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## **ATTITUDE INSTRUMENT FLYING IN HELICOPTERS**

### **INTRODUCTION**

Attitude instrument flying in helicopters is essentially visual flying with the flight instruments substituted for the various reference points on the helicopter and the natural horizon. Control changes, required to produce a given attitude by reference to instruments, are identical to those used in helicopter VFR flight, and your thought processes are the same. Basic instrument training is intended as a building block towards attaining an instrument rating. It will also enable you to do a 180° turn in case of inadvertent incursion into instrument meteorological conditions (IMC).

### **FLIGHT INSTRUMENTS**

When flying a helicopter with reference to the flight instruments, proper instrument interpretation is the basis for aircraft control. Your skill, in part, depends on your understanding of how a particular instrument or system functions, including its indications and limitations. With this knowledge, you can quickly determine what an instrument is telling you and translate that information into a control response.

### **PITOT-STATIC SYSTEMS**

Pitot pressure, or impact air pressure, is sensed through an open-end tube pointed directly into the relative wind flowing around the aircraft. The pitot tube connects to pressure operated flight instruments such as the airspeed indicator (ASI) [5].

#### **Static Pressure**

Other instruments depend upon accurate sampling of the ambient still air atmospheric pressure to determine the height and speed of movement of the aircraft through the air, both horizontally and vertically. This pressure, called static pressure, is sampled at one or more locations outside the helicopters. The pressure of the static air is sensed at a flush port where the air is not disturbed. On some aircraft, air is sampled by static ports on the side of the electrically heated pitot-static head [Figure 1]. Other aircraft pick up the static pressure through flush ports on the side of the fuselage or the vertical fin. These ports are in locations proven by flight tests to be in undisturbed air, and they are normally paired, one on either side of the

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aircraft. This dual location prevents lateral movement of the aircraft from giving erroneous static pressure indications. The areas around the static ports may be heated with electric heater elements to prevent ice forming over the port and blocking the entry of the static air [2, 5] .

Three basic pressure-operated instruments are found in most aircraft instrument panels. These are the sensitive altimeter, ASI, and vertical speed indicator (VSI). All three receive pressures sensed by the aircraft pitot-static system. The static ports supply pressure to the ASI, altimeter, and VSI.

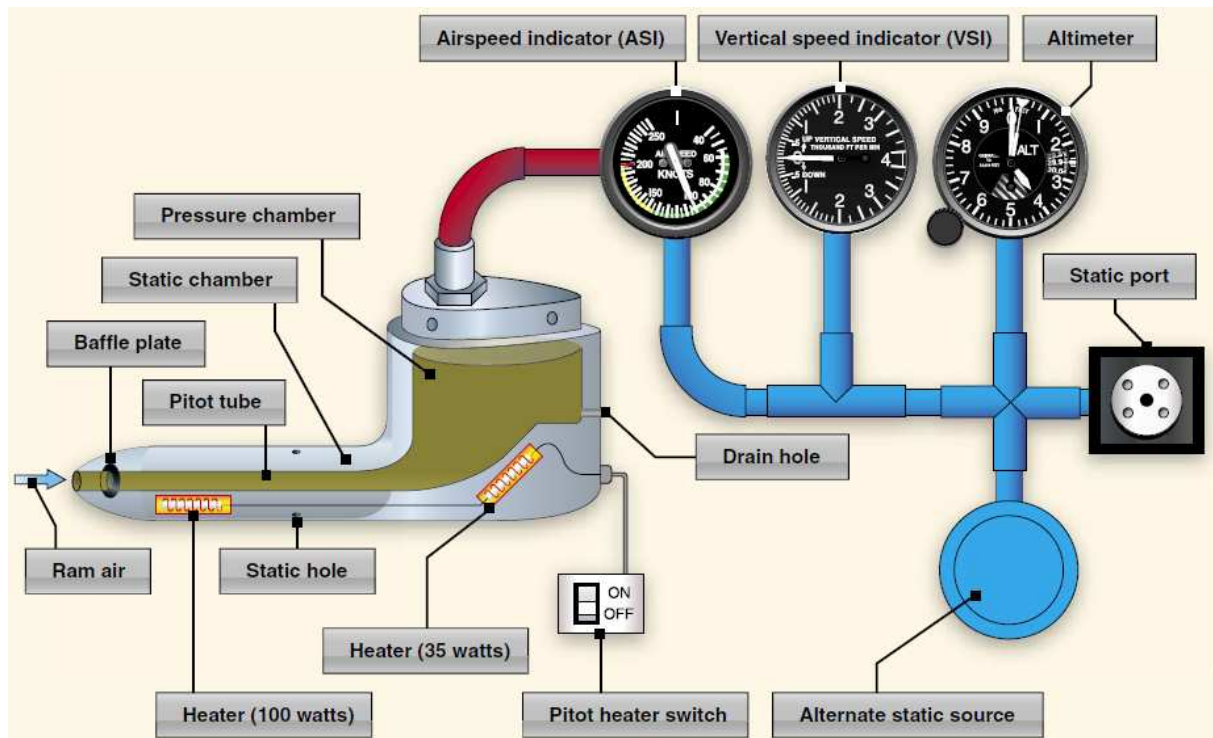


Figure 1. A Typical Electrically Heated Pitot-Static Head [2].

## Blockage Considerations

The pitot tube is particularly sensitive to blockage especially by icing. Even light icing can block the entry hole of the pitot tube where ram air enters the system. This affects the ASI and is the reason most airplanes are equipped with a pitot heating system.

### *Indications of Pitot Tube Blockage*

If the pitot tube becomes blocked, the ASI displays inaccurate speeds. At the altitude where the pitot tube becomes blocked, the ASI remains at the existing airspeed and doesn't reflect actual changes in speed.

- At altitudes above where the pitot tube became blocked, the ASI displays a higher-than-actual airspeed increasing steadily as altitude increases.
- At lower altitudes, the ASI displays a lower-than-actual airspeed decreasing steadily as altitude decreases.

### *Indications from Static Port Blockage*

Many aircraft also have a heating system to protect the static ports to ensure the entire pitot-static system is clear of ice. If the static ports become blocked, the ASI would still function but could produce inaccurate indications. At the altitude where the blockage occurs, airspeed indications would be normal.

- At altitudes above which the static ports became blocked, the ASI displays a lower-than-actual airspeed continually decreasing as altitude is increased.
- At lower altitudes, the ASI displays a higher-than-actual airspeed increasing steadily as altitude decreases.

The trapped pressure in the static system causes the altimeter to remain at the altitude where the blockage occurred. The VSI remains at zero. On some aircraft, an alternate static air source valve is used for emergencies. [Figure 2] If the alternate source is vented inside the airplane, where static pressure is usually lower than outside static pressure, selection of the alternate source may result in the following erroneous instrument indications:

1. Altimeter reads higher than normal,
2. Indicated airspeed (IAS) reads greater than normal, and
3. VSI momentarily shows a climb. Consult the Pilot's Operating Handbook/Airplane Flight Manual (POH/AFM) to determine the amount of error.

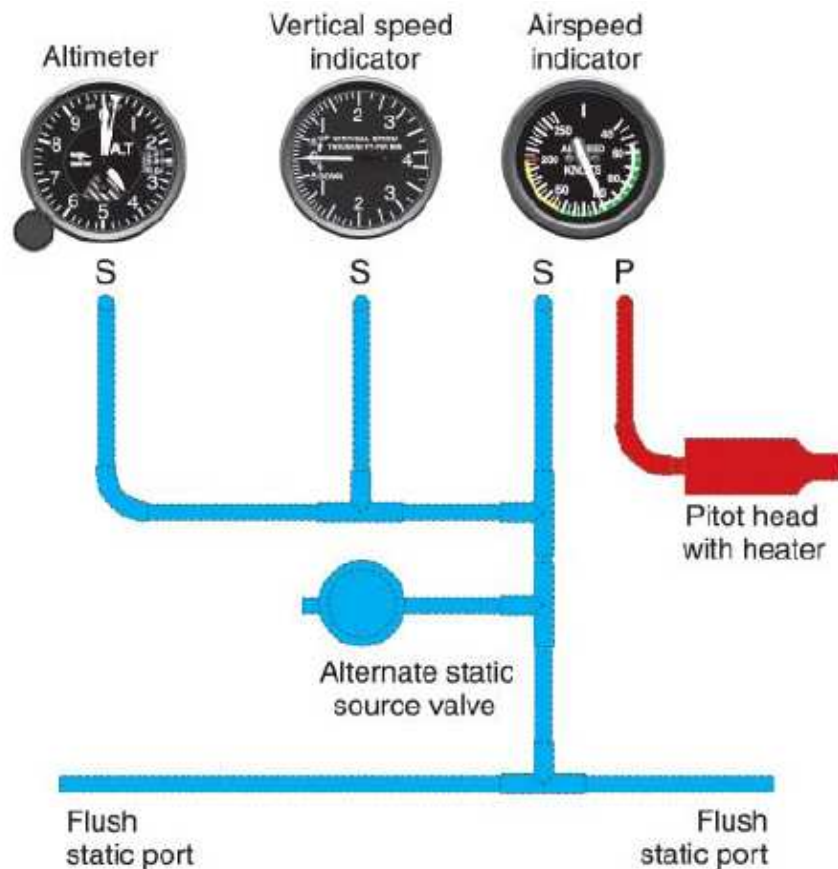


Figure 2. A Typical Pitot-Static System [5].

### *Effects of Flight Conditions*

The static ports are located in a position where the air at their surface is as undisturbed as possible. But under some flight conditions, particularly at a high angle of attack with the landing gear and flaps down, the air around the static port may be disturbed to the extent that it can cause an error in the indication of the altimeter and ASI. Because of the importance of accuracy in these instruments, part of the certification tests for an aircraft is a check of position error in the static system.

The POH/AFM contains any corrections that must be applied to the airspeed for the various configurations of flaps and landing gear.

## PITOT-STATIC INSTRUMENTS

The pitot-static instruments, which include the airspeed indicator, altimeter, and vertical speed indicator, operate on the principle of differential air pressure. Pitot pressure, also called impact, ram, or dynamic pressure, is directed only to the airspeed indicator, while static pressure, or ambient pressure, is directed to all three instruments. An alternate static source may be included allowing you to select an alternate source of ambient pressure in the event the main port becomes blocked.

### **Airspeed indicator (ASI)**

The airspeed indicator displays the speed of the helicopter through the air by comparing ram air pressure from the pitot tube with static air pressure from the static port—the greater the differential, the greater the speed. The instrument displays the result of this pressure differential as indicated airspeed (IAS) [6].

Manufacturers use this speed as the basis for determining helicopter performance, and it may be displayed in knots, miles per hour, or both. [Figure 3] When an indicated airspeed is given for a particular situation, you normally use that speed without making a correction for altitude or temperature. The reason no correction is needed is that an airspeed indicator and aircraft performance are affected equally by changes in air density. An indicated airspeed always yields the same performance because the indicator has, in fact, compensated for the change in the environment.

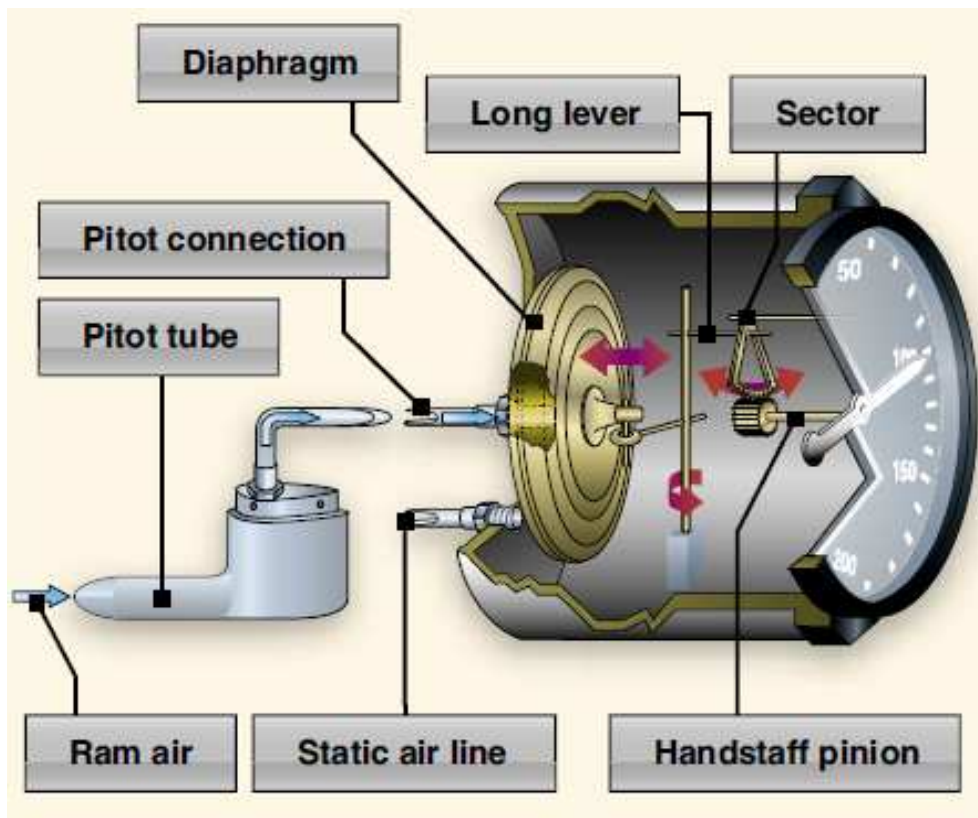


Figure 3. Mechanism of an Airspeed Indicator [2].

**INSTRUMENT CHECK**—During the preflight, ensure that the pitot tube, drain hole, and static ports are unobstructed. Before liftoff, make sure the airspeed indicator is reading zero. If there is a strong wind blowing directly at the helicopter, the airspeed indicator may read higher than zero, depending on the wind speed and direction. As you begin your takeoff, make sure the airspeed indicator is increasing at an appropriate rate. Keep in mind, however, that the airspeed indication might be unreliable below a certain airspeed due to rotor downwash.

## Altimeter

The altimeter displays altitude in feet by sensing pressure changes in the atmosphere. There is an adjustable barometric scale to compensate for changes in atmospheric pressure. [Figure 4]

The basis for altimeter calibration is the International Standard Atmosphere (ISA), where pressure, temperature, and lapse rates have standard values. However, actual atmospheric conditions seldom match the standard values. In addition, local pressure readings within a given area normally change over a period of time, and pressure frequently changes as you fly from one area to another. As a result, altimeter indications are subject to errors, the extent of which depends on how much the pressure, temperature, and lapse rates deviate from standard, as well as how recently you have set the altimeter. The best way to minimize altimeter errors is to update the altimeter setting frequently. In most cases, use the current altimeter setting of the nearest reporting station along your route of flight per regulatory requirements [1, 2, 4, 5, 6].

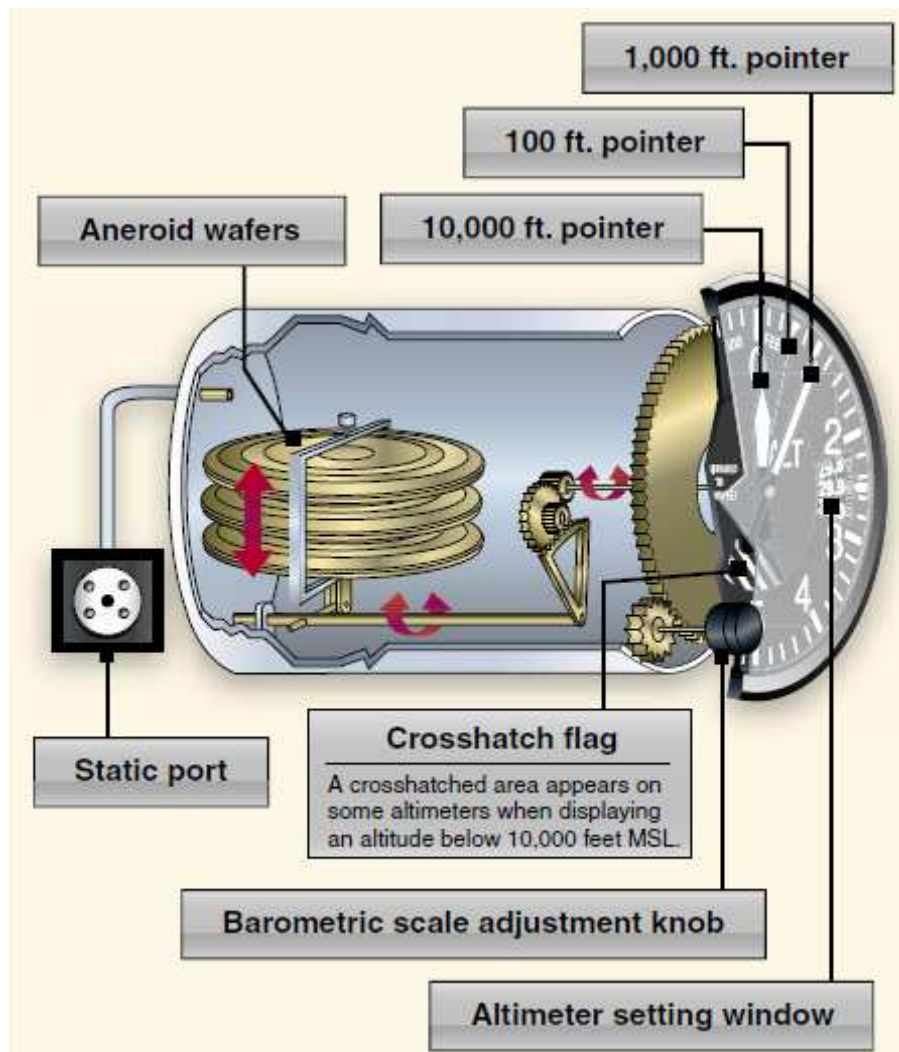


Figure 4. Altimeter [2]

**INSTRUMENT CHECK**—During the preflight, ensure that the static ports are unobstructed. Before lift-off, set the altimeter to the current setting. If the altimeter indicates within 75 feet of the actual elevation, the altimeter is generally considered acceptable for use.

### Vertical speed indicator

The vertical speed indicator (VSI) displays the rate of climb or descent in feet per minute (f.p.m.) by measuring how fast the ambient air pressure increases or decreases as the helicopter changes altitude. Since the VSI measures only the rate at which air pressure changes, air temperature has no effect on this instrument. [Figure 5] [1, 2, 4, 5, 6].



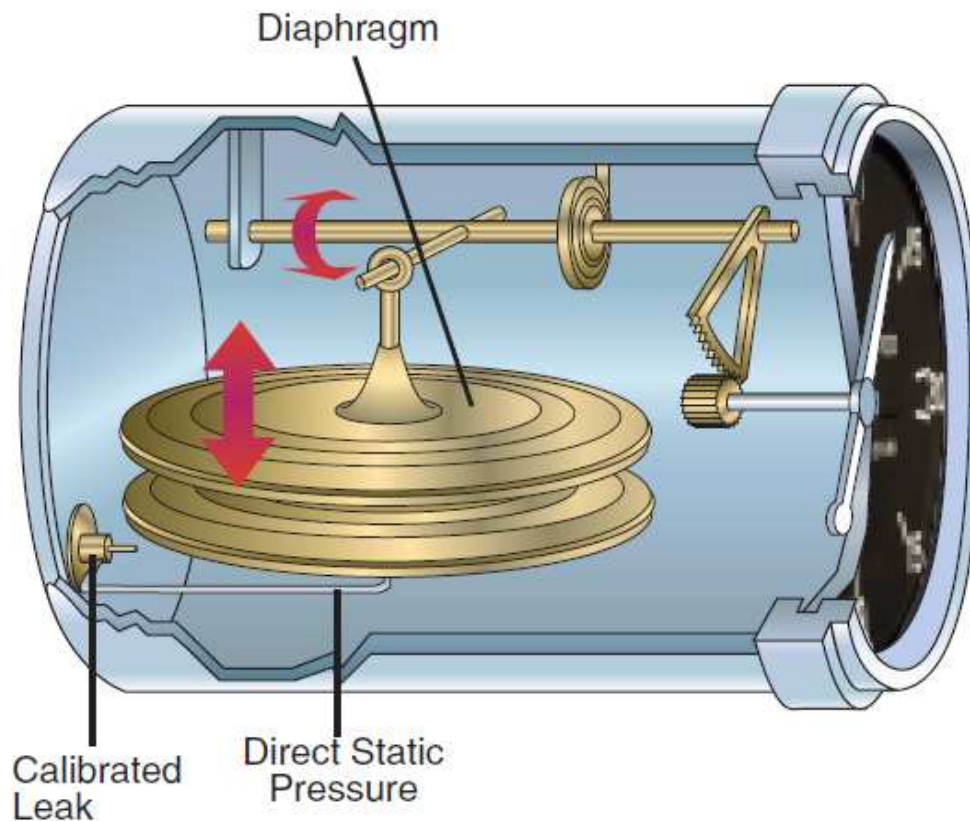


Figure 5. Vertical speed indicator (VSI) [6].

There is a lag associated with the reading on the VSI, and it may take a few seconds to stabilize when showing rate of climb or descent. Rough control technique and turbulence can further extend the lag period and cause erratic and unstable rate indications. Some aircraft are equipped with an instantaneous vertical speed indicator (IVSI), which incorporates accelerometers to compensate for the lag found in the typical VSI.

**INSTRUMENT CHECK**—During the preflight, ensure that the static ports are unobstructed. Check to see that the VSI is indicating zero before lift-off. During takeoff, check for a positive rate of climb indication.

### System errors

The pitot-static system and associated instruments are usually very reliable. Errors are generally caused when the pitot or static openings are blocked. This may be caused by dirt, ice formation, or insects. Check the pitot and static openings for obstructions during the preflight. It is also advisable to place covers on the pitot and static ports when the helicopter is parked on the ground.

The airspeed indicator is the only instrument affected by a blocked pitot tube. The system can become clogged in twoways. If the ram air inlet is clogged, but the drain hole remains open, the airspeed indicator registers zero, regardless of airspeed. If both the ram air inlet and the drain hole become blocked, pressure in the line is trapped, and the airspeed indicator reacts like an altimeter, showing an

increase in airspeed with an increase in altitude, and a decrease in speed as altitude decreases. This occurs as long as the static port remains unobstructed.

If the static port alone becomes blocked, the airspeed indicator continues to function, but with incorrect readings. When you are operating above the altitude where the static port became clogged, the airspeed indicator reads lower than it should. Conversely, when operating below that altitude, the indicator reads higher than the correct value. The amount of error is proportional to the distance from the altitude where the static system became blocked. The greater the difference, the greater the error. With a blocked static system, the altimeter freezes at the last altitude and the VSI freezes at zero.

Both instruments are then unusable. Some helicopters are equipped with an alternate static source, which may be selected in the event that the main static system becomes blocked. The alternate source generally vents into the cabin, where air pressures are slightly different than outside pressures, so the airspeed and altimeter usually read higher than normal. Correction charts may be supplied in the flight manual.

## GYROSCOPIC INSTRUMENTS

The three gyroscopic instruments that are required for instrument flight are the attitude indicator, heading indicator, and turn indicator. When installed in helicopters, these instruments are usually electrically powered.

Gyros are affected by two principles—rigidity in space and precession. Rigidity in space means that once a gyro is spinning, it tends to remain in a fixed position and resists external forces applied to it. This principle allows a gyro to be used to measure changes in attitude or direction.

Precession is the tilting or turning of a gyro in response to pressure. The reaction to this pressure 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 from where the pressure was applied. This principle allows the gyro to determine a rate of turn by sensing the amount of pressure created by a change in direction. Precession can also create some minor errors in some instruments.

### **Attitude indicator**

The attitude indicator provides a substitute for the natural horizon. It is the only instrument that provides an immediate and direct indication of the helicopter's pitch and bank attitude. Since most attitude indicators installed in helicopters are electrically powered, there may be a separate power switch, as well as a warning flag within the instrument, that indicates a loss of power. A caging or "quick erect" knob may be included, so you can stabilize the spin axis if the gyro has tumbled. [Figure 6]



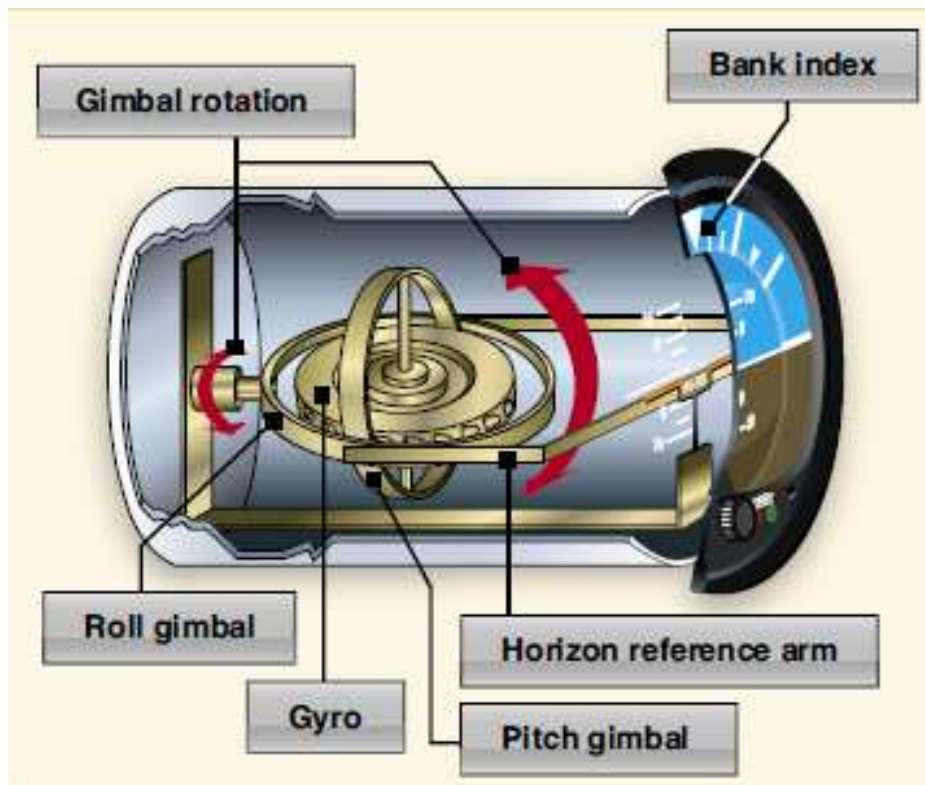


Figure 6. Attitude indicator [2]

Every pilot should be able to interpret the banking scale illustrated in Figure 7. Most banking scale indicators on the top of the instrument move in the same direction from that in which the aircraft is actually banked. Some other models move in the opposite direction from that in which the aircraft is actually banked. This may confuse the pilot if the indicator is used to determine the direction of bank. This scale should be used only to control the degree of desired bank. The relationship of the miniature aircraft to the horizon bar should be used for an indication of the direction of bank. The attitude indicator is reliable and the most realistic flight instrument on the instrument panel. Its indications are very close approximations of the actual attitude of the aircraft [1, 2, 5, 6].

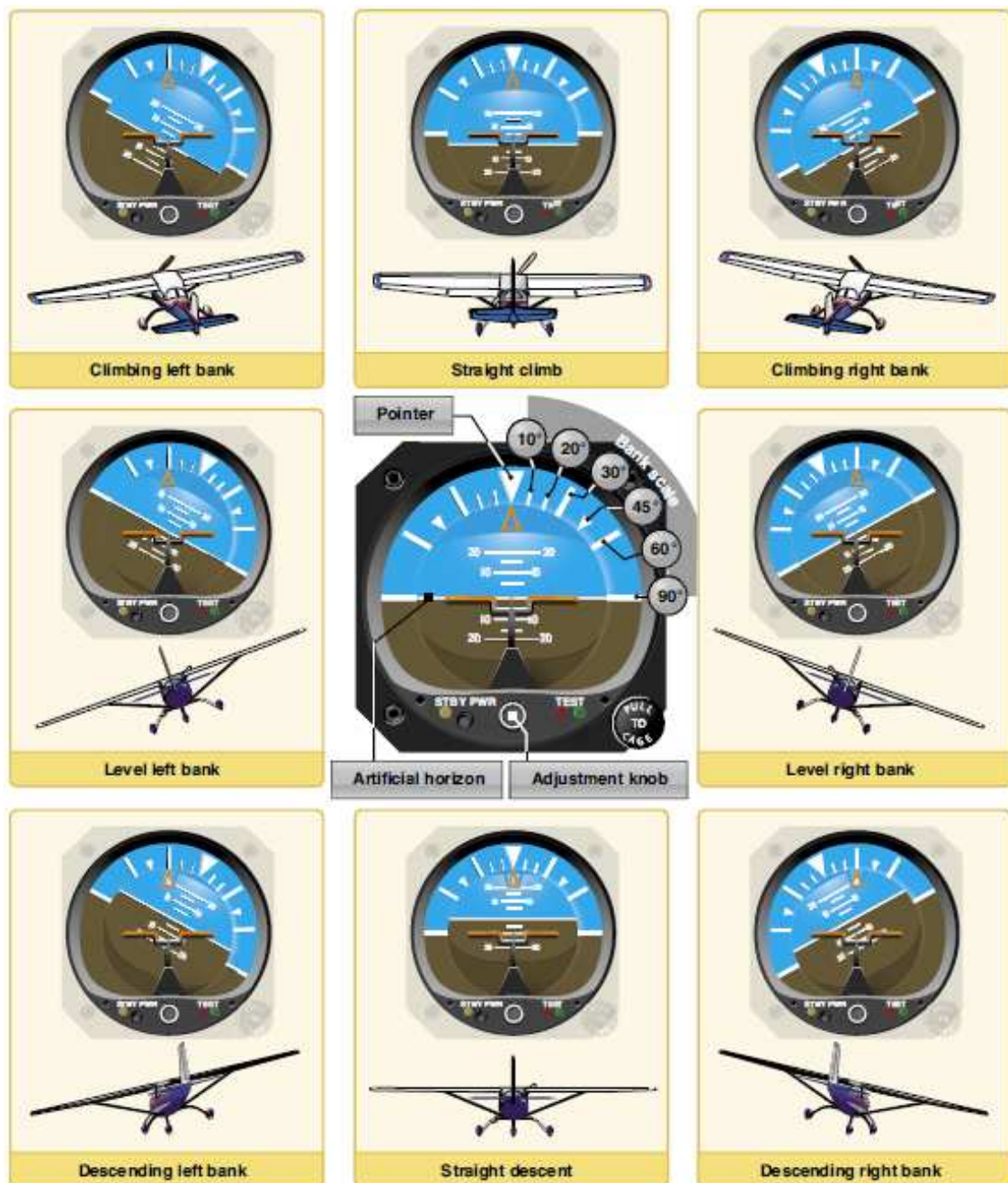


Figure 7. Attitude representation by the attitude indicator corresponds to the relation of the aircraft to the real horizon [2].

## Heading indicator

The heading indicator, which is sometimes referred to as a directional gyro (DG), senses movement around the vertical axis and provides a more accurate heading reference compared to a magnetic compass, which has a number of turning errors. [Figure 8].

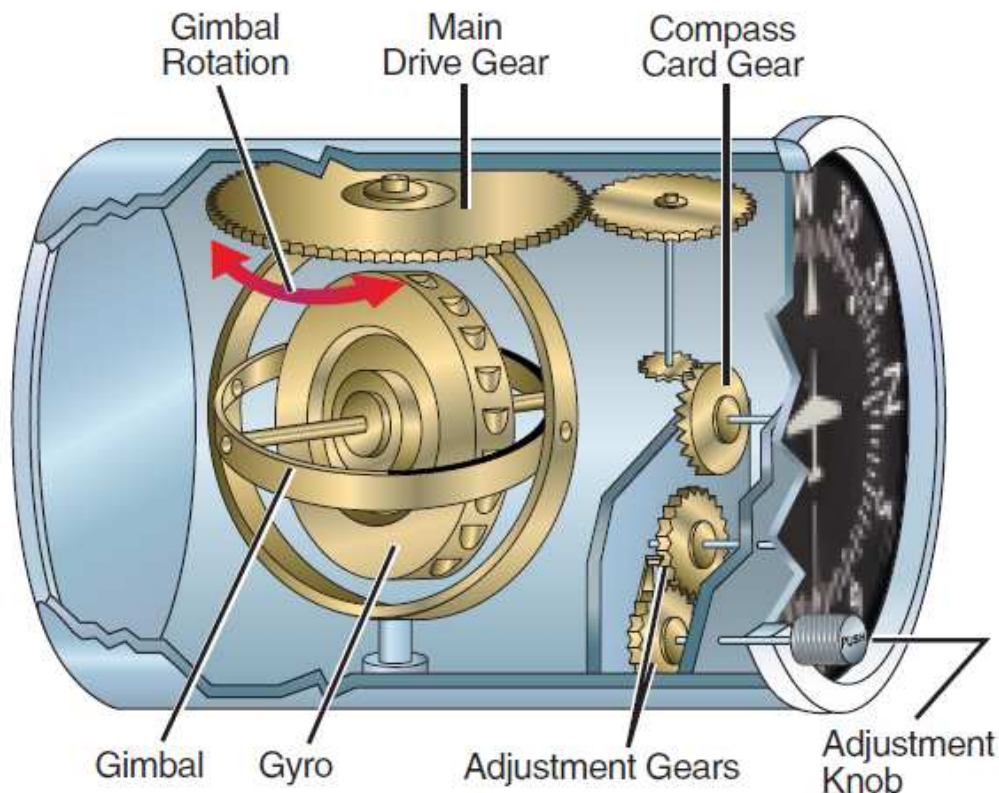


Figure 8. A heading indicator displays headings based on a 360° azimuth, with the final zero omitted. For example, a 6 represents 060°, while a 21 indicates 210°. The adjustment knob is used to align the heading indicator with the magnetic compass [6].

Due to internal friction within the gyroscope, precession is common in heading indicators. Precession causes the selected heading to drift from the set value. Some heading indicators receive a magnetic north reference from a remote source and generally need no adjustment. Heading indicators that do not have this automatic north-seeking capability are often called “free” gyros, and require that you periodically adjust them. You should align the heading indicator with the magnetic compass before flight and check it at 15 minute intervals during flight. When you do an in-flight alignment, be certain you are in straight-and-level, unaccelerated flight, with the magnetic compass showing a steady indication.

## Turn indicators

Turn indicators show the direction and the rate of turn. A standard rate turn is 3° per second, and at this rate you will complete a 360° turn in two minutes. A halfstandard rate turn is 1.5° per second. Two types of indicators are used to display this information. The turn-and-slip indicator uses a needle to indicate direction and turn rate. When the needle is aligned with the white markings, called the turn index, you are in a standard rate turn. A half-standard rate turn is indicated when the needle is halfway between the indexes. The turn-and-slip indicator does not indicate roll rate. The turn coordinator is similar to the turn-and-slip indicator, but the gyro is canted, which allows it to sense roll rate in addition to rate of turn. The turn coordinator uses a miniature aircraft to indicate direction, as well as the turn and roll rate. [Figure 9]



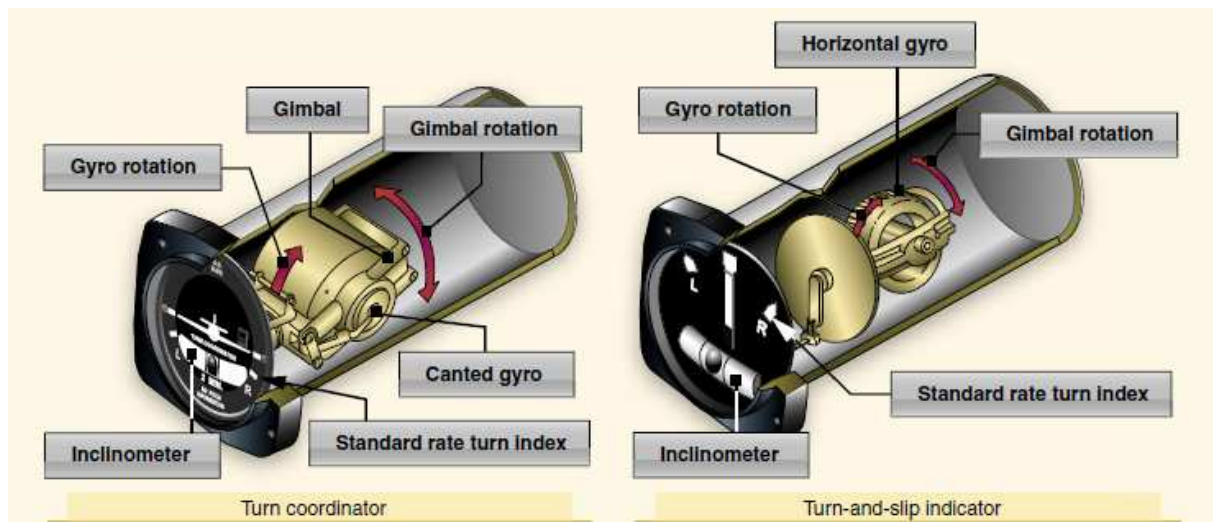


Figure 9. The turn coordinator and the turn-and-slip indicator [2]

Another part of both the turn coordinator and the turn-and-slip indicator is the inclinometer. The position of the ball defines whether the turn is coordinated or not. The helicopter is either slipping or skidding anytime the ball is not centered, and usually requires an adjustment of the antitorque pedals or angle of bank to correct it. [Figure 10]



Figure 10. In a coordinated turn (instrument 1), the ball is centered. In a skid (instrument 2), the rate of turn is too great for the angle of bank, and the ball moves to the outside of the turn.

Conversely, in a slip (instrument 3), the rate of turn is too small for the angle of bank, and the ball moves to the inside of the turn [6].

**INSTRUMENT CHECK**—During your preflight, check to see that the inclinometer is full of fluid and has no air bubbles. The ball should also be resting at its lowest point. Since almost all gyroscopic instruments installed in a helicopter are electrically driven, check to see that the power indicators are displaying off indications.

Turn the master switch on and listen to the gyros spool up. There should be no abnormal sounds, such as a grinding sound, and the power out indicator flags should not be displayed. After engine start and before liftoff, set the direction indicator to the magnetic compass.

During hover turns, check the heading indicator for proper operation and ensure that it has not precessed significantly. The turn indicator should also indicate a turn in the correct direction. During takeoff, check the attitude indicator for proper indication and recheck it during the first turn.

## MAGNETIC COMPASS

In some helicopters, the magnetic compass is the only direction seeking instrument. Although the compass appears to move, it is actually mounted in such a way that the helicopter turns about the compass card as the card maintains its alignment with magnetic north.

### Compass errors

The magnetic compass can only give you reliable directional information if you understand its limitations and inherent errors. These include magnetic variation, compass deviation, and magnetic dip.

### Magnetic variation

When you fly under visual flight rules, you ordinarily navigate by referring to charts, which are oriented to true north. Because the aircraft compass is oriented to magnetic north, you must make allowances for the difference between these poles in order to navigate properly. You do this by applying a correction called variation to convert a true direction to a magnet direction.

Variation at a given point is the angular difference between the true and magnetic poles. The amount of variation depends on where you are located on the earth's surface. Isogonic lines connect points where the variation is equal, while the agonic line defines the points where the variation is zero. [Figure 11]

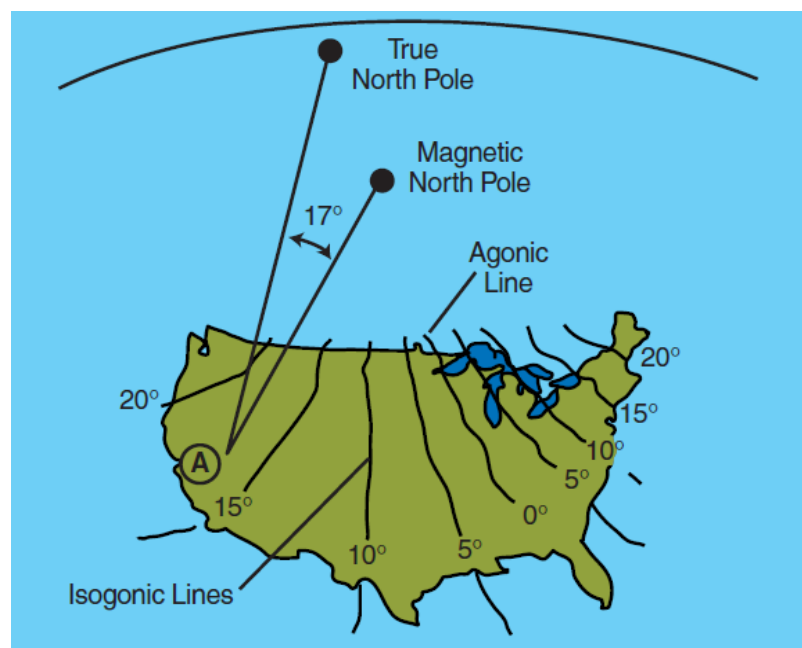


Figure 11. Variation at point A in the western United States is 17°. Since the magnetic north pole is located to the east of the true north pole in relation to this point, the variation is easterly. When the magnetic pole falls to the west of the true north pole, variation is westerly [6].

## Compass deviation

Besides the magnetic fields generated by the earth, other magnetic fields are produced by metal and electrical accessories within the helicopter. These magnetic fields distort the earth's magnet force and cause the compass to swing away from the correct heading. Manufacturers often install compensating magnets within the compass housing to reduce the effects of deviation. These magnets are usually adjusted while the engine is running and all electrical equipment is operating. Deviation error, however, cannot be completely eliminated; therefore, a compass correction card is mounted near the compass. The compass correction card corrects for deviation that occurs from one heading to the next as the lines of force interact at different angles.

## Magnetic dip

Magnetic dip is the result of the vertical component of the earth's magnetic field. This dip is virtually nonexistent at the magnetic equator, since the lines of force are parallel to the earth's surface and the vertical component is minimal. As you move a compass toward the poles, the vertical component increases, and magnetic dip becomes more apparent at these higher latitudes. Magnetic dip is responsible for compass errors during acceleration, deceleration, and turns.

Acceleration and deceleration errors are fluctuations in the compass during changes in speed. In the northern hemisphere, the compass swings toward the north during acceleration and toward the south during deceleration.

When the speed stabilizes, the compass returns to an accurate indication. This error is most pronounced when you are flying on a heading of east or west, and decreases gradually as you fly closer to a north or south heading. The error does not occur when you are flying directly north or south. The memory aid, ANDS (Accelerate North, Decelerate South) may help you recall this error. In the southern hemisphere, this error occurs in the opposite direction.

Turning errors are most apparent when you are turning to or from a heading of north or south. This error increases as you near the poles as magnetic dip becomes more apparent. There is no turning error when flying near the magnetic equator. In the northern hemisphere, when you make a turn from a northerly heading, the compass gives an initial indication of a turn in the opposite direction. It then begins to show the turn in the proper direction, but lags behind the actual heading.

The amount of lag decreases as the turn continues, then disappears as the helicopter reaches a heading of east or west. When you make a turn from a southerly heading, the compass gives an indication of a turn in the correct direction, but leads the actual heading. This error also disappears as the helicopter approaches an east or west heading.

**INSTRUMENT CHECK**—Prior to flight, make sure that the compass is full of fluid. During hover turns, the compass should swing freely and indicate known headings. Since that magnetic compass is required for all flight operations, the aircraft should never be flown with a faulty compass.



# SUMMARY

Flight instruments enable an helicopters to be operated with maximum performance and enhanced safety, especially when flying long distances. Manufacturers provide the necessary flight instruments, but to use them effectively, pilots need to understand how they operate. As a pilot, it is important to become very familiar with the operational aspects of the pitot-static system and associated instruments, the vacuum system and associated instruments, the gyroscopic instruments, and the magnetic compass.

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