DOCUMENT
GSM-G-CPL.016

DOCUMENT TITLE
FLIGHT INSTRUMENTS

CHAPTER 10 – THE ARTIFICIAL HORIZON

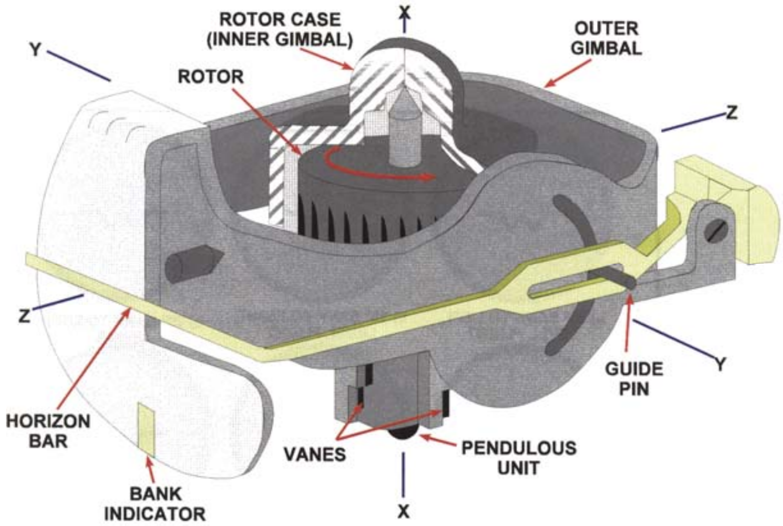
Version 1.0
September 2012

CONTENTS .... PAGE

THE ARTIFICIAL HORIZON (AH)

The Artificial Horizon provides an indication of the aircraft attitude in PITCH and BANK. It is a master instrument and has no lag. The horizon indication replaces the earth's natural horizon as a reference when the natural horizon is not visible.

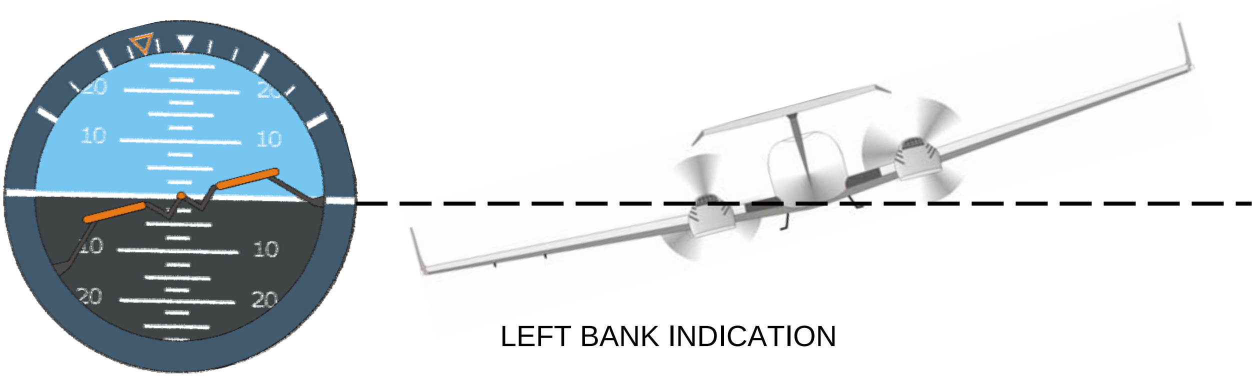
The AH (also referred to as an Attitude Indicator or AI) uses a tied gyro. Gravity sensing devices are used to influence the rotor axis to keep it pointing at the centre of the earth. This type of tied gyro is called an earth gyro. The rotor is powered by either a vacuum (air) system or electrical; the gravity seeking devices are also either vacuum or electrical. The rotor plane of rotation is horizontal, the rotor axis is vertical. The horizon indicator is attached to the outer gimbal and is therefore horizontal when the rotor axis is vertical.



THE VACUUM POWERED ARTIFICIAL HORIZON

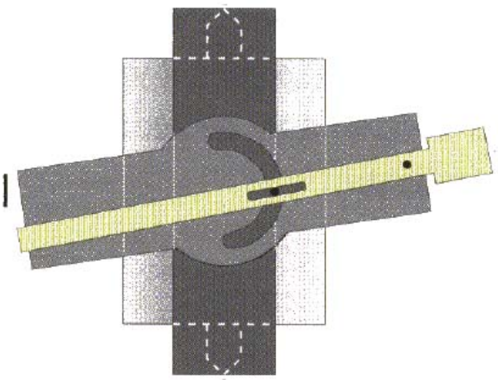
PRINCIPLE OF THE ARTIFICIAL HORIZON

The AH makes use of the gyroscopic property of rigidity to provide the pitch and bank indications. When the aircraft manoeuvres, the rotor and inner gimbal maintain their alignment and the aircraft moves around them. There are a number of possible displays with the indication of bank appearing at the top or bottom of the instrument. In the diagram below, the horizon bar and the bank scale are connected to the outer gimbal and the bank pointer is attached to the instrument case.

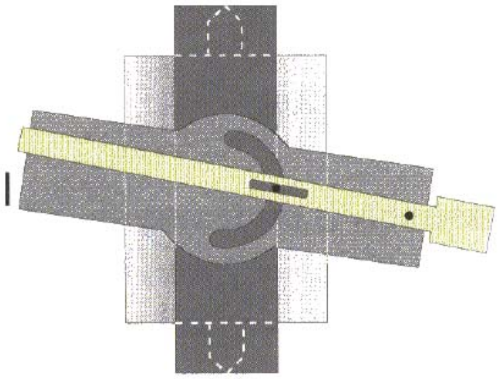


LEFT BANK INDICATION

The indication of PITCH attitude is given by the position of the horizon bar, in relation to the aircraft symbol. Pitch attitude is measured by the angle between the outer and inner gimbals but as this could only be viewed from the side, the horizon bar is needed to bring this information to the face of the instrument. The horizon bar is pivoted at the rear of the instrument and is controlled by a guide pin from the inner gimbal which projects through a curved slot cut into the outer gimbal. The outer gimbal pitches with the aircraft.



PITCH UP
(horizon bar moves down compared to outer gimbal)



PITCH DOWN
(horizon bar moves up compared to outer gimbal)

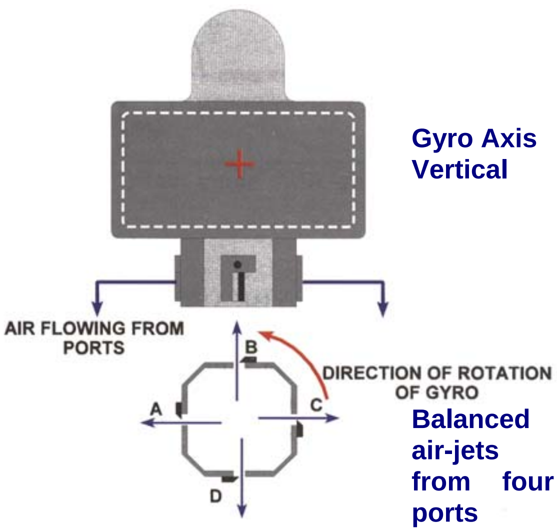
ERECTION SYSTEM

A number of mechanical erection systems have been developed. These devices sense gravity (centre of the earth) and tie the AH rotor axis to the vertical. The diagram shows a vacuum driven AH which has a pendulous unit at the lower end of the rotor.

The pendulous unit has two main functions :

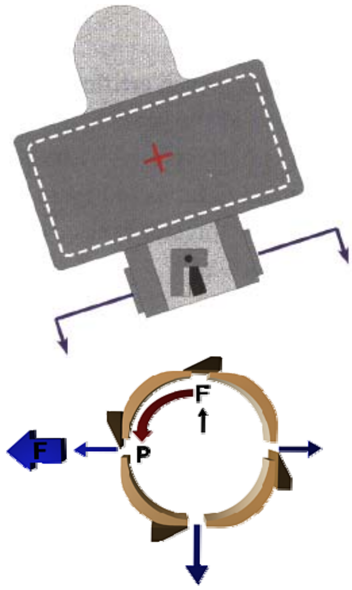
A. When the rotor is not turning the mass causes the gyro to rest with its axis vertical; when vacuum is applied and the rotor starts, it will be very near its normal operating position; and

B. The pendulous vanes are part of the pendulous unit so they act to keep the rotor axis vertical after the vacuum is applied. If the axis is displaced from the vertical by turbulence or topples, the vanes sense gravity and precesses the axis towards its correct vertical alignment.



Gyro Axis Vertical

Balanced air-jets from four ports



Gyro Axis Toppled

Unbalanced air-jets create force leading to precession which corrects topple

GIMBAL LIMITS

Physically fitting a gyroscope into a small instrument casing has its own set of problems. The AH gimbals (tied gyro) have freedom in three axes, but there is a physical limit on at least one axis. Modern instruments have 360° freedom in roll, but are limited to $\pm$ 85° in pitch.

If the limit stop is reached during flight a large force is applied to a gimbal, a rapid precession is caused and the gyro will '<u>topple</u>'.

CAGING

Older gyros were fitted with a mechanical locking device to cage (to hold the gyro gimbals locked at 90°). This would allow the pilot to complete manoeuvres which could topple the gyro. The instrument would then be 'uncaged' and it would resume its normal function.

<u>NB</u> : Not all gyros have caging devices. This means that if the gyro topples, its reference is lost (rotor axis displaced). The erection system will re-establish the reference but this could take as long as 15 minutes. The erection rate on vacuum driven artificial horizons is usually fairly slow($\cong$ 8° per minute) to avoid causing other errors.

ACCELERATION ERROR

When an aircraft is accelerated an error is induced in the AH. This is a small but noticeable error which is more obvious on vacuum powered horizons.

a. **Roll Error** - The mass at the bottom of the gyro tends to lag. This applies a force to the inner gimbal which is transferred to the rotor, resulting in precession at 90° (in direction of rotation) to the direction of lag. The result of this precession is a false indication of right bank (right wing down).

b. **Pitch Error** - The pendulous vanes (side vanes) also lag. The unbalanced airflow produces a force on the side of the inner gimbal that results in a precession which causes the horizon indicator to move down and the false indication is a climb.

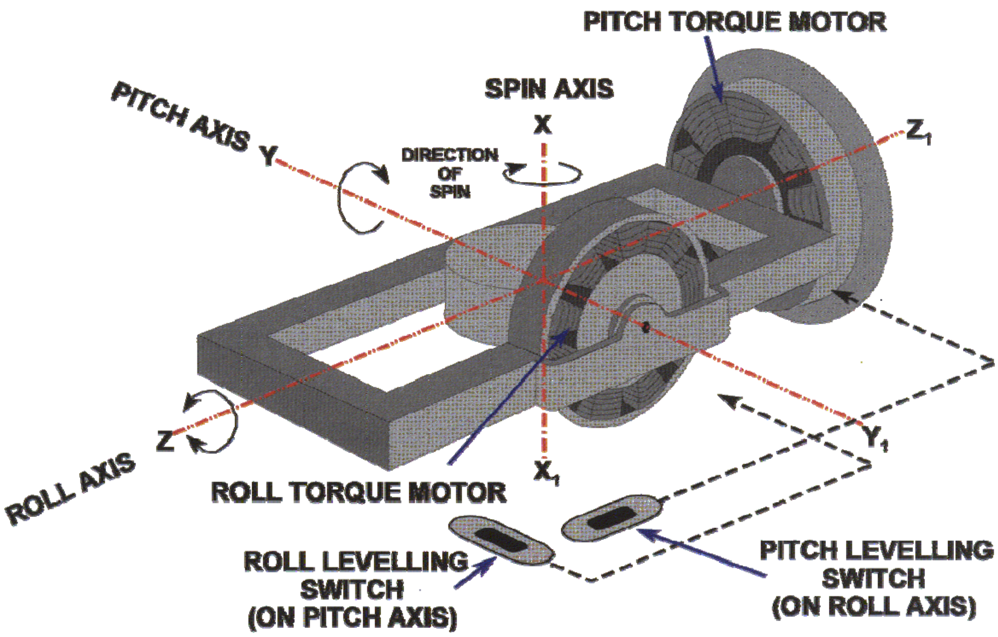
NB : **Acceleration error** - in the AH is an indication of a **pitch up** and **bank to the right** in the order of 2 - 3°. This error exists while the acceleration is applied and for about a minute after the acceleration is removed. Deceleration error is opposite to acceleration error.

TURN ERRORS

When an aircraft turns, the mass at the bottom of the gyro tends to continue in its original direction (thrown outwards); the pendulous vanes now sense the resultant of gravity and turning forces and an error is induced. The magnitude of this error depends on the aircraft speed, the rate of turn and length of time the turn is maintained. The pendulous vanes are modified and the erection rate is kept low to minimise the turn error.

THE ELECTRICALLY POWERED ARTIFICIAL HORIZON

The principle of operation of the electric powered artificial horizon is similar to the vacuum system. The rotor has an electric motor incorporated in its construction usually powered by alternating current with a rotation speed of about 23,000 RPM. Gravity sensing is achieved by a number of mercury switches. When the rotor axis is 'off vertical', mercury switches allow electric current to flow to torque motors. The torque motor provides a force at one of the gimbals which causes a precession to drive the rotor axis back to the vertical position. At this position the mercury switches are level and switch off leaving the gyro in its correct position.



ELECTRIC CONTROL

The mercury switch normal erection rate is set at 3° or 4° per minute. An advantage of this electric control system is that 'cut out' switches (also mercury switches) will turn the erection system off if an error is likely to be caused. While a caging device is not available, a 'Fast erect push switch' is. This will erect the gyro at a rate of 120° per minute if a limit stop has been exceeded and the gyro has toppled. The normal erection rate occurs when 20 V AC (400 Hz) supply is provided for that circuit. During fast erection 115 V AC is provided.

FAST ERECTION PRECAUTIONS

1. Must only be activated when the aircraft is straight and level with zero acceleration (to prevent the gyro being driven to a larger error).

2. The fast erect switch must not be activated for more than 15 seconds (the high current could overheat the torque motors).

ACCELERATION AND TURN ERRORS (ELECTRICAL AH)

These errors still exist in electric horizons, however, because of the cut out switches (0.18g or 10° Bank), these errors are minimised. Errors are also reduced by the higher rotor speeds of the electric horizons and by the absence of a heavy base. This is not required as the electric horizon is equipped with a fast erection system for initial alignment.

NB : Direct current electric artificial horizons are uncommon. Most electric horizons are powered by Alternating Current. As most General Aviation aircraft have DC electric systems, they usually use vacuum powered artificial horizons. Some larger General Aviation aircraft are fitted with 'inverters' that make AC power available for instrumentation. Large transport aircraft are fitted with high quality electric artificial horizons.

PRE-FLIGHT CHECKS

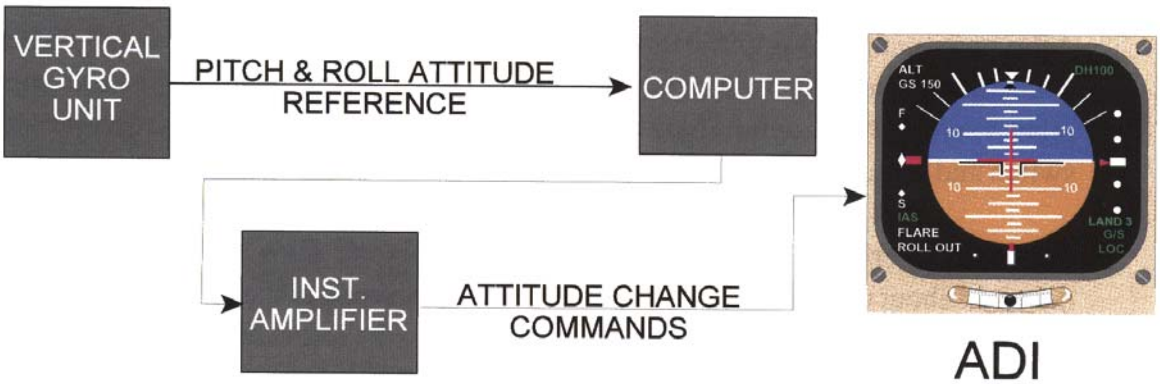
- Glass Clean.
- Vacuum in green or electric flag away.
- Datum set (aircraft silhouette). Note: Do not adjust in flight.
- Wings remain level during taxi.

STAND-BY ATTITUDE INDICATOR

Large RPT aircraft are often fitted with back-up systems should a primary system fail. The stand-by horizon has its own vertical gyro and is usually powered by an inverter connected to the battery. This satisfies the requirement of separate and independent power sources.

THE REMOTE VERTICAL GYRO

A Remote Vertical Gyro performs the same functions as an Artificial Horizon in that it provides a stable reference for the measurement of pitch and roll attitude. However instead of providing the attitude displays by direct means, the remote gyro makes use of a synchro system to transmit pitch and roll information to the attitude display. The synchro system also provides attitude signals to the auto flight control system (autopilot).



The Remote Vertical Gyro provides an input to 'integrated' attitude director displays which bring together attitude, radio navigation and auto-pilot/ flight director derived information. The same inputs are combined within the Automatic Flight Control System to provide flight guidance. More information on this subject is provided in the Electrics and Auto-flight study unit.