

COMPASSES

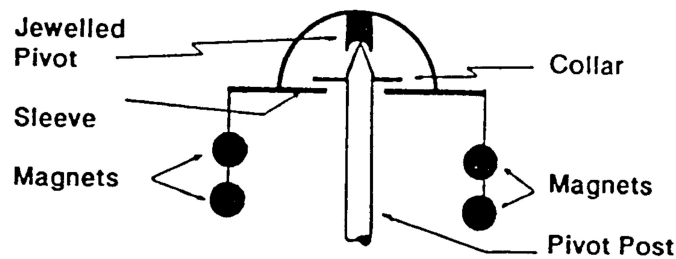
THE DIRECT READING MAGNETIC COMPASS

An aircraft compass must satisfy 3 basic requirements:

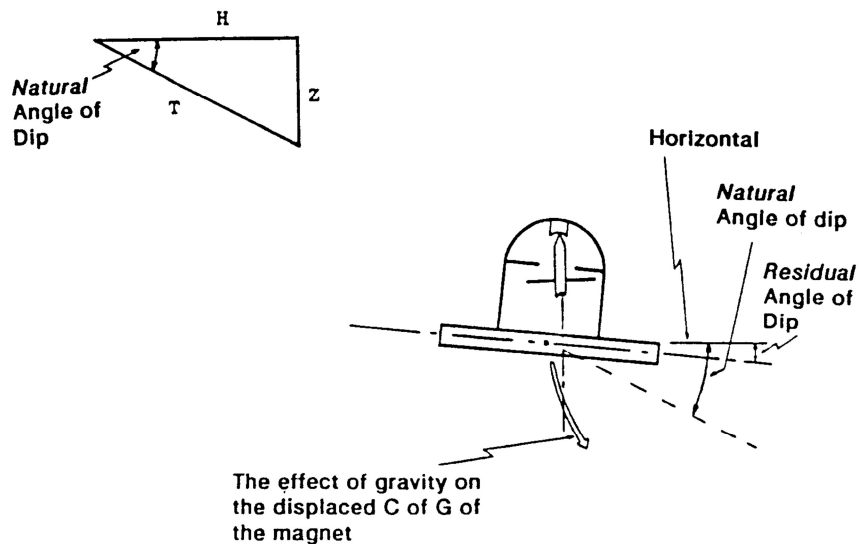
- Must lie horizontal.
- Must be sensitive.
- Must be Aperiodic.

Must Lie Horizontal

The directional force of the Earth's Total Field is H. Therefore, the needle must lie horizontal for maximum efficiency.



In an actual case, the magnet still dips slightly towards the nearer pole. This is called residual Dip.



Residual Dip = $\pm 3^\circ$ at mid Latitudes.
Max Residual Dip = 30° .

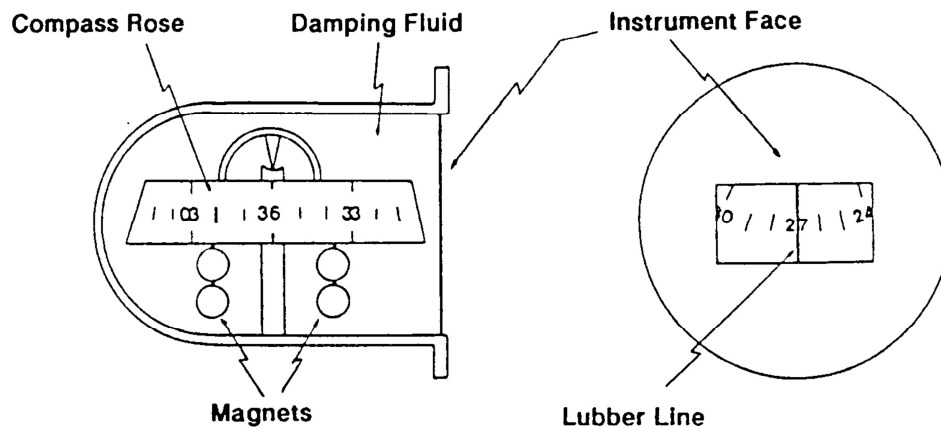
Sensitivity

This is achieved by:

Using more than one magnet.

Using an iridium pivot and sapphire cup to reduce pivot friction.

Immersing the compass in a suitable liquid (silicon) to reduce friction and increase buoyancy.



Aperiodicity

An aperiodic compass is one which takes up its direction immediately without oscillation. This is achieved by:

Immersing the compass in a suitable liquid (Damping effect).

Damping Wires.

Magnets are made light as possible, and as short as possible to reduce their moment of inertia.

OCCASIONS WHEN A COMPASS SHOULD BE SWUNG

Upon installation.

Every 12 months.

Newly registered a/c

After lightning strike.

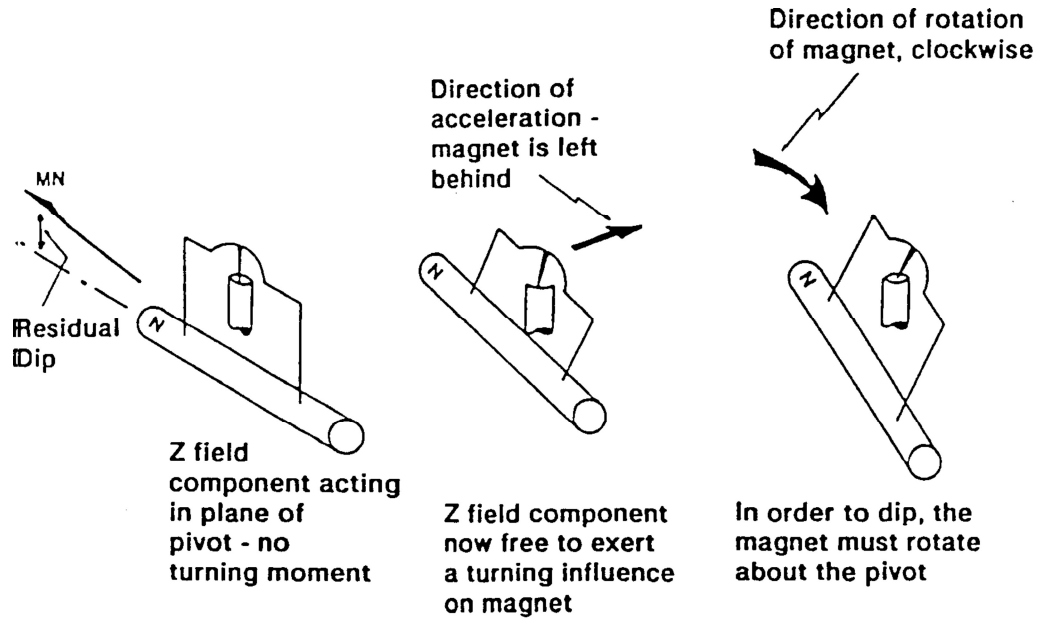
After engine change.

When magnetic material is carried in a/c.

ACCELERATION AND DECELERATION ERRORS

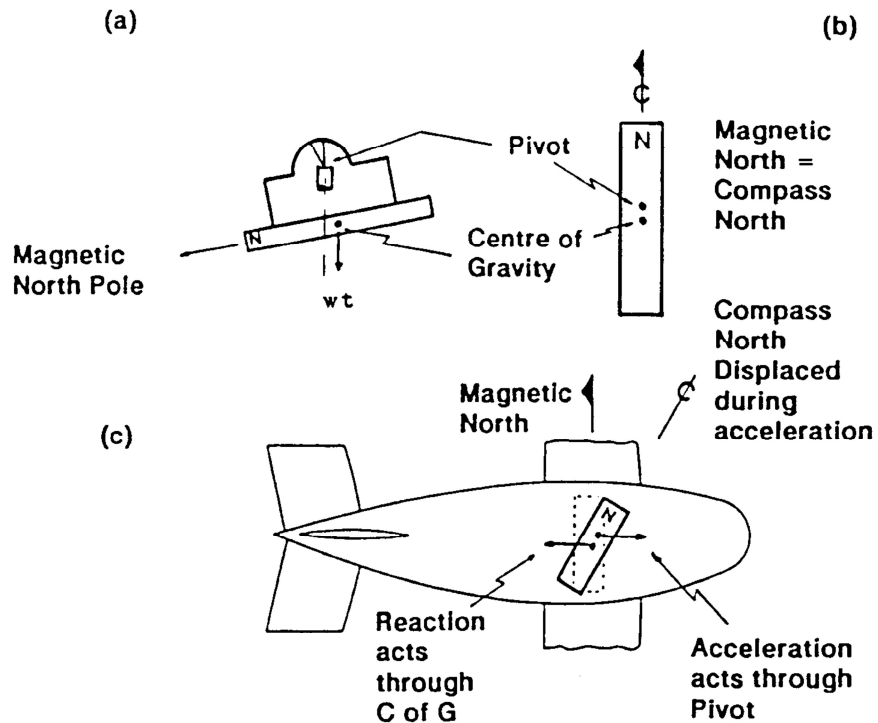
REMEMBER:

The Z force and C of G are on opposite sides of the pivot point. The Z force act on the side of the nearer pole. The C of G is on the side of the equator. An acceleration is a force. The equal and opposite force is inertia. Inertia acts on the C of G.



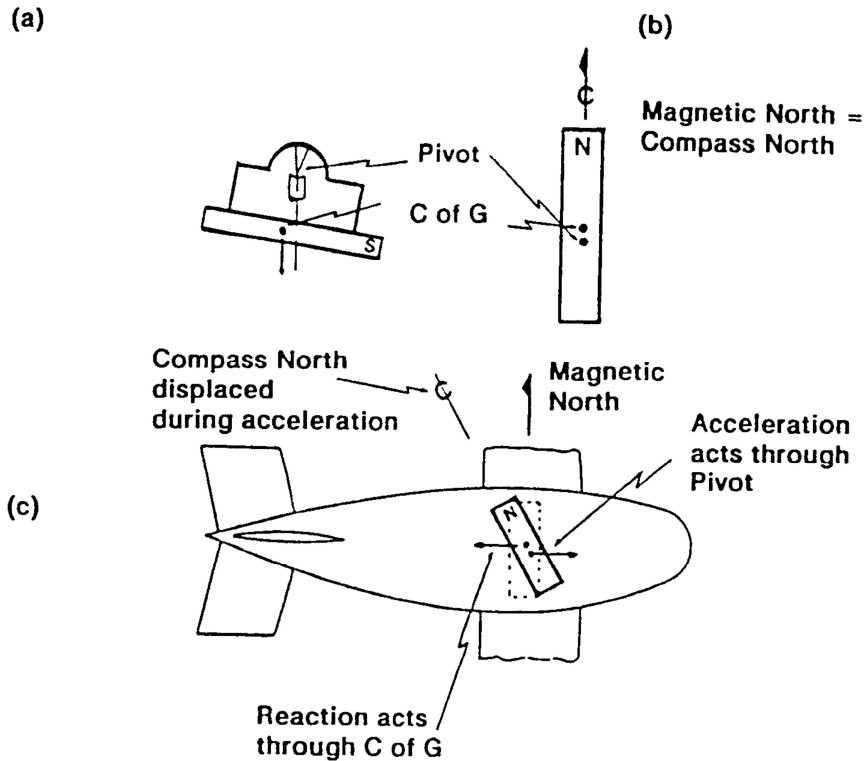
This causes an apparent turn when the aircraft accelerates or decelerates.

Northern Hemisphere



Equator - There will be no error because - No Z.

Southern Hemisphere



Acceleration on E or W causes an apparent turn to the south.

ASDN or SAND

Northern Hemisphere - Errors Reversed

TURNING ERRORS

Turning errors are caused by 2 factors (they are additive).

Mechanical Error

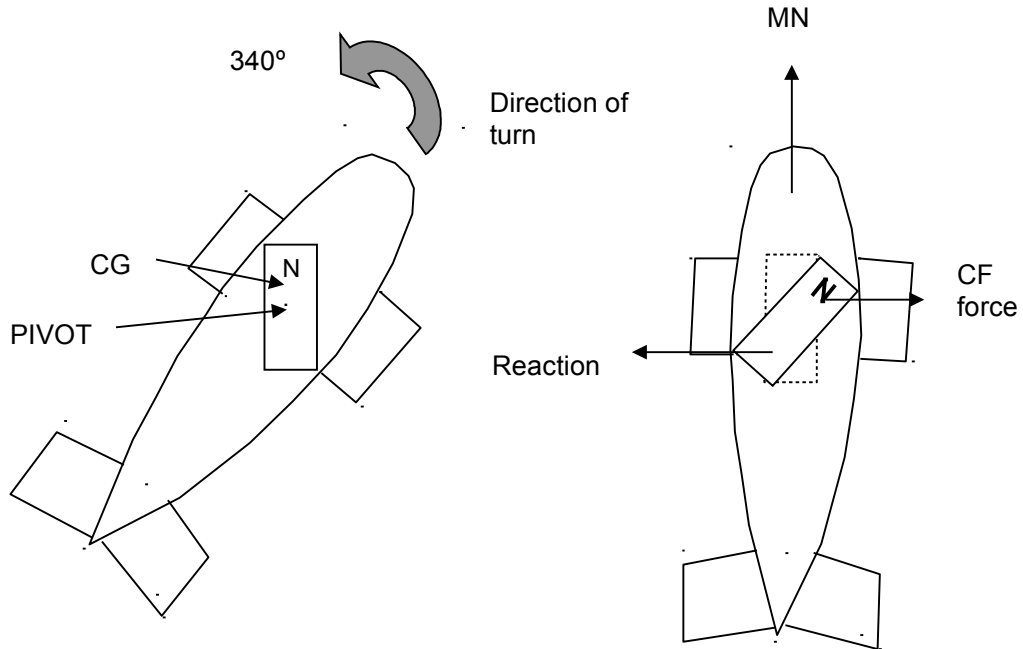
The C of G is acted on by Centrifugal Force (C.F.) in a turn.
 The error is MAX on N/S.
 The Error is ZERO ON E/W.

Magnetic Error

During a turn, Weight will act in the aircraft's vertical, but the Z force of the magnet, will continue to act in the true vertical. The two forces acting in different planes, cause a couple that will have the same effect as the mechanical error.

- i.e. They are additive.
- The Error is MAX on N/S.
- The Error is ZERO on E/W.

Southern Hemisphere

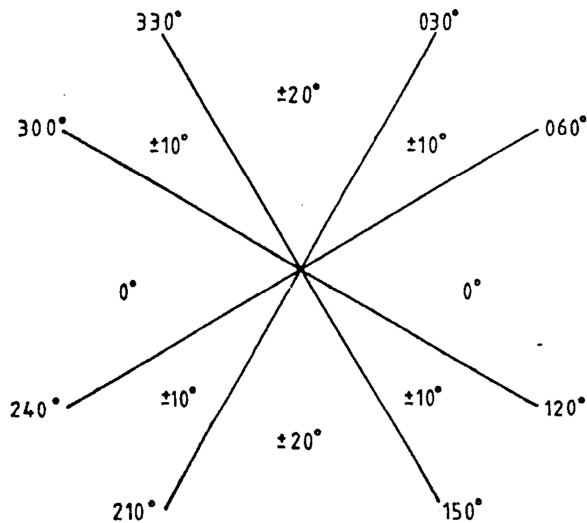


When making a turn through north the compass gives an indication of a turn in the correct direction but at a much faster rate. The compass leads the aircraft.

To Rectify Combined Mechanical and Magnetic Error:

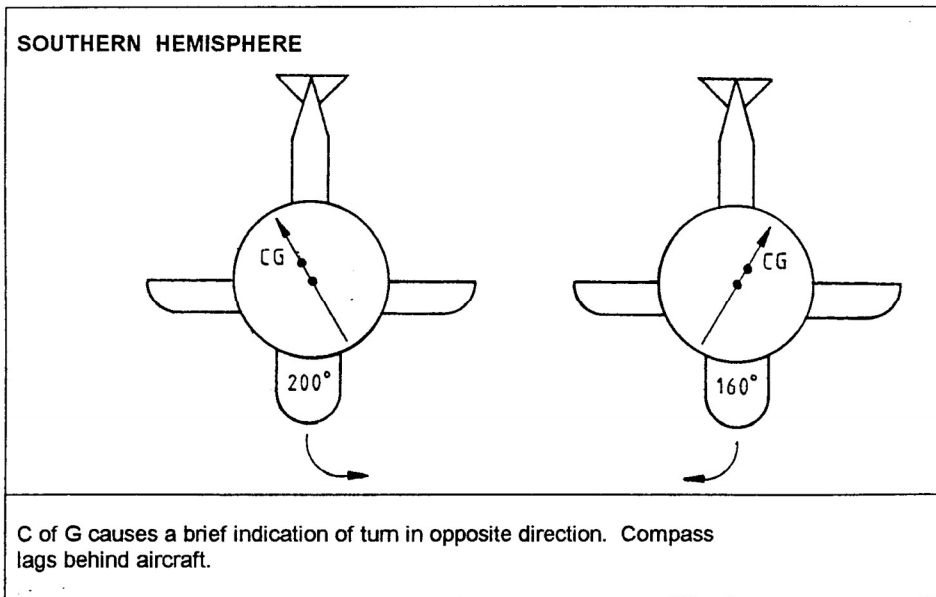
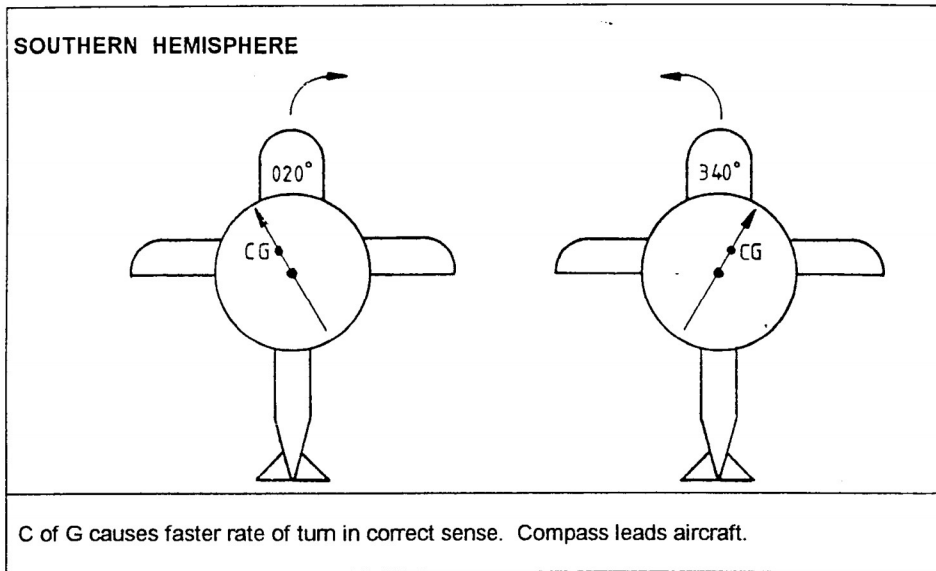
COMMAND RULE **ONUS** – Pilot must Overshoot on North and Undershoot on South.
(The ONUS is on the pilot)

SOUTHERN HEMISPHERE



TURNING	COMPASS	PILOT ACTION
Left turn from 000 to 180	LEADS	- UNDERSHOOT Roll out on 200.
Right turn from 000 to 180	LEADS	- UNDERSHOOT Roll out on 160.
Left turn from 180 to 000	LAGS	- OVERSHOOT Roll out on 340.
Right turn from 180 to 000	LAGS	- OVERSHOOT Roll out on 020.

SUMMARY OF TURNING ERROR



Error is reversed in Northern Hemisphere.

SWIRL ERROR

In turns, friction between the liquid and the bowl sets a swirl in the same direction as the turn. When The compass needle is turning in the same direction as the aircraft the swirl will add to the turning error. When the compass needle is turning in the opposite direction to the aircraft the swirl will reduce the turning error.

In Southern Hemisphere turning through North Swirl reduces turning error
 turning through South swirl increases turning error

THE SPERRY GYROSCOPIC COMPASS SYSTEM

This system overcomes many of the problems associated with the direct reading magnetic compass.

One unit placed for each pilot overcomes parallax error.

The detector unit is placed in the wing tip or tail so it does not suffer from Soft Iron interference from cockpit.

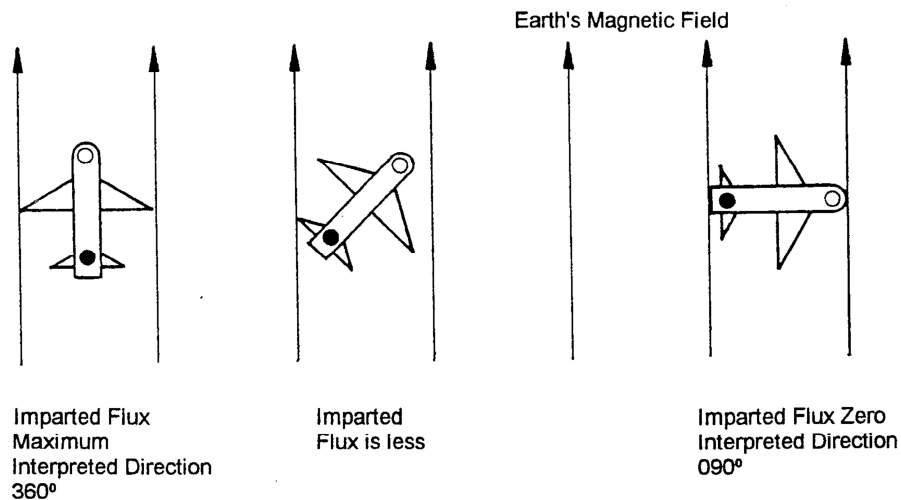
Turning and acceleration errors are suppressed and not shown.

At very high latitudes, where H is small and therefore unreliable, the magnetic component can be uncoupled and the compass becomes a pure D.I. (D.G. Switch).

PRINCIPLE OF OPERATION

The detector unit is fixed to the aircraft's fore/aft axis and it senses the direction of magnetic North. It senses the direction of the Earth's Magnetic field passing through the detector unit.

Fluxvalve Theory



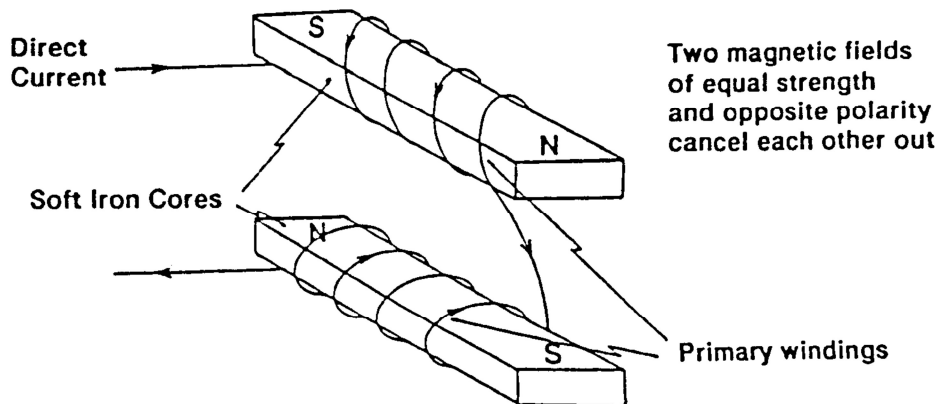
As can be seen here: Imparted Flux = Cos Heading

i.e. Maximum Flux = 360° (Cos 360 = 1)
 Zero Flux = 090° (Cos 090 = 0)

But now we are faced with 2 problems:

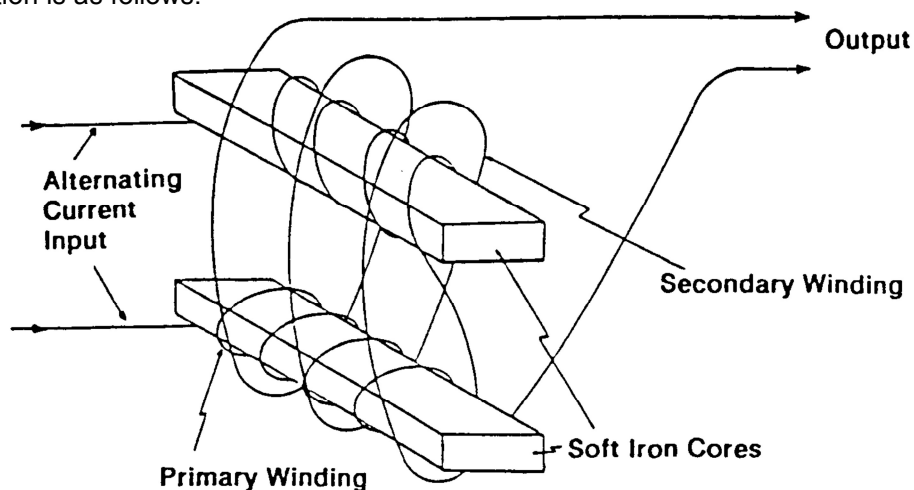
We have to measure the amount of induced flux and interpret it as a heading.

This is done electro magnetically.

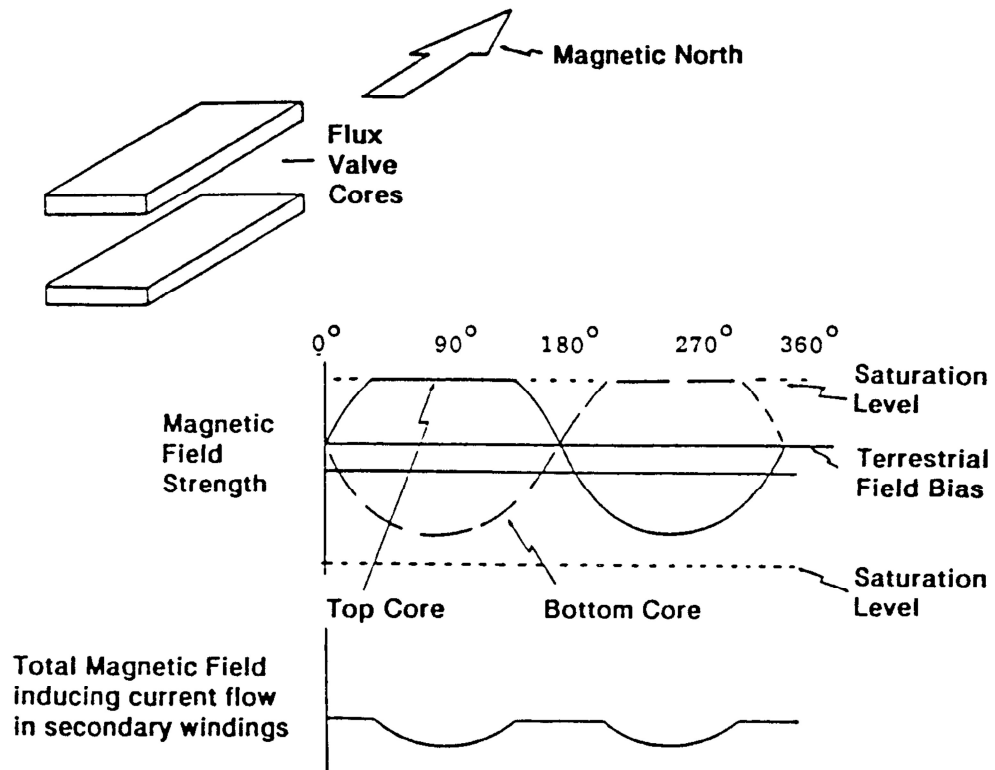


Now the problem is that electro magnetically we can only measure a changing flux. A constant flux dies away immediately after being imparted.

The solution is as follows:



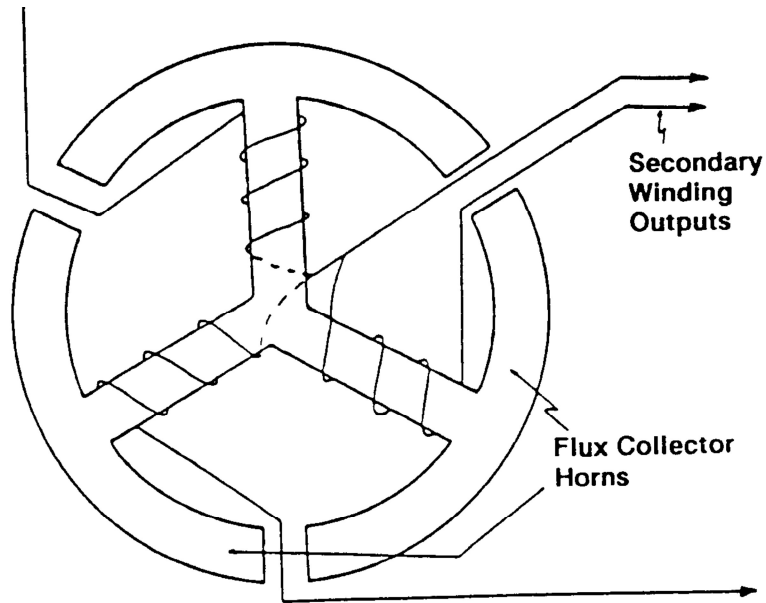
The AC current fed to the coil is 400 cycles per second (CPS). Thus there are 800 peaks (positive and negative) when the earth's field is not induced and 800 zeros per second when the earth's field is induced. This 800 times per second of induced earth's magnetic field is what we need to measure direction (changing magnetic Flux).



Ambiguity

The fluxvalve resolves heading according to the cosine of the induced current. Unfortunately, there is ambiguity. The $\text{Cos } 180^\circ = \text{Cos } 360^\circ$ and $\text{Cos } 90^\circ = \text{Cos } 270^\circ$.

To solve this problem, the detector unit employs 3 fluxvalves at 120° apart. All 3 have a common primary coil situated in the centre and the rest of the principles remain the same. The resultant of the 3 induced currents, each resolved according to Cosine now give the heading and there can be no ambiguity.

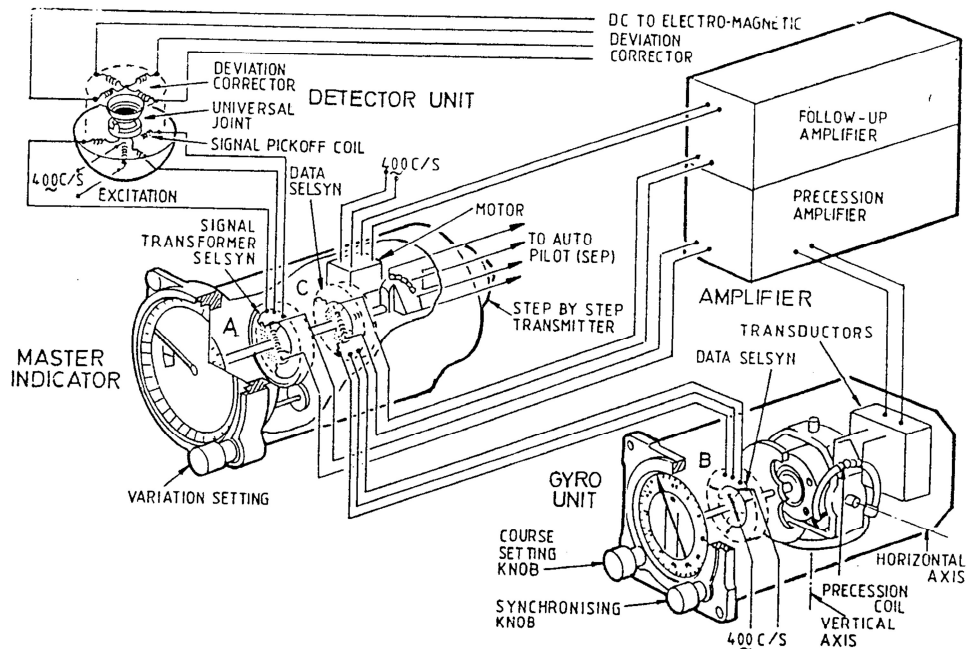


The detector unit is usually mounted on a wing-tip and contains the fluxvalve. It is mounted pendulously by a device known as a Hooke's Joint and has $\pm 25^\circ$ freedom of movement in pitch and roll.

- It is fixed to the aircraft's fore/aft axis.
- It is filled with oil for damping.
- The casing has facilities to correct for Co-eff A, B and C.

For co-eff A the whole flux-valve is rotated.

For co-eff B and C the adjustment is made on the corrector box by turning the B or C corrector screws.



OPERATION OF CL-2

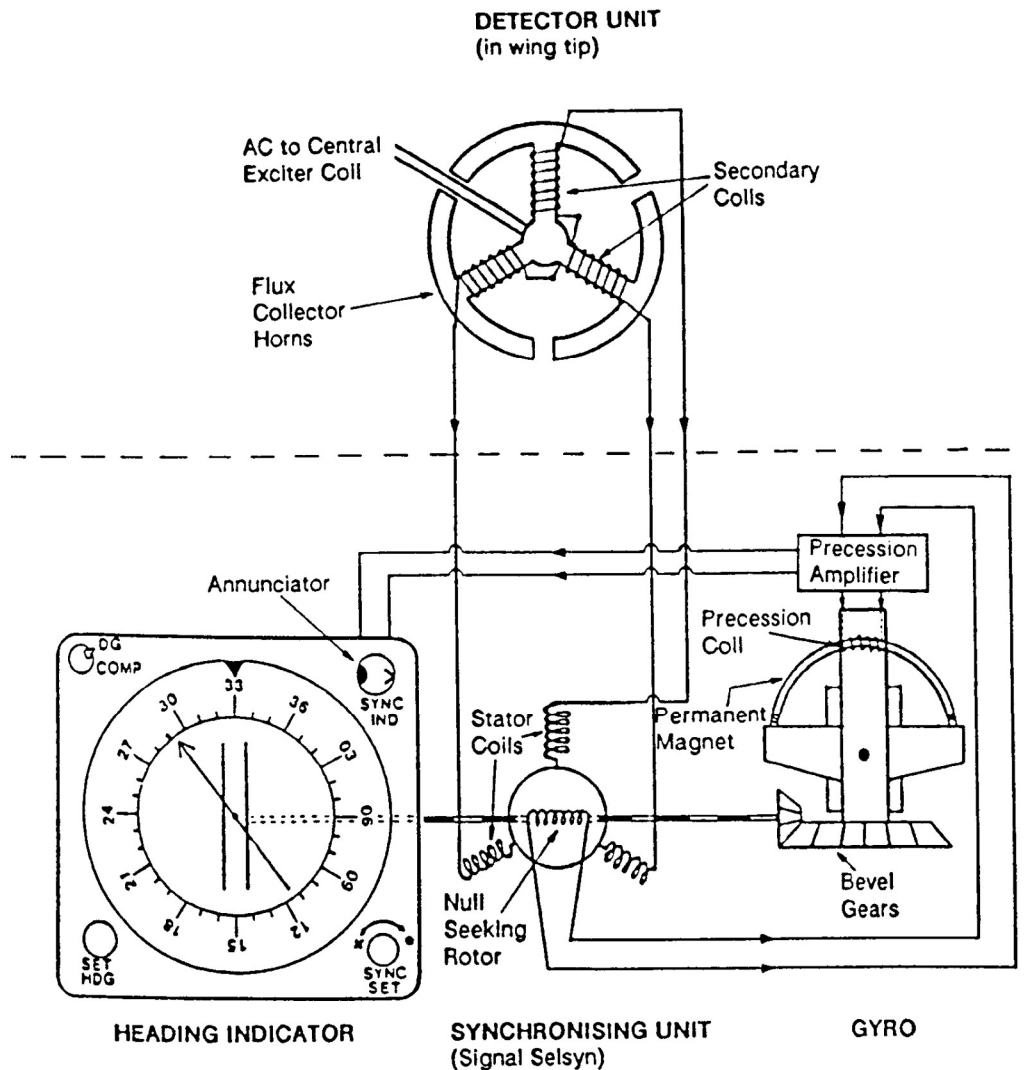
- 1) 3 stators in detector unit have induction according to magnetic heading.
- 2) These 3 stators send identical current to 3 stators in signal selsyn A which is self synchronous.
- 3) Rotor in centre of Selsyn A is designed to be in null position to indicate true heading.
- 4) If it is not in null position - there will be current induced in it.
- 5) If there is current in the rotor - it transmits to precession amplifier.
- 6) Precession amplifier interprets phase of signal - incorrect left/right. It amplifies the signal, transforms it to D.C. and sends to precession coil.
- 7) Precession coil precesses Gyro.
- 8) Gyro is linked to indicator needle - turns to correct heading. It is also linked to rotor arm in Data selsyn B.
- 9) Rotor arm in Data selsyn B is fed by 400 CPS.
- 10) These 3 stators are linked to 3 stators in Data selsyn C.
- 11) Rotor in Data selsyn C has resultant current induced in it.
- 12) Current goes to follow up amplifier.
- 13) Follow up amplifier sends signal to motor.
- 14) Motor turns C rotor to null position - No more signal to amplifier.

- 15) Rotor A is linked on same shaft as rotor C so it also moves to null position \therefore no more signal to precession amp.
- 16) The indicator on the Master Unit is also linked on the same shaft so it indicates the correct heading.

Operation In A Turn

- 1) When the A/C turns, the Gyro has rigidity.
- 2) Gyro is linked to the indicator and indicates turn. Gyro is also linked to Rotor B.
- 3) Selsyn B is duplicated in selsyn C.
- 4) Motor is activated
 - Turns rotor C to null.
 - Turns rotor A to null.
 - Turns Master indicator to hdg.
- 5) Now detector unit has turned with A/C \therefore Rotor A should still be in null position.
- 6) If not, the whole system is precessed to indicate correctly.

CL-2 PRECESSION MECHANISM



- 1) Rotor at Signal Selsyn is not in null position - current induced.
- 2) Current activates precessional amplifier.
- 3) Precession amp sends D.C. current to precession coil and it induces magnetic field.
- 4) Like poles repel/unlike poles attract at horn magnets causing a force.
- 5) Force precesses at gyro - moves horizontal bevel gear.
- 6) Horizontal bevel gear moves vertical bevel gear.
- 7) Vertical bevel gear rotates - turns rotor at signal selsyn to null position and also turns indicator needle.

Manual Synchronising

An annunciator indicates whether or not the compass is synchronised. When the system is operating normally, alternate dots and crosses appear in the annunciator window. If for some reason this is not the case, then just turn the synchronising knob until alternate dots and crosses appear.

The precessional rate of the gyro is kept low (2° - 3° per minute). This is to correct for gyro drift. i.e. To keep the gyro tied to the magnetic meridian.

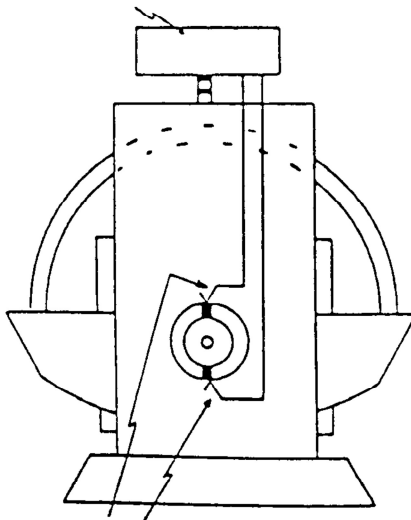
TURNING AND ACCELERATION ERRORS

These errors are suppressed. The errors do not reach the indicators due to the slow precessional rate (2° - 3° per minute). Therefore they are not corrected for, but only suppressed.

The Erection Mechanism

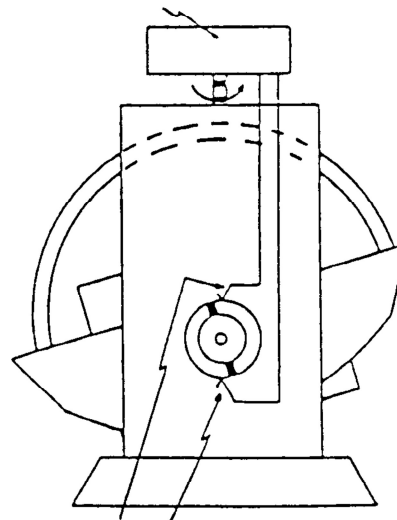
The gyro in the CL 2 must be maintained horizontal and the erection mechanism ensures this. It consists of a 2 phase torque motor with its stators mounted on the outer gimbal and a levelling switch mounted on the inner gimbal. Commutator switches detect any topple of the gyro (relative to the aircraft) and pass a signal to the torque motor which applies a precessing force to the gyro to bring it back to level.

Torque Motor (de-energised)



Pick-off brushes in contact with insulating segments - no current flows

Torque Motor (energised)



Pick-off brushes in contact with semi-circular segments current flows to torque motor to re-erect gyro

Important Points

- 1) The detector unit is fixed to the fore/aft axis of the A/C.
- 2) Gyroscopic rigidity provides Hdg control.
- 3) Precession corrects for errors and gyro drift.
- 4) Turning and acceleration errors are suppressed by the slow precessional rate of 2° - 3° per minute.

QUESTIONS

1. During the correcting swing of a direct reading magnetic compass the following readings were noted.

MAGNETIC HEADING	COMPASS HEADING
359	001
090	088
181	179
269	273

Calculate the value of Coefficients A, B and C. What will the compass read after compensation of Coefficients B and C on the Southerly and Westerly headings?

2. The following figures appear on an aeroplane deviation card:

FOR MAGNETIC	STEER COMPASS
045	038
090	092

The compass heading to steer to maintain a heading of 075 (M) is:

- a) 072
 - b) 074
 - c) 076
3. During a compass swing the following reading were noted:

MAGNETIC HEADING	COMPASS HEADING
000	358
089	092
178	182
269	268

After correction for coefficients B and C, the compass reading on the westerly heading was:

- a) 266
 - b) 270
 - c) 271
4. The following Coefficients apply to a particular compass system:
Co-eff A + 2 Co-eff B + 4 Co-eff C - 3
- What deviation would you expect on heading 135 (C)?

- a) 6.95
- b) 2.71
- b) 1.29

5. A compass system has Co-eff A + 1 and Co-eff B + 3. The deviation on heading 230 (C) is - 3. What is the value of Co-eff C?
- +2.65
 - 9.82
 - 3.71
6. Coefficient A+3 is corrected on heading 300 (C). What is the compass reading after correction of Co-eff A?
- 330 (C)
 - 303 (C)
 - 297 (C)
7. A compass system has Co-eff A -2, B-4, C+3. Required track 022 (T), Drift 7 left. Variation 16W. The compass heading to steer will be:
- 042 (C)
 - 045 (C)
 - 048 (C)
8. Compass deviation on 130 (C) is 4 W.
Compass deviation on 230 (C) is 8 E.
Compass deviation on 315 (C) will be:
- 4.7
 - 1.5
 - +3.3
9. A direct reading magnetic compass has coefficients A, B and C only. Deviations on 000° (C) is 0°. Deviation on 090° (C) is + 3. Coefficient C is +2. The deviation on 180° (C) is:
- 2
 - 4
 - 0
10. During a compass swing the following deviations were found.
- | HEADING | COMPASS DEVIATION |
|---------|-------------------|
| 000 | 0 |
| 090 | -5 |
| 180 | -4 |
- The value of Coefficients A, B and C were:
- A-3 B-3 C-2
 - A-2 B-3 C+2
 - A-2 B+2 C+2
11. An agonic line joins places of:
- Equal magnetic variation.
 - Zero magnetic variation.
 - Equal horizontal force H.

12. Variation is called Westerly when:
- a) Magnetic North is to the West of True North.
 - b) True North is to the West of Magnetic North.
 - c) The Magnetic Meridian is to the West of Compass North.
13. You are turning right from 150 (C) onto 220 (C) in the Southern Hemisphere. On what compass heading would you roll out of the turn?
- a) 210 (C)
 - b) 220 (C)
 - c) 230 (C)
14. An aeroplane heading 030° (C) in the Southern Hemisphere, turns left onto 170° (C) using a direct reading magnetic compass. The roll out of the turn should be initiated on a compass heading off:
- a) 145
 - b) 170
 - c) 195
15. Compass deviation is caused by:
- a) The difference in the location of the Earth's Magnetic and Geographic Poles.
 - b) The angle of magnetic dip.
 - c) Aircraft magnetism distorting the Earth's magnetic field.
16. A magnetic compass will show an apparent turn to the North in the Southern Hemisphere when:
- a) The aircraft accelerates on 000 (C).
 - b) The aircraft accelerates on 090 (C).
 - c) The aircraft decelerates on 270 (C).
17. The direct reading magnetic compass has magnetic correctors for:
- a) Coefficient A, B and C.
 - b) Coefficients B and C only.
 - c) Coefficients B, C and R.
18. In regard to acceleration errors, they are caused because:
- a) The C. of G. of the magnet system is above the pivot.
 - b) The C. of G. of the magnet system lies between the pivot and the nearer pole.
 - c) The C. of G. lies between the pivot and the equator.

19. Select the true statement regarding the magnetic compass in the southern hemisphere.
- a) If on a westerly heading and the aircraft's speed is decreased, the aircraft will indicate a turn to the north.
 - b) If on a northerly heading a turn is made toward the west, the compass will indicate a turn in the opposite direction.
 - c) If on an easterly heading the aircraft is accelerated, the compass will indicate a turn to the north.
20. The magnetic system of a compass is suspended pendulously to counteract the effect of component:
- a) H
 - b) Z
 - c) P
21. An aircraft being manufactured in the Northern Hemisphere is parked facing South West:
- a) Parameter P is positive.
 - b) Parameter Q is positive.
 - c) Parameter R is positive.
22. Parameter P is:
- a) Fore and aft magnetism affecting Co eff. B.
 - b) Athwart ship magnetism affecting Co eff. B.
 - c) Fore and aft magnetism affecting Co eff. C.
23. A compass swing should be conducted:
- a) with the radio equipment off.
 - b) with the engine shut down.
 - c) with the engine running.
24. A magnetic material that is easily magnetised is called:
- a) soft iron magnetic material.
 - b) permanent magnet.
 - c) hard iron.
25. Compass accuracy is greatest:
- a) in mid latitudes.
 - b) at the poles.
 - c) at magnetic equator.
26. The secular change in variation has a cycle of:
- a) 96 years.
 - b) 690 years.
 - c) 960 years.

27. An aircraft constructed in South Africa has a red pole in the nose and right wing and blue poles in the tail and left wing. The heading during construction was:
- a) 045 degrees.
 - b) 315 degrees.
 - c) 135 degrees.
28. Which statement is true regarding magnetism:
- a) compass deviation is the angular difference between true north and magnetic north.
 - b) magnetic variation is the deflection of the compass needle which is caused by magnetic attractions in the aircraft.
 - c) magnetic dip increases with an increase in latitude.
29. The type of compass least likely to suffer from parallax is:
- a) Direct reading compass.
 - b) Remote reading compass.
 - c) A standby compass.
30. When a magnet cannot be made any more magnetic, it is said to be:
- a) Impermeable.
 - b) Permeable.
 - c) Saturated.
31. In direct reading magnetic compass, the effect of dip is counteracted by:
- a) Low centre of gravity.
 - b) Compass liquid.
 - c) Powerful magnets.
32. Assuming the compass to be only affected by hard iron magnetism causing deviation, if the latitude changed the deviation would change because:
- a) of the change in the aircraft's hard iron magnetism.
 - b) of the change in the Earth's total force.
 - c) of the change in the strength of the Earth's directive force.
33. With reference to the Sperry Gyrosyn CL2 compass system. The precession rate of the gyro is kept low in order to:
- a) Maintain the gyro axis in the horizontal plane.
 - b) Suppress turning and acceleration errors.
 - c) Allow the master unit to follow the gyro unit.
34. The Sperry CL2 compass system remains synchronised in a turn because:
- a) The follow up motor keeps the compass synchronised.
 - b) The precession circuit is activated causing the gyro to follow the turn.
 - c) The signals from the detector unit to the signal selsyn change at the same rate as the rotor of the signal selsyn turns.

35. The Sperry CL2 compass system does not indicate turning and acceleration errors because of:
- a) The annunciator circuits.
 - b) The slow precession rate of the gyro.
 - c) The Hooks joint suspension of the detector unit.
36. The Sperry CL2 compass system indicates aircraft heading by:
- a) The detector unit senses the angle between the aircraft fore and aft axis and the magnetic meridian.
 - b) The detector unit aligns itself with the magnetic meridian.
 - c) The signal selsyn measures aircraft heading.
37. During a turn the remote indicator of a CL2 compass remains synchronised with the actual heading because:
- a) the horizontal gyro due to its rigidity drives the pointers keeping them aligned with the heading;
 - b) error signals raised in the stators of the gyro unit data selsyn are repeated in the stators of the master indicator;
 - c) the detector unit, signal selsyn stator and horizontal gyro, rotate with the aircraft in the same direction at the same rate.