditions

Sea level
RAM AIR

True airspeed 130 knots

True airspeed 098 knots

Indicated airspeed 100 knots (A)

Calibrated airspeed 98 knots (B)

Indicated airspeed 100 knots (A)

Calibrated airspeed 98 knots (B)

| Normal static source | | |
|----------------------|-----------|--|
| FLAPS UP | | |
| KIAS | 60 80 120 | |
| KCAS | 59 78 119 | |

True altitude

Pressure altitude

Standard datum plane

Pitot-Static Instruments

There are two major divisions in the pitot-static system:

1. Impact air pressure due to forward motion (flight) captured in the pitot tube transferred to instruments by way of air pressure lines or tubing.
2. Static or free air pressure sensed at static air ports designed to be free of motion induced pressure variations. This reference pressure is necessary because the free pressure of the atmosphere decreases as altitude increases and changes due to the current weather (barometric) pressure variations. This static or free air pressure is transferred to instruments by way of the static pressure lines or tubing.

Impact and Static Pressure Lines

The impact air pressure (air striking the glider because of its forward motion) is taken from the pitot tube, which is mounted on either the nose or the vertical stabilizer. [Figure 4-1] Pitot tubes are aligned with the relative wind. These locations minimize air disturbance or turbulence during glider flight through the air.

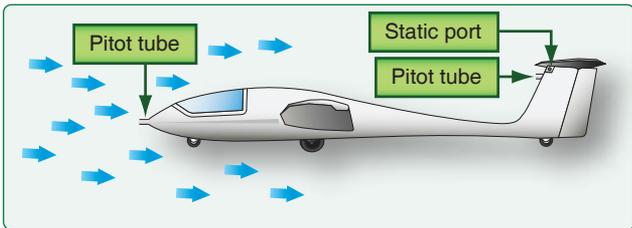


Figure 4-1. A pitot tube is often mounted in the glider's nose or the vertical fin, the open end of which is exposed directly to the oncoming airflow.

When a glider is in flight, the oncoming air tries to flow into the open end of the pitot tube. [Figure 4-2] Connecting a diaphragm to the back end of the pitot tube means that the air flowing in has nowhere to go. The pressure in the diaphragm rises until it is high enough to prevent any further air from

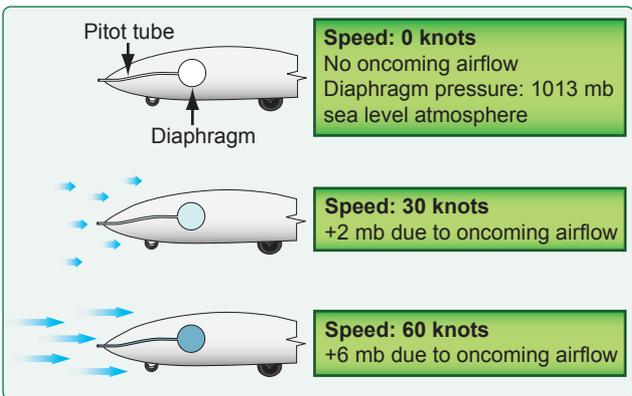


Figure 4-2. Pressure inside the capsule increases as airspeed increases.

entering. Increasing the airspeed of the glider causes the force exerted by the oncoming air to rise. More air is able to push its way into the diaphragm and the pressure within the diaphragm increases. The pressure inside the diaphragm to oncoming airflow increases as airspeed increases.

The static pressure (pressure of the still air) is taken from the static line that is attached to a port, or ports, mounted flush with the side of the fuselage or tube mounted on the vertical stabilizer. [Figure 4-3] Gliders using a fuselage flush mounted static source 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.

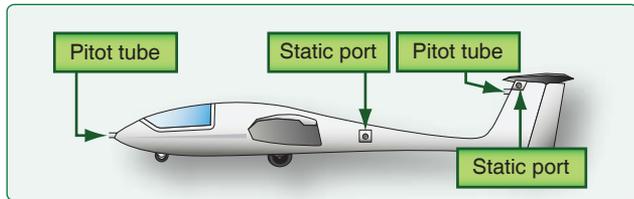


Figure 4-3. Static ports mounted flush with the side of the fuselage or tube mounted on the vertical stabilizer.

The openings of both the pitot tube and the static port(s) should be checked during the preflight inspection to ensure they are free from obstructions. Clogged, or partially clogged, openings should be cleaned by a certificated mechanic. Blowing into these openings is not recommended, because this could damage flight instruments.

Airspeed Indicator

The airspeed indicator displays the indicated airspeed (IAS) of the glider through the air. [Figure 4-4] Some airspeed indicator dials provide color-coded arcs that depict permissible airspeed ranges for different phases of flight. The



Figure 4-4. Airspeed indicator.

upper (top) and lower (bottom) limits of the arcs correspond to airspeed limitations for specific gliders configurations which are discussed later in this chapter. These speed limitations are set by the manufacturer. *Figure 4-5* shows the anatomy of the airspeed indicator and where the pitot and static pressure inlets are located.

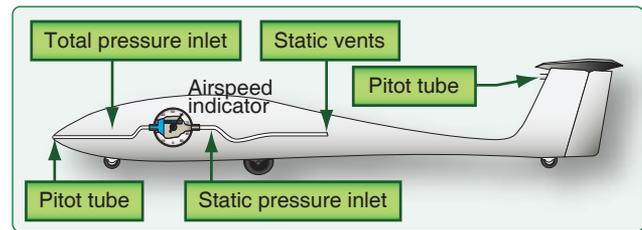


Figure 4-6. The functionality of the airspeed indicator depends on both pitot and static pressure.

The airspeed indicator depends on both pitot pressure and static pressure. [*Figure 4-6*] When pitot pressure and static pressure are the same, zero airspeed is indicated. As pitot pressure becomes progressively greater than static pressure, airspeed is indicated by the needle pointing to the speed scale. The airspeed instrument contains a diaphragm that senses differential pitot and static pressure. The diaphragm expands or contracts according to the difference of static and pitot pressures; this movement drives the needle (airspeed needle pointer) on the face of the instrument. [*Figure 4-7*]

The Effects of Altitude on the Airspeed Indicator

Like pressure, air density also decreases with altitude. The airspeed indicator's diaphragm is calibrated to correctly display airspeed when the air through which the aircraft is moving is of average sea level density. Above sea level, due to the lower air density, the buildup of pressure in the diaphragm is lower, and the airspeed indicator reads artificially low. The higher the altitude above sea level, the more erroneous the airspeed indicator value. [*Figure 4-8*]

Types of Airspeed

There are three kinds of airspeed that the pilot should understand: IAS, calibrated airspeed (CAS), and true airspeed (TAS). [*Figure 4-9*]

Indicated Airspeed (IAS)

IAS is the direct instrument reading obtained from the airspeed indicator, uncorrected for variations in atmospheric density, installation error, or instrument error. *Figure 4-10*

shows that the IAS at which a glider stalls in steady wings-level flight does not vary with altitude. However, pilots must remember that different gliders stall at different speeds. The IAS shown in *Figure 4-10* may not be the stall speed for each particular glider.

The IAS at which never exceed speed (V_{NE}) is reached decreases with altitude. The glider flight manual (GFM) should include a table, such as the one shown in *Figure 4-11*, that details how V_{NE} should be reduced with altitude. These figures vary from glider to glider; therefore, pilots should always refer to the manual specific to the glider they are flying, which should show a chart similar to the one in *Figure 4-11*.

Calibrated Airspeed (CAS)

CAS is IAS corrected for installation and instrument error. Although manufacturers attempt to keep airspeed errors to a minimum, it is impossible to eliminate all errors throughout the airspeed operating range. At certain airspeeds and with certain flap/spoiler settings, the installation and instrument error may be significant. The error is generally greatest at low airspeeds. In the cruising and higher airspeed ranges, IAS and CAS are approximately the same.

It is important to refer to the airspeed calibration chart to correct for possible airspeed errors because airspeed limitations, such as those found on the color-coded face of the airspeed indicator, on placards in the cockpit, or in

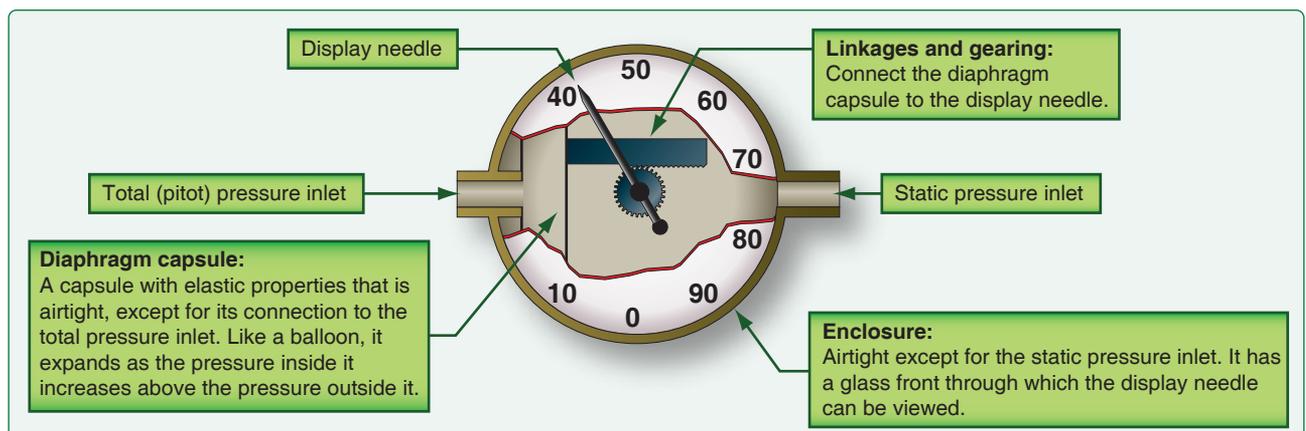


Figure 4-5. Anatomy of the airspeed indicator.

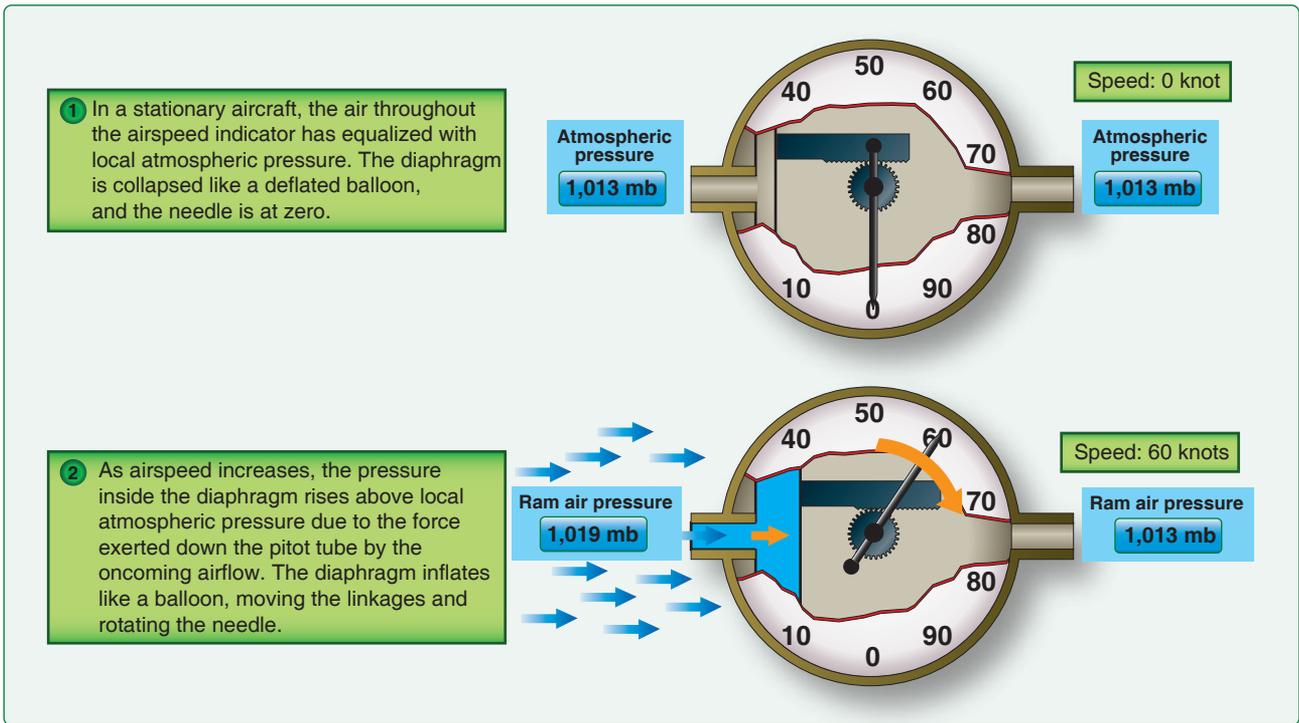


Figure 4-7. Airspeed indicator operation.

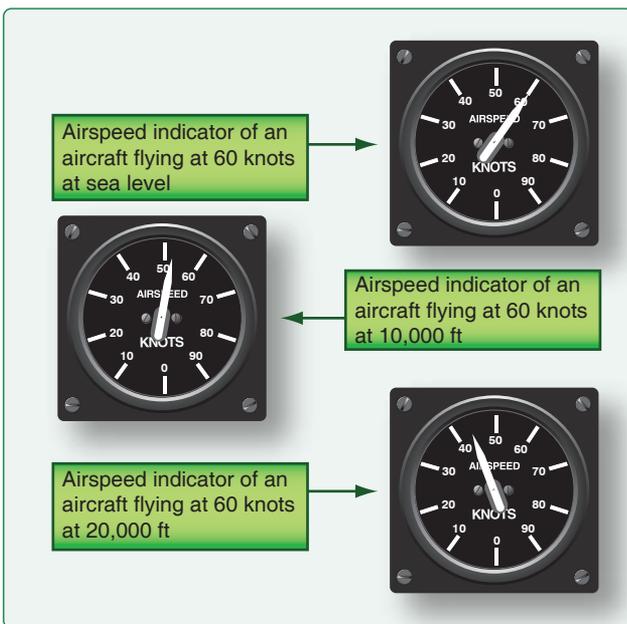


Figure 4-8. Effects of altitude on the airspeed indicator.

the GFM or Pilot's Operating Handbook (GFM/POH), are usually CAS. Some manufacturers use IAS rather than CAS to denote the airspeed limitations mentioned. The airspeed indicator should be calibrated periodically.

Dirt, dust, ice, or snow collecting at the mouth of the pitot tube may obstruct air passage and prevent correct indications. Vibrations may also destroy the sensitivity of the diaphragm.

True Airspeed (TAS)

TAS is the true speed at which the aircraft is moving through the air. The airspeed indicator is calibrated to indicate TAS only under standard atmospheric conditions at sea level (29.92 inches of mercury ("Hg) and 15 °C or 59 °F). Because air density decreases with an increase in altitude, the glider must be flown faster at higher altitudes to cause the same pressure difference between pitot impact pressure and static pressure. Therefore, for a given TAS, IAS decreases as altitude increases; for a given IAS, TAS increases with an increase in altitude.

Fortunately for the pilot, the amount by which the airspeed indicator underreads approximately cancels out the air density related changes to the glider's flight dynamics. This means that if the IAS at the point of stall at 1,000 feet in steady wings-level flight is 40 knots, then the IAS at 20,000 feet at the point of the stall is also 40 knots, despite the fact that the stall is actually occurring at a TAS that is 14 knots higher. Therefore, the pilot needs to remember only one set of numbers that work at all altitudes. A decrease in air density with altitude also affects a glider's flight dynamics. For example, a glider that stalls at a TAS of 40 knots in steady wings-level flight at 1,000 feet stalls at a TAS of 54 knots at 20,000 feet. Consider the inconvenience that this would cause if the airspeed indicator did actually display TAS. The pilot would need to use quick reference cards continuously to look up the stall speed, best L/D speed, and minimum sink speed for the current altitude—not a

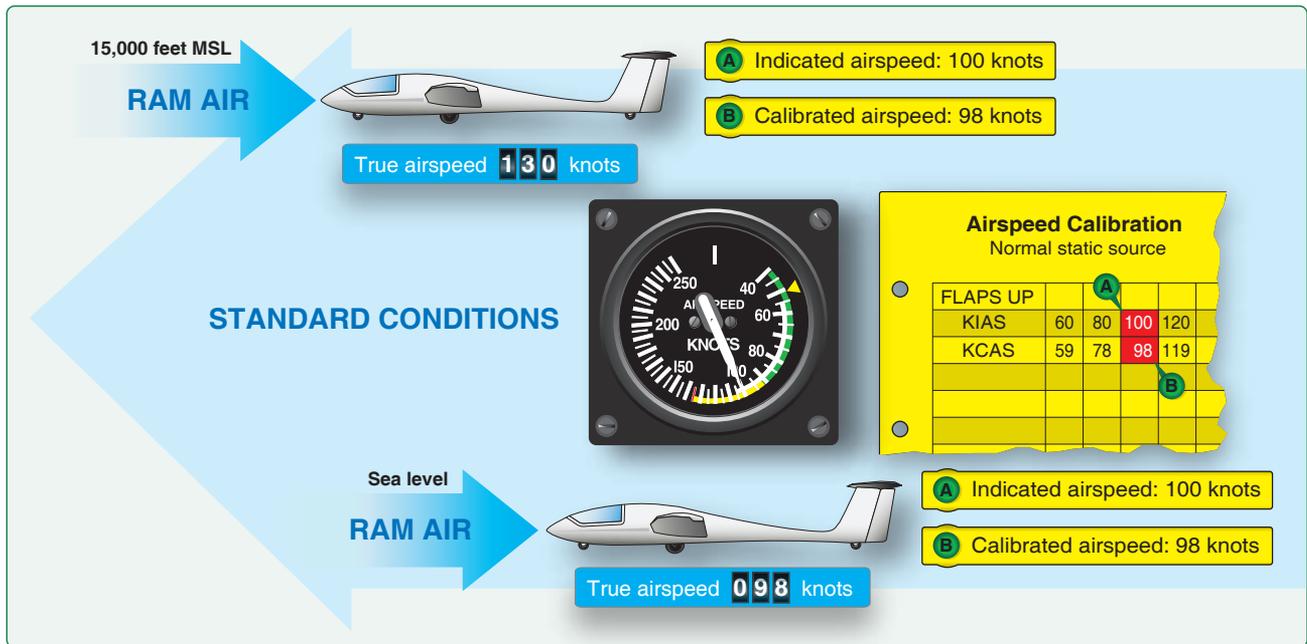


Figure 4-9. The three types of airspeed are IAS, CAS, and TAS.

| 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 4-10. In steady wings-level flight, IAS does not vary with altitude.

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

Figure 4-11. IAS at which V_{NE} is reached decreases with altitude.

particularly convenient thing to do while trying to fly. Figure 4-10 shows how steady, wings-level flight stall speed is affected by different altitudes. Figure 4-10 is only an example, and the figures used in it do not pertain to all gliders. For specific stall speeds, always refer to the POH of the glider that is being flown.

A pilot can find TAS by two methods. The first method, which is more accurate, involves using a flight computer. In this method, the CAS is corrected for temperature and pressure variation by using the airspeed correction scale on the computer. A second method, which is a rule of thumb, can be used to compute the approximate TAS. This is done by adding to the IAS 2 percent of the IAS for each 1,000 feet of altitude.

Airspeed Indicator Markings

Aircraft weighing 12,500 pounds or less, manufactured after 1945 and certificated by the Federal Aviation Administration (FAA), are required to have airspeed indicators that conform to a standard color-coded marking system. [Figure 4-4] This system enables the pilot to determine, at a glance, certain airspeed limitations that are important to the safe operation of the aircraft. For example, if during the execution of a maneuver, the pilot notes that the airspeed needle is in the yellow arc and is rapidly approaching the red line, immediate corrective action to reduce the airspeed should be taken. It is essential that the pilot use smooth control pressure at high airspeeds to avoid severe stressors upon the glider structure.

The following is a description of what the standard color-code markings are on an airspeed indicator and how they correspond to maneuvers and airspeeds.

- The white arc—flap operating range
- The lower limit of the white arc—stalling speed with the wing flaps and landing gear in the landing position.
- The upper limit of the white arc—maximum flaps-extended speed. This is the highest airspeed at which the pilot should extend 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 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 speed should never be exceeded intentionally.

Other Airspeed Limitations

There are other important airspeed limitations not marked on the face of the airspeed indicator. These speeds are generally found on placards [Figure 4-12] in the view of the pilot and in the GFM/POH.

- Maneuvering speed (V_a)—maximum speed at which the limit load can be imposed (either by gusts or full deflection of the control surfaces for one cycle) without causing structural damage. If rough air or severe turbulence is encountered during flight, the airspeed should be reduced to maneuvering speed or less to minimize the stress on the glider structure. Maneuvering speed is not marked on the airspeed indicator. For gliders, if there is a rough airspeed (V_b) limitation published the pilot should be below that speed for maximum gust intensity.
- Landing gear operating speed—maximum speed for extending or retracting the landing gear if using glider equipped with retractable landing gear.
- Minimum sink speed—important when thermalling.
- 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 that the glider may safely be towed without causing structural damage.

Altimeter

The altimeter measures the static air pressure of the surrounding air mass. A flexible plastic tube connects the altimeters static pressure inlet to the static port holes located on the side of the glider. [Figure 4-13] If set to the proper local pressure, the altimeter needles and dial indicate heights above mean sea level (MSL). [Figures 4-14 and 4-17] Glider pilots must be fully aware of the ground elevations on

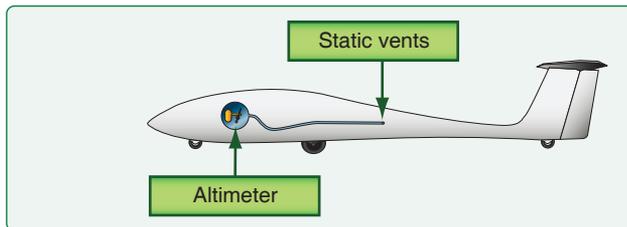


Figure 4-13. Static vents and altimeter plumbing.

the flight route or area in order to make flight decisions concerning soaring or landing options.

Atmospheric Pressure and Altitude

Atmospheric pressure is caused by the weight of the column of air above a given location. At sea level, the overlying column of air exerts a force equivalent to 14.7 pounds per square inch, 1013.2 mb, or 29.92 inches of mercury. The higher the altitude is, the shorter the overlying column of air is and the lower the weight of that column is. Therefore, atmospheric pressure decreases with altitude. At 18,000 feet, atmospheric pressure is approximately half that at sea level. [Figure 4-16]

Principles of Operation

The pressure altimeter is simply an aneroid barometer that measures the pressure of the atmosphere at the level at which the altimeter is located and presents an altitude indication in feet. The altimeter uses static pressure as its source of operation. Air is denser at the surface of the earth than aloft; as altitude increases, atmospheric pressure decreases. This difference in pressure at various levels causes the altimeter to indicate changes in altitude. Figures 4-15 and 4-17 illustrate how the altimeter functions. The presentation of altitude varies considerably between different types of altimeters. Some have one pointer while others have more.

The dial of a typical altimeter is graduated with numerals arranged clockwise from 0 to 9 inclusive, as shown in Figure 4-14. Movement of the aneroid element is transmitted through a gear train to the three hands, which sweep the calibrated dial to indicate altitude. The shortest hand indicates altitude in tens of thousands of feet; the intermediate hand in thousands of feet; and the longest hand in hundreds of feet, subdivided into 20-foot increments.

| 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 | 10 km/hr IAS |

Figure 4-12. Speed limitation placards placed in the glider and in view of the pilot.

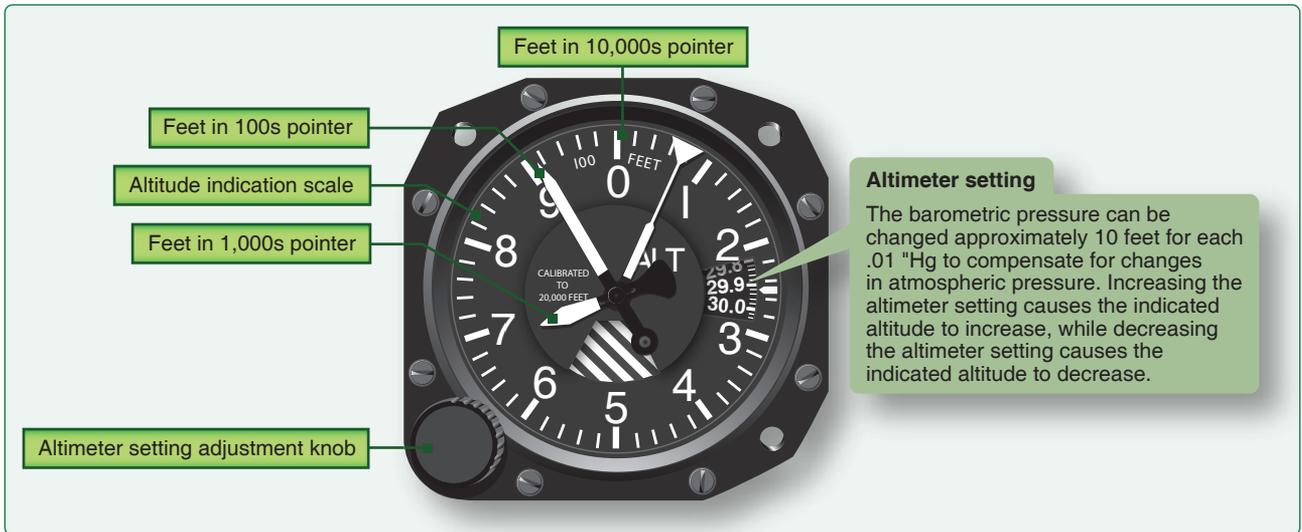


Figure 4-14. Altimeter.

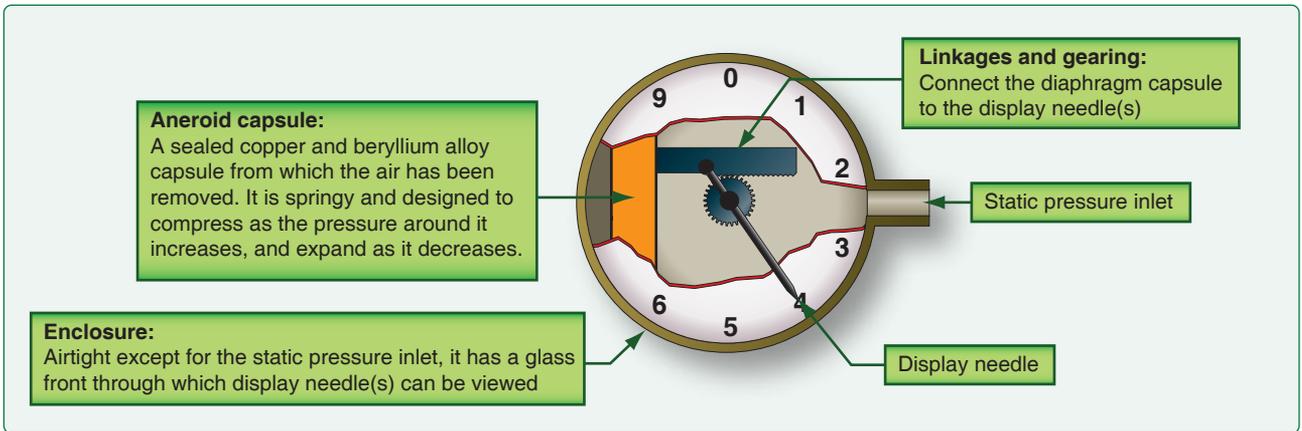


Figure 4-15. Inside the altimeter.

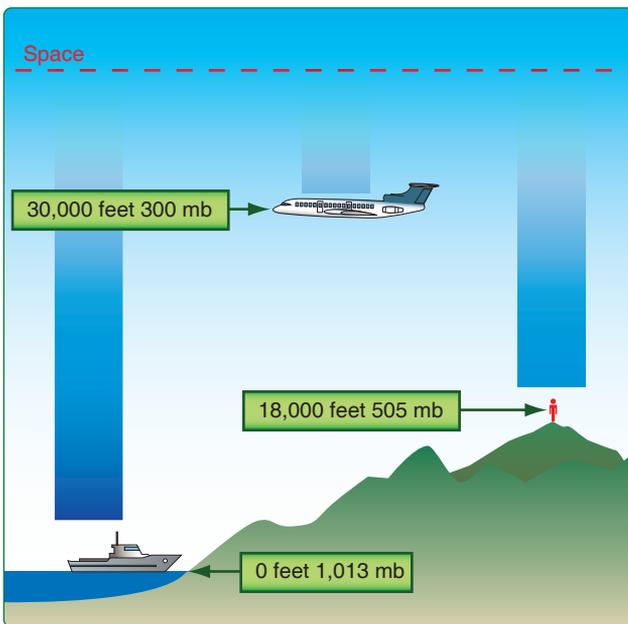


Figure 4-16. Atmospheric pressure and altitude.

The altitude indicated on the altimeter is correct only if the sea level barometric pressure is standard (29.92 "Hg), the sea level free air temperature is standard (+15 °C or 59 °F), and the pressure and temperature decreases at a standard rate with an increase in altitude. Since atmospheric pressure continually changes, a means is provided to adjust the altimeter to compensate for nonstandard conditions. This is accomplished through a system by which the altimeter setting (local station barometric pressure reduced to sea level) is set to a barometric scale located on the face of the altimeter. Only after the altimeter is set properly will it indicate the correct altitude.

Effect of Nonstandard Pressure and Temperature

If no means were provided for adjusting altimeters to nonstandard pressure, flight could be hazardous. For example, if a flight is made from a high-pressure area to a low-pressure area without adjusting the altimeter, the actual altitude of the glider is lower than indicated altitude. When flying from a low-pressure area to a high-pressure area, the actual altitude

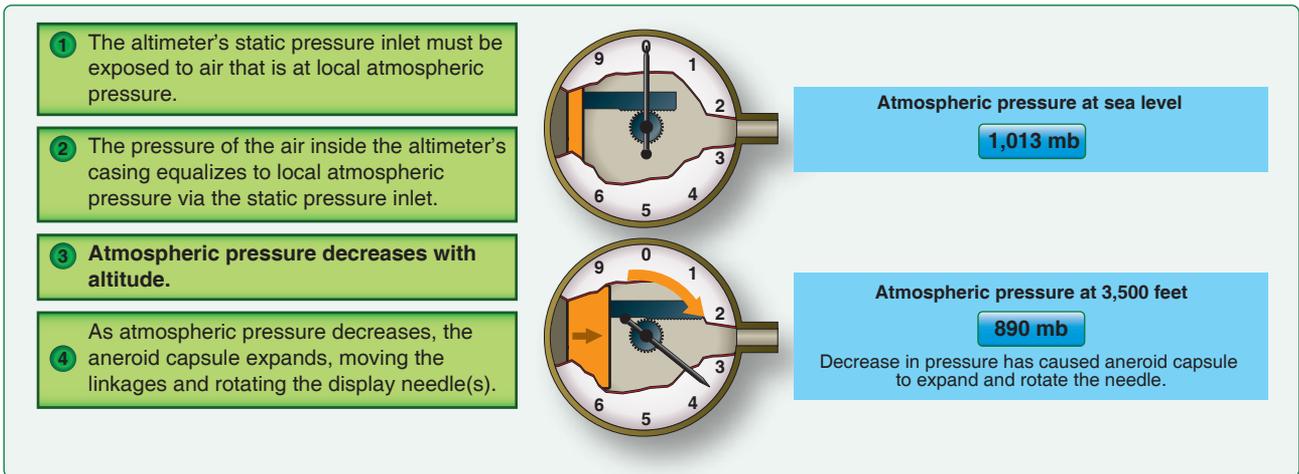


Figure 4-17. How the altimeter functions.

of the glider is higher than the indicated altitude. Fortunately, this error can be corrected by setting the altimeter properly. When flying in the local area and communication with ATC is not available to provide the current altimeter setting, there is an alternative procedure. Set the altimeter on zero while on the ground to directly read AGL referenced to the landing zone. However, for cross-country flights and flights from higher elevation airports, that procedure may not be an option due to the excessive Kollsman window setting instrument required. In those instances, the altimeter can be set to read the field elevation and either disregard the Kollsman window setting or applying a correction factor, or set in the barometric altimeter setting and remember if it reads high or low.

volume than on a cold day, and consequently the pressure levels are raised. For example, the pressure level at which the altimeter indicates 10,000 feet is higher on a warm day than under standard conditions. On a cold day, the reverse is true, and the 10,000-foot level would be lower. The adjustment made by the pilot to compensate for nonstandard pressures does not compensate for nonstandard temperatures. Therefore, if terrain or obstacle clearance is a factor in the selection of a cruising altitude, particularly at higher altitudes, remember to anticipate that colder than standard temperature places the glider lower than the altimeter indicates. Therefore, a higher altitude should be used to provide adequate terrain clearance. A memory aid in applying the above is “from a high to a low or hot to cold, look out below.” [Figure 4-18]

Variations in air temperature also affect the altimeter. On a warm day, the expanded air is lighter in weight per unit

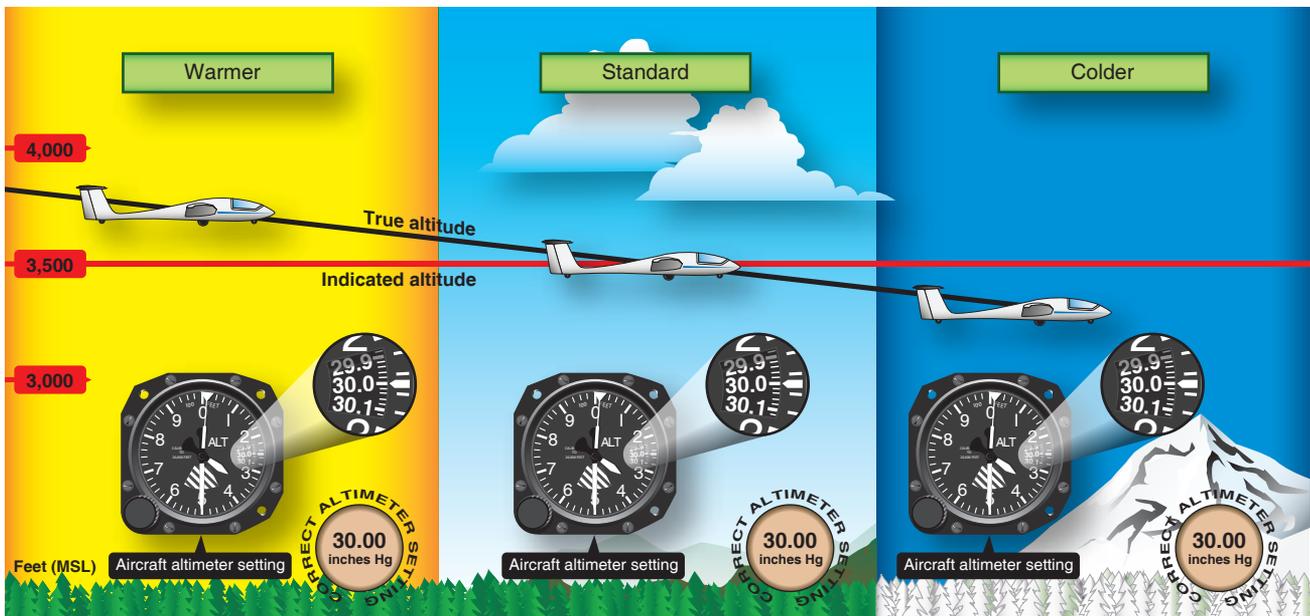


Figure 4-18. Nonstandard pressure and temperature.

Setting the Altimeter (Kollsman Window)

To adjust the altimeter for variation in atmospheric pressure, the pressure scale in the altimeter setting window (Kollsman Window), calibrated in inches of mercury ("Hg), is adjusted to correspond with the given altimeter setting. Altimeter settings can be defined as station pressure reduced to sea level, expressed in inches of mercury. Pilots should be aware of three altimeter setting acronyms: QNH, QFE, and QNE. The pilot sets QNH to read MSL, sets QFE to read the altitude above ground level (AGL), and QNE when flying above the transition level (18,000 feet in the United States). A glider pilot would use this setting when wave flying and is above 18,000 feet or flight level 180 (FL180). To read QNH, pilots should set the current altimeter setting into the altimeter's barometric setting window. The altimeter should read what the approximate field elevation is, which is a good way to check if it is working properly. A good memory aid for this step is to think of "H" (QNH) for home. QFE is set at zero when on the field. As a memory aid, think of the F in QFE as "field." Many altimeters cannot be set to read zero when operating from the higher elevation airports.

The station reporting the altimeter setting takes an hourly measurement of the station's atmospheric pressure and corrects this value to sea level pressure. These altimeter settings reflect height above sea level only in the vicinity of the reporting station. Aircraft flying above the transition level (in the United States, FL180), must use the standard altimeter setting of 29.92 "Hg (QNE). When flying below 18,000 feet MSL, it is necessary to adjust the altimeter setting as the flight progresses from one station to the next.

When flying over high mountainous terrain, certain atmospheric conditions can cause the altimeter to indicate an altitude of 1,000 feet, or more, higher than the actual altitude. For this reason, a generous margin of altitude should be allowed—not only for possible altimeter error, but also for possible downdrafts that are particularly prevalent if high winds are encountered.

To illustrate the use of the altimeter setting system, follow a cross-country flight from TSA Gliderport, Midlothian, Texas, to Winston Airport, Snyder, Texas, via Stephens County Airport, Breckenridge, Texas. Before takeoff from TSA Gliderport, the pilot receives a current local altimeter setting of 29.85 from the Fort Worth automated flight service station (AFSS). This value is set in the altimeter setting window of the altimeter. The altimeter indication should then be compared with the known airport elevation of 660 feet. Since most altimeters are not perfectly calibrated, an error may exist. VFR flights altimeters do not need to be calibrated but if an altimeter indication differs from the field

elevation by more than 75 feet, the accuracy of the instrument is questionable, and it should be referred to an instrument repair station.

When over Stephens County Airport, assume 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, a new altimeter setting of 29.69 is received from the Automated Weather Observing System (AWOS), and applied to the altimeter. If the pilot desires to enter the traffic pattern at approximately 1,000 feet above terrain, and the field elevation of Winston Airport is 2,430 feet, an indicated altitude of 3,400 feet should be used.

$$2,430 \text{ feet} + 1,000 \text{ feet} = 3,430 \text{ feet, rounded to } 3,400 \text{ feet}$$

The importance of properly setting and reading the altimeter cannot be overemphasized. Let us assume that the pilot neglected to adjust the altimeter at Winston Airport to the current setting, and uses the Stephens County area setting of 29.94. If this occurred, the glider would be approximately 250 feet below the airport downwind entry altitude of 3,200 feet when entering the Winston Airport traffic pattern, and the altimeter would indicate approximately 250 feet higher than the field elevation (2,430 feet) upon landing.

This altitude error is another reason for a glider pilot to always fly a safe visual approach angle to the landing zone and not solely depend on instrument readings or past selection of turn points for the traffic pattern. The visual angle to the landing zone is the one item of information that will always be true. Reports of wind and barometric pressure if available may still be suspect. The glider pilot must always ensure sufficient altitude is available for expected or possible winds to allow landing in the landing zone.

$$\text{Actual altimeter setting} = 29.94$$

$$\text{Correct altimeter setting} = 29.69$$

$$\text{Difference} = .25$$

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

$$.25 \times 1,000 \text{ feet} = 250 \text{ feet}$$

The previous calculation may be confusing, particularly in determining whether to add or subtract the amount of altimeter error. The following additional explanation is offered and can be helpful in finding the solution to this type of problem.

There are two means by which the altimeter pointers can be moved. One utilizes changes in air pressure, while the other utilizes the mechanical makeup of the altimeter setting system.

When the glider altitude is changed, the changing pressure within the altimeter case expands or contracts the aneroid barometer that, through linkage, rotates the pointers. A decrease in pressure causes the altimeter to indicate an increase in altitude, and an increase in pressure causes the altimeter to indicate a decrease in altitude. If the glider is flown from a pressure level of 28.75 "Hg to a pressure level of 29.75 "Hg, the altimeter would show a decrease of approximately 1,000 feet in altitude.

The other method of moving the pointers does not rely on changing air pressure, but on the mechanical construction of the altimeter. When the knob on the altimeter is rotated, the altimeter setting pressure scale moves simultaneously with the altimeter pointers. This may be confusing because the numerical values of pressure indicated in the window increase while the altimeter indicates an increase in altitude, and decrease while the altimeter indicates a decrease in altitude. This is contrary to the reaction on the pointers when air pressure changes and is based solely on the mechanical makeup of the altimeter. To further explain this point, assume that the correct altimeter setting is 29.50, or a .50 difference. This would cause a 500 foot error in altitude. In this case, if the altimeter setting is adjusted from 30.00 to 29.50, the numerical value decreases and the altimeter indicates a decrease of 500 feet in altitude. Before this correction was made, the glider was actually flying at an altitude of 500 feet lower than was shown on the altimeter. It is important to calibrate the altimeter for all VFR flights because if they are off by more than a comfortable margin, calibration or repair is advisable.

Types of Altitude

Knowing the glider's altitude is vitally important to the pilot for several reasons. The pilot must be sure that the glider is flying high enough to clear the highest terrain or obstruction along the intended route. To keep above mountain peaks, the pilot must be aware of the glider's altitude and elevation of the surrounding terrain at all times. Knowledge of the altitude is necessary to calculate TAS.

Altitude is vertical distance above some point or level used as a reference. There may be as many kinds of altitude as there are reference levels from which altitude is measured, and each may be used for specific reasons.

The following are the four types of altitude that affect glider pilots. [Figure 4-19]

- Indicated altitude—altitude read directly from the altimeter (uncorrected) after it is set to the current altimeter setting (QNH) in the Kollsman window. Indicated altitude can be used for maintaining terrain/obstacle clearance and estimating distance to glide over the terrain without benefit of lift.
- True altitude—true vertical distance of the glider above sea level (known as MSL). This altitude is measured above a standard datum due to the shape of the earth (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). With

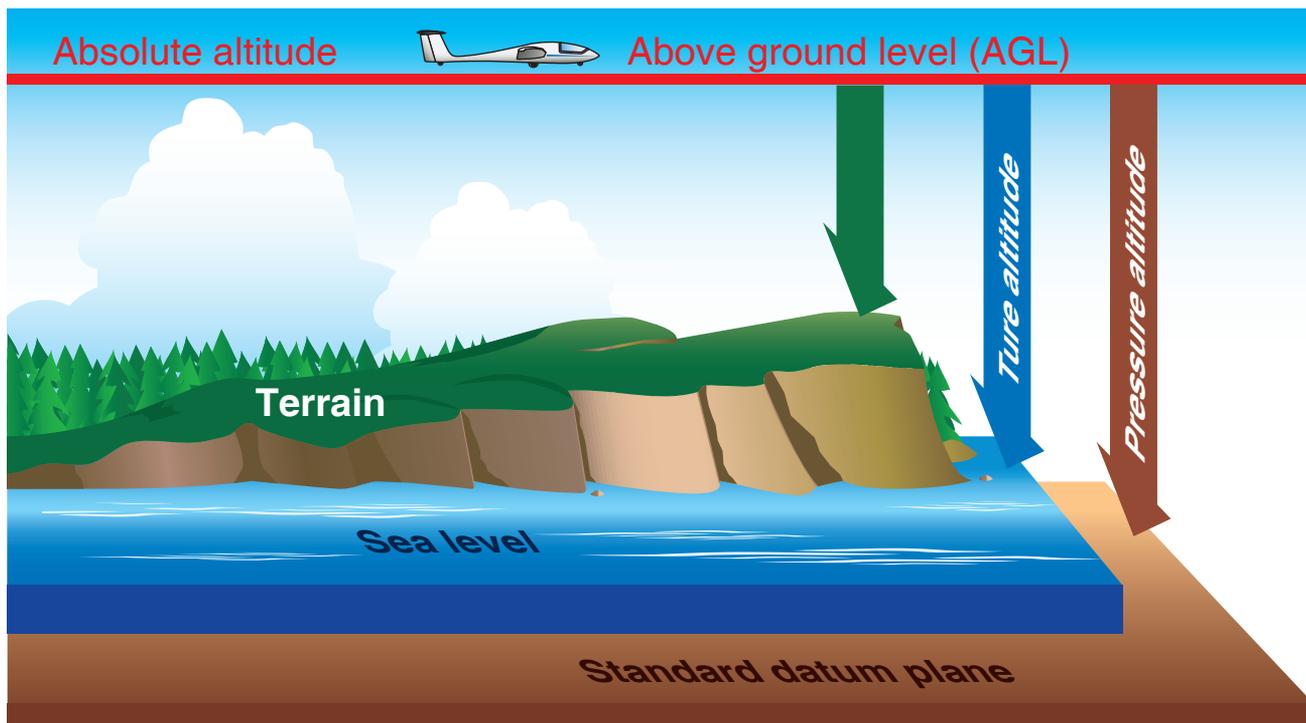


Figure 4-19. Types of altitude.

proper local altimeter setting (QHN), indicated and true altitude are synonymous.

- Absolute altitude—vertical distance above the terrain, above ground level (AGL). An altimeter set to the proper pressure reading (QFE setting) indicates zero feet at touchdown. It is referred to as QFE. The METAR weather report in the remarks section lists this setting as sea level pressure (SLP) and is expressed in millibars (mb). Absolute altitude is very important when flying low and determining when an out landing must be accomplished. An out landing is a glider landing not at the intended airfield but required when lift is insufficient to remain aloft.
- Pressure altitude—altitude indicated at which the altimeter setting window (barometric scale) is adjusted to 29.92 is the standard datum plane, a theoretical plane where air pressure (corrected to 15 °C or 59 °F) is equal to 29.92 "Hg. Pressure altitude is used for computer solutions to determine density altitude, true altitude, TAS, etc.
- Density altitude—pressure altitude corrected for nonstandard temperature variations. Density altitude is a yardstick by which we can reference the density of air. The wings of the glider are affected by the density of air because they use air molecules to generate lift. Thinner air restricts fuel burn and lowers compression in the engine thereby reducing the power output. Thinner air necessitates an increased AOA to generate the same amount of lift. High density altitudes decrease towplane (and self-launching combustion powerplant) power, so expect much longer takeoff runs during tows, slower climbs, and the higher TAS results in longer landing rollouts due to higher ground speeds.

When conditions are standard, pressure altitude and density altitude are the same. Consequently, if the temperature is above standard, the density altitude is higher than pressure altitude. If the temperature is below standard, the density altitude is lower than pressure altitude. The density altitude determines the gliders performance and greatly affects the performance of towplanes and powerplants in self-launching gliders.

Variometer

Variometer instruments measure the vertical ascent or descent of the local air mass and glider combined and displays that information as speed. The principles of operation are similar to the altimeter. The variometer is viewed as a critical part of the glider's instrument display, giving the pilot information on performance of the glider while flying through the atmosphere. 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. The tubing is plumbed from the reference chamber through the variometer instrument to an outside static port. [Figure 4-20]

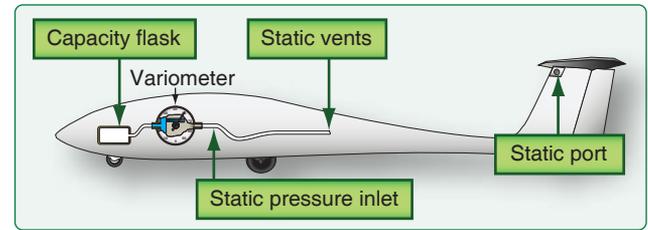


Figure 4-20. Uncompensated variometer plumbing.

A variometer with tubing is connected to an outside static port is uncompensated. The internal hairspring mechanism determines sensitivity of the variometer. The variometer has a very rapid response due to the small mass and lightweight construction of the moving parts. [Figure 4-21]

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 is greater than the pressure outside, air flows out of the reference chamber through the mechanical variometer to the outside environment. When air pressure outside the reference chamber is greater than pressure inside, air flows through the variometer and into the reference chamber until pressure is equalized. The variometer needle indicates a vertical descending air mass or sink which is falling air that forces the glider to lose height. Figures 4-22 and 4-23 illustrate how the variometer works in level flight and while the glider is ascending. In addition, Figure 4-24 illustrates certain flight maneuvers that cause the variometer to display changes in altitude.

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 operate by the cooling effect of airflow on an element called a thermistor, a heat-sensitive electrical resistor. The electrical resistance of the thermistor changes when temperature changes. As air flows into or out of the reference chamber, it flows across two thermistors in a bridge circuit. An electrical meter measures the imbalance across the bridge circuit and calculates the rate of climb or descent. It then displays the information on the variometer.

Newer electric variometers operate on the transducer principle. A tiny vacuum cavity on a circuit board is sealed with a flexible membrane. Variable resistors are embedded in the membrane. When pressure outside the

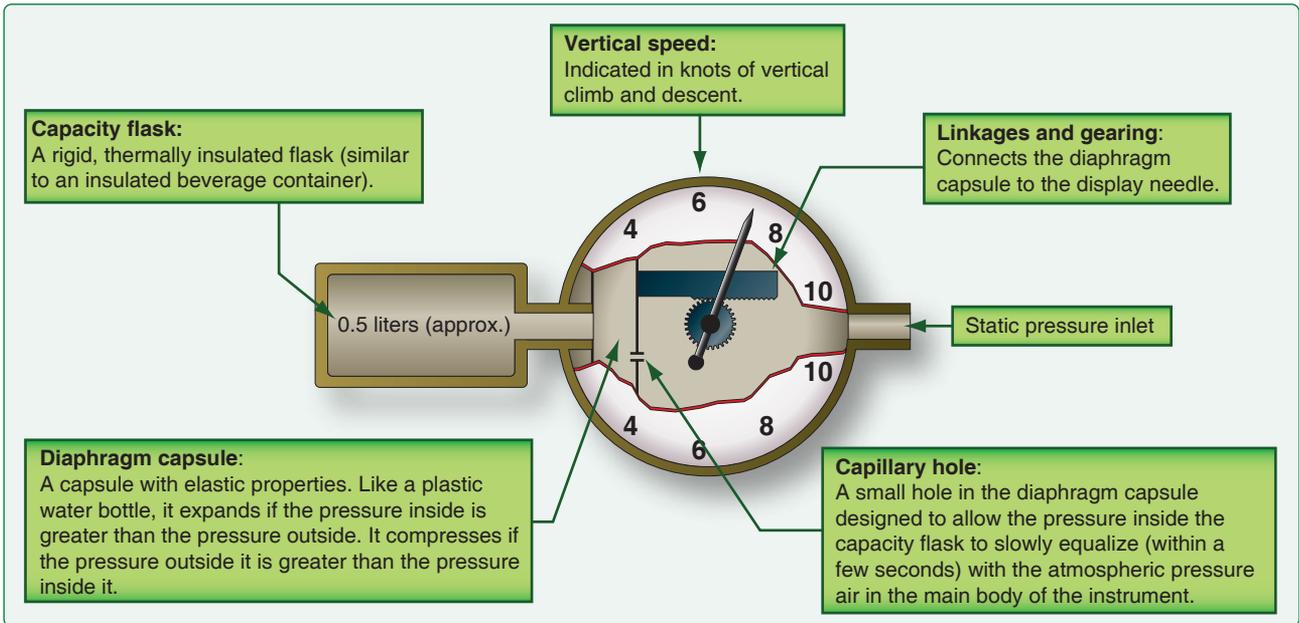


Figure 4-21. A variometer diaphragm anatomy.

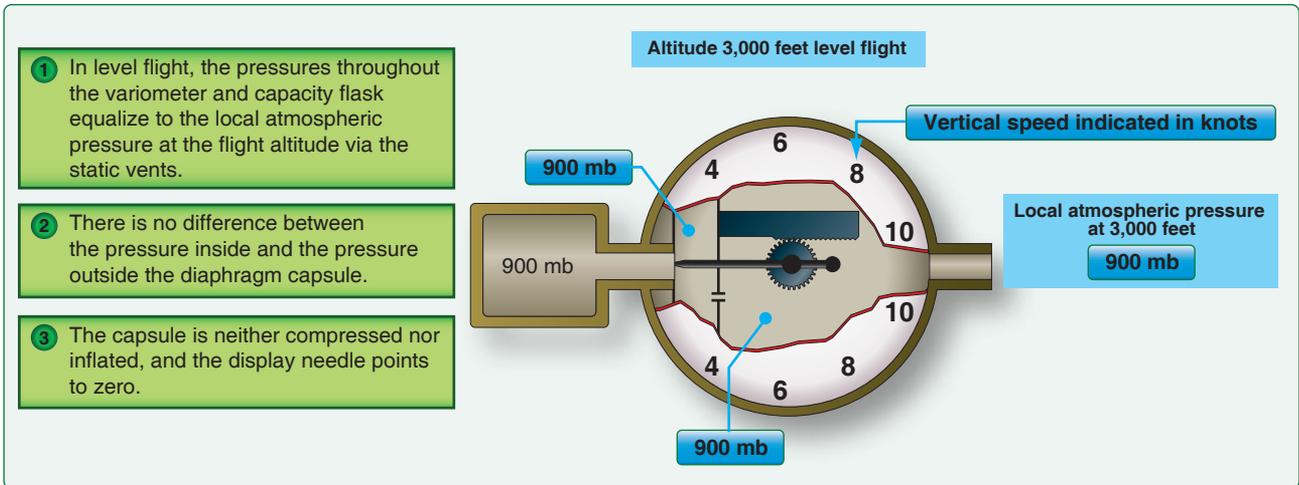


Figure 4-22. Uncompensated variometer in level flight.

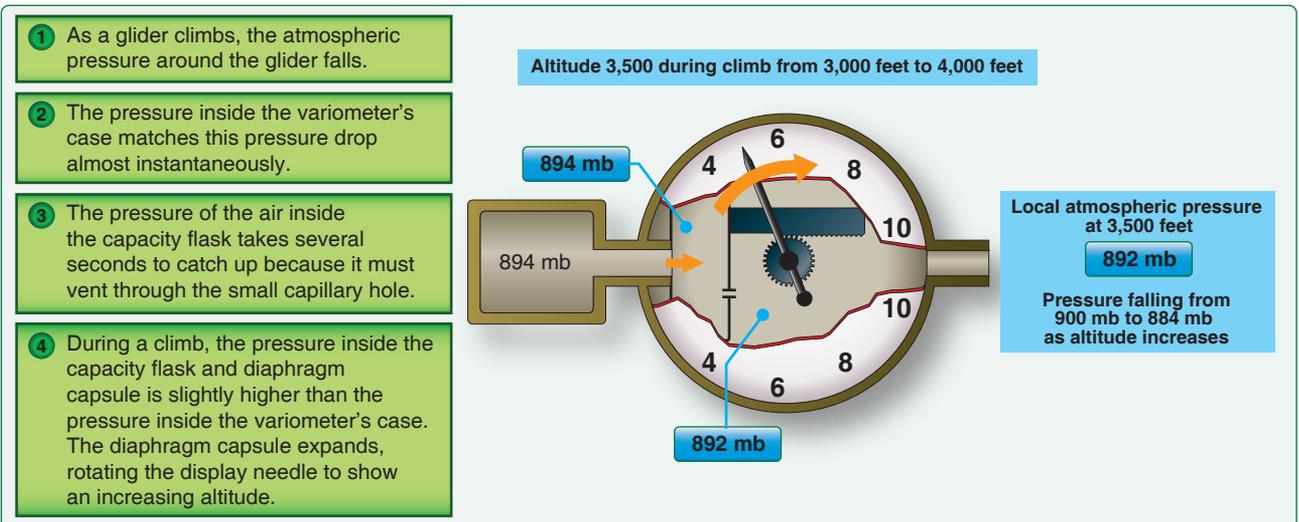


Figure 4-23. Uncompensated variometer in a climb.

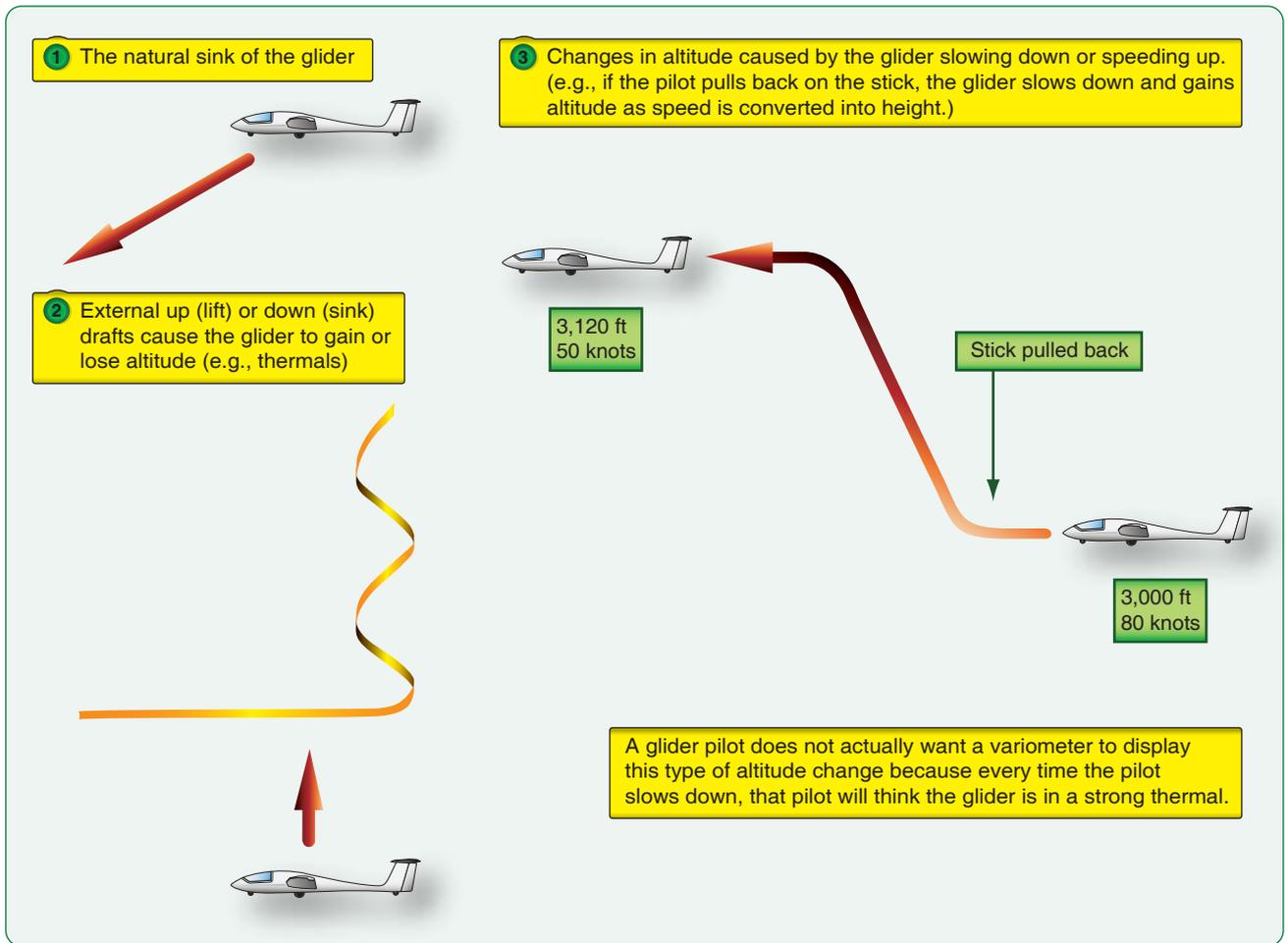


Figure 4-24. Flight maneuvers that display altitude changes on an uncompensated variometer.

cavity changes, minute alterations in the shape of the membrane occur. As a result, electrical resistance in the embedded resistors changes. These changes in electrical resistance are interpreted by a circuit board and indicated on the variometer dial as climb or descent.

Many electrical variometers provide audible tones, or beeps, that indicate the rate of climb or rate of descent of the glider. Audio variometers enhance safety of flight because they make it unnecessary for the glider pilot to look at the variometer to discern the rate of climb or rate of descent. Instead, the pilot can hear the rate of climb or rate of descent. This allows the pilot to minimize time spent looking at the flight instruments and maximize time spent looking outside for other air traffic. [Figure 4-25]

Some variometers are equipped with 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 index arrow is set at the rate of climb expected in the next thermal. On the speed ring, the

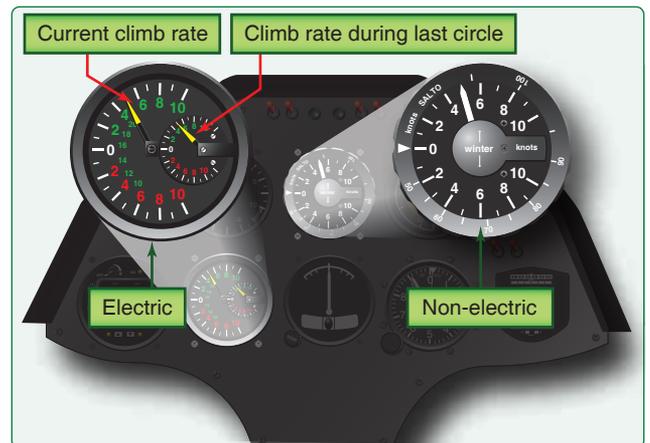


Figure 4-25. When an electric variometer is mounted to the glider, a non-electric variometer is usually installed as a backup.

variometer needle points to the optimum speed to fly (STF) between thermals. If expected rate of climb is low, optimum interthermal cruise airspeed is relatively low. When expected lift is strong, however, optimum interthermal cruise airspeed is much faster. [Figure 4-26] A MacCready ring has single

pilot values in front and dual pilot values for the second seat instrument. Marked for specific aircraft, some may have empty ballast and full ballast values.



Figure 4-26. The MacCready ring.

Variometers are sensitive to changes in pressure altitude caused by airspeed. In still air, when the glider dives, the variometer indicates a descent. When the glider pulls out of the dive and begins a rapid climb, the variometer indicates an ascent. This indication is sometimes called a stick thermal. A glider lacking a compensated variometer must be flown at a constant airspeed to receive an accurate variometer indication.

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 is desirable because the glider pilot wants to know how rapidly the air mass is rising or descending despite changes in airspeed.

A popular type of total energy system consists of a small venturi mounted in the air stream and connected to the static outlet of the variometer or simply as a slot or pair of holes on the back side of a quarter inch vertical tube. When airspeed increases, more suction from the venturi moderates (offsets) the pressure at the static outlet of the variometer. Similarly, when airspeed decreases, reduced suction from the venturi moderates (offsets) the pressure at the static outlet of the variometer. If the venturi is properly designed and installed, the net effect is to reduce climb and dive indications caused by airspeed changes. To maximize the precision of this compensation effect, the total energy probe needs to be in undisturbed airflow ahead of the aircraft nose or tail fin (the "Braunschweig tube", the long cantilevered tube with a kink in the end that can be seen projecting from the leading edge of the tail fin on most modern sailplanes.) [Figure 4-27]

Another type of total energy system is designed with 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 is proportional to the effect the airspeed change has on pitot pressure. In effect, the diaphragm modulates pressure changes in the capacity flask. When properly adjusted, the diaphragm compensator does an adequate job of masking stick thermals. [Figure 4-28]

Netto

A variometer that indicates the vertical movement of the air mass, regardless of the glider's climb or descent rate, is called a Netto variometer system. Some Netto variometer systems employ a calibrated capillary tube that functions as a tiny

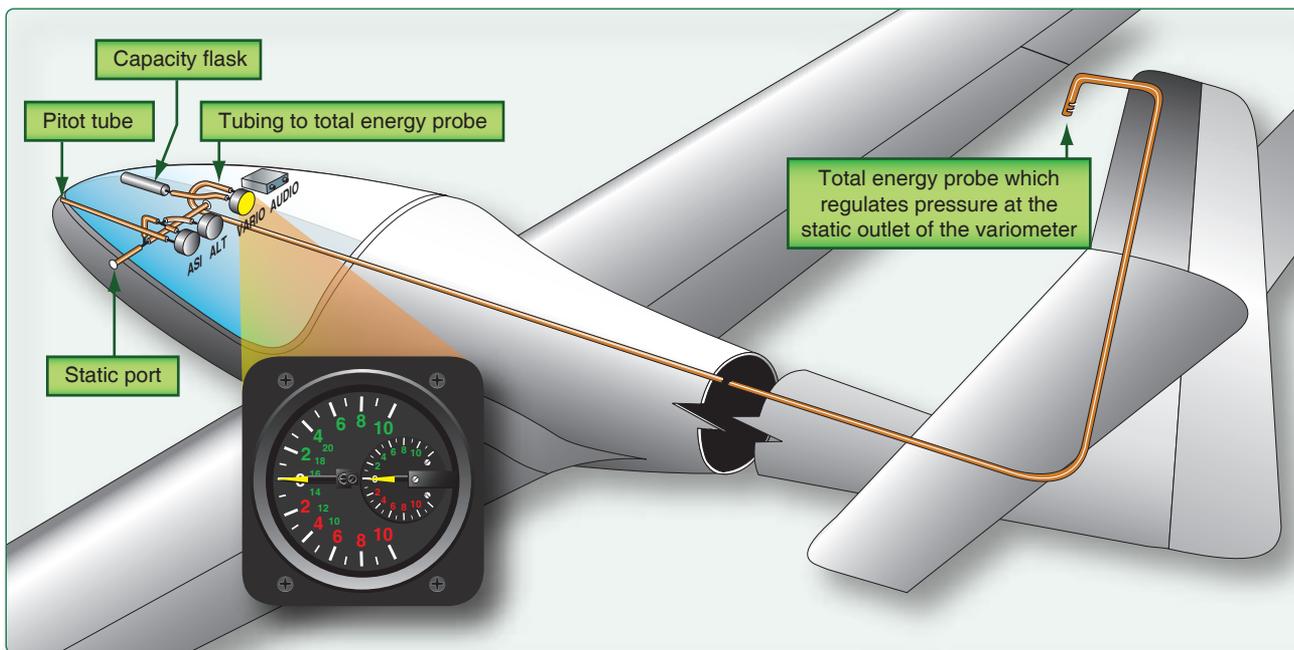


Figure 4-27. A total energy variometer system.

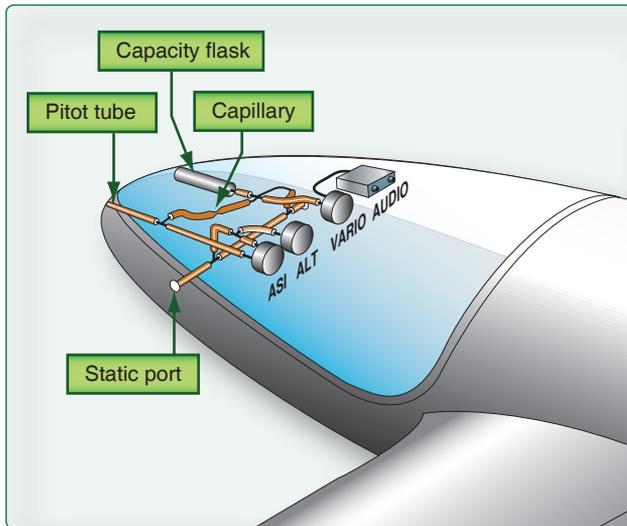


Figure 4-28. An example of a Netto variometer system.

valve. Pitot pressure pushes minute quantities of air through the valve and into the reference chamber tubing. The effect is to remove the glider's sink rate at various airspeeds from the variometer indication (polar sink rate). [Figure 4-28]

Computerized (electronic) Netto variometers employ a different method to remove the glider performance polar sink rate from the variometer indication. In this type of system, sensors for both pitot pressure and static pressure provide airspeed information to the computer. The sink rate of the glider at every airspeed is stored in the computer memory. At any given airspeed, the sink rate of the glider is mathematically removed, and the variometer displays the rate of ascent or descent of the air mass itself.

Electronic Flight Computers

Electronic flight computers are found in the cockpits of gliders that are flown in competition and cross-country soaring. Since nonpowered gliders lack a generator or alternator, electrical components, such as the flight computer and very high frequency (VHF) transceiver, draw power from the glider battery or batteries. The battery is usually a 12- or 14-volt sealed battery. Solar cells are sometimes 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 are 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. Shown in Figure 4-29 is a high end glider flight computer.



Figure 4-29. High end flight computer system.

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

- Where you are
- Where you have been
- Distance to planned destination
- How fast you are going there
- How high you need to be to glide there
- How fast you are climbing or descending
- The optimum airspeed to fly to the next area of anticipated lift
- 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 can easily be divided into two areas: navigation assistance and performance (speed) enhancement.

Fundamental to the use of the flight computer is the concept of waypoint. A waypoint is simply a point in space. The three coordinates of the point are 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, a triangle, a quadrilateral or other type of polygon, or a series of waypoints laid out more or less in a straight line. The glider pilot must navigate 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 and in summarizing how the flight is going. When strong lift is encountered, and if the pilot believes it is likely that the strong lift source may be worth returning to after rounding a turnpoint, the flight computer can mark the location of the

thermal. Then, the glider pilot can round a nearby turnpoint and use the flight computer to guide the return to the marked thermal in the hopes of making a rapid climb and heading out on course toward the next turnpoint.

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.

Most flight computers incorporate an electronic audiovisual variometer. The rate of climb or descent can be viewed on the computer's visual display. The variometer also provides audible rate of climb information through a small loudspeaker. The loudspeaker allows the pilot to hear how fast the glider is climbing or descending. Because this information is received through hearing, the pilot's vision can be constantly directed outside the glider to enhance safety of flight and cross-country performance.

Flight computers also provide information to help the pilot select and fly the optimum airspeed for the weather conditions being encountered. When lift is strong and climbs are fast, higher airspeeds around the course are possible. The flight computer detects the rapid climbs and suggests very high cruise airspeeds to enhance performance. When lift is weak and climbs are slow, optimum airspeed is significantly lower than when conditions are strong. The flight computer, sensing the relatively low rate of climb on a difficult day, compensates for the weaker conditions, and suggests optimum airspeeds that are lower than they would be if conditions were strong. The flight computer relieves the pilot of the chore of making numerous speed-to-fly calculations during cross-country flight. This freedom allows 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.

The presence of water ballast alters the performance characteristics of the glider. In racing, the ability to make faster glides without excess altitude penalty is very valuable. The additional weight of water in the glider's ballast tanks allows flatter glides at high airspeeds. The water ballast glider possesses the strongest advantage when lift conditions are strong and rapid climbs are achievable. The flight computer compensates for the amount of 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 condition of the glider. Other flight computers automatically compensate for the effect of water ballast by constantly measuring the performance of the glider and deducting the operating weight of the glider from these measurements. If the wings of the glider become contaminated with bugs, glider performance declines. The glide computer can be adjusted to account for the resulting performance degradation.

Magnetic Compass

Some gliders do not have compass deviation cards because they are not required instrumentation per the Type Certificate Data Sheets (TCDS). Most gliders are not considered powered aircraft as referenced in Title 14 of the Code of Federal Regulations (14 CFR) part 91, section 91.205, and are only subject to regulations specifying "civil aircraft." Two examples that show these are 14 CFR part 91, section 91.209 and 91.211.

Yaw String

The most effective, yet least expensive, slip/skid indicator is made from a piece of yarn mounted in the free airstream in a place easily visible to the pilot, as shown in *Figure 4-30*. The yaw string indicates whether the pilot is using the rudder and aileron inputs together in a coordinated fashion. When the controls are properly coordinated, the yarn points straight back, aligned with the longitudinal axis of the glider. During a slipping turn, the tail of the yaw string is offset toward the outside of the turn. In flight, the rule to remember is simple: step on the head of the yaw string. If the head of the yaw string is to the right of the tail, then the pilot needs to apply right pedal. If the head of the yaw string is to the left of the tail, then the pilot should apply left pedal.

Inclinometer

Another type of slip/skid indicator is the inclinometer. Like the magnetic compass, this instrument requires no electrical power or input from other aircraft systems. The inclinometer is influenced by centrifugal force and gravity. Mounted in the bottom of a turn-and-bank indicator or mounted separately in the instrument panel, the inclinometer consists of a metal ball in an oil-filled, curved glass tube. When the glider is flying 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. Remember the phrase, "step on the ball" in reference to the inclinometer; it helps coordinate the turn using rudder inputs. The long glider wing tends to increase the adverse yaw effects from the ailerons and requires more rudder control than many aircraft.



Figure 4-30. Left turn condition indications of a yaw string and inclinometer.

Gyroscopic Instruments

Gyroscopic instruments are found in virtually all modern airplanes but are infrequently found in gliders. Self-launching gliders often have one or more gyroscopic instruments on the panel. Gliders without power rarely have gyroscopic instruments installed. The three gyroscopic instruments found most frequently in a glider are the heading indicator, attitude indicator, and turn coordinator.

G-Meter

Another instrument that can be mounted in the instrument panel of a glider is a G-meter. G-meters register positive G forces from climbs and turns, as well as negative G forces when diving down or pushing over from a climb. The G-meter measures and displays the load imposed on the glider during flight. During straight, unaccelerated flight in calm air, a glider experiences a load factor of 1 G (1.0 times the force of gravity). During aerobatics or during flight in turbulent air, the glider and pilot experience G-loads greater than 1 G. These additional loads result from accelerations imposed on the glider. Some of these accelerations result from external sources, such as flying into updrafts or downdrafts. Other accelerations arise from pilot input on the controls, such as pulling back or pushing forward on the control stick. G-loads are classified as positive or negative.

Positive G is felt when increasing pitch rapidly for a climb. Negative G is felt when pushing over into a dive or during sustained inverted flight. Each glider type is designed to withstand a specified maximum positive G-load and a specified maximum negative G-load. The GFM/POH is 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. This is useful in 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 4-31]

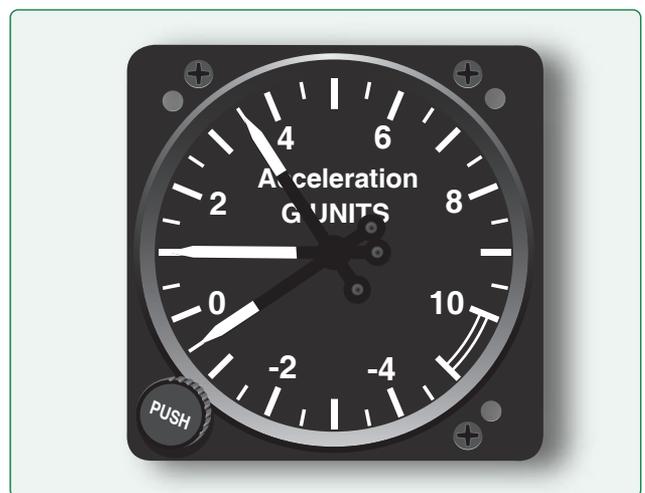


Figure 4-31. The G-meter.

FLARM Collision Avoidance System

Mid-air collisions are a long standing danger in aviation and glider pilots have additional mid-air threats due to thermalling, cloud-street flying, and ridge running. All of these can put the glider in close proximity to other gliders and other aircraft. No matter how vigilant pilots are, too many stories of "near misses" exist. There are mid-air collisions or near misses each year in both club flying and in competition and between gliders and towplanes.

As a way to mitigate mid-air collisions, the FLARM collision avoidance system was developed for glider pilots by glider pilots. FLARM warns FLARM-equipped pilots of impending collisions and gives the location of non-threatening nearby FLARM-equipped gliders. *Figure 4-32* shows the interior of an ASW 19 glider with a FLARM unit on top of the instrument panel. It only works if both gliders have FLARMS. FLARM knows about the unique flight characteristics of gliders and stays quiet unless there is a real hazard.



Figure 4-32. FLARM unit on top of the instrument panel.

FLARM (the name being inspired from 'flight alarm') obtains its position from an internal global positioning system (GPS) and a barometric sensor and then broadcasts this with forecast data about the future 3D flight track. Its receiver listens for other FLARM devices within typically 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.

Unlike conventional transponders in aircraft, FLARM has a low-power consumption and is relatively inexpensive to buy and to install. Furthermore, conventional Airborne Collision Avoidance Systems (ACAS) are of little use in preventing gliders from colliding with each other because gliders are

frequently close to each other without being in danger of collision. ACAS would provide continuous and unnecessary warnings about all aircraft in the vicinity, whereas FLARM only gives selective alerts to aircraft posing a collision risk. Versions are sold for use in light aircraft and helicopters, as well as gliders. However, the short range of the signal makes FLARM unsuitable for avoiding collisions with fast moving aircraft, such as commercial and military jets.

Outside Air Temperature Gauge

The outside air temperature gauge (OAT) is a simple and effective self-contained device mounted so that the sensing element is exposed to the outside air. The sensing element consists of a bimetallic-type thermometer in which two dissimilar metals are welded together into a single strip and twisted into a helix. One end is anchored into a protective tube, and the other end is affixed to the pointer that reads against the calibration on a circular face. OAT gauges are calibrated in degrees Celsius, degrees Fahrenheit, or both. An accurate air temperature provides the glider pilot with useful information about temperature lapse rate with altitude change. A very fast reading OAT gauge can give glider pilots another indication of the hottest center portion of thermals for maximum loft and where the edge of the lifting currents are located.

When flying a glider loaded with water ballast, knowledge of the height of the freezing level is important to 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. [*Figure 4-33*]

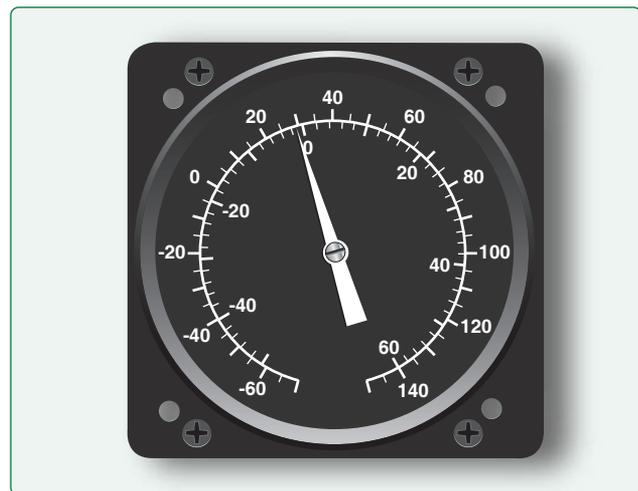


Figure 4-33. Outside air temperature (OAT) gauge.