DOCUMENT
GSM-G-CPL.016

DOCUMENT TITLE
FLIGHT INSTRUMENTS

CHAPTER 11 – THE TURN AND BALANCE INDICATOR

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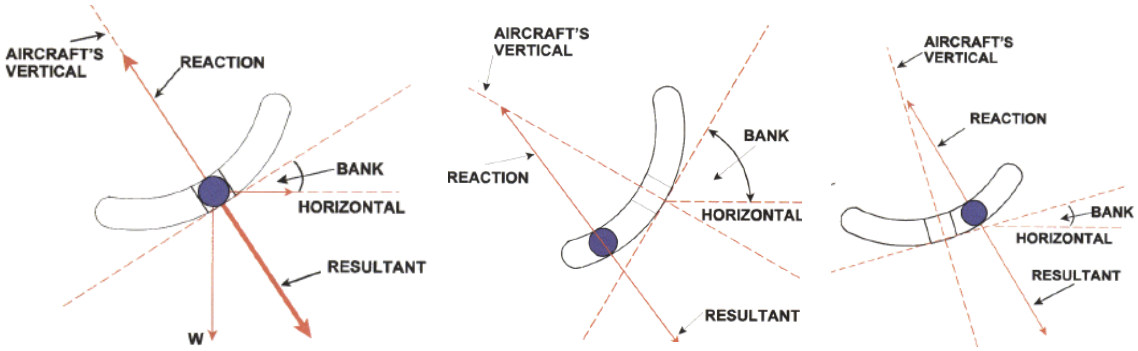
TURN AND BALANCE INDICATOR

BALANCE INDICATOR

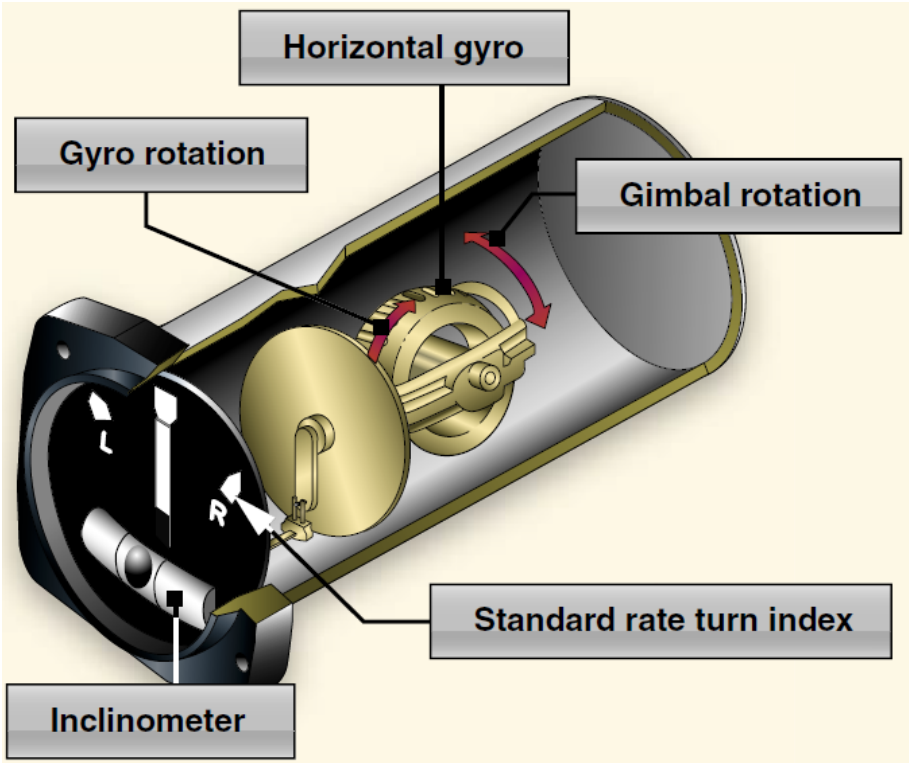
If an aircraft is not in balanced flight, it will be either slipping or skidding. A curved glass tube filled with damping oil and containing a ball is provided to indicate slip or skid. The position of the ball is determined by the resultant of centrifugal reaction and weight.



Balanced | **Slip** (Too much Bank) | **Skid** (Not enough Bank)

TURN INDICATOR

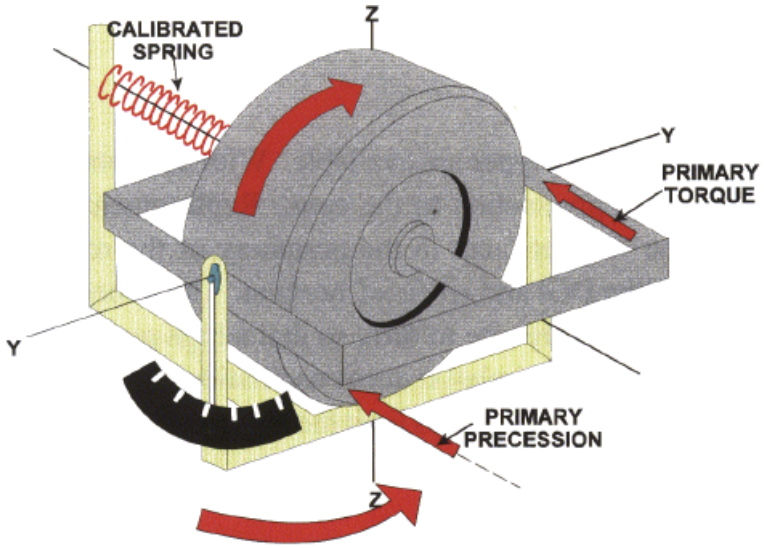
The turn indicator uses a rate gyro which has freedom in the aircraft's rolling and pitching planes but which is denied freedom in the yawing plane. Aircraft movement in the yawing plane causes a force to be applied to the gyro rotor (primary torque). The resulting precession moves the pointer to indicate the rate of turn.



PRINCIPLE OF OPERATION

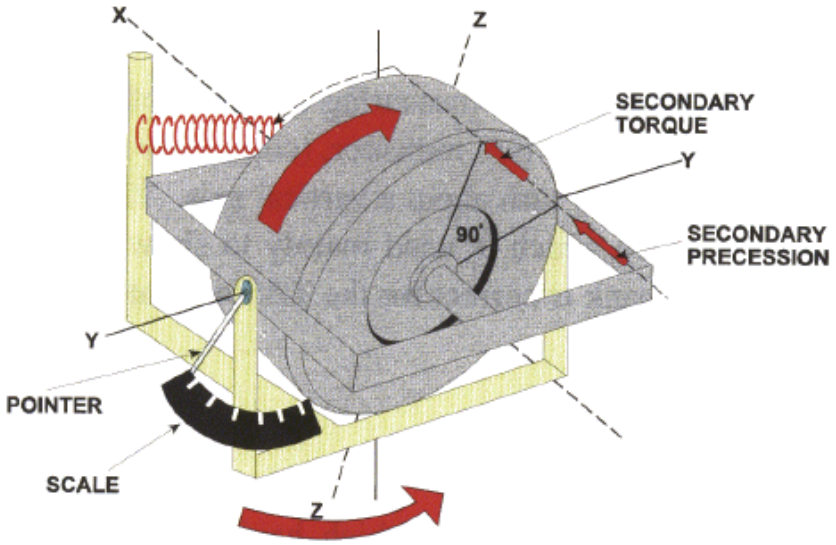
The turn indicator is required to show a steady indication for any given rate of turn but if during the turn a force continues to be applied, the precession will continue and the indicated rate of turn will increase. It is important to understand how the force between the aircraft and gyro rotor is canceled.

It is necessary to the design of the turn indicator that the spin axis of the rotor is transverse and that the rotor spins up and away (as viewed by the pilot).



In the diagram above, the aircraft is yawing to the left. The rotor is denied freedom in the yawing plane and so a force (primary torque) is applied. This force turned through 90° results in primary precession which is tilt of the gimbal to the right.

The tilt of the gimbal causes a force (secondary torque) from the spring to be applied resulting in SECONDARY PRECESSION which is in the direction of yaw of the aircraft.



Under the influence of the primary torque, the gimbal tilts until there is enough spring force (secondary torque) to produce secondary precession at a rate equal to the rate of YAW of the aircraft. At this point, there is no longer a primary torque between aircraft and gyro. There will be no further tilt of the gimbal and so a steady indication of rate of turn is achieved. **Rate of secondary precession equals rate of yaw.**

RATES OF TURN

Rate 1 = 180°/min	or	3° / second
Rate 2 = 360°/min	or	6° / second
Rate 3 = 540°/min	or	9° / second

A rate 1 turn to the left with skid

ELECTRICAL AND SUCTION DRIVEN GYROS

Older turn indicators were powered by vacuum systems, however these indicators could have rotor speed problems. Most modern turn indicators are electrically powered by Direct Current (ie. Battery power). On light aircraft, it is common for the DG and AH to be vacuum powered. The electrically powered turn indicator allows the aircraft to meet the IFR equipment requirements of having a separate and independent power source.

ERRORS OF THE TURN INDICATOR

VARIATION IN ROTOR SPEED

As described earlier, the correct and steady indication of rate of turn occurs when the spring force (F_2) is producing secondary precession (P_2) equal to the rate of aircraft yaw. If rotor speed is allowed to vary, rigidity will vary and so will the force required to produce a given rate of precession. For example if rotor speed falls, less spring force will be required to produce secondary precession equal to the rate of yaw. The gimbal will tilt less and so the instrument will under-read the true rate of turn.

Rule: Under-speed causes Under-read, and Over-speed causes Over-read

VARIATION IN TAS

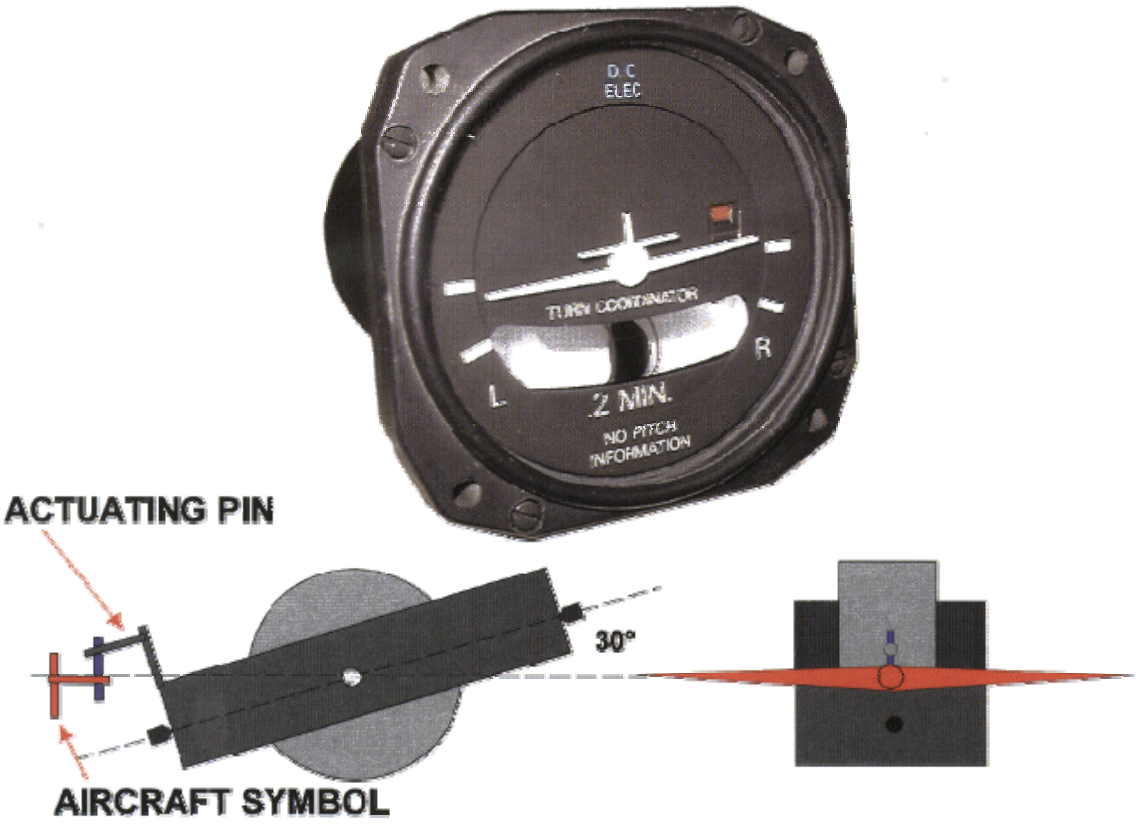
The angle of bank required for a given rate of turn varies with TAS. If the TAS of the aircraft is significantly different from the TAS values assumed for the calibration of the instrument, a small error will result. This occurs because the alignment of the gimbal relative to the horizontal is affected by the angle of bank so moving the sensitive axis of the rate gyro away from the vertical.

LOOPING ERROR

If the aircraft pitches in the plane in which the rotor is spinning, no force will be applied to the gyro rotor. If however the aircraft pitches when the gimbal is tilted (relative to the aircraft), force is applied to the rotor resulting in an indication of an increased rate of turn.

TURN COORDINATOR

The turn coordinator is a version of the turn indicator which is found in light aircraft. The gimbal is tilted upwards by about 36° so altering the direction of the sensitive axis. As a result the turn coordinator is sensitive to roll as well as yaw.



When the aircraft commences a turn, it is roll which is first sensed by the turn coordinator. Once the required bank has been established, the yaw rate increases and so it this that the turn coordinator is reacting to. It gives a more rapid indication of a wing that has dropped than the turn indicator which only responds to yaw but, on the other hand, creates difficulties in determining whether the indication is due primarily to bank or yaw. Turn coordinators are not as well damped as turn indicators because this would remove some of their usefulness as roll indicators. Unfortunately this means that in turbulent conditions they are very difficult to interpret. If the aircraft is skidding, with yaw and roll in opposition to each other, it is possible that the turn coordinator will show wings level.

As the turn coordinator does not behave like a turn indicator, the appearance is changed to a miniature symbolic aircraft with reference marks opposite its wing tips. To avoid confusion with the Artificial Horizon, the Turn Coordinator is placarded "NO PITCH INFORMATION".