



CHAPTER 16

INSTRUMENTS

16¹ ENGINE INSTRUMENTS

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Instruments provide the pilot with essential information about the aircraft. Taken in the context of general observation and sensations, aircraft instruments provide increased situational awareness and safety. It is vital that the instruments are used and read correctly – rubbish in, rubbish out. Understanding the purpose and mechanisms by which the instruments function is helpful. Each aircraft has its own unique array of instruments. This chapter describes the common instruments used in general aviation to increase understanding of the principles behind these instruments.

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ENGINE INSTRUMENTS

Which instruments provide information about engine performance and how do they work?

Tachometers gauges

A tachometer, measuring revolutions per minute (RPM), gauge indicates the rotational speed of the engine or propeller. A **centrifugal-type tachometer** contains weights that move around the rotating drive shaft. The faster the shaft rotates (higher RPM), the greater the weights are displaced away from the shaft. This displacement is sensed and converted to display an engine RPM. A **drag cup tachometer** has a magnet fixed to the drive shaft. The shaft and magnet rotate within an electro-conductive cup. This creates an interaction between two magnetic fields (magnet on shaft and cup), producing a drag force (torque) and a small electrical current that is proportional to the rotational speed of the shaft (RPM).

Manifold pressure and boost gauges

Manifold pressure (MAP) and boost gauges indicate the pressure within the air induction system of the engine. Opening the throttle allows more fuel/air mixture into the engine and increases manifold pressure. Manifold pressure is, therefore, a measure of how much power an engine is producing. Similarly, a boost gauge is installed in super or turbocharged engines and indicates how much “boost” or extra air (therefore power) is being supplied to the engine by the supercharger or turbocharger.

Direct reading oil pressure gauges

These gauges read the pressure of the oil being supplied to the engine components by the oil pump. The pressure gauge is connected via tubing into the engine oil system. As a result, changes in oil pressure will alter the force applied to the oil within the tubing that allows the pressure to be read.

Vacuum gauges

Vacuum gauges indicate the (negative) pressure created by the **vacuum pump**. By measuring the vacuum pressure within the lines of the vacuum system, the gauge confirms the satisfactory operation of the vacuum system. The vacuum system is required to drive the gyros within the various cockpit instruments (see below).

Outside air temperature gauges

The outside air temperature provides the pilot with information about the expected engine performance and identifies when freezing temperatures are reached.

Fuel quantity gauges

A sensor or float switch within the fuel tanks are used to measure the quantity of fuel within them.

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PRESSURE INSTRUMENTS

What are pressure instruments?

Pressure instruments are so-called because they utilise air pressure measurement in order to function. The three main pressure instruments are as follows:

- Airspeed indicator (ASI)
- Altimeter (ALT)
- Vertical speed indicator (VSI)

What is the difference between static and dynamic pressure?

Static pressure is the air pressure applied to an object at rest. As altitude increases, there is a decrease in air pressure (a reduction of static pressure). Dynamic pressure is created when either the object or fluid in which it travels (in this case, air) is moving. The more significant the speed difference between the two (object and air), the greater the dynamic pressure applied to the object. For example, when you put your hand out of the car window, a greater dynamic pressure is felt as the car moves faster.

How are dynamic and static pressures measured?***Static vents***

Vents located on the sides of the aircraft fuselage provide an air source to measure static air pressure. As they are located on the sides of the aircraft (*Figure 120*) and do not face the direction of travel, they are not exposed to any dynamic pressure. Static vents allow the

pressure within the pitot-static system to equilibrate with the static pressure outside/around the aircraft. The static pressure measurement can be converted into an altitude reading.



Figure 120. Photograph of a static vent on a general aviation aircraft.

Pitot tube

The pitot is a tubular metal device that protrudes from the main aircraft structure into the airflow (*Figure 121*). When this occurs, the end of the pitot tube is exposed to ram air pressure or impact air pressure. This ram or impact air pressure is the total air pressure experienced by the aircraft and is the sum of both static and dynamic air pressure. Therefore, the dynamic air pressure reading is derived from the difference between the ram air pressure read by the pitot tube and the static air pressure read by the static vents.

$$\text{Dynamic air pressure} = \text{ram air pressure} - \text{static air pressure}$$



Figure 121. Photograph of a pitot tube on a general aviation aircraft.

Combined pitot-static head

A combined pitot-static head combines a static vent and a pitot tube into one physical unit (*Figure 122*).



Figure 122. Photograph of a combined pitot-static tube with the pitot port on front of the tube (left) and the static port on the under surface towards the rear of the tube.

How are pressures converted into an airspeed?

The indicated airspeed is proportional to the dynamic air pressure. An airspeed indicator (ASI) uses the difference between pitot ram air pressure and static vent air pressure to read dynamic pressure. The mechanism within the ASI contains a diaphragm that is caused to expand by ram air pressure and caused to contract by static air pressure (*Figure 123*). Therefore, the resultant movement of the diaphragm is proportional to the dynamic pressure. The ASI translates this diaphragm expansion/contraction into the movement of a dial on the face of the ASI. Whilst grounded and stationary, the ASI should read close to zero as the pitot ram air pressure will be equal to the static air pressure. A positive indicated airspeed should appear shortly after starting the take-off roll.

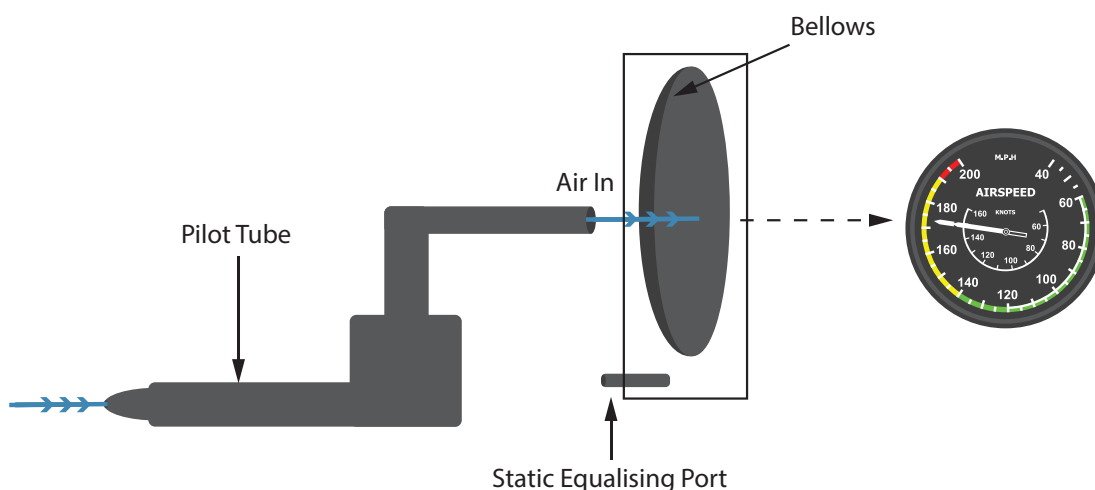


Figure 123. Diagram representing the mechanism of the airspeed indicator. Air is allowed to enter the diaphragm at ram air pressure through the pitot tube. This causes it to expand. Air leaves the diaphragm by the static air-line (causing a contraction of the diaphragm) with the amount leaving dependent upon the static air pressure. The diaphragm size is therefore proportional to the dynamic air pressure, which is converted by a series of levers to be presented as indicated airspeed on a dial.

What are the colour coding schemes used on an airspeed indicator?

To make pilots aware of airspeed limitations relevant to aircraft handling, the airspeed indicator is often colour-coded to aid in recall of specific speeds (*Figure 124*).



Figure 124. Photograph of an airspeed indicator from a general aviation aircraft. Note the white, green and yellow arcs and the red band.

Some of the speeds (in knots) that are often colour-coded are:

- **V_{S0} – Stall speed** of the aircraft in the **landing configuration** (landing flap/gear extended) indicated by the lower limit of a white arc.
- **V_{S1} – Stall speed** of the aircraft in the **clean configuration** (flaps and landing gear retracted) indicated by the lower limit of a green arc.
- **V_{FE} – Maximum flap extension speed.** The maximum speed at which the flaps can be extended indicated by the upper limit of a white arc.
- **V_{NO} – Maximum structural cruise speed.** The maximum operating speed range of aircraft in still, non-turbulent conditions indicated by a yellow arc. When operating within this range, no sudden/extreme flight control manoeuvres should be performed.
- **V_{NE} – Never exceed speed (knots).** The maximum speed the aircraft is designed to be flown indicated by a red line.

What are potential sources of error in the airspeed indicator?

Common sources of error that affect the airspeed indicator are:

- **Instrument error** – This occurs due to friction and inefficiencies created between the mechanical connections within the instrument itself.
- **Position error** – This is caused by pitot-static ports of an aircraft presenting to the relative airflow at differing angles (e.g. during turns, climbs). The aircraft manufacturer will publish details of position errors for the specific aircraft within the flight manual,

dependent upon the location of the ports. There are often correction factors within the manual that may be applied to provide a more accurate representation of airspeed.

How is ASI “indicated airspeed” different from true airspeed and ground speed?

Indicated airspeed (IAS) is what is shown on the airspeed indicator (ASI) within the aircraft. While the IAS is a reasonably accurate indication of airspeed in ISA conditions (sea level, +15°C), any deviation in altitude or temperature from the ISA standard would result in the indicated airspeed being different the speed the aircraft is moving through the air. The aircraft's true airspeed (TAS) is a consequence of making corrections to the IAS based on altitude/temperature. As general aviation is at relatively low altitudes, the IAS is largely representative of the TAS. As altitude is gained (density decreasing), the gap between the IAS and TAS increases (*Figure 125*).

Think of Indicated Airspeed as an air pressure measurement that is determined by the number of particles encountered per second.

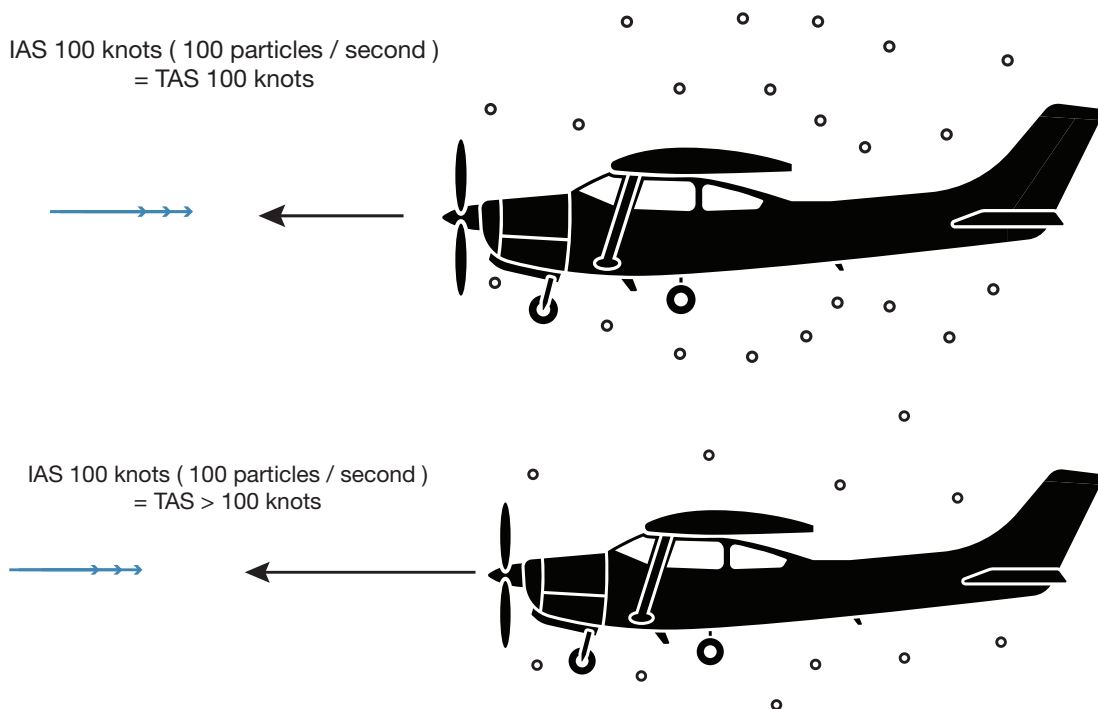


Figure 125. Diagram to explain Indicated Airspeed (IAS). The number of air particles encounter per unit time can be thought of as indicated air speed. Recall at a lower altitude, there is a higher density of air particles (number per unit volume). For explanation purposes, we can apply some arbitrary figures. At the lower altitude, the aircraft encounters 1000 air particles per second to give an indicated airspeed of 100 knots. In this instance, we can say the true airspeed is equal to indicated airspeed. At the higher altitude, there is reduced density of air particles. Therefore, to achieve the same indicated airspeed of 100 knots i.e. encounter 1000 air particles per second, the aircraft needs to travel faster through the air (higher true airspeed). Therefore, the true airspeed is higher than the indicated airspeed.

Ground speed (GS) is the aircraft's speed relative to travel overground. It can be calculated using the TAS +/- wind (headwind/tailwind) component. Therefore, the IAS and TAS are aerodynamic and performance measures of speed, whereas ground speed is more useful for navigation. For an aircraft with the same TAS, a headwind will result in a slower ground speed, or a tailwind will result in a higher ground speed.

How does the altimeter work?

The altimeter is connected only to the **static system**. A capsule (an **aneroid barometer**) within the altimeter expands and contracts with climbs and descents, respectively. This, in turn, moves gears and levers to produce an indicated altitude/height above a datum (dictated by the subscale setting). On the ground, the altimeter should indicate a value that is close to the known altitude above mean sea level or zero if set to read height above ground, with an increasing/decreasing value as the aircraft climbs/descends (*Figure 126*).



Figure 126. Photograph of an altimeter from a general aviation aircraft. The large hand represents hundreds of feet and the small hand represents thousands of feet. The subscale can be seen at the three o'clock position (air pressure in hPa).

Why is there a subscale setting and what is the difference between settings QNH and QFE?

The altimeter has a subscale setting (adjusted by turning the subscale knob) that allows the pilot to set a datum from which the altimeter is calibrated. By changing the subscale, the pilot can set either:

- **QNH** – Setting sea level pressure on the subscale. The altimeter will indicate the aircraft's altitude above mean sea level (AMSL).
- **QFE** – Setting zero feet on the altimeter when grounded. The altimeter will indicate the aircraft's height above ground level (AGL).

What errors can occur with the altimeter?

Common altimeter errors include:

- **Position error** – This results from the location or surroundings of the static ports creating an environment where the pressure within the static system is not equivalent to the actual static pressure.
- **Hysteresis error** – Fatigue of the aneroid capsule (from repeated expansion/contraction) resulting in the elasticity of the capsule changing. This means that there is a loss in calibration or a slower change in size.
- **Lag and reversal** – Abrupt changes in altitude cause the altimeter to indicate an incorrect value momentarily.
- **Subscale setting error** – When the pilot sets the incorrect setting for the subscale (e.g., wrong QNH will therefore read a wrong altitude).

What is the vertical speed indicator and how does it work?

The **vertical speed indicator (VSI)** operates on a similar principle to the altimeter, requiring that only static pressure is read via static ports as the instrument input. However, the capsule/diaphragm within the VSI has a tiny hole allowing the capsule to leak, returning to its original size after each expansion/contraction associated with a change in altitude. The rate at which the capsule changes size is translated using a system of mechanical gears and pins to indicate either a rate of climb or descent on the instrument face.

What errors affect the VSI?

Certain errors that affect VSI include:

- **Position error** – Created by the position of the static source being affected by the relative airflow, causing the VSI to indicate a climb/descent during a level turn or while accelerating.
- **Lag** – Created by sudden changes of altitude creating a situation where air within the aircraft's static air system has to play catch-up with the actual static air pressure outside the aircraft.

If the pitot static system were to fail, it would prove very dangerous. Are there any built-in protective features or redundancies?

Drain holes, heating and pitot cover

To ensure water/contaminants do not get into the pitot-static system, drain holes are incorporated into the design. Any water within the pitot-static system could freeze during a flight, so a pitot heat system is used to melt any ice formed. On the ground, a pitot cover protects the pitot tube against insects or foreign debris from entering the pitot tube.

Alternate pressure source

If a static vent becomes blocked, instruments relying on static pressure will no longer produce an accurate reading. In this situation, an alternate pressure source can be selected, allowing static air from an alternate source (usually within the cockpit) to be used as the source of static pressure.

How can the pitot-static system be checked to ensure it is working correctly?

A thorough pre-flight inspection should include a visual examination of the pitot tube and static ports for any blockages or damage that could affect normal operation. Similarly, pitot-static instruments within the cockpit should indicate expected values on the ground when set to the correct subscale settings – for instance, when QNH is set, it should read the altitude AMSL of the airfield.

What can go wrong with pitot-static tubes?**Blockage of the pitot tube**

Blockage of the pitot tube might not be immediately noticeable, with only the ASI being affected. The ASI will indicate the airspeed immediately before the blockage occurred. Suppose the static source is not also blocked. In that case, the ASI begins to function as an altimeter – with changes in altitude causing the indicated speed to increase with an increase in altitude and vice versa. Total blockage of the pitot tube is unlikely. What is more common is a partial blockage, causing the airspeed indicator to be sluggish.

*If you notice fluctuating airspeeds during a flight in colder temperatures (especially if visible moisture is present), selecting pitot heat **ON** as early as possible will help to prevent/remove any ice that may have formed on the pitot tube.*

Blockage of the static source

Blockage of the static source affects all instruments connected to the pitot-static system, causing the altimeter and VSI to no longer function properly. In this situation, the altimeter will indicate the altitude at which the blockage occurred and the VSI will not indicate any climb or descent, regardless of any actual aircraft altitude changes. The ASI will display the airspeed at the altitude where the blockage occurred. However, it will be under-read in a climb or over-read in a descent from that altitude. Selecting the alternate static source **ON** will allow the static system to access static air from another source (usually sourced from within the aircraft).

*Blockages will affect the ASI following “PUDSOD”: **P**itot [**B**lockage] **U**nder-read [**o**n] **D**escent, **S**tatic [**B**lockage] **O**ver-read [**o**n] **D**escent.*

16³

THE COMPASS

How does the aircraft compass work?

Direct-reading compasses consist of a non-magnetic metal bowl filled with fluid and a clear glass front (*Figure 127*). A circular card (disc) imprinted with compass bearings and attached magnetised needles are balanced on a pivot within the bowl. This allows the card to rotate freely, allowing the magnetised needles to swing the card in alignment with the earth's magnetic field. The magnetic heading is read off the card through the glass window on the front of the compass bowl face. The fluid within the compass bowl provides a dampening effect on the moving internal components of the compass. This helps to prevent the compass from oscillating and vibrating during turns and turbulence which can cause erroneous readings.



Figure 127. Photograph of a general aviation aircraft compass.

The lubber line is a fixed line drawn on the glass front of the compass face. The line indicates the centre-line of the aircraft with respect to the aircraft's current compass direction (the direction in which the aircraft is pointing).

What errors affect the compass reading in flight?

Magnetic dip

The Earth's geomagnetic field (flux lines) connect the north magnetic pole with the south magnetic pole (*Figure 128*). In this invisible forcefield, the magnetic lines are vertical at the poles (pointing straight up/down) and horizontal at the magnetic equator. Magnets (compasses) try to align with these magnetic lines. They therefore would naturally try to align horizontally north/south at the equator and vertically at the magnetic poles, causing a dip everywhere except the equator. This dip increases with higher latitudes up to a maximum at the polar regions.

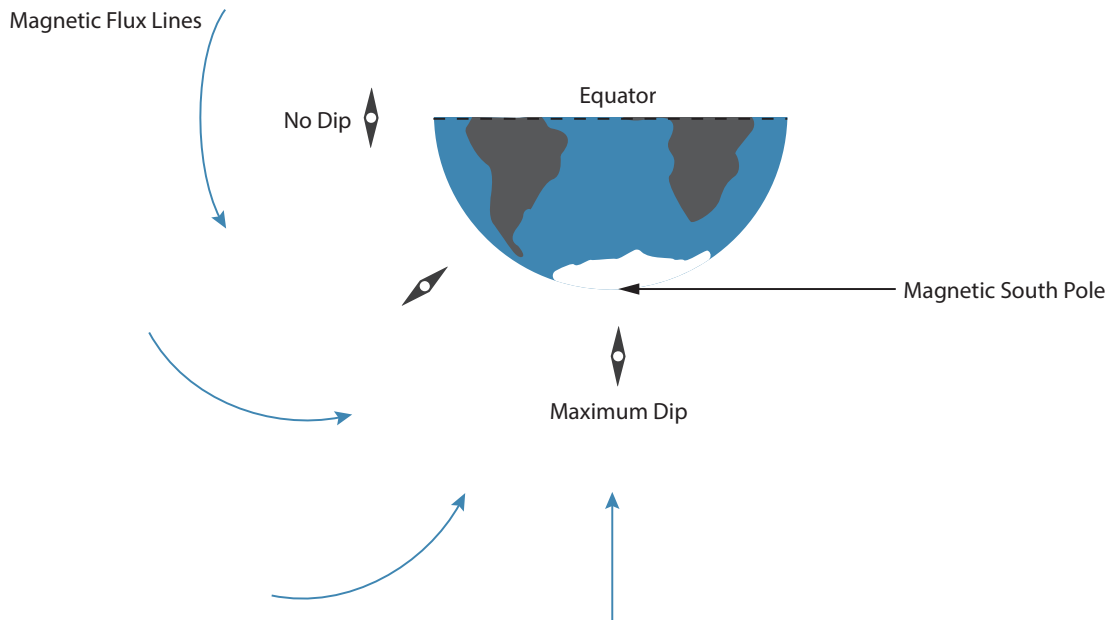


Figure 128. The diagram showing the magnetic flux lines. The flux lines orientate horizontally at the equator and vertically at the pole. The compass needle also aligns with these is causes magnetic dip. This also means there is little or no dip in equatorial regions and increases to a maximum towards the pole.

Weights added to the base of the compass card work to prevent it from tilting and aligning with the flux lines and attempt to counteract the effect of magnetic dip. Even with the weights compensating for a magnetic dip, the magnets and cards within the compass still tend to dip in alignment with the flux lines. Up to 3° of residual dip at mid-latitudes is acceptable and has a minimal detrimental effect on the compass indication.

Acceleration error

Acceleration error affects the compass when the aircraft changes velocity. Accurate compass readings can, therefore, only be performed when the aircraft is in straight and level flight at a constant velocity. The error causes the compass to swing in a north/south direction and is most profound when the aircraft is on a due east/west heading. Accelerating or decelerating on a due north/south heading will cause the compass to dip up/down, but generally it will not swing. This is due to the inertia caused during acceleration, pushing the compass needle's centre of gravity rearwards and producing an inaccurate turning moment.

*In the Southern Hemisphere, the acronym **SAND** can be used for acceleration error: the compass will swing and show an apparent **S**outhern turn during **A**cceleration and a **N**orthern turn during **D**eceleration. The opposite applies to the Northern Hemisphere.*

Turning error

During a turn, the compass is affected by the centrifugal force of the turn and the vertical

component of the dip. In the Southern Hemisphere, if the aircraft heads north and begins a turn in any direction, the compass will accelerate in that direction at a faster rate than the aircraft is actually turning. This is because magnetic dip during a turn will begin to act in the direction of the turn and be additive. Therefore, to end the turn flying straight and level with the correct compass heading, the turn to the north will continue past the compass heading (overturn) to compensate.

Conversely, if the aircraft were heading south and began a turn, the compass would momentarily swing backwards (reverse) before indicating a turn in the correct direction. Therefore, the turn needs to be completed before reaching the desired compass heading (*Figure 129*). This error is highest (30°) when heading due north/South, reducing to zero (0°) when heading due east/west.

An acronym to perform compass turns in the Southern hemisphere is: “ONUS” (Overturn North, Underturn South). The opposite applies in the Northern Hemisphere.

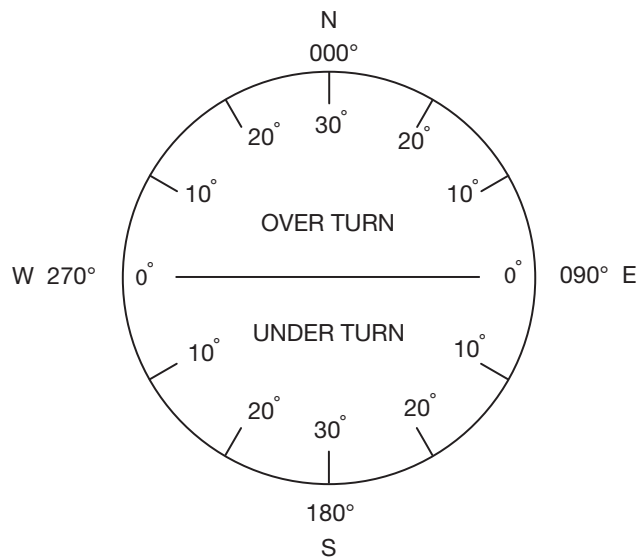


Figure 129. Diagram showing the turning error correction circle showing the amount of overturn/under turn required for the turn. For Northerly headings (270° to 090°) there is an over turn and for Southerly headings (090° to 270°) an under turn is required. The number of degrees to overturn/under turn by is shown in the diagram below. The maximum correction is 30° when final heading is exactly due North or South and no correction is required when final heading is exactly due East or West. There is gradual change in correction required between these headings.

Example

Your aircraft is flying due west in New Zealand, and you begin a right-hand turn, intending to roll out on a compass heading north (000°). The pilot would overturn through north and aim to roll out on a heading of 030°. Once straight and level on the heading of 030°, the compass would swing back to indicate the correct heading of north (000°).

What are compass serviceability checks?

The compass should be inspected pre-flight to ensure that there is fluid within the compass bowl, that no fluid discolouration or bubbles obstruct the compass from being read and that there are no cracks. The compass should also indicate a known magnetic direction. This can be confirmed by aligning the aircraft with a runway (using the runway heading as a reference). Care should be taken when metal/magnetic objects are carried aboard the aircraft, as they may affect the compass and lead to erroneous readings due to the formation of small magnetic fields around them. The compass deviation card for the aircraft should also be present and not expired.

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GYROSCOPIC INSTRUMENTS**What are commonly used gyroscopic instruments?**

The main instruments are:

- Attitude indicator
- Heading/directional indicator
- Turn indicator/coordinator
- Coordination/balance ball

What does gyroscopic mean?

A gyroscope is a spinning disc that maintains its spinning direction despite the orientation of the outer arms. It retains its direction due to inertia and is always orientated to the centre of the Earth.

How do they work?

An engine-powered vacuum pump drives the gyroscopic instruments. The vacuum pump generates sufficient airflow across air-catching buckets on the gyroscopic instruments and causes the gyroscope to spin at high speed and enable its function. The pump is mounted on the engine's accessory section and is spun by reduction gearing attached to the engine crankshaft. In some very old aircraft, a Venturi tube is located on the exterior of the fuselage and is used to generate the suction required to power the gyroscopic instruments. If the vacuum pressure is reduced or lost, the gyroscopic instruments will be unstable and unusable.

Vacuum-driven instruments are essential, so it is essential to properly scan and cross-check the instruments for early detection of a possible failure.

What are the properties of a gyroscope?

Rigidity

Gyroscopes are constructed to allow a heavy weight on the edge of the assembly to spin rapidly around a central axis (*Figure 130*). As this heavy weight spins, it becomes rigid in space. That is, it resists movement in any axis other than around the axis on which it spins, i.e., it has inertia. This allows the aircraft to essentially rotate around the gyroscope (as the gyroscope effectively remains fixed in space). Attitude and heading indicators operate on the principle of gyroscopic rigidity. Airspeed must be of sufficient velocity to move the gyro wheels at high speed. Otherwise, the gyroscopic rigidity that makes these instruments function correctly will be lost. There may be a suction flag/vacuum indicator or other indication on the face of the gyro instruments to indicate a vacuum failure.

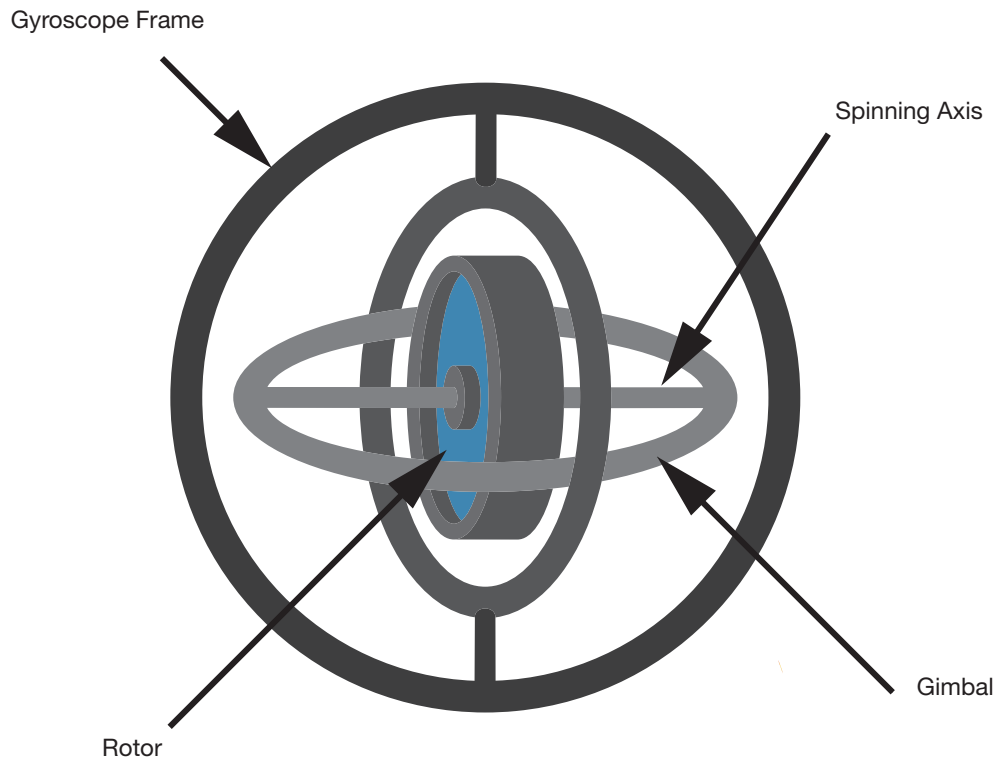


Figure 130. Diagram showing a gyroscope in its simplest form. The spinning disc, spins around its axis and will demonstrate principles of rigidity (inertia) and precession when acted upon as the gyroscope frame. The gimbal moves freely around the spinning disc.

Precession

Gyroscopic precession refers to the behaviour of a gyroscope when an outside force acts upon it. When a force is placed on a spinning gyro, the force acts not where it is applied, but at 90 degrees in the direction of rotation. The turn and bank indicators function on the principle of gyroscopic precession. When an aircraft yaws or turns, it imposes a force on the

gyro, resulting in precession that can indicate the direction of the turn.

Internal resistance and other errors impose some degree of unwanted precession on every gyroscopic system, so periodic resetting of the heading indicator by referencing the magnetic compass is required.

How do the turn indicator and coordinator work?

The rate of turn gyroscope comes in two varieties: the turn indicator and the turn coordinator. The gyro is mounted vertically and aligned with the longitudinal axis of the aircraft. When the aircraft turns, it causes gyroscopic precession of the gyroscope. Therefore, the force is applied at 90 degrees to the direction of the gyro's rotation, causing it to move in the same direction of the turn. Most modern gyroscopes are electrically powered, providing a suitable backup to pneumatic gyroscopic instruments.

What's the difference between a turn indicator and coordinator?

The turn indicator was the original IFR instrument that only provides information about the rate of turn. As the force of precession acts on the gyro, the gyroscope assembly moves against calibration springs that resist its motion. This way, when the turn indicator needle is at the index marks ("doghouses"), the aircraft is performing a standard rate turn (*Figure 131*).



Figure 131. Photograph of a turn indicator in a general aviation aircraft.

The turn coordinator operates on the same principle of gyroscopic precession. As it is installed canted 30 degrees upward, it can show movement in both the yaw and roll axis, and therefore it can additionally display the bank of the aircraft. Once the turn is stabilised, the turn rate is indicated relative to the standard rate. Instead of a needle and "doghouses", the turn coordinator uses an aircraft outline and index marks (*Figure 132*).

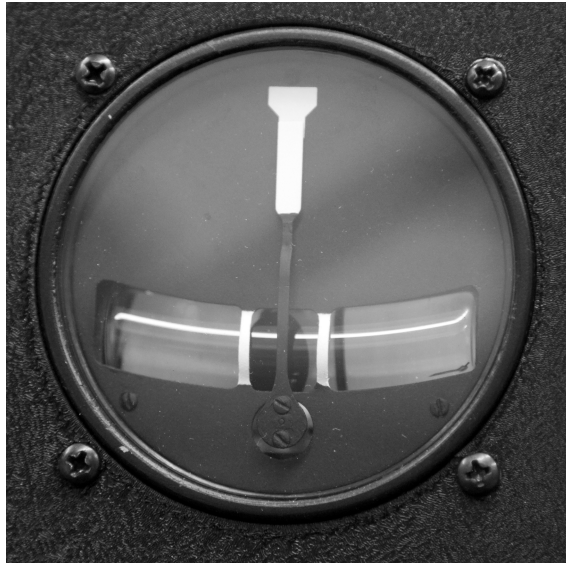


Figure 132. Photograph of a turn coordinator in a general aviation aircraft. The ball underneath the aircraft is the balance ball.

What is the function of coordination (balance) balls?

A coordination ball, or inclinometer, is a simple instrument that is used to measure whether the relationship between bank and rudder is being managed correctly. It is simply a fluid-filled curved capsule with a weighted ball that senses gravity. If the amount of rudder applied is too little for an angle of bank, the ball will be pushed to the inside of the turn. If the rudder is overly used during a banked turn, the ball will be pushed to the outside of the turn.

“Step on the ball”: By applying rudder pressure in the direction of ball movement, you can move the ball back to the centre to enable coordinated flight.

What does the attitude indicator display?

Pitch and roll are both displayed simultaneously on the attitude indicator (*Figure 133*). The horizon is represented by a horizontal line dividing two background colours – usually brown (ground) and blue (sky). Pitch and roll angles in degrees are represented by index marks on the face of the instrument. The movement of the attitude indicator is the same as the movement of the horizon as you pitch and roll the aircraft.

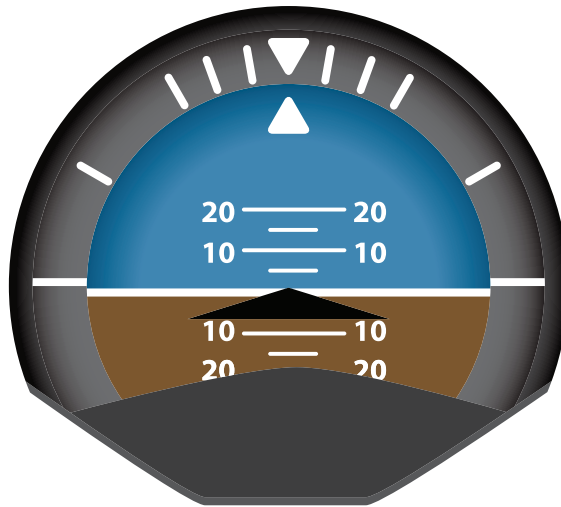


Figure 133. Diagram of the attitude indicator.

How does the attitude indicator work?

The attitude indicator functions through the principle of gyroscopic rigidity. It is mounted upright but has freedom of movement across all three axes. It remains in its plane of rotation due to the Earth's gravitational pull, as long as sufficient rotational velocity is applied to the gyro. Since the gyro remains upright relative to the Earth (and thus, the horizon), the aircraft essentially rotates around the gyro as the aircraft pitches and rolls.

How is the attitude indicator checked to ensure it is working correctly?

The attitude indicator is the primary indicator for an instrument flight, so ensuring it is functioning correctly is a necessity. After the engine start, verify that there is adequate vacuum pressure by looking at the suction gauge. The horizon line should be aligned with the miniature aircraft symbol and indicates level flight. If it isn't, many general light aircraft attitude indicators have a "caging" mechanism that will reset the attitude indicator to straight and level flight. When flying, a careful instrument scan will reveal if the gyros rigidity is decaying – a failing gyro moves slowly or gives false indications of the level. Some attitude indicators incorporate warning flags to alert the pilot to a malfunctioning instrument.

What are the benefits of the heading/directional indicator?

While the magnetic compass is an utterly dependable instrument due to its simplicity, the gyroscopic heading/directional indicator has advantages over the compass. It makes flying in the right direction easier (Figure 134). These include:

- **Moving in the same direction as the turn** – The heading indicator rotates in the direction of the turn, while the wet compass rotates opposite the direction of the turn.
- **Reduced movement** – The magnetic compass tends to bounce around in any kind of turbulence, while the heading/direction indicator remains relatively stable.

- **Reduced errors** – The heading indicator is unaffected by compass errors such as magnetic dip, turning errors and acceleration errors.



Figure 134. Diagram of a directional/heading indicator.

How is the heading/directional indicator synchronised with the compass?

All gyroscopes tend to have some amount of precession, and the heading indicator is no different. As a vertically mounted gyroscope, the accuracy degrades over time as the aircraft repeatedly turns. A periodic resetting of the directional gyro (about every 15 minutes) is key to maintaining accurate indications. This resetting must occur when the compass is stable and when the aircraft is in straight and level, unaccelerated flight.

Gyroscopes do not function without spinning. After starting the engine, the directional indicator/heading must be set to the proper heading.

What are heading/directional indicator serviceability checks?

Determining the functionality of the heading/directional indicator is much the same as the attitude indicator. After the engine start, ensure that adequate vacuum pressure is available via the suction gauge. Once underway, ensure that it is periodically reset and note the amount of precession. A gyroscope with an unreasonable amount of precession needs to be serviced.

What common errors occur in gyroscopic instruments?

Gyroscope rotor RPM is low

If the gyroscope RPM becomes low due to a failing vacuum pump or a faulty instrument, the

gyroscope will “tumble.” The rigidity of the gyroscopic instruments depends on an adequate rotational speed, and thus they will lose their ability to function correctly.

Indications of “toppling”

Gyros can “topple” or “tumble” for two reasons: the rotational velocity of the gyro is insufficient to retain its rigidity in space, or the motion of the aircraft has exceeded the gimbal limits of the gyro (such as during aerobatic manoeuvres). Gyros that have tumbled display inaccurate information and must be reset in straight and level flight.

Indication of a power failure for an electrically-driven gyroscope

Like the turn coordinator, electrically powered gyroscopes also depend on adequate rotational speed to function. While they do not “tumble” (due to the rigid mounting), they will cease to indicate the proper direction and rate of turn.

16⁵

GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)

What is a Global Navigation Satellite System (GNSS)?

GNSS is an all-encompassing term that utilises a constellation of satellites stationed about 11,000 miles above the Earth. The function of these satellites is to provide a hyper-accurate time signal to a receiver on an aircraft. The GNSS satellite system includes various systems launched by different nations. For example, GPS (Global Position System, USA), Galileo (Europe) and GLONASS (Russia, etc.). The most common GNSS subsystem in use is the GPS.

How does the GNSS work?

Satellites placed into orbit around the Earth follow specific pathways around the Earth. There are generally six planes of orbit for each system and the number of satellites for each plane varies with the system. A receiver communicates with the orbiting satellites to enable position detection. Therefore, the receiver needs to have a line of sight with a sufficient number of satellites to allow accurate positioning (*Figure 135*).

The satellites contain a database of times and positions in their orbits over the Earth. The receiver information is checked against this database to perform distance, time, speed calculations and provide navigational information.

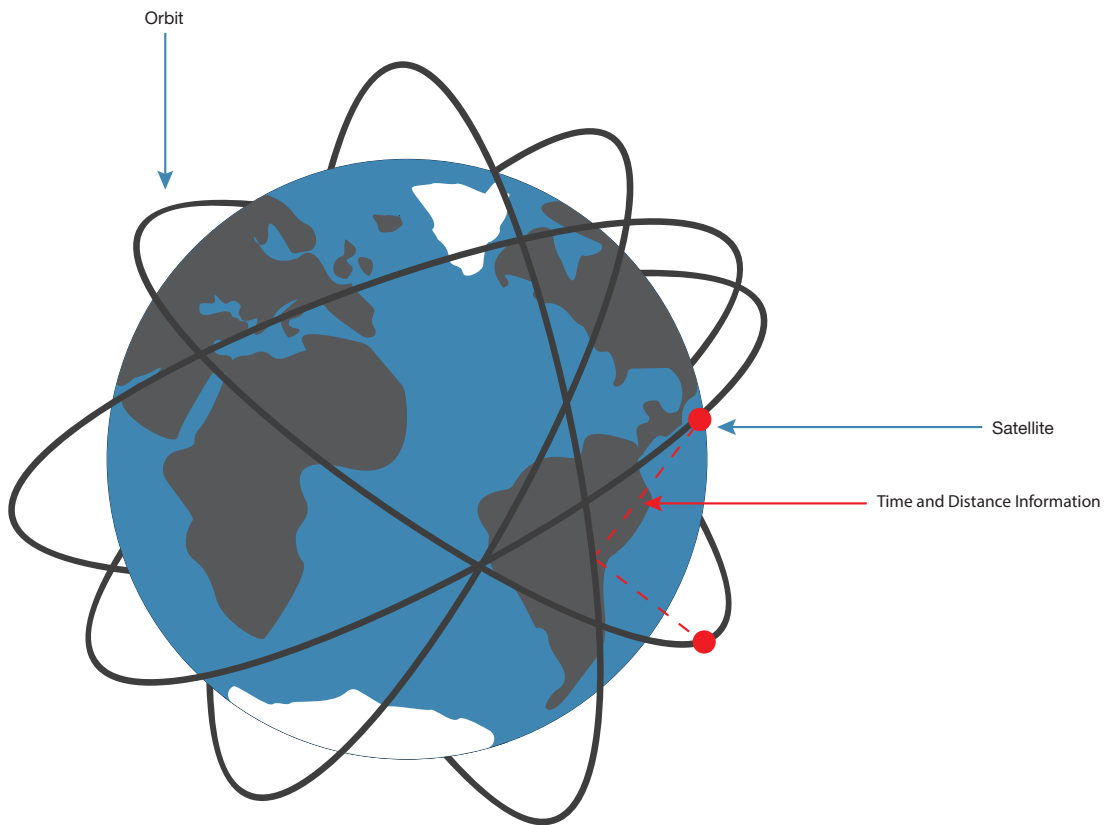


Figure 135. Diagram to show a GNSS system. Satellites travel around the Earth in precise, pre-determined orbits. Each system will utilise 6 planes with multiple satellites for each plane. The satellites compare user GNSS data to a database of time/position to provide accurate Earth positions.

What are some helpful features of the GNSS?

- Real-time position on aviation charts
- Notifications of airspace boundaries
- Navigation to waypoints/aerodromes
- Advice for radio communication frequencies
- Instrument approaches
- Autopilot

Alternatively, smartphones and tablets can provide accurate and up-to-date navigational information through various apps. Such use is becoming increasingly common, with many apps having legal and CAA approval.

What are the advantages and limitations of using GNSS systems?

The GNSS system is highly accurate and reliable. In the rare event of a failure, the GNSS

receiver will warn the pilot of a degraded condition. Additionally, receivers that are certified for instrument approaches incorporate a function called Receiver Autonomous Integrity Monitoring (RAIM), which warns the pilot of degradation of capability. GNSS systems can fail due to electrical supply or inadequate signals being received. This can be due to the global position not being served well by the prescribed satellites or local weather phenomena. Portable GNSS systems tend to use battery power very quickly and can overheat in the cockpit environment and cease to operate. For these reasons, carrying paper aeronautical charts is a requirement for flight.

How does a portable GNSS work?

Electronic flight bags are specifically designed software for aviation available on smartphones and tablets. They can combine GNSS data with aeronautical chart data to assist flight planning and navigation.