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DOCUMENT TITLE

AIRCRAFT GENERAL KNOWLEDGE

CHAPTER 14 – DIRECT READING MAGNETIC COMPASS

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THE DIRECT INDICATING COMPASS

14.1 Construction and Components

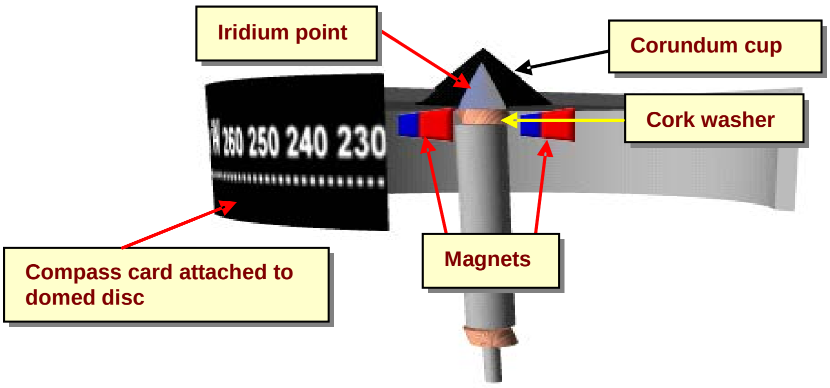
The direct reading magnetic compass (DRMC) is mounted inside an instrument case which gets bolted to the aircraft's instrument panel.

The compass card is attached to a domed disc or float, to which a number of magnets are attached. The disc/float contains a corundum cup. (Corundum is a hard mineral of the sapphire and ruby family)

This is balanced on top of an Iridium pivot which is fixed to a cork washer. (Iridium is a hard metal of the platinum family)

Two or four small magnets are mounted close to the pivot on the underside of the domed disc/float. The instrument case is filled with methyl alcohol.

The example shown is of generic nature. Different makes of DRMC may have the components in different positions but the basic components are the same for all.



14.1.1 Deviation

In addition to magnetic north the compass is also sensitive to the magnetic fields of various parts of the aircraft such as electrically driven components and instruments and all the metallic engine components. These “secondary” magnetic fields may cause the compass to deviate from pointing at magnetic north.

To compensate for these deviations a “COMPASS SWING” may be carried out where the aircraft’s indicated heading is checked against a known accurate external hand held compass. Adjustments are made to the compass on a number of different headings, with the engines, avionics and other instruments all running, to reduce this DEVIATION.

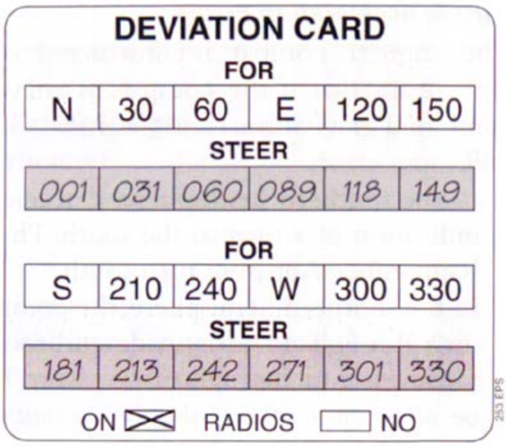
14.1.2 Occasions for Compass Swings

As the residual aircraft magnetism can change, it is common for aircraft to be swung at least once a year. Some other occasions when a compass swing is considered necessary are as follows:

- Replacement of the compass or compass system component
- When the accuracy of compass is in doubt
- As required by maintenance schedules
- Aircraft modification, engine change, electrical re-wiring, significant avionics changes
- Lightning strike
- A large change of magnetic latitude
- After aircraft has been in long term storage
- When carrying ferro magnetic loads.

When this is complete a COMPASS DEVIATION CARD is compiled and fitted close to the Compass which gives corrections to steer for known headings.

For example, if a pilot wishes the aircraft to track on a true magnetic heading of **210°**, he would steer on a heading of **213°** as indicated by the compass.



DEVIATION CARD

FOR	N	30	60	E	120	150
STEER	001	031	060	089	118	149
FOR	S	210	240	W	300	330
STEER	181	213	242	271	301	330

ON ☒ RADIOS ☐ NO

14.1.3 Compass Serviceability Checks

It is important that the direct reading magnetic compass is assessed for serviceability before departure to ensure accurate indications in flight. Typically the compass would be checked for the following:

- Security of attachment
- Glass clean
- No discolouration of the fluid
- No bubbles visible
- Indications within 5° of a known heading (runway)
- Presence of the deviation card.

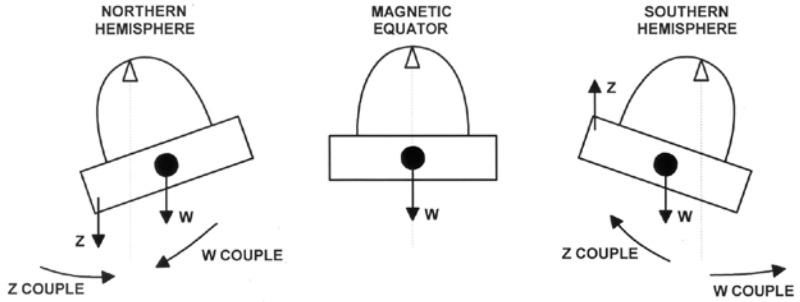
14.2 Compass Requirements

The direct reading compass comprises a pivoted magnet able to align itself and remain aligned with the horizontal component of the Earth's field. For the compass to succeed, certain requirements must be satisfied. The most important of these are that the magnet system must be:

- Horizontal
- Sensitive
- Aperiodic (the ability of the magnet assembly to settle quickly, pointing towards the magnetic north pole, following displacement during manoeuvres or turbulence).

14.2.1 Horizontality

In order to measure direction in the horizontal, the magnets (normally two or four) must lie as nearly as possible in the horizontal plane during normal straight and level flight. A freely suspended magnet assembly would align itself with the earth's total field so that the magnets would only be horizontal at the magnetic equator. To achieve horizontally, therefore, the magnet assembly is 'pendulously suspended', the centre of gravity of this assembly being lower than its supporting pivot.



EFFECT OF PENDULOUS SUSPENSION

In this way, the tilting effect caused by the vertical component of the Earth's field is opposed by the weight of the magnet assembly. This equilibrium being achieved at the cost of only a slight residual tilt of the magnet's south-seeking end points down by about 2° at mid latitudes in the southern hemisphere, north-seeking end points down in the Southern hemisphere.

14.2.2 Sensitivity

The compass sensing system responds to the horizontal component of the Earth's field in all areas except near the magnetic poles where the horizontal component is inadequate. The compass sensitivity therefore depends on the strength of the external field and on the magnetic moment of the magnet. The magnetic moment also depends on the magnet's length and the pole strength. The pole strength is increased by using two or four or six short magnets made of an alloy which will accept and retain the high degree of magnetism required. Friction is reduced by using a jewelled pivot and immersing the assembly in a liquid, a clear light oil.

14.2.3 Aperiodicity

The magnetic assembly is required to be aperiodic (or 'dead-beat') which means that it should settle down quickly again on a steady north indication after being displaced from the meridian by turbulence or manoeuvres. Any tendency to oscillate must be quickly 'damped out'. The desired aperiodicity is achieved as follows:

- Several short magnets are used instead of one longer one. This keeps the mass of the assembly near the centre, so reducing the moment of inertia and consequently making any oscillations easier to damp out. The sensing assembly is constructed of a light alloy—this also reduces the effects of inertia.
- The whole assembly is immersed in a liquid which has a natural damping effect. Additional damping wires are fitted to the assembly of some direct indicating compasses to interact with the liquid.

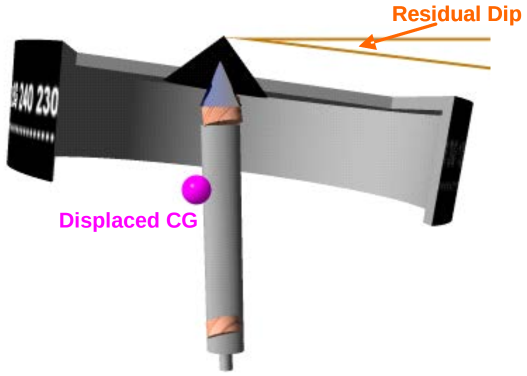
The use of this liquid causes other problems. Errors occur in sustained turns as a result of 'liquid swirl'. During a turn, the liquid in contact with the inside of the bowl tends to be dragged round with the bowl, so producing in the liquid small eddies which drift inwards from the circumference and deflect the magnet assembly in the direction of turn. This effect is due to viscosity, so the liquid chosen should have a low viscosity to minimise the liquid swirl error.

The main properties required of a compass liquid are listed below:

- Low coefficient of expansion
- Low viscosity
- Transparency
- Low freezing point
- High boiling point
- Non-corrosiveness
- Good lubrication.

14.3 Errors encountered with the DRMC

Even though the pendulous mountings of the magnets in the DRMC compensate for dip, there is still a measure of residual dip present. This residual dip causes the centre of gravity (CG) to be displaced from the DRMC pivot. In both hemispheres the CG is displaced toward the equator. It is this residual dip which results in:

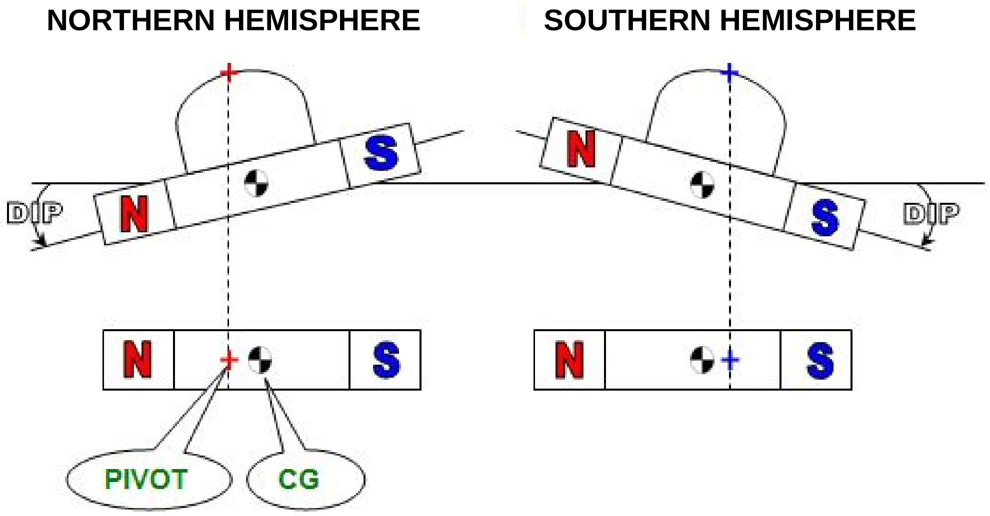


- Acceleration and deceleration errors
- Turning errors.

14.3.1 Turning and Acceleration Errors

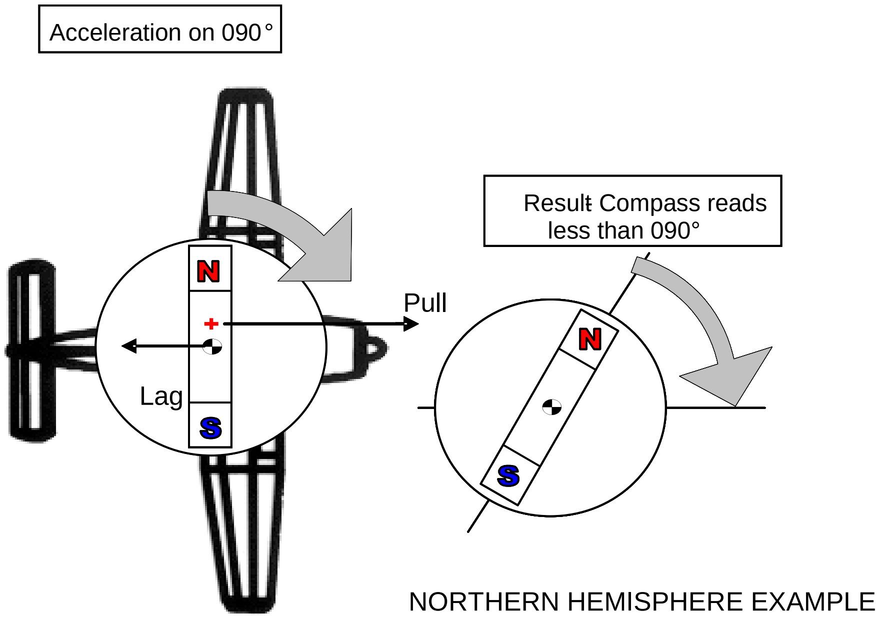
The direct reading compass has been constructed with a pendulous suspension system (high pivot point) to ensure horizontality where possible. However, as the latitude increases, the 'dip' has an increasing effect and this causes a misalignment between the pivot point and the centre of gravity of the compass.

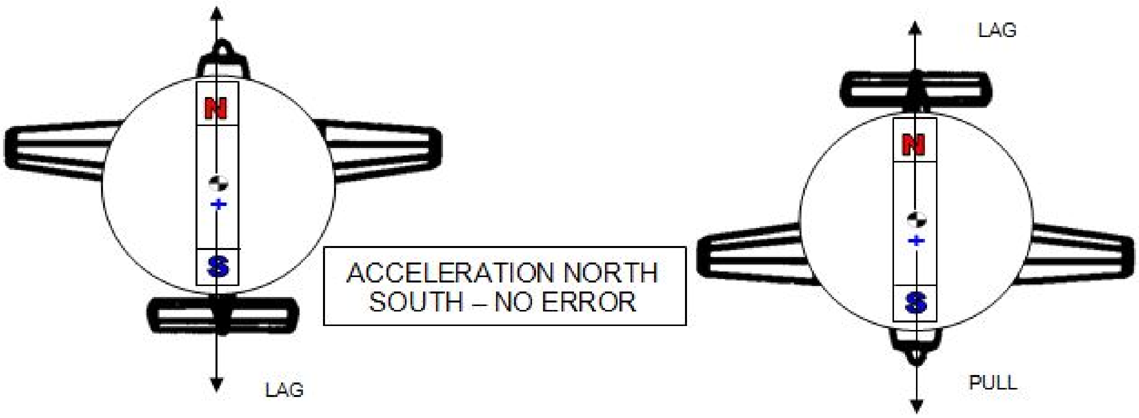
When the compass is viewed from above the pivot point and centre of gravity are displaced. Note that irrespective of hemisphere, the centre of gravity is always displaced to the equatorial side of the pivot.



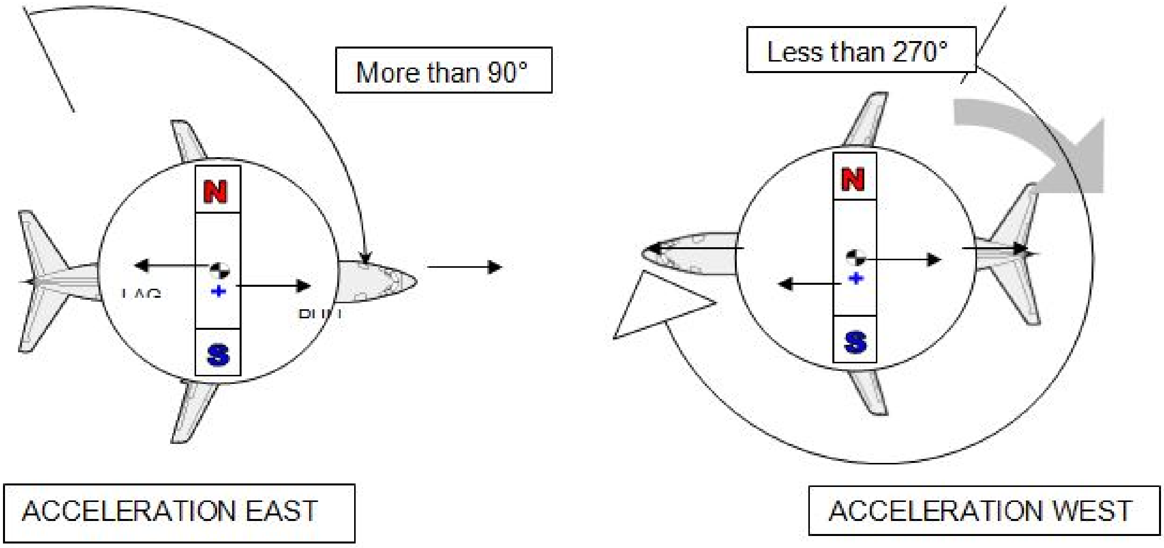
14.3.2 Acceleration Errors

When accelerating **EAST** or **WEST**, the displacement of the pivot and the CG causes there to be a couple between the pull of the acceleration acting through the pivot and the lag (inertia) acting through the CG.





SOUTHERN HEMISPHERE EXAMPLE



RESULT - APPARENT TURN TO SOUTH IN SOUTHERN HEMISPHERE
APPARENT TURN TO NORTH IN NORTHERN HEMISPHERE

NOTE:

1. There is no acceleration error when heading NORTH or SOUTH as the pivot and the CG are in line.
2. The size of the acceleration error depends on:
    - Aircraft heading
    - Magnitude of the acceleration
    - Magnetic latitude.
3. The errors are maximum near the magnetic poles, decreasing to zero at the magnetic equator.
4. The direction of the errors is opposite in northern and southern hemisphere.
5. Deceleration has the opposite effect to acceleration. For example, deceleration in the northern hemisphere causes an apparent turn to south.

Below are 2 acronyms that may be of use in remembering these errors:

IN THE SOUTHERN HEMISPHERE

(The COMPASS will-)

S Swing S on

A Acceleration

N North on

D Deceleration

IN THE NORTHERN HEMISPHERE

(The COMPASS will-)

A On Acceleration, Swing

N North

D and on Deceleration

S Swing South

14.3.3 Summary of Acceleration and Deceleration Errors

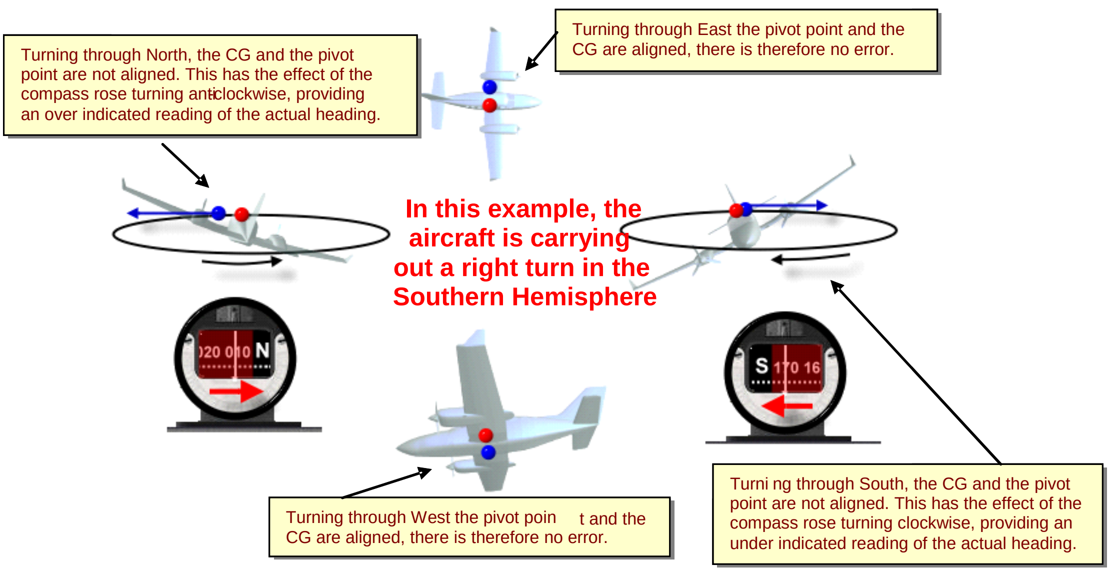
Hemisphere	Heading	Acceleration	Deceleration
Northern	North	No error – the CG and the pivot point are aligned	
	South		
	East	Apparent turn to the north	Apparent turn to the south
	West	Apparent turn to the north	Apparent turn to the south
Southern	North	No error – the CG and the pivot point are aligned	
	South		
	East	Apparent turn to the south	Apparent turn to the north
	West	Apparent turn to the south	Apparent turn to the north

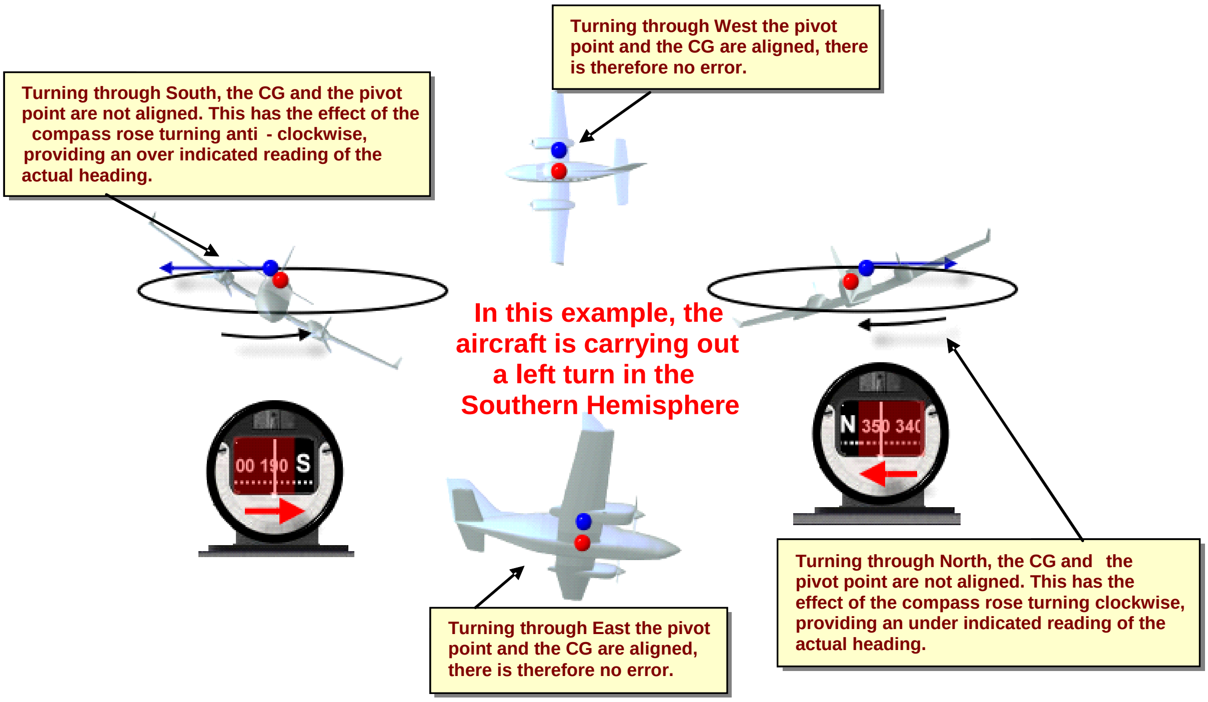
14.3.4 Turning Errors

When an aircraft is engaged in a turn it experiences altered forces on the aircraft. These altered forces are also a form of acceleration due to changes in direction. Turning errors are comprised of two components, which each add to the error. These components are:

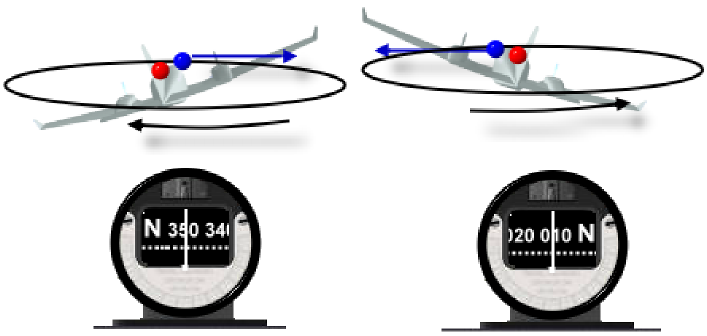
- A mechanical component
- A magnetic component
- A turning aircraft will experience centrifugal force (CF) acting on it. This CF acts on both the pivot point of the DRMC, and on the centre of gravity of the DRMC. Because the pivot point is attached to the aircraft and the CG is not, the CF will affect them differently. In the case of the turning the aircraft the CF has the effect of "pulling" the CG toward the outside of the turn. It is this action that causes errors in DRMC.

14.3.4.1 Mechanical Component (CG error)





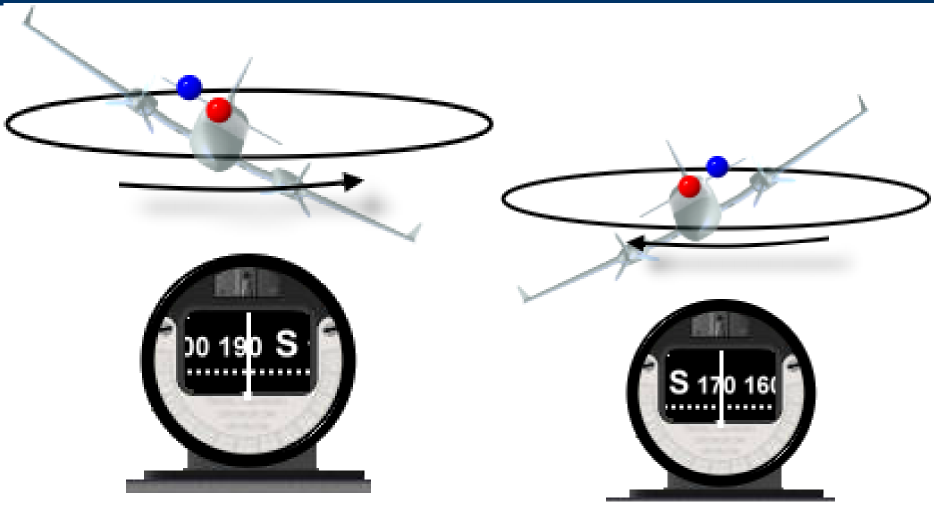
14.3.4.2 Leading and Lagging Turns



When an aircraft is in straight and level flight on a northerly heading, and commences a turn in the southern hemisphere, the compass reading will indicate as follows:

<u>Left Turn</u> : the CG as affected by the CF lags behind (due to inertia). This lag causes the compass card to rotate clockwise, indicating a turn in the correct direction, but at a much higher rate than the aircraft is actually turning. In this case the compass is said to be leading the turn (ahead of the turn).

<u>Right Turn</u>: the CG as affected by the CF lags behind (due to inertia). This lag causes the compass card to rotate anti clockwise, indicating a turn in the correct direction, but at a much higher rate than the aircraft is actually turning. In this case the compass is said to be leading the turn (ahead of the turn).

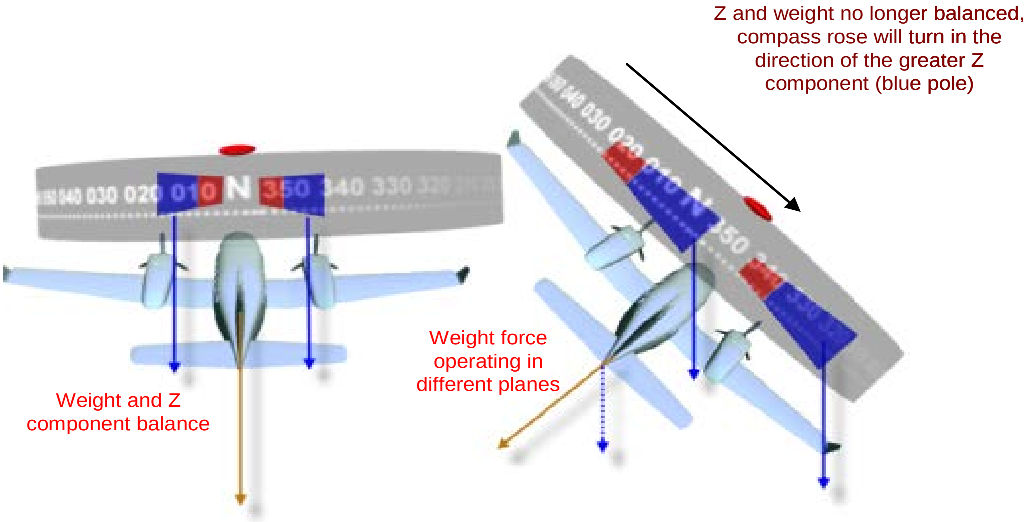


When an aircraft is in straight and level flight on a southerly heading, and commences a turn in the Southern hemisphere, the compass reading will indicate as follows:

Left Turn: the CG as affected by the CF lags behind (due to inertia). This lag causes the compass card to rotate anti clockwise, indicating a turn in the opposite direction. In this case the compass is said to lag.

Right Turn: the CG as affected by the CF lags behind (due to inertia). This lag causes the compass card to rotate clockwise, indicating a turn in the opposite direction. In this case the compass is said to lag.

14.3.4.3 Magnetic Component



When an aircraft (heading north) is straight and level, the Z (vertical) component of the Earth's total field and the weight acting through the CG balance each other.

When the aircraft turns however, weight is no longer acting only in the vertical plane, but is made up of separate components. Z however continues to act in the true vertical plane, and as a result is greater than the true vertical component of weight. This imbalance creates a turning motion in the magnet toward the greater Z component.

14.3.4.4 Turning Error - Summary

Hemisphere	Heading	Left Turn	Right Turn
Northern	North	Undershoot	Undershoot
	South	Overshoot	Overshoot
	East	No error	
	West		
Southern	North	Overshoot	Overshoot
	South	Undershoot	Undershoot
	East	No error	
	West		

The combination of forces that act on a compass in a turn are such that the compass reading **RUNS AHEAD** of the aircraft's true heading when turning onto North in the Southern hemisphere. It **LAGS BEHIND** the aircraft's true heading when turning onto South

The compass is **NIPPY ON NORTH – SLUGGISH ON SOUTH**

The pilot should **OVERSHOOT NORTH**
UNDERSHOOT SOUTH

Turning errors are most apparent when turning to or from a heading of **North** or **South.**

Pilot's action is to **O**vershoot

When turning **Thru** **N**orth

And **U**ndershoot

when turning **Thru** **S**outh