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FLIGHT INSTRUMENTS

CHAPTER 9 – THE DIRECTIONAL GYROSCOPE

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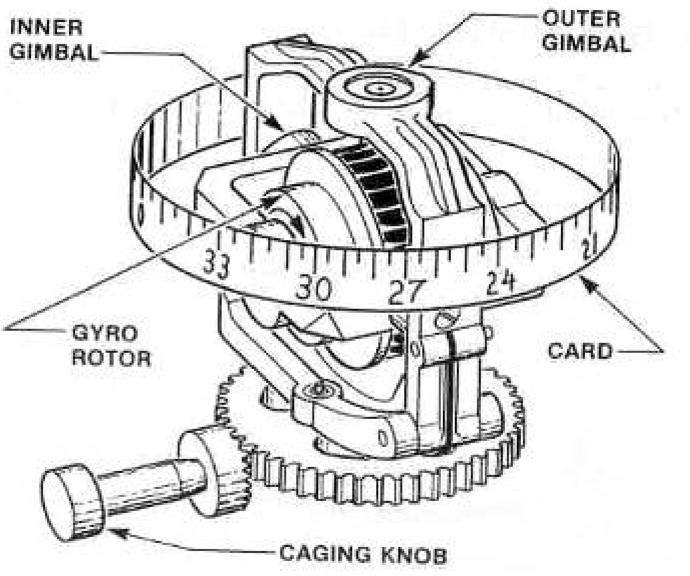
THE DIRECTIONAL GYROSCOPE (DG)

The Directional Gyroscope sometimes referred to as the Directional Indicator or DI, forms the basic heading reference in many light aircraft. The gyroscope provides an excellent, stable (rigid) reference for direction information which is displayed on a rotating card which looks like a compass. The DG, however, is not a compass as it does not seek magnetic north. When the DG is started, the direction information is not valid until the pilot selects a datum (starting direction). This datum is normally magnetic north and so the pilot must align the DG with the compass before take-off for the DG to be useful. The DG cannot seek its datum and it needs to be realigned during flight to counter the effects of real and apparent drift.



CONSTRUCTION

The DG in its basic form illustrated above consists of a vertical card graduated in degrees attached to the vertical outer gimbal of a gyro with a horizontal spin axis. The card is referenced against a lubber line fixed to the aircraft. When the rotor is spinning the rotor, gimbals and vertical card maintain their alignment through the property of the rigidity. When the aircraft alters heading, the movement of the lubber line relative to the card provides the indication of the change of heading.

The Directional Gyroscope has its rotor axis tied to the horizontal by a simple levelling system. Normal operations require the DG to be reset about every 15 minutes and this resetting process is completed while the aircraft is straight and level. Resetting levels the rotor axis and aligns the axis to magnetic north. Most small aircraft DGs are vacuum driven, the airflow is directed at the rotor through twin jets or a knife edge levelling device. If the rotor axis is not level, a small force is generated causing a precession which drives the rotor to level the axis.

When spinning and aligned, the DG provides a good stable reference with magnetic north as its datum. Unfortunately, the gyro will drift from this datum and will need to be realigned periodically.

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DIRECTIONAL GYROSCOPE ERRORS

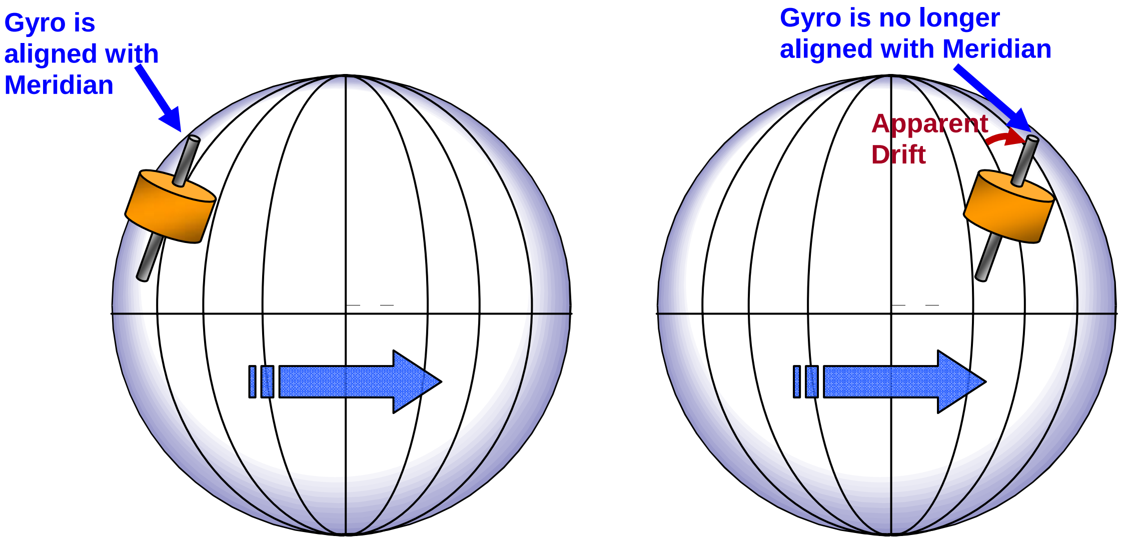
REAL DRIFT

Real drift is caused by gimbal bearing friction and imbalance (mechanical imperfections). Careful manufacturing minimises the drift, however it cannot be eliminated and so the DG must be reset every 15 minutes to reduce real drift and other errors. Real drift rates of basic air driven instruments can exceed 15° per hour but modern electrical gyro compasses operated in the DG mode have drift rates of 1° per hour or less.

Another cause of real drift is **Gimballing Error**. The purpose of the gimbals is to allow the aircraft to pitch, roll and yaw around the gyro rotor without applying forces that would disturb the gyro. Provided that the aircraft's heading is aligned with the gimbals (or is at 90^{O} to the gimbals), pitch and roll movements can take place. However the geometry of the simple 3-axis gimbal system is such that on the other headings combined pitch and roll movements apply forces that result in a small amount of real drift.

APPARENT DRIFT DUE TO EARTH ROTATION

Assume a gyroscope with a rotor axis horizontal is initially aligned with true north. The gyroscope accepts the aligned position as a point in space (not referenced to the earth). As the earth rotates the DG 'looks like' it is drifting. The gyro is not at fault here as this apparent drift is due only to the rotation of the earth. Consider an aircraft parked facing 090°T.



NORTHERN HEMISPHERE: Gyro Readings appear to DECREASE
SOUTHERN HEMISPHERE: Gyro Readings appear to INCREASE

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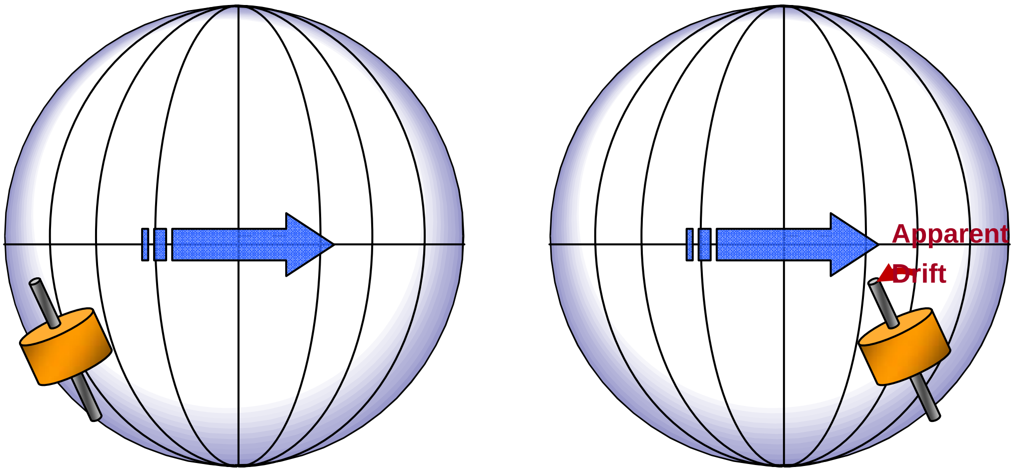


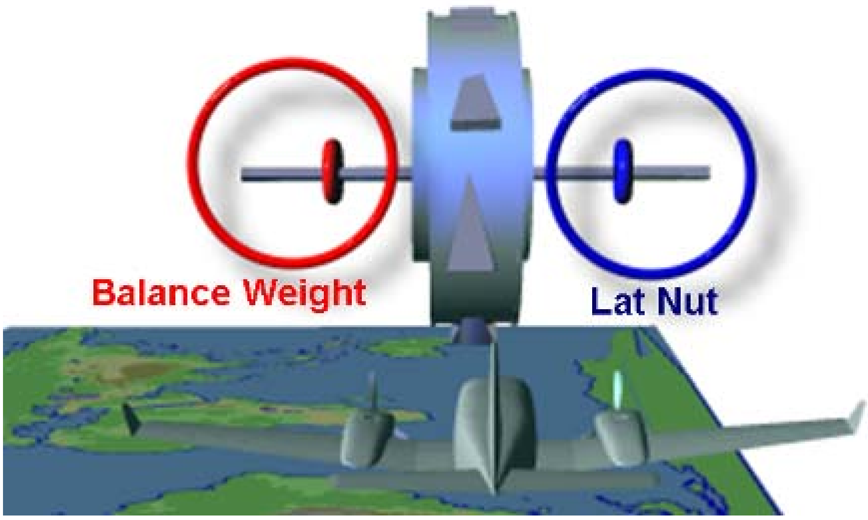
A study of this drift indicates that at the equator no error (drift) occurs while at the poles the error is 15°/hr. This is due to the earth's rate of rotation, 360° in approximately 24 hrs. As the equator is Latitude 0° and the poles are latitude 90°, this drift is noted to be proportional to the sine of the latitude.

∴ **Earth Rate = 15° Sin Lat (per hour).**

Note : *The actual error is 15.04° / hour which is a function of earth rotation and the earth's orbit around the sun.*

COMPENSATION FOR APPARENT DRIFT DUE TO EARTH ROTATION

Apparent drift due to Earth Rotation is predictable (15° Sin Lat) and can be accurately calculated. A compensation device (the LATITUDE NUT) is fitted to the inner gimbal of the DG. This device is set for latitude and provides a torque proportional to the earth rate error at that latitude. This torque is applied to the inner gimbal causing precession of the rotor in the opposite direction to the expected apparent drift.



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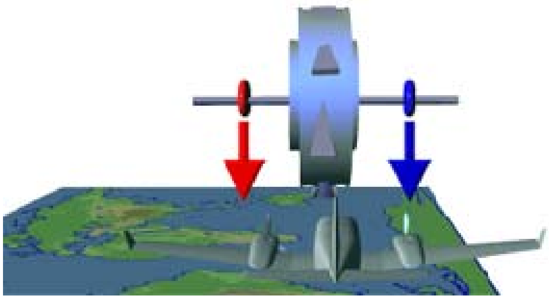
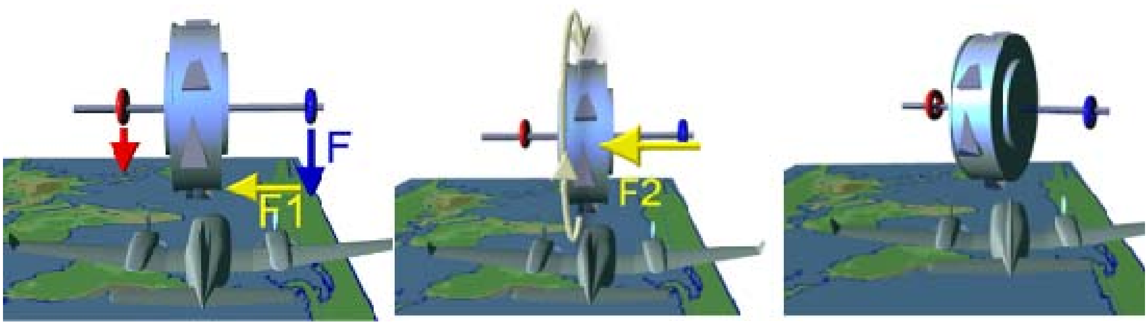
Below we can see that by moving the Latitude Nut towards or away from the rotor, an unbalanced force is set up which will cause the gyro to precess. The rate of precession will be equal and opposite to the rate of earth rotation at the compensated latitude.



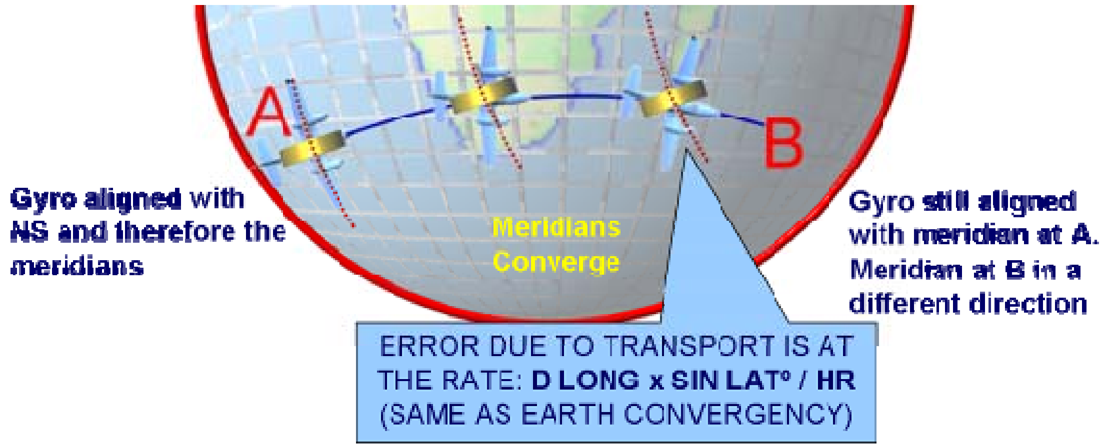


Provided that there is no real drift, a compensated stationary DG will remain aligned with the local meridian at the latitude for which compensation was made. Flight to latitudes North or South of the latitude of compensation will result in drift because the error due to earth rotation will change. Flights to the East or West will be across the Earth's meridians and because of convergency, another error called **Transport** is introduced.

APPARENT DRIFT DUE TO TRANSPORT

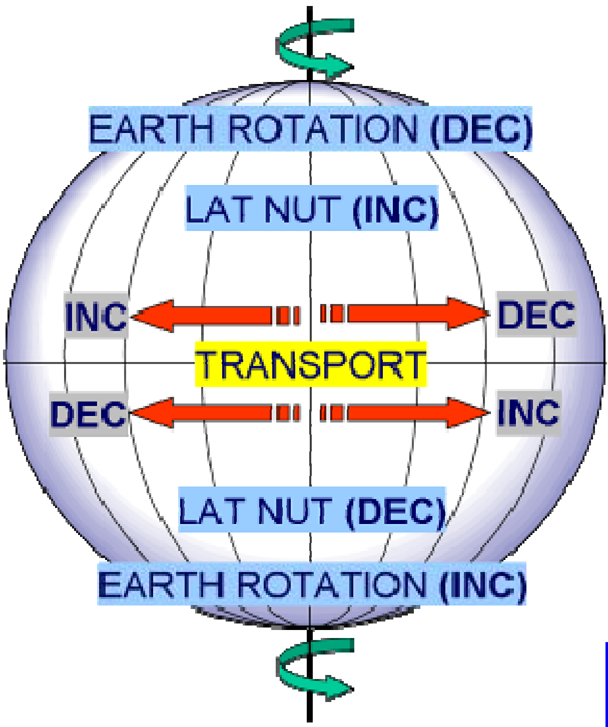
The compensation for apparent drift is based on the gyroscope being stationary and the earth rotating at the known rate for that latitude. When the aircraft flies either east or west, it moves with or against the earth rotation. The gyro is not compensated for this new rate and an error occurs.

This error due to the movement of the DG over the earth is known as 'transport error'. This error is not normally compensated in light aircraft but is minimised by re-setting the DG to the compass heading every 15 minutes.



THE EFFECTS OF APPARENT DRIFT.

By means of a simple diagram it can be seen that earth rotation will cause gyro readings (for constant true heading) to **DECREASE in Northern Hemisphere**. Transport in the direction of earth rotation (to the East) has a similar effect. Flight to the West has an opposite effect. The Latitude Nut is designed to increase gyro readings in the Northern Hemisphere. In the Southern Hemisphere all these effects are reversed.



TOTAL DRIFT = RANDOM DRIFT
± LAT NUT
± EARTH RATE
± TRANSPORT

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FORMULAE FOR APPARENT DRIFT

Earth Rotation................................. 15^O sin Lat. per hour
Latitude Nut.................................... 15^O Sin Lat. of compensation per hour
Transport.. Ch. $long^O$ Sin Lat. per hour

or $\frac{GS\ (E - W)}{60}$ Tan. $Lat.^O$ per Hour

CALCULATION OF TOTAL DG DRIFT.

Example question: A DG which is free of random real drift error has been compensated for Latitude 30^ON. The DG is carried in an aircraft which tracks to the West at GS 360 kt at latitude 45^ON. What is the total drift rate of the DG?

Assume Sin 30^O = .5 Sin 45^O = .7 Tan 45^O = 1

Working: A general formula for total drift is as follows. According to the question, some factors such as Random drift may not apply and so can be crossed out. Work the problem using columns.

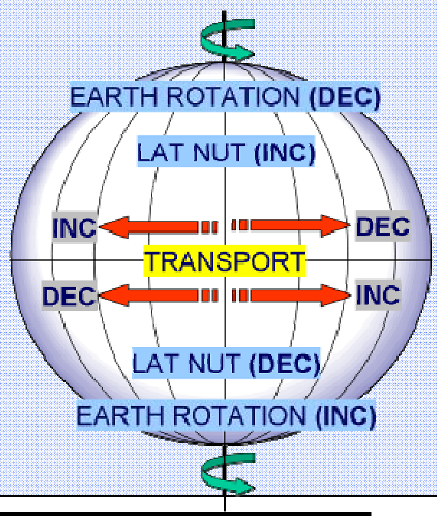
TOTAL DRIFT = RANDOM DRIFT
± LAT NUT
± EARTH RATE
± TRANSPORT

Total Drift	**=**	**Random**	**± Lat Nut**	**± Earth Rate**	**± Transport**
	=	nil	15°Sin Lat of compensation	15°Sin Lat of AC	$\frac{GS}{60}$ Tan Lat
	=	nil	+ 15 Sin 30	-15 Sin 45	+ $\frac{360}{60}$ Tan 45
	=	nil	+ 7.5°/hr	-10.5°/hr	+6°
Total Drift	**=**	**+3°/hr**	An increase in gyro reading implies an anti-clockwise rotation of the gyroscope, irrespective of hemisphere.		

Note

- LAT NUT effect is INCREASE (+) because it compensates for earth rotation at 30°N.
- EARTH RATE effect is DECREASE (-) because the aircraft is in the Northern Hemisphere.

TRANSPORT effect is INCREASE (+) as the aircraft is tracking to the West in



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