CHAPTER 4
Flight Instruments

Flight instruments in the glider cockpit provide information regarding the glider's direction, altitude, airspeed, and performance. These instruments are categorized according to their method of operation. The categories include pitot-static, magnetic, gyro-scopic, electrical, or self-contained. Examples of self-contained instruments and indicators that are useful to the pilot include the yaw string, inclinometer, and outside air temperature gauge (OAT).

Gyroscopic instruments, including the attitude indicator, turn coordinator, and heading indicator, are discussed in this chapter to give you an understanding of how they function. Self-launch gliders often have one or more gyroscopic instruments on the panel. Gliders without power rarely have gyroscopic instruments installed.

PITOT-STATIC INSTRUMENTS

There are two major parts of the **pitot-static system**: (1) impact pressure lines; and (2) static pressure lines, which provide the source of ambient air pressure for the operation of the altimeter, variometer, and the airspeed indicator.

IMPACT AND STATIC PRESSURE LINES

The impact air pressure (air striking the glider because of its forward motion) is taken from a pitot tube, which is mounted either on the nose or the vertical stabilizer, and aligned with the relative wind. These locations minimize disturbance or turbulence caused by the motion of the glider through the air.

The static pressure (pressure of the still air) is taken from the static line, which is attached to a vent or vents mounted flush with the side of the fuselage or tube mounted on the vertical stabilizer. Gliders using a flush-type static source with two vents, have one vent on each side of the fuselage. This compensates for any possible variation in static pressure due to erratic changes in glider attitude.

The openings of both the pitot tube and the static vent(s) should be checked during the preflight inspection to enure 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 any of the three instruments.

AIRSPEED INDICATOR

The airspeed indicator displays the speed of the glider through the air. Some airspeed indicator dials provide color-coded arcs that depict permissible airspeed ranges for different phases of flight. The upper and lower limits of the arcs correspond to airspeed limitations specific to the glider in which the instrument is mounted. [Figure 4-1]

The airspeed indicator is the only instrument that depends on both pitot pressure and static pressure. When pitot pressure and static pressure are the same, zero airspeed is indicated. As pitot pressure becomes progressively greater than static pressure, indicated air-

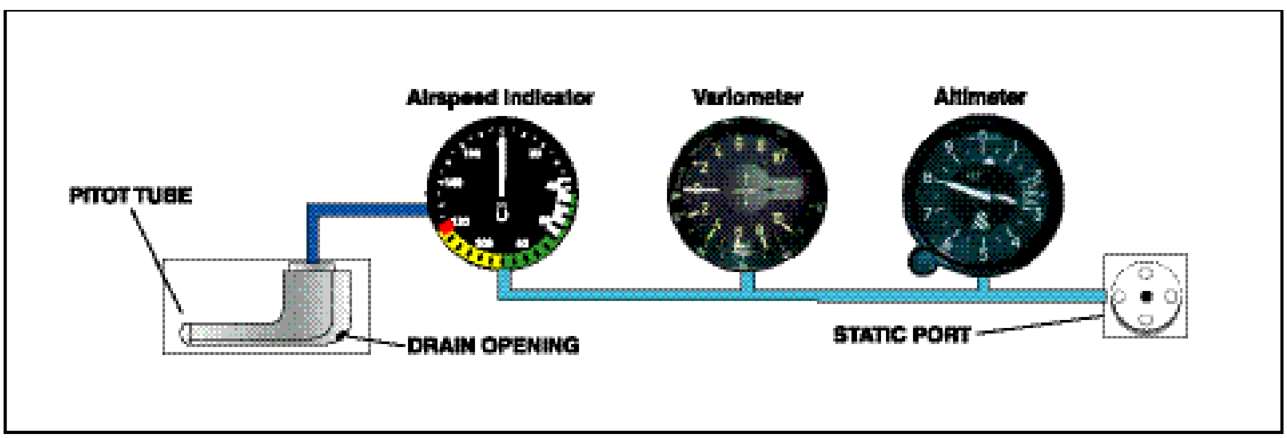


Figure 4-1. The airspeed indicator uses both the pitot and static system.

speed increases. The airspeed indicator contains a small diaphragm that drives the needle on the face of the instrument.

TYPES OF AIRSPEED

There are three kinds of airspeed that the pilot should understand: indicated airspeed, calibrated airspeed, and true airspeed. [Figure 4-2]

INDICATED AIRSPEED

Indicated airspeed (IAS) is the direct instrument reading obtained from the airspeed indicator, uncorrected for variations in atmospheric density, installation error, or instrument error.

CALIBRATED AIRSPEED

Calibrated airspeed (CAS) is indicated airspeed 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, indicated airspeed and calibrated airspeed 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 the Glider Flight Manual or Pilot's Operating Handbook (GFM/POH), are usually calibrated airspeeds. Some manufacturers use indicated rather than calibrated airspeed to denote the airspeed limitations mentioned. The airspeed indicator should be calibrated periodically.

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

TRUE AIRSPEED

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

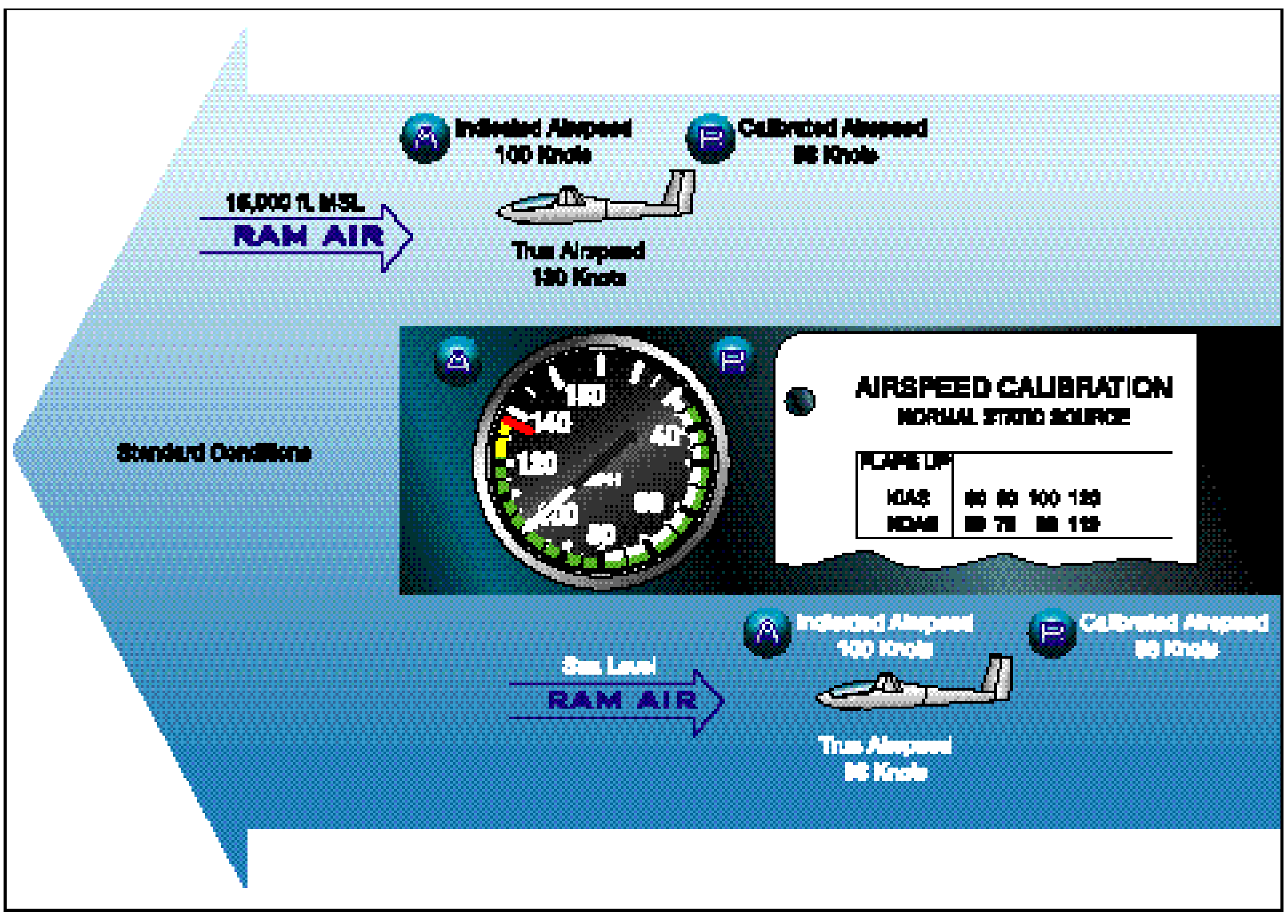


Figure 4-2. The three types of airspeed you should know include calibrated airspeed, indicated airspeed, and

A pilot can find true airspeed by two methods. The first method, which is more accurate, involves using a computer. In this method, the calibrated airspeed 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 true airspeed. This is done by adding to the indicated airspeed 2 percent of the indicated airspeed for each 1,000 feet of altitude.

AIRSPEED INDICATOR MARKINGS

Aircraft weighing 12,500 pounds or less, manufactured after 1945 and certificated by the FAA, are required to have airspeed indicators that conform to a standard color-coded marking system. This system enables the pilot to determine at a glance certain airspeed limitations, which 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 stresses upon the glider structure. [Figure 4-3]

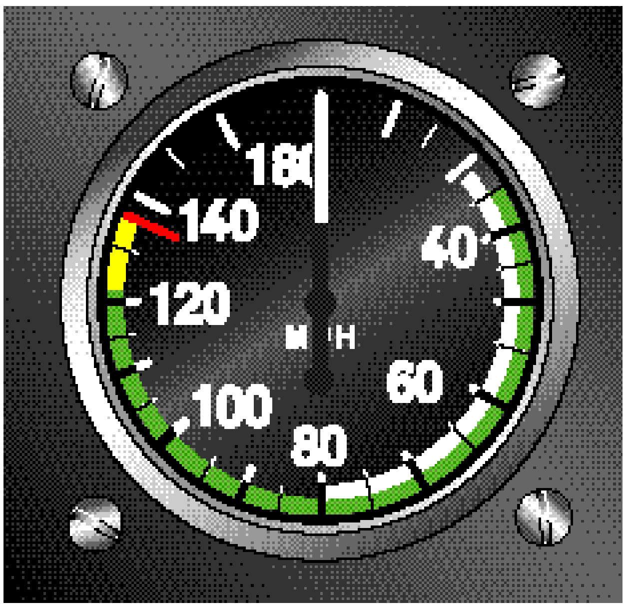


Figure 4-3. Airspeed indicator with color markings.

The following is a description of the standard color-code markings on airspeed indicators.

- FLAP OPERATING RANGE (the white arc).
- STALLING SPEED WITH THE WING FLAPS AND LANDING GEAR IN THE LANDING POSITION (the lower limit of the white arc).
- MAXIMUM FLAPS EXTENDED SPEED (the upper limit of the white arc). 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.
- NORMAL OPERATING RANGE (the green arc).
- STALLING SPEED WITH THE WING FLAPS AND LANDING GEAR RETRACTED (the lower limit of the green arc).
- MAXIMUM STRUCTURAL CRUISING SPEED (the upper limit of the green arc). This is the maximum speed for normal operation.
- CAUTION RANGE (the yellow arc). The pilot should avoid this area unless in smooth air.
- NEVER-EXCEED SPEED (the red line). 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 in view of the pilot and in the GFM/POH.

MANEUVERING SPEED is the maximum speed at which the **limit load** can be imposed (either by gusts or full deflection of the control surfaces) without causing structural damage. If during flight, rough air or severe turbulence is encountered, 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.

Other important airspeeds include LANDING GEAR OPERATING SPEED, the maximum speed for extending or retracting the landing gear if using glider equipped with retractable landing gear; the MINIMUM SINK SPEED, important when thermaling; and the BEST GLIDE SPEED, the 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 is the maximum airspeed that the glider may safely be towed without causing structural damage.

The following are abbreviations for performance speeds.

V_A—design maneuvering speed.
V_C—design cruising speed.
V_F—design flap speed.

V_{FE}—maximum flap extended speed.
V_{LE}—maximum landing gear extended speed.
V_{LO}—maximum landing gear operating speed.
V_{NE}—never-exceed speed.
V_S—the stalling speed or the minimum steady flight speed at which the glider is controllable.
V_{S0}—the stalling speed or the minimum steady flight speed in the landing configuration.
V_{S1}—the stalling speed or the minimum steady flight speed obtained in a specified configuration.

ALTIMETER

The altimeter measures the height of the glider above a given level. Since it is the only instrument that gives altitude information, the altimeter is one of the most important instruments in the glider. To use the altimeter effectively, the pilot must thoroughly understand its principle of operation and the effect of atmospheric pressure and temperature on the altimeter. [Figure 4-4]

PRINCIPLE OF OPERATION

The pressure altimeter is simply an aneroid barometer that measures the pressure of the atmosphere at the level where 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, therefore as altitude increases, atmospheric pressure decreases. This difference in pressure at various levels causes the altimeter to indicate changes in altitude.

The presentation of altitude varies considerably between different types of altimeters. Some have one pointer while others have more. Only the multi-pointer type will be discussed in this handbook.

The dial of a typical altimeter is graduated with numerals arranged clockwise from 0 to 9 inclusive as shown in Figure 4-4. 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.

The altitude indicated on the altimeter is correct only if the sea level barometric pressure is standard (29.92 in. Hg.), the sea level free air temperature is standard (+15° C or 59° F), and the pressure and temperature decrease 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 will be LOWER than the indicated altitude. When flying from a low-pressure area to a high-pressure area, the actual altitude of the glider will be HIGHER than the indicated altitude. Fortunately, this error can be corrected by setting the altimeter properly.

Variations in air temperature also affect the altimeter. On a warm day, the expanded air is lighter in weight per unit volume than on a cold day, and consequently the pressure levels are raised. For example, the pressure level where the altimeter indicates 10,000 feet will be 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

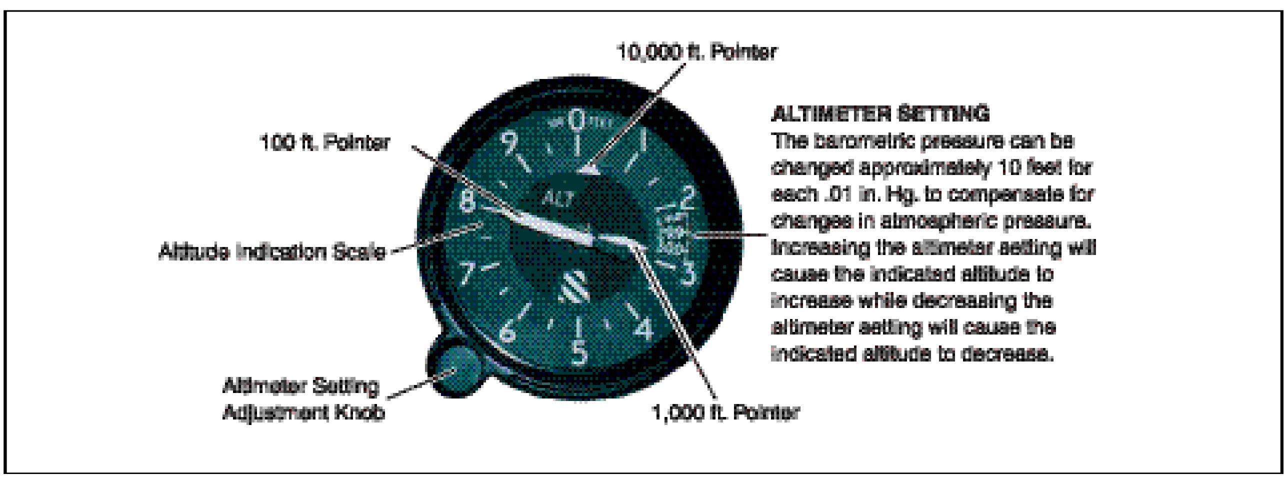


Figure 4-4. The altimeter indicator.

of a cruising altitude, particularly at higher altitudes, remember to anticipate that COLDER-THAN-STANDARD TEMPERATURE will place 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 4-5]

SETTING THE ALTIMETER

To adjust the altimeter for variation in atmospheric pressure, the pressure scale in the altimeter setting window, calibrated in inches of mercury (in. 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.

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. Therefore, it is necessary to adjust the altimeter setting as the flight progresses from one station to the next.

Title 14 of the Code of Federal Regulations (14 CFR) part 91 provides the following concerning altimeter settings. The cruising altitude of an aircraft below 18,000 feet mean sea level (MSL) shall be maintained by reference to an altimeter that is set to the current reported altimeter setting of a station located along the route of flight and within 100 nautical miles (NM) of the aircraft. If there is no such station, the current reported altimeter setting of an appropriate available station shall be used. In an aircraft having no radio, the altimeter shall be set to the elevation of the departure airport or an appropriate altimeter setting available before departure.

Many pilots confidently expect that the current altimeter setting will compensate for irregularities in atmospheric pressure at all altitudes. This is not always true because the altimeter setting broadcast by ground stations is the station pressure corrected to mean sea level. The altimeter setting does not account for the irregularities at higher levels, particularly the effect of nonstandard temperature.

It should be pointed out, however, that if each pilot in a given area were to use the same altimeter setting, each altimeter will be equally affected by temperature and pressure variation errors, making it possible to maintain the desired separation between aircraft.

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

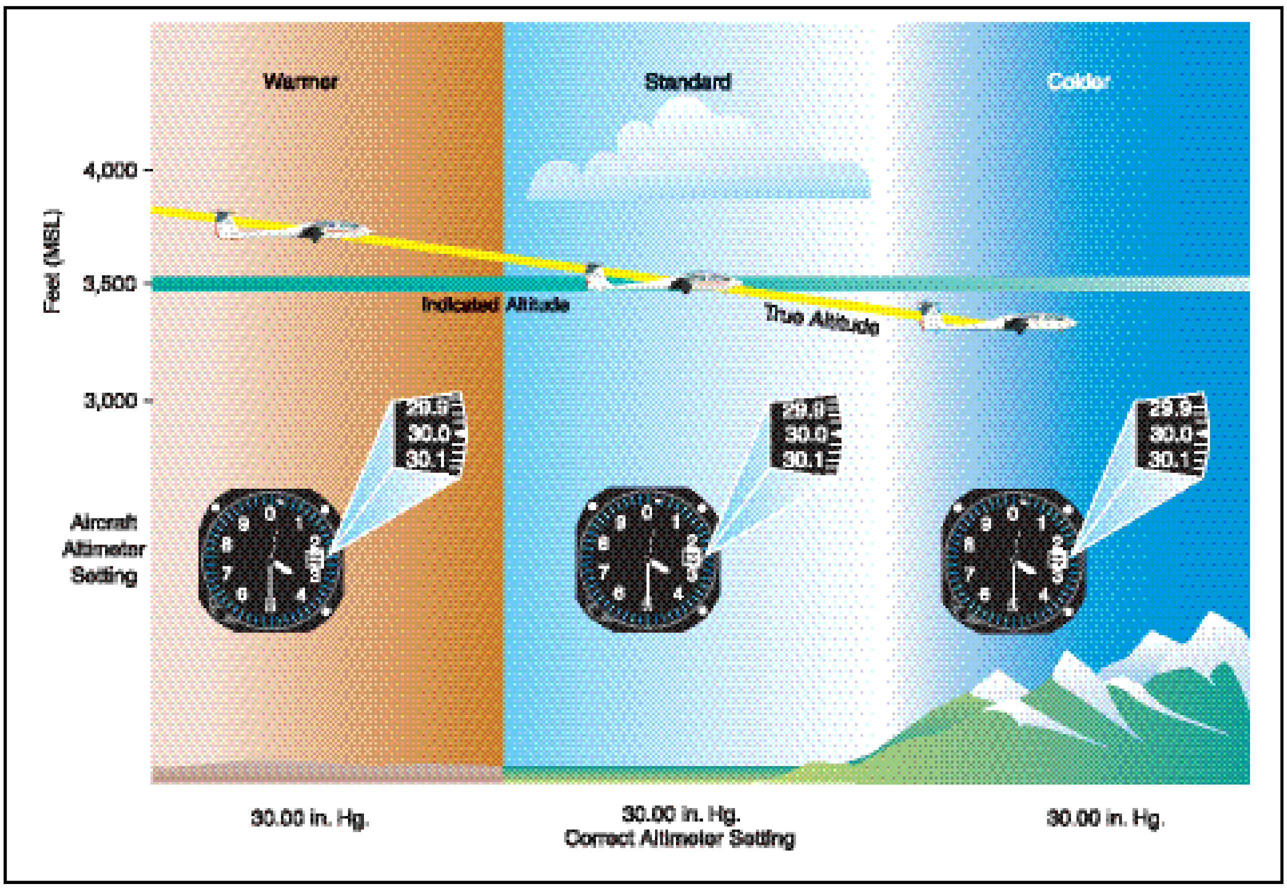


Figure 4-5. Nonstandard pressure and temperature.

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 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. If an altimeter indication varies from the field elevation 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 feet + 1000 feet = 3,420 feet, rounded to 3,400 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 CO area setting of 29.94. If this occurred, the glider, when entering the Winston Airport traffic pattern, would be approximately 250 feet below the proper traffic pattern altitude of 3,200 feet, and the altimeter would indicate approximately 250 feet more than the field elevation (2,430 feet) upon landing.

Actual altimeter setting	29.94
Correct altimeter setting	29.69
Difference	.25

(1 inch of pressure is equal to approximately 1,000 feet of altitude—.25 x 1,000 feet = 250 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. It is obvious then that if the glider is flown from a pressure level of 28.75 in. Hg. to a pressure level of 29.75 in. Hg., the altimeter would show a decrease of approximately 1,000 feet in altitude. [Figure 4-6]

The other method of moving the pointers does not rely on changing air pressure, but the mechanical construction of the altimeter. When the knob on the altimeter is rotated, the altimeter setting pressure scale moves

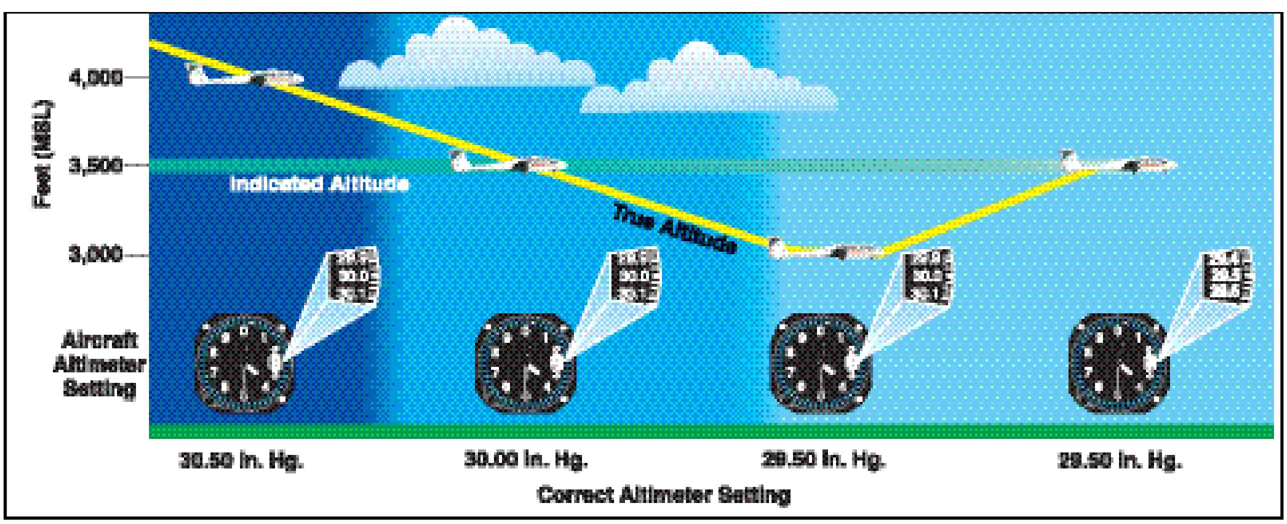


Figure 4-6. Flying from an area of high pressure to an area of lower pressure, without resetting your altimeter, results in your glider's true altitude being lower than indicated.

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; or 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 flying at an altitude of 500 feet lower than was shown on the altimeter.

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; this is especially important when visibility is restricted. 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 true airspeeds.

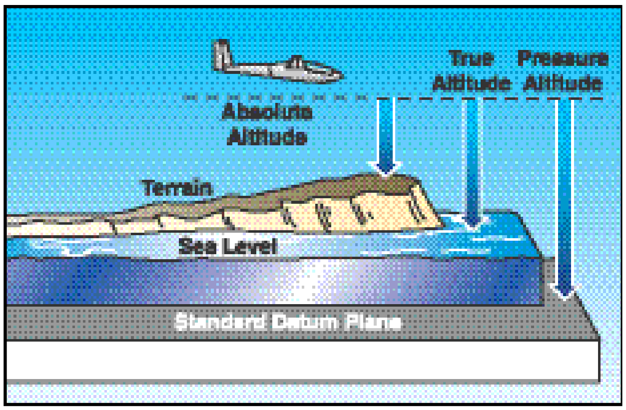


Figure 4 -7. Types of altitude.

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 4-7]

Indicated Altitude—That altitude read directly from the altimeter (uncorrected) after it is set to the current altimeter setting.

True Altitude—The true vertical distance of the glider above sea level—the actual altitude. (Often expressed in this manner: 10,900 feet MSL.) Airport, terrain, and obstacle elevations found on aeronautical charts are true altitudes.

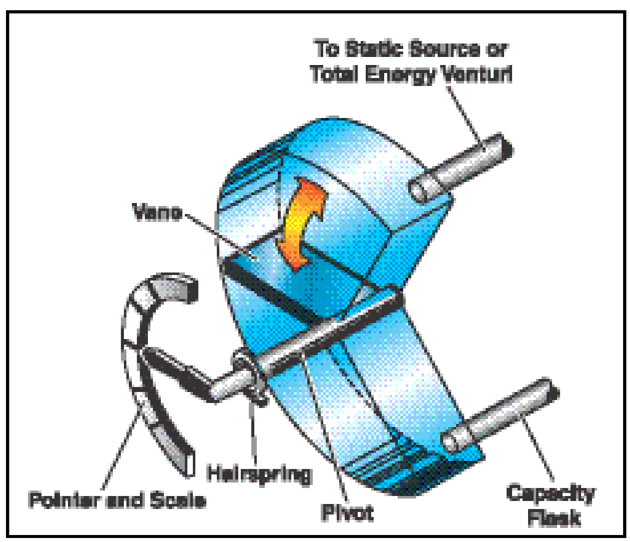
Absolute Altitude—The vertical distance above the terrain.

Pressure Altitude—The altitude indicated when the altimeter setting window (barometric scale) is adjusted to 29.92. This is the standard datum plane, a theoretical plane where air pressure (corrected to 15° C or 59° F) is equal to 29.92 in. Hg. Pressure altitude is used for computer solutions to determine density altitude, true altitude, true airspeed, etc.

Density Altitude—This altitude is pressure altitude corrected for nonstandard temperature variations. When conditions are standard, pressure altitude and density altitude are the same. Consequently, if the temperature is above standard, the density altitude will be higher than pressure altitude. If the temperature is below standard, the density altitude will be lower than pressure altitude. This is an important altitude because it is directly related to the glider's takeoff and climb performance.

VARIOMETER

The **variometer** gives the glider pilot information on performance of the glider while flying through the atmosphere. The variometer operates on the same principle as the altimeter, however, it indicates rate of climb or descent instead of vertical distance. The variometer depends upon the pressure lapse rate in the atmosphere to derive information about rate of climb or rate of descent. Most non-electrical variometers use a separate insulated tank, such as a Thermos or capacity flask, as a reference chamber. The tubing is plumbed from the reference chamber through the variometer to an outside static port. By using different hairsprings, the sensitivity of the variometer can be controlled. The variometer has a very rapid response due to the small mass and lightweight construction of the moving parts.



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, displacing a vane inside the variometer. The vane, in turn, drives the needle to display a climb indication. 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 descent. [Figure 4-8]

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 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.

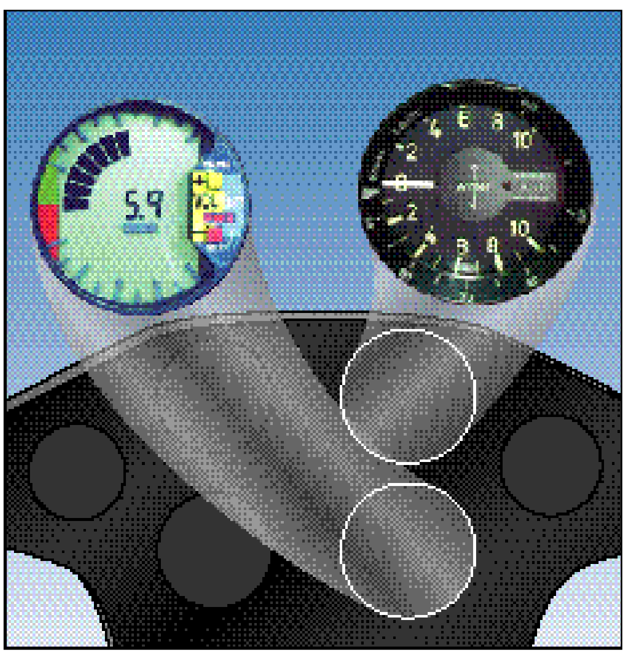


Figure 4-9. When an electric variometer is mounted in the glider a non-electric variometer is usually installed as a backup.

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 4-9]

Figure 4-10. The MacCready ring.

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 variometer needle points to the optimum speed to fly between thermals. If expected rate of climb is slow, optimum inter-thermal cruise airspeed will be relatively slow. When expected lift is strong, however, optimum inter-thermal cruise airspeed will be much faster. [Figure 4-10]

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 airmass is rising or descending despite changes in airspeed.

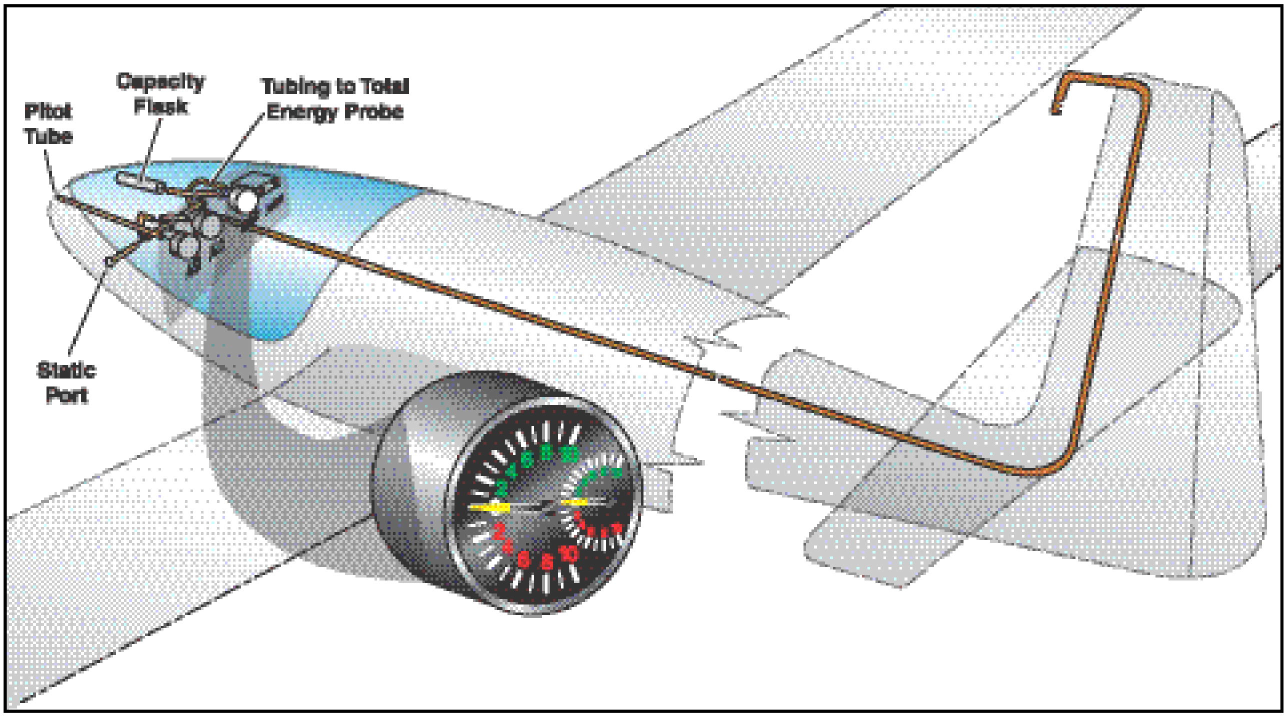


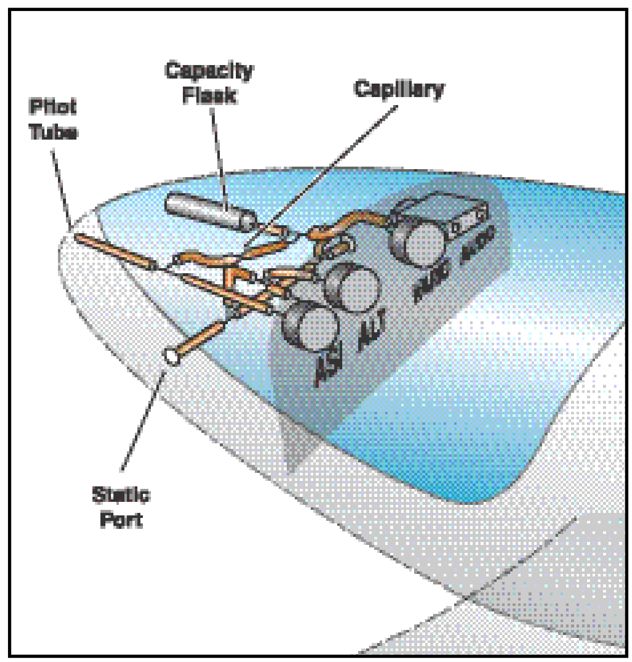
Figure 4-11. A total energy variometer system.

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. When airspeed increases, more suction from the venturi moderates the pressure at the static outlet of the variometer. Similarly, when airspeed decreases, reduced suction from the venturi moderates 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.

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 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 4-11]

NETTO

A variometer that indicates the vertical movement of the airmass, regardless of the sailplane'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 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 4-12]



Electronic, computerized 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 airmass itself.

ELECTRONIC FLIGHT COMPUTERS

Electronic flight computers are found in the cockpits of gliders that are flown in competition and cross-country soaring. Since non-powered gliders lack a generator or alternator, electrical components, such as the flight computer and 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 Global Positioning Satellite (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. [Figure 4-13]

The GPS-coupled flight computer can provide you with the following information.

- Where you are.
- Where you have been.
- Where you are going.
- 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 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, optimum airspeed to fly, glider

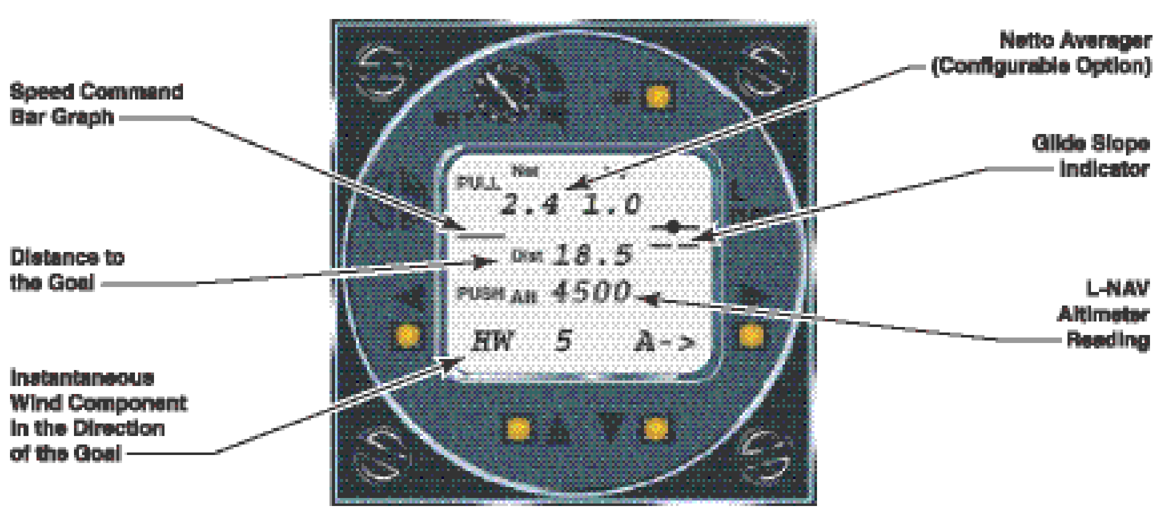


Figure 4-13. Flight computer system display.

groundspeed, and the amount of time it will take to reach the goal.

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 fast cruise airspeeds to enhance performance. When lift is weak and climbs are slow, optimum airspeed will be significantly slower than when conditions are strong. The flight computer, sensing the relatively slow rate of climb on a difficult day, compensates for the weaker conditions and suggests optimum airspeeds that are slower 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 will decline. The glide computer can be adjusted to account for the resulting performance degradation.

MAGNETIC COMPASS

The magnetic compass, which is the only direction-seeking instrument in the glider, is simple in construction. It contains two steel magnetized needles fastened to a float around which a compass card is mounted. The needles are parallel, with their north-seeking ends pointed in the same direction. The compass card has letters for cardinal headings, and each 30° interval is represented by a number, the last zero of which is omitted. For example, 30° would appear as a 3 and 300° would appear as 30. Between these numbers, the card is graduated for each 5°. [Figure 4-14]

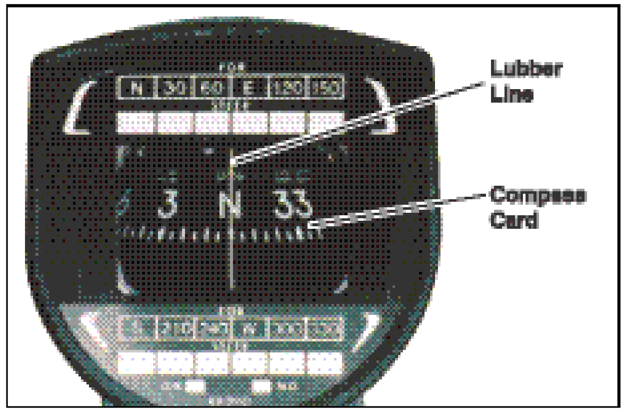


Figure 4-14. A magnetic compass.

The float assembly is housed in a bowl filled with acid-free white kerosene. The purposes of the liquid are to dampen out excessive oscillations of the compass card, and relieve by buoyancy part of the weight of the float from the bearings. Jewel bearings are used to mount the float assembly on top of a pedestal. A line (called the lubber line) is mounted behind the glass of the instrument that can be used for a reference line when aligning the headings on the compass card.

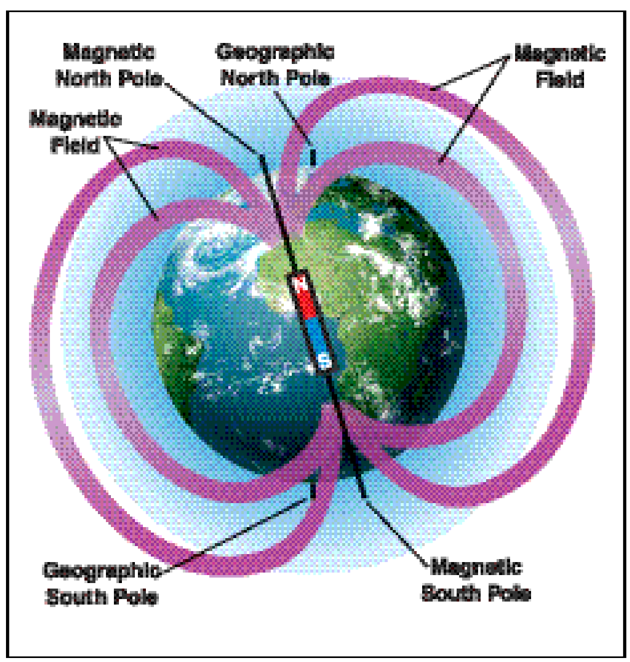


Figure 4-15. Earth magnetic force flow.

The magnetic compass works on the principle of magnetism. The glider pilot must have a basic understanding of the principles of operation of the magnetic compass. A simple bar magnet has two centers of magnetism, which are called poles. Lines of magnetic force flow out from each pole in all directions, eventually bending around and returning to the other pole. The area through which these lines of force flow is called the field of the magnet. For the purpose of this discussion, the poles are designated "north" and "south." If two bar magnets are placed near each other, the north pole of one will attract the south pole of the other. There is evidence that there is a magnetic field surrounding the Earth, and this theory is applied in the design of the magnetic compass. It acts very much as though there were a huge bar magnet running along the axis of the Earth, which ends several hundred miles below the surface. [Figure 4-15]

The lines of force have a vertical component (or pull), which is zero at the Equator, but builds to 100 percent of the total force at the poles. If magnetic needles, such as the glider magnetic compass bars, are held along these lines of force, the vertical component causes one end of the needle to dip or deflect downward. The amount of dip increases as the needles are moved closer and closer to the poles. It is this deflection or dip that causes some of the larger compass errors.

MAGNETIC VARIATION

Although the magnetic field of the Earth lies roughly north and south, the Earth's magnetic poles do not coincide with its geographic poles, which are used in the construction of aeronautical charts. Consequently, at most places on the Earth's surface, the direction-sensitive steel needles, which seek the Earth's magnetic field, will not point to True North but to Magnetic North. Furthermore, local magnetic fields from mineral deposits and other conditions may distort the Earth's magnetic field and cause an additional error in the position of the compass' north-seeking magnetized needles with reference to True North. The angular difference between True North and the direction indicated by the magnetic compass—excluding deviation error—is variation. Variation is different for different points on the Earth's surface and is shown on the aeronautical charts as broken lines connecting points of equal variation. These lines are isogonic lines. The line where the magnetic variation is zero is an agonic line. [Figure 4-16]

MAGNETIC DEVIATION

A compass is very rarely influenced solely by the Earth's magnetic lines of force. Magnetic disturbances from magnetic fields produced by metals and electrical accessories in a glider disturb the compass needles and produce an additional error known as deviation.

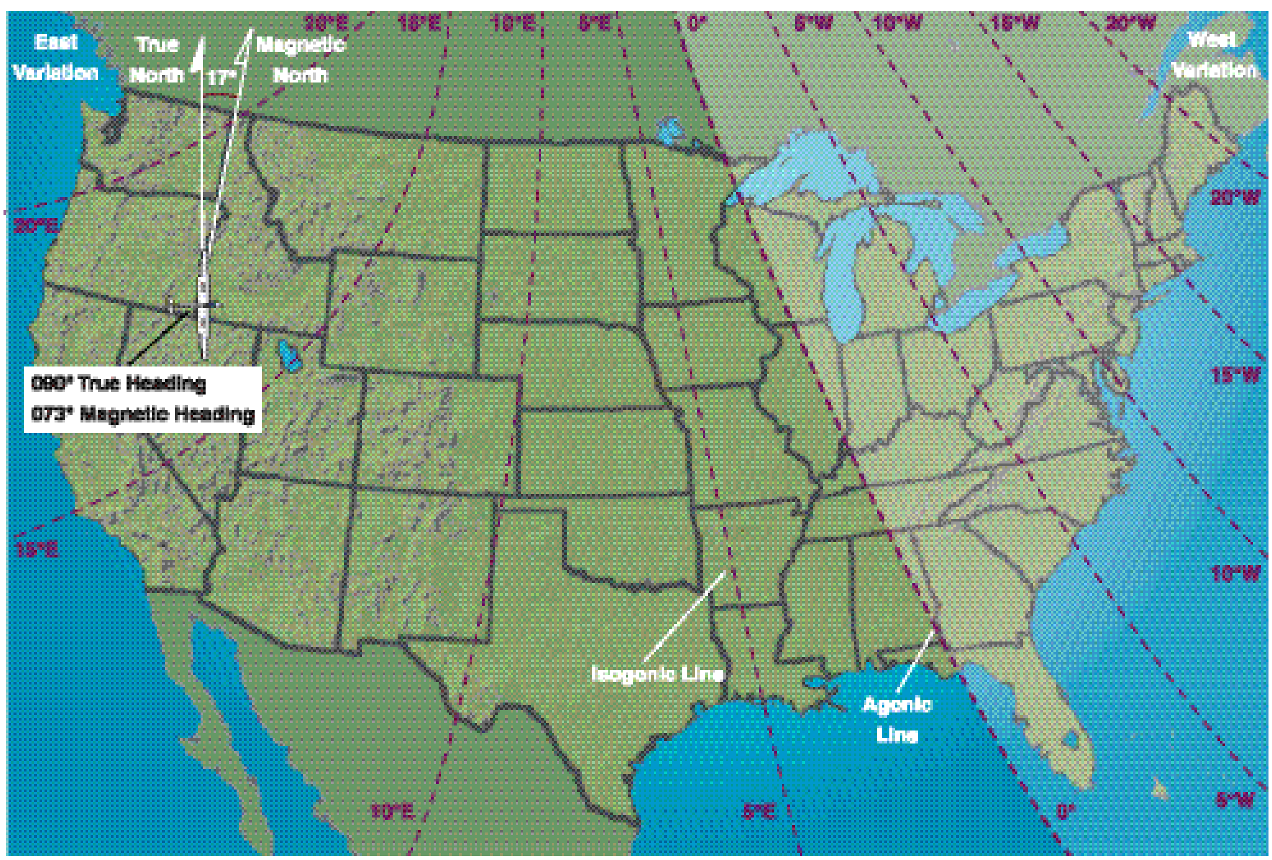


Figure 4-16. Earth's magnetic field.

FOR (MH)	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°
STEER (CH)	359°	30°	60°	88°	120°	152°	183°	212°	240°	268°	300°	329°
RADIO ON ☑						RADIO OFF ☐						

Figure 4-17. Compass correction card.

If a glider changes heading, the compass' direction-sensitive magnetized needles will continue to point in about the same direction while the glider turns with relation to it. As the glider turns, metallic and electrical equipment in the glider change their position relative to the steel needles; hence, their influence on the compass needle changes and deviation changes. The deviation depends, in part, on the heading of the glider. Although compensating magnets on the compass are adjusted to reduce this deviation on most headings, it is impossible to eliminate this error entirely on all headings. A deviation card is installed in the cockpit in view of the pilot, enabling the pilot to maintain the desired magnetic headings. [Figure 4-17]

COMPASS ERRORS

Since the compass card is suspended in fluid, the magnetic compass is sensitive to in-flight turbulence. In light turbulence, you may be able to use the compass by averaging the readings. For example, if the compass swings between 40º and 70º, you can estimate the approximate magnetic heading of 55º. In severe turbulence, however, the magnetic compass may be so disturbed that is unusable for navigation.

Since the magnetic compass is the only direction-seeking instrument in most gliders, the pilot must be able to turn the glider to a magnetic compass heading and maintain this heading. It will help to remember the following characteristics of the magnetic compass, which are caused by magnetic dip. These characteristics are only applicable in the Northern Hemisphere. In the Southern Hemisphere the opposite is true.

ACCELERATION ERROR

When on an east or west heading, no error is apparent while entering a turn to north or south. However, an increase in airspeed or acceleration will cause the compass to indicate a turn toward north; a decrease in airspeed or acceleration will cause the compass to indicate a turn toward south. On a north or south heading, no error will be apparent because of acceleration or deceleration. [Figure 4-18]

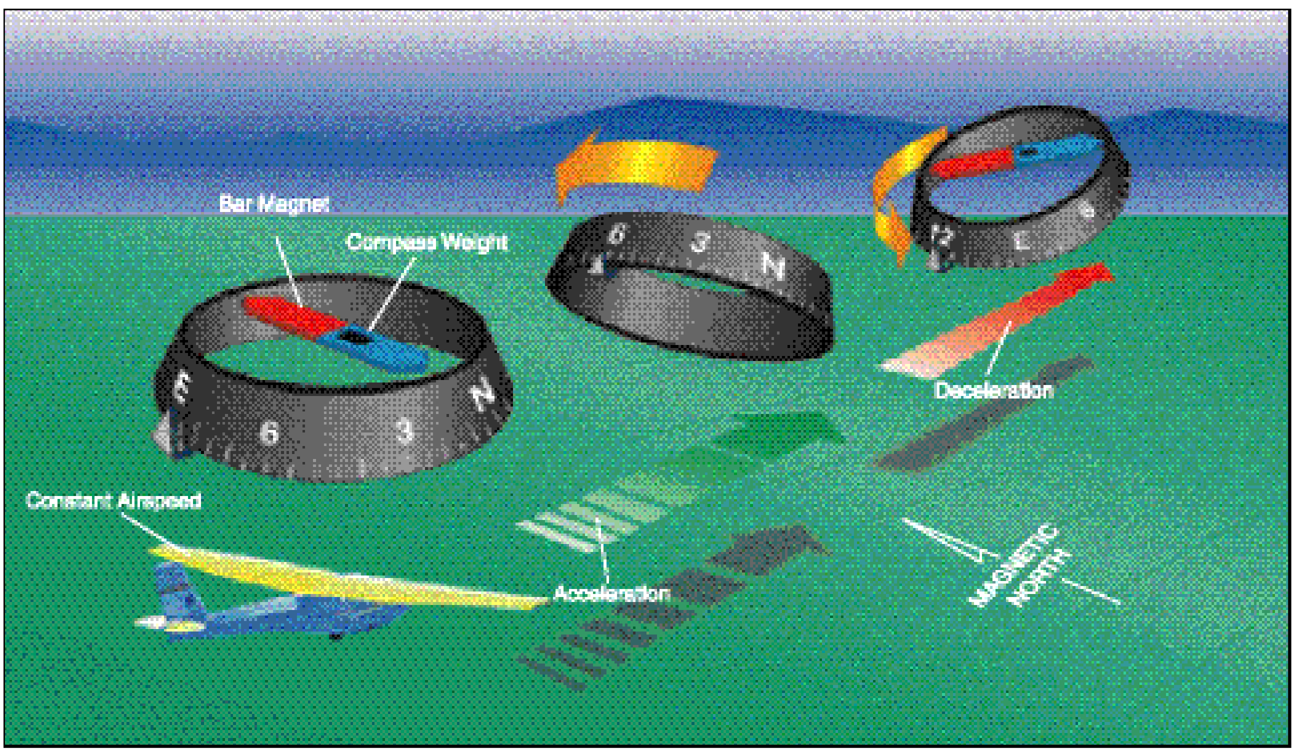
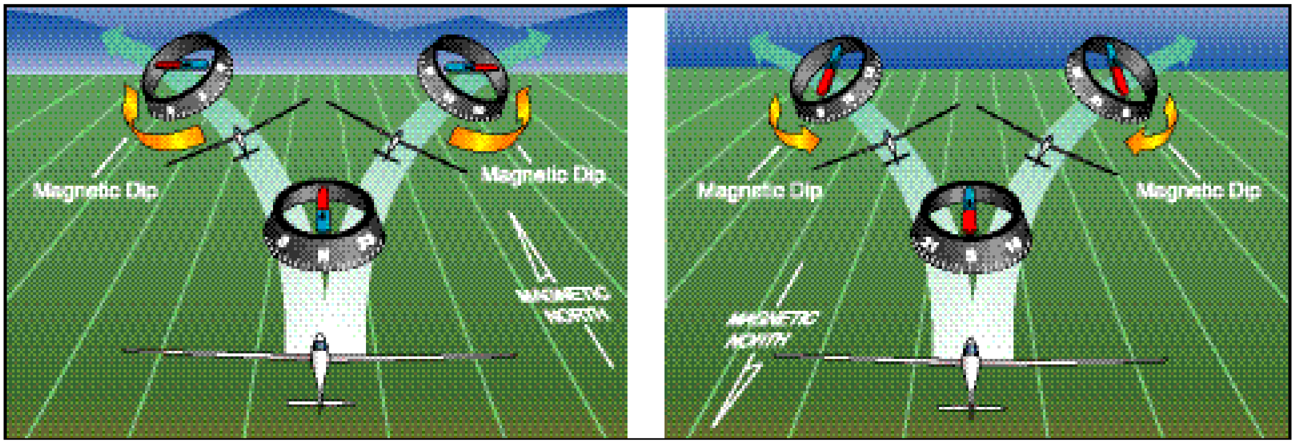


Figure 4-18. Acceleration error on a compass in the Northern Hemisphere.



TURNING ERROR

The turning error is directly related to magnetic dip; the greater the dip, the greater the turning error. It is most pronounced when you are turning to or from headings of north or south. When you begin a turn from a heading of north, the compass starts to turn in the opposite direction and it lags behind the actual heading. As the turn continues, the amount of lag decreases, then disappears, as the glider reaches a heading of east or west.

When initiating a turn from a heading of east or west to a heading of north, there is no error as you begin the turn. As the heading approaches north, the compass increasingly lags behind the glider's actual heading.

When you turn from a heading of south, the compass initially indicates a turn in the proper direction but at a faster rate, and leads the glider's actual heading. This error also cancels out as the glider reaches a heading of east or west. Turning from east or west to a heading of south causes the compass to move correctly at the start of a turn, but then it increasingly leads the actual heading as the glider nears a southerly direction. [Figure 4-19]

The amount of lead or lag is approximately equal to the latitude of the glider. For example, if you are turning from a heading of south to a heading of west while flying at 35º north latitude, the compass will rapidly turn to a heading of 215º (180º+35º). At the midpoint of the turn, the lead will decrease to approximately half (17.5º), and upon reaching a heading of west, it will be zero. The lead and lag errors discussed here are only valid in the Northern Hemisphere. Lead and lag errors in the Southern Hemisphere act in opposite directions.

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 4-20. The yaw string helps you coor-

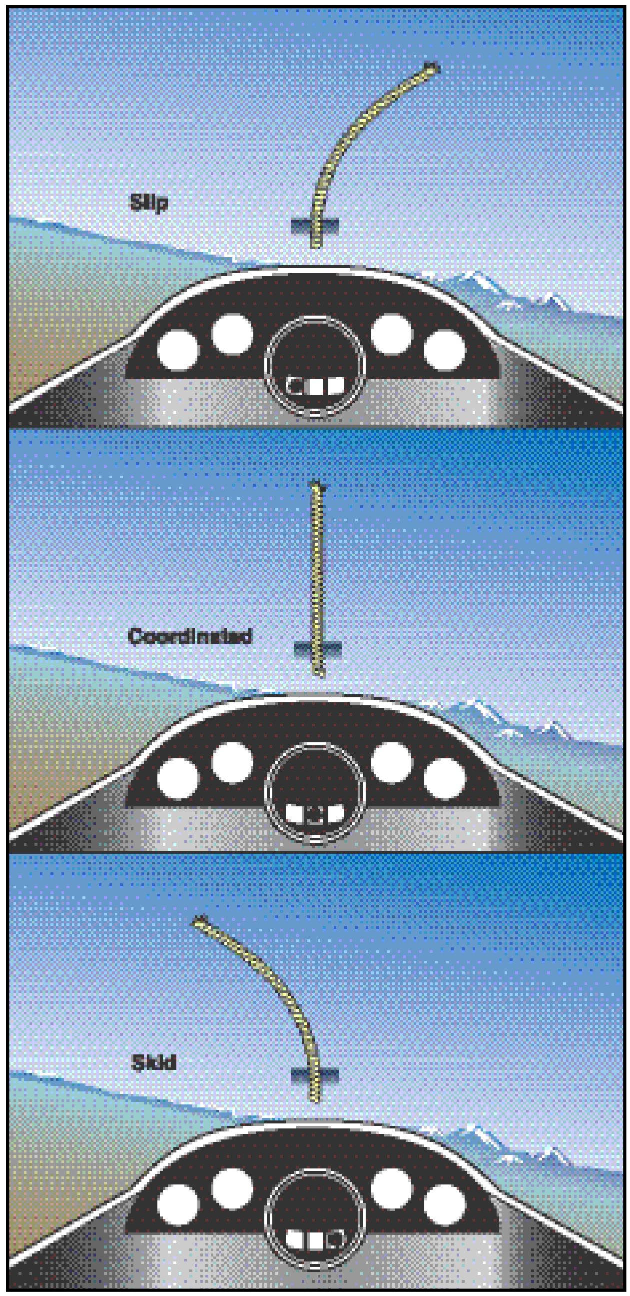


Figure 4-20. The yaw string and Inclinometer.

dinate rudder and aileron inputs. 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 will be offset toward the outside of the turn. To center the yaw string in a slipping turn, add pressure to the rudder pedal that is opposite the tail of the yaw string. During a skidding turn, the tail of the yaw string will be offset toward the inside of the turn. To center the yaw string in a skidding turn, add pressure to the rudder pedal that is opposite the tail of the yaw string.

INCLINOMETER

Another type of slip/skid indicator is the inclinometer. 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. If you remember the phrase "step on the ball" in reference to the inclinometer, it will help you coordinate the turn using rudder inputs.

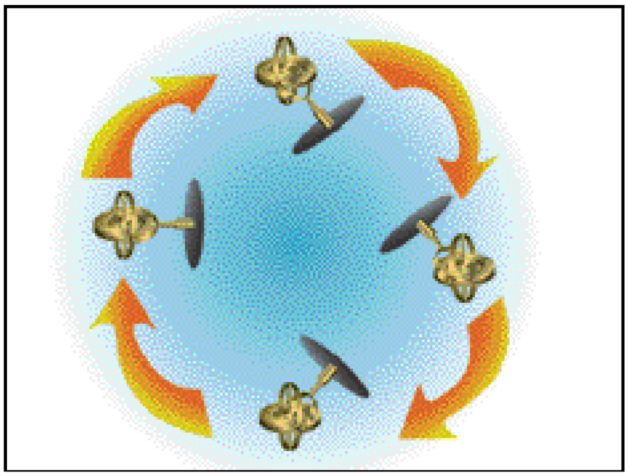


Figure 4-21. Regardless of the position of its base, a gyro tends to remain rigid in space, with its axis of rotation pointed tin a constant direction.

GYROSCOPIC INSTRUMENTS

Gyroscopic instruments are found in virtually all modern airplanes but are infrequently found in gliders. This section is designed to provide you with a basic understanding of how gyroscopic instruments function. The three gyroscopic instruments found most frequently in a glider are the heading indicator, the attitude indicator, and the turn coordinator.

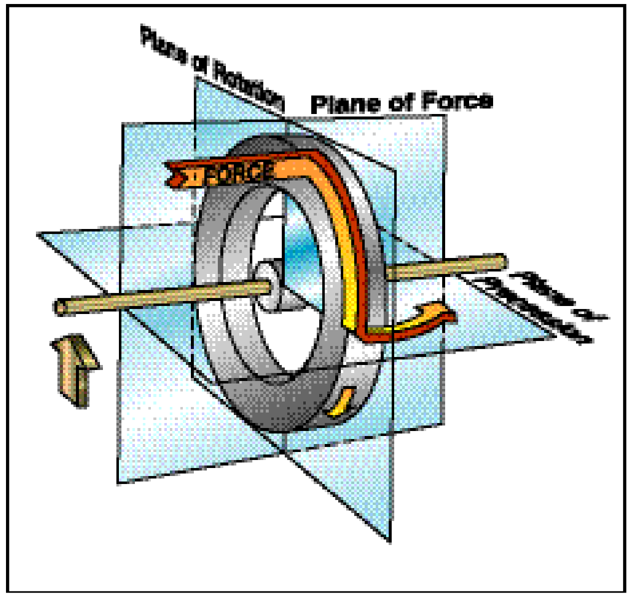


Figure 4-22. Precession of a gyroscope results from an applied deflective force.

RIGIDITY IN SPACE

Rigidity in space and precession are the two fundamental concepts that affect the operation of gyroscopic instruments. Rigidity in space refers to the principle that a gyroscope remains in a fixed position in the plane in which it is spinning. By mounting this wheel, or

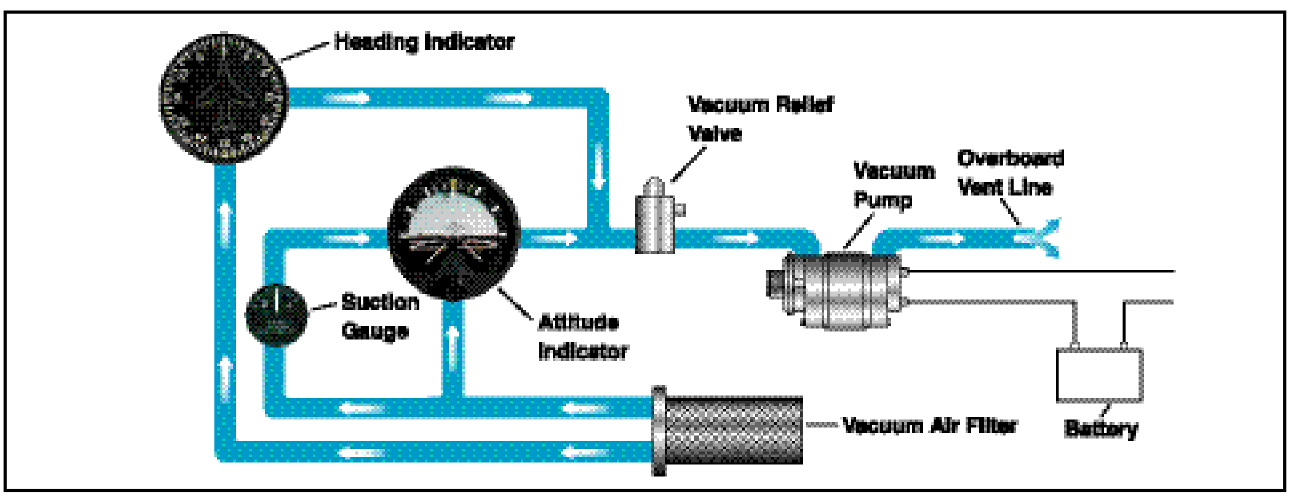
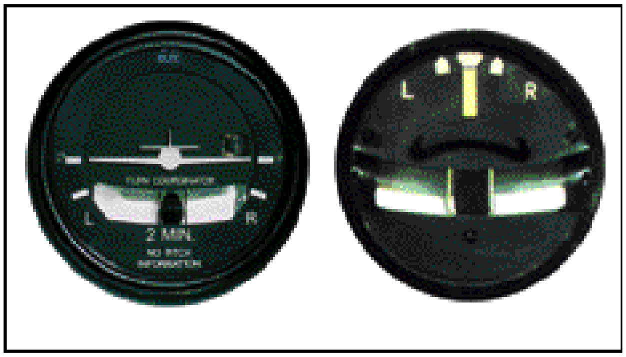


Figure 4-23. Electric powered gyro system.

gyroscope, on a set of gimbal rings, the gyro is able to rotate freely in any direction. Thus, if the gimbal rings are tilted, twisted, or otherwise moved, the gyro remains in the plane in which it was originally spinning. [Figure 4-21]

PRECESSION

Precession is the tilting or turning of a gyro in response to a deflective force. The reaction to this force does not occur at the point where it was applied; rather, it occurs at a point that is 90° later in the direction of rotation. This principle allows the gyro to determine a rate of turn by sensing the amount of pressure created by a change in direction. The rate at which the gyro precesses is inversely proportional to the speed of the rotor and proportional to the deflective force. [Figure 4-22]



Gyroscopic instruments require a power source to keep the gyro rotating at a constant rate. The most common power source for gliders is an electric battery. [Figure 4-23]

The turn coordinator and turn-and-slip indicator both provide an indication of turn direction, rate, and quality. The main difference between the turn coordinator and the turn-and-slip indicator is the manner in which turn information is displayed. The turn coordinator uses a miniature aircraft, while the turn-and-slip indicator utilizes a pointer called a turn needle.

We will discuss the turn coordinator. During a turn, the miniature aircraft in the turn coordinator banks in the same direction the glider is banked. The turn coordinator enables you to establish a standard-rate-turn. You do this by aligning the wing of the miniature aircraft with the turn index. At this rate, the aircraft will turn 3º per second, completing a 360º turn in two minutes. The turn coordinator is designed to indicate the rate of turn, not the angle of bank. The turn coordinator is also equipped with an inclinometer to help you coordinate your turn. [Figure 4-24]

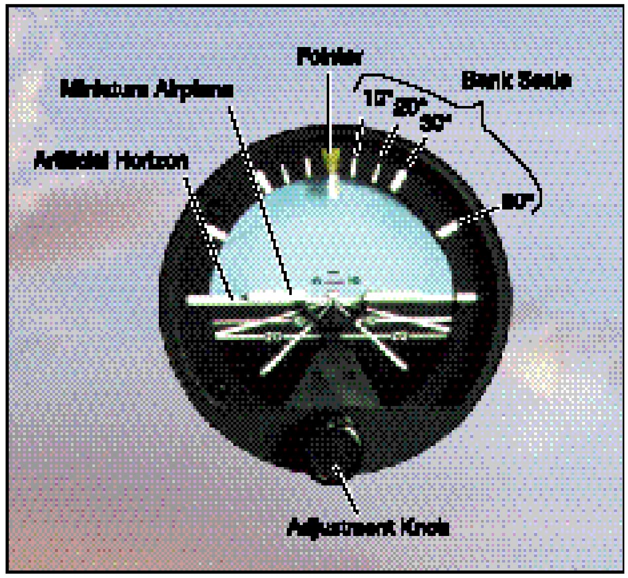


Figure 4-25. Attitude Indicator.

ATTITUDE INDICATOR

The attitude indicator, with its miniature aircraft and horizon bar, displays a picture of the attitude of the glider. The relationship of the miniature aircraft to the horizon bar is the same as the relationship of the real aircraft to the actual horizon. The instrument gives an instantaneous indication of even the smallestchanges in attitude. [Figure 4-25]

The gyro in the attitude indicator is mounted on a horizontal plane and depends upon rigidity in space for its operation. The horizon bar represents the true horizon. This bar is fixed to the gyro and remains in a horizontal plane as the glider is pitched or banked about its lateral or longitudinal axis, indicating the attitude of the glider relative to the true horizon.

An adjustment knob is provided to allow the pilot to move the miniature aircraft up or down to align the miniature aircraft with the horizon bar to suit the pilot's line of vision. Normally, the miniature aircraft is adjusted so the wings overlap the horizon bar when the glider is in straight-and-level cruising flight. The attitude indicator is reliable and the most realistic flight

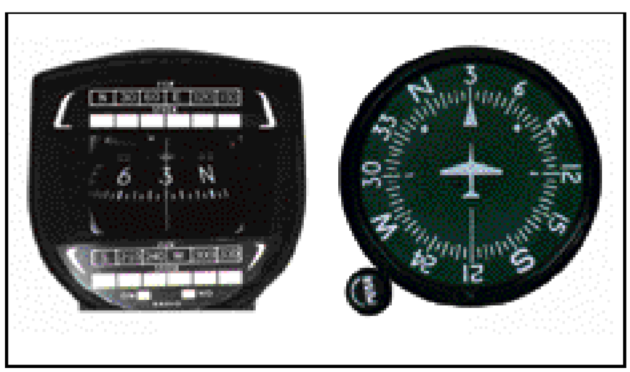


Figure 4-26. Setting the heading indicator.

instrument on the instrument panel. Its indications are very close approximations of the actual attitude of the glider.

HEADING INDICATOR

The operation of the heading indicator depends upon the principle of rigidity in space. The rotor turns in a vertical plane, and fixed to the rotor is a compass card. Since the rotor remains rigid in space, the points on the card hold the same position in space relative to the vertical plane. As the instrument case and the glider revolve around the vertical axis, the card provides clear and accurate heading information.

Because of precession, caused chiefly by friction, the heading indicator will creep or drift from a heading to which it is set. Among other factors, the amount of drift depends largely upon the condition of the instrument. If the bearings are worn, dirty, or improperly lubricated, the drift may be excessive.

Bear in mind that the heading indicator is not direction seeking, as is the magnetic compass. It is important to check the indications frequently and reset the heading indicator to align it with the magnetic compass when required. Adjusting the heading indicator to the magnetic compass heading should be done only when the glider is in wings-level unaccelerated flight; otherwise erroneous magnetic compass readings may be obtained. [Figure 4-26]

G-METER

Another instrument that can be mounted in the instrument panel of a glider is a G-meter. 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 1G (1.0 times the force of gravity). During aerobatics or during flight in turbulent air, the glider and pilot experience G-loads greater than 1G. 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 4-27]

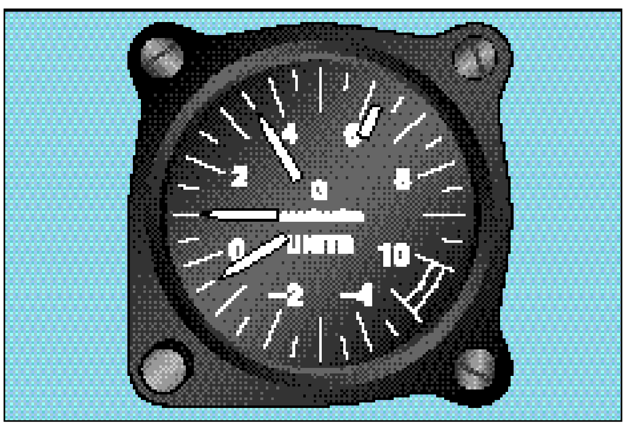


Figure 4-27. The G-meter.

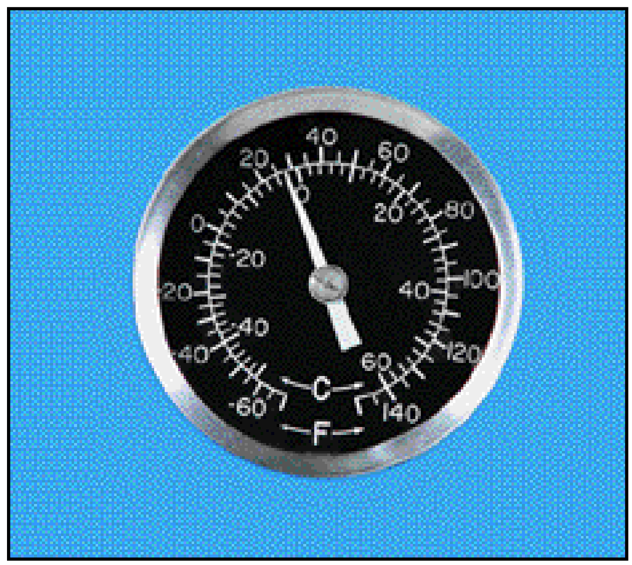


Figure 4-28. A typical outside air temperature (OAT) gauge.

OUTSIDE AIR TEMPERATURE GAUGE

The outside air temperature gauge (OAT) is a simple and effective 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, which reads against the calibration on a circular face. OAT gauges are calibrated in degrees Celsius, degrees Fahrenheit, or both. An accurate air temperature will provide the glider pilot with useful information about temperature lapse rate with altitude change.

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 4-28]