TURNING ERRORS of VERTICAL GYRO INSTRUMENTS

By J. D. DURE

Instruments such as the AN Gyro Horizon, the Electrical Gyro Horizon, and the Attitude Gyro which employ a gyro whose spin axis is vertical, are subject to errors which result from the acceleration forces experienced in a turn. The spin axes of these instruments are maintained in the vertical by means of a pendulous erection system which establishes a reference which is in line with the resultant of the forces applied to it. The erection system then causes the gyro to precess until its spin axis is in line with the established reference.

The erection device may consist of a pendulous vane or magnet, or a bubble type of level combined with electric torque motors. As a result of the forces exerted on the gyro and on the pendulum during a turn, several errors develop in the indications of the instruments. The main errors are Erection Turn Error and Pendulosity Turn Error.

In normal flight, gravity is the only force acting on the erection system, and the gyro is maintained in a true vertical reference. In turning flight, centrifugal force, (F_C , Fig 1) also acts on the pendulum in addition to gravity, causing it to establish a reference which makes an angle θ with the vertical. The gyro is then precessed toward this non vertical reference, causing the instrument to give a false indication. This type of error is called "Erection Turn Error".

As a result of the outward swing of the pendulum, the top of the gyro is tilted toward the centre of the turn. The angle of pendulum swing (θ) is proportional to the air speed (V) and the rate of turn (R), and is assumed for any but a shallow turn to be large enough that the pendulum applies full erection rate to the gyro. The precession rate toward the centre of the turn can then be assumed a constant which we will call , P_e . In Fig. 2, this precession is represented by the vectors P_1, P_2, etc., where the length of the vector represents the amount of precession over

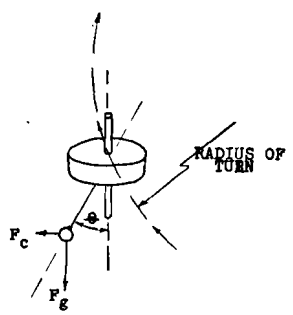

FIG. 1

the adjacent 30 degree portion of the turn, and the direction of the vector represents the average direction of all of this precession. The precession represented by the vectors is resolved into Southerly components and Easterly components marked "S" and "E". Adding the components for 90 degrees of turn shows that at this position, the attitude of the gyro is forward (East) and to the right (South). Should the pilot straighten out and try to fly straight and level by the instrument, he would be in a dive and right bank, which in the example shown amounts to 2½ degrees, for the rate of turn and airspeed assumed. Adding the components of precession from 90 to 180 degrees shows that after 180 degrees of turn, the east and west components of precession have cancelled out, while the south components add up to 5 degrees of forward (south) tilt toward the nose of the plane. If the pilot were to fly by the instrument, he would be in a 5 degree dive for the conditions assumed. Similiarly, after 270 degrees of turn, the attitude of the gyro would be 2½ degrees forward (west) and 2½ degrees to the left (south). After a full 360 degree turn the erection turn error would be completely cancelled out, and the instrument would give a correct indication. A similar analysis can be made for a left hand turn.

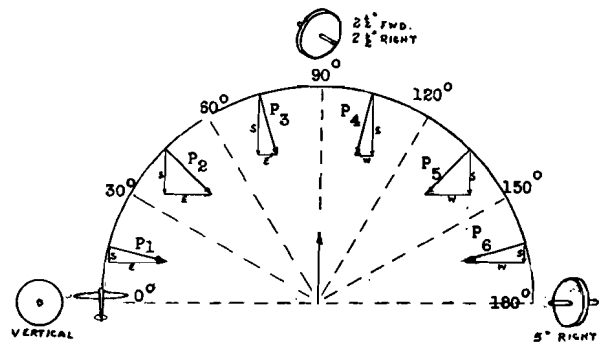

FIG. 2

Erection turn error is corrected for a certain rate of turn by tilting the axis of the gyro forward. In Fig. 2, assume that the erection system is maintaining the axis of the gyro with a 2½ degree forward (north) tilt at the start of the turn. Also assume that the rate of turn is the same as in the examples in the previous paragraph. Analysing the precessions. during the turn, it will be found that after 90 degrees, the 2½ degree north tilt has been gradually brought to zero by the 2½ degree south precession. However, the gyro will still have a 2½ degree forward tilt, because the gyro has also precessed 2½ degrees east, and the plane is now heading east. From 90 to 180 degrees, the east tilt will be brought to zero by the west precession, and the south precession will appear as a 2½ degree forward tilt because the plane is now heading south. Thus the gyro maintains its 2½ degree forward tilt through a full 360 degrees of turn.

In order to show that forward tilt corrects erection turn error for one given rate of turn, consider the effect of tilt alone with no erection. The gyro remains rigid in space, and as the plane turns relative to it, the top of the gyro moves with respect to the