PART 2 : SECTION 1

CHAPTER 3

DIRECTION INDICATORS

MK. 1 SERIES

Purpose

1. The purpose of a direction indicator is to provide the pilot with a stable directional reference for accurate course steering and a means of turning precisely on to any desired heading.

Implementation

2. The requirements are fulfilled by use of the gyroscopic principle of rigidity.

3. The direction indicator is non-magnetic and not subject, as a magnetic compass needle is, to northerly turning error, dip, acceleration or deceleration errors, or to magnetic disturbances. This instrument does not, however, replace the magnetic compass, but is used in conjunction with it. The operating gyroscope may wander slowly ; the direction indicator must therefore be synchronized initially with the magnetic compass and the setting must thereafter be checked periodically. Any deviation of the aircraft from its compass heading is shown instantly by the direction indicator. The advantages of this instrument are best appreciated by comparison with the magnetic compass, in which the slightest turn may induce oscillation which will not disappear until after the aircraft has resumed straight and level flight. Furthermore, the magnetic compass does not always respond immediately when the aircraft begins to turn. Both the Mk. 1 and Mk. 1A direction indicators are air-driven, and on both types the cylindrical scale and index (lubber) line are either luminous or fluorescent so that they can be read easily during darkness.

Description

4. Each type of instrument is operated by a tied gyroscope mounted in gimbal rings and so arranged that its normal axis of spin is horizontal. The gyroscope rotor, which is driven by air jets from nozzles, spins at about 10,000 r.p.m. and is operated by a suction of 4 inches of

Fig. 1. Direction Indicator, Mk. 1.

mercury. The suction is normally provided by an engine-driven pump, but a venturi head may be provided as an alternative. By one or other of these media air is drawn from the instrument case, producing a partial vacuum, and replacement air discharges into the case through twin nozzles and impinges as a jet on a series of buckets cut into the periphery of the gyro rotor, thus spinning the rotor.

5. The internal mechanism of the Mk. 1 model is shown in Fig. 2. The rotor spins about a horizontal axis (A). It is supported by bearings in the inner gimbal ring which is free to turn about a horizontal axis (B) on bearings in the vertical outer gimbal ring. The outer ring is free to turn about the vertical axis (V). The cylindrical scale which is attached to the vertical ring is observed by the pilot through the rectangular opening (Fig. 1) in the front of the instrument case. When in motion the rotor obeys the fundamental gyroscopic principle of *rigidity*, *i.e.* it has a natural tendency to maintain a fixed axis of rotation. Thus the rotor, gimbal rings, and cylindrical scale remain fixed in azimuth regardless of aircraft movement.

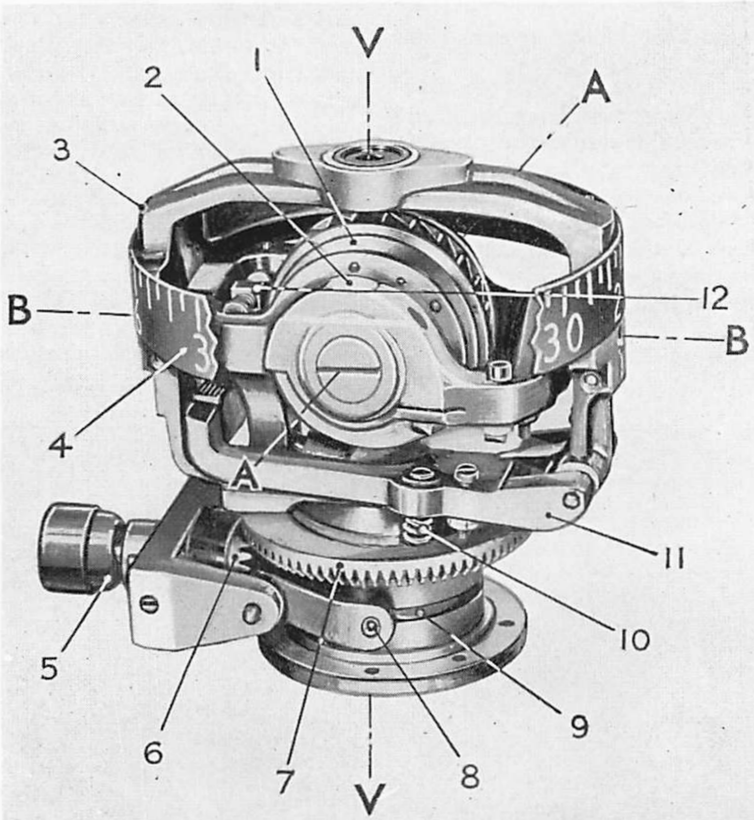

Fig. 2. Mechanism of Direction Indicator, Mk. I.

Rotor	I	Bevel gear	7
Inner gimbal ring	2	Stirrup pin	8
Vertical gimbal ring	3	Sleeve	9
Cylindrical scale	4	Spring plunger	10
Caging knob	5	Caging arm	II
Bevel pinion	6	Jets and nozzle	I2

Horizontal axis of rotor ... ... A
Horizontal axis of inner gimbal ring ... ... B
Vertical axis of vertica gimbal ring V

6. The cylindrical scale is observed in relation to a vertical lubber line on the front of the instrument. The caging knob is used to synchronize the direction indicator initially with the magnetic compass and also to reset it at regular intervals.

7. Air enters the instrument through the filter on the underside of the instrument case, passing directly into the lower bearing and through channels in the spindle to a pipe fixed to the outer gimbal ring. The pipe leads to two jets in the nozzle (Fig. 2 (12)), which are directed towards the buckets in the periphery of the rotor.

8. Since the jets are attached to the outer ring (3), when the inner ring tilts, the airflow is not perpendicular to the line of the buckets, although it has a perpendicular component sufficient to maintain the required speed. The side thrust due to the air impinging on the sides of the buckets provides a torque, about the vertical axis, which moves the axis of the gyro rotor back to the horizontal, thus maintaining it in the horizontal plane. This is shown graphically in Fig. 3.

9. The direction indicator Mk. 1A is slightly different in construction from the Mk. 1, but serves a similar purpose and is completely interchangeable with the Mk. 1 on the instrument panel. Both instruments are described in detail in A.P. 1275A, Instrument Manual.

Errors

10. During flight the plane of rotation of the rotor appears to change direction. This characteristic is known as *drift* and may be investigated under two main headings—*mechanical drift* and *apparent drift*.

Mechanical Drift

11. Mechanical drift may be due to precessional forces induced by bearing friction, static unbalance of gimbals, shift of the centre of gravity, warping, or excessive air turbulence. Drift due to these causes should not exceed 4° in 15 minutes, and is minimized by accurate manufacture and assembly, and by care of the instrument. Drift caused by re-erection of the gyro may also be included under this heading ; for examination of the 90° rule reveals that the corrective force exerted by the air jets when the rotor is tilted, results in movement of the outer gimbal ring, causing a small change in the indicated heading. For this reason the instrument should be uncaged or resynchronized only when the aircraft is level.

Apparent Drift

12. Apparent drift may be caused by either :—

(*a*) The effect of the earth's rotation, or

(*b*) The effect of change of longitude.

13. In Fig. 4 three direction indicators are shown, one at each of the poles and one on the equator. An observer standing at point A at 0600 hours and reading the D.I. scale as 090° would be at point B at 1800 hours, and would then read the D.I. scale as 270°. The D.I. would not have moved at all, but the earth's rotation during the 12 hours of observation would have caused an apparent drift of *minus* 180°, *i.e.* minus 15° per hour.

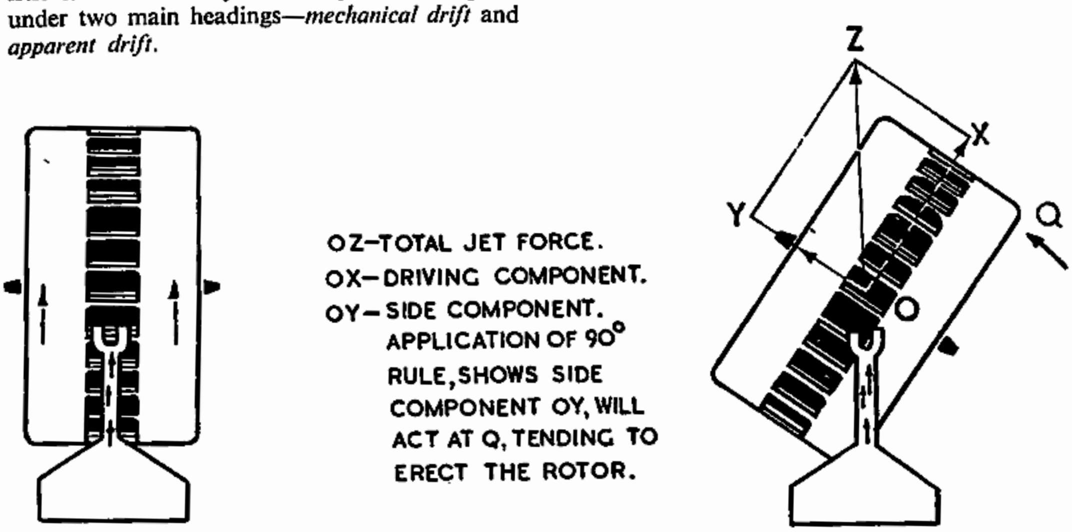

Fig. 3. Erection of D.I. Rotor.

14. An observer standing at point C on the equator at 0600 hours and reading the D.I. scale as zero, would be at point D at 1800 hours but would still read the scale as zero, since apparent drift is not experienced at the equator.

15. An observer standing at point E at 0600 hours would be completely inverted relative to the observer at point A. The observer at point E would therefore read the D.I. scale as 270° at 0600 hours and as 090° at 1800 hours, *i.e.* an apparent drift of *plus* 180° per 12 hours, or plus 15° per hour, would have been observed.

16. This apparent drift of minus 15° per hour at the North Pole and plus 15° per hour at the South Pole varies proportionately in the intermediate latitudes, as is shown graphically in Fig. 4.

17. **Compensation for Apparent Drift Caused by the Earth's Rotation.** Apparent drift due to the earth's rotation is compensated in the D.I. by the application of a precessional force to the inner gimbal ring to cause an equal and opposite drift. This compensation force is provided by the weight of an adjustable drift nut fastened to the inner gimbal ring. The nut is adjusted for the latitudes in which the aircraft is operating and readjusted whenever a change of latitude of more than 60° is contemplated. Abnormal rotor speeds vary the effectiveness of this compensating device. At rotor speeds below normal (caused by incorrect suction, leaks, or choked filters) the nut over-corrects because of diminished rotor rigidity. Conversely, at rotor speeds above normal the increased rigidity results in under-correction by the drift nut.

18. **Apparent Drift Caused by Change of Longitude.** When an aircraft is flying on a great circle track across the meridians in polar regions, it is changing heading rapidly in relation to the pole. As the D.I. gives a constant reading (ignoring other drift factors) it appears to have a large apparent drift when checked against the magnetic compass. Under these conditions the D.I. gives a more useful indication of direction than the magnetic compass.

Gimballing Errors

19. Gimballing errors are not concerned with gyro precession but are the result of the geometry of the gimbal system in that, unless the gyro frame (*i.e.* the aircraft) is rotated about one of the gyro axes, the outer gimbal ring must itself move if the direction of the rotor axis is to remain undisturbed. The error thus introduced can therefore be truly described as *gimballing error*, and can best be understood from an examination of Fig. 5.

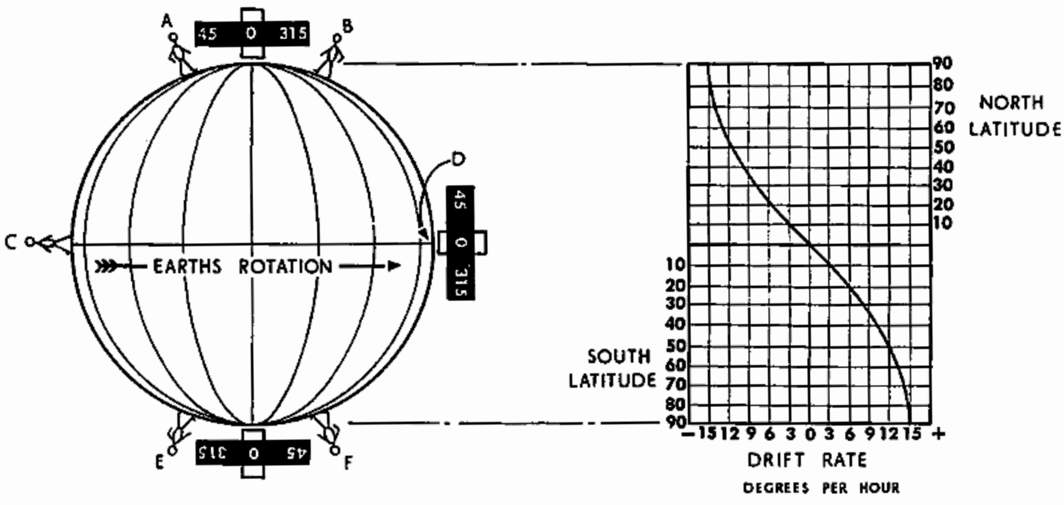

Fig. 4. Drift Due to the Earth's Rotation.

20. In Fig. 5 the gyro frame carrying the outer ring bearings is fixed to the aircraft, the rotor axis is pointing north-south, and in the first four sections (A to D) the aircraft is heading west. In A the aircraft is flying straight and level, so that the outer ring is vertical, the bearings of the inner ring are horizontal, and the inner ring is itself in the horizontal plane. In B the aircraft is being banked to port and the gyro frame and bearings of the outer ring are tilted to port ; the rotor axis must not change its direction, which means that the outer ring pivots about the horizontal fore-and-aft axis of the inner ring. No angular movement of the outer ring relative to the gyro frame occurs, so that there is no error in indications read from the cylindrical scale on the outer ring against the lubber line on the gyro frame.

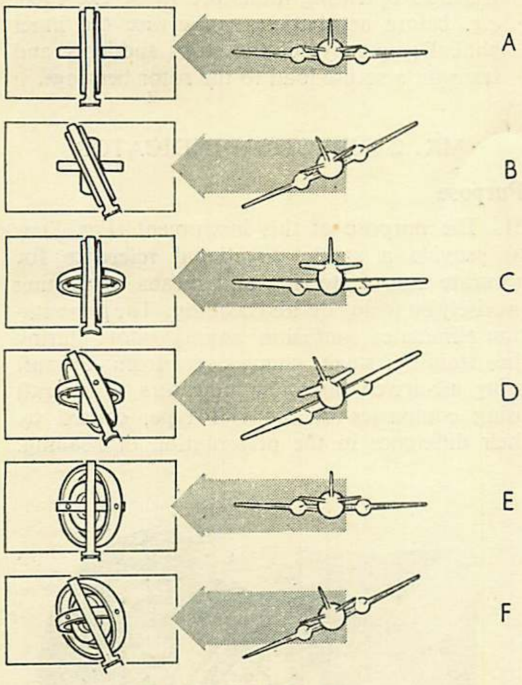

Fig. 5. Gimballing Errors.

21. In C the aircraft dives ; therefore the gyro frame, outer ring, and inner ring all rotate about the rotor axis, while retaining the same relationship to each other, and there is still no error in indication. Exactly the same conditions apply, incidentally, if an aircraft heading south banks either to port or starboard. Thus there is no error in the indication when flying on cardinal headings if the rotor axis is also aligned with a cardinal heading.

22. In D, however, the aircraft is made to bank to port and dive. The rotor axis must still point in the same direction, and the inner ring can only rotate, therefore, about the rotor axis, and the pivot points of the inner ring in the outer ring must move in a vertical plane. For this to happen, and for the outer ring to tilt to port as well as forward, the outer ring must also rotate about its own axis in the gyro frame, thus causing a change in the indicated heading. No actual change of heading occurs ; therefore the indication given by the instrument is erroneous. This is known as *gimballing error*.

23. Exactly the same thing happens if the aircraft is flying on an intercardinal heading, as in E (with the rotor axis north-south), and then simply banks to port (F) while retaining its level pitch attitude.

24. Thus gimballing error can occur during simple banking on intercardinal headings, or during combined pitch and roll changes on all headings, except when the plane of the rotor coincides with the plane of the resultant attitude change or a plane at right angles to the resultant.

25. Fig. 6 shows the gimballing error on all headings at various angles of bank, and reveals that the error reaches a maximum on headings of 045°, 135°, 225°, and 315°. It can be seen that the error is small during moderately banked turns.

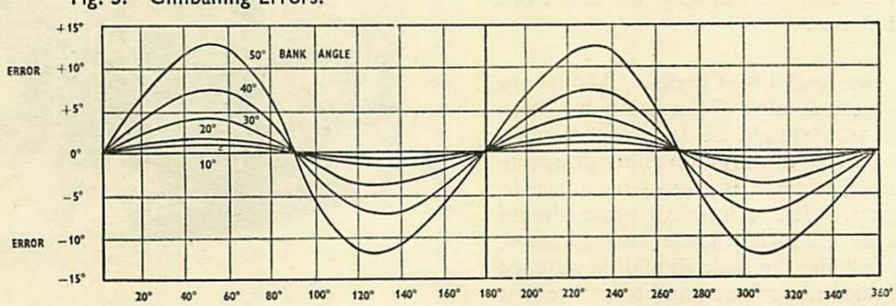

Fig. 6. Gimballing Errors on all Headings at Angles of Bank of 10°, 20°, 30°, 40°, and 50°.

26. It should be remembered that although angular movement of the inner gimbal ring relative to the outer gimbal ring occurs during the motions just described, and hence the automatic precession device (controlling the inner ring to maintain it perpendicular to the outer gimbal ring) comes into play, this control is insufficient to have any appreciable effect on instrument indication since manœuvres involving gimballing are of short duration. In addition, gimballing errors occur only during the changed attitude of the aircraft and are reduced to zero as soon as normal level flight is resumed.

Limitations

27. The Mk. 1 and Mk. 1A direction indicators are suitable for use at temperatures between −40°C. and +60°C. The operating limitations are 55° in roll and pitch, and if these are exceeded the inner gimbal ring bears against the stop. This leads to spinning of the outer gimbal ring and scale, which continues as long as the inner gimbal ring is on the stops. Under certain conditions, however, the limits can be exceeded without toppling the gyro. For instance, if the rotor axis lies athwartships it is possible to rotate the aircraft through 360° in the looping plane. Similarly, if the rotor axis lies fore and aft full movement in the rolling plane is possible without toppling. These conditions prevail on the cardinal headings as shown on the scale, and the pilot should ascertain on which headings the instrument in his particular aircraft permits full freedom in pitch and roll. Whenever the gyro topples, resetting with the caging device enables it to resume immediate normal operation.

Operation

28. The rotor spins as soon as suction is applied, but it does not reach full rotational speed until three or four minutes after starting up. While it is speeding up the reading may be somewhat inaccurate, but the errors are not serious after the full suction has been applied for about one and a half minutes.

29. **Pilot's Serviceability Checks.** About one and a half minutes after full suction has been applied, the gyro should be tested for rigidity by caging the knob, turning it in either direction, and checking that there is a firm resistance to this movement. The cylindrical scale should then be synchronized with the magnetic compass, and, during taxying, the scale should be watched for correct indication of turns and to ensure that it stops dead when the aircraft stops turning. Before take-off a further check should be made to ensure that the cylindrical scale reading agrees with that of the magnetic compass.

30. **Air Procedure.** The following procedure should be adopted in the air :—

(*a*) The D.I. should be synchronized with the compass every 15 minutes and after manœuvres in which drift due to re-erection occurs, *i.e.* after turns, prolonged climbing or descending.

(*b*) When synchronizing, care must be taken to ensure that the aircraft is laterally level and in steady flight, so that re-erection drift and incorrect settings due to compass acceleration and turning errors are eliminated. Compass deviation must be taken into account.

(*c*) The D.I. should be caged at all times when its operating limits are to be exceeded, *e.g.* before aerobatics ; otherwise the inner gimbal ring may hit the stops suddenly and transmit a severe load to the rotor bearings.

MK. 2 DIRECTION INDICATOR

Purpose

31. The purpose of this instrument (Fig. 7) is to provide a stable directional reference for accurate course steering and means of turning precisely on to any desired heading. The presentation eliminates confusion among pilots during the training stage changeover from aircraft using air-driven direction indicators to aircraft using compasses of the G.4 type, caused by their difference in the presentation of heading.

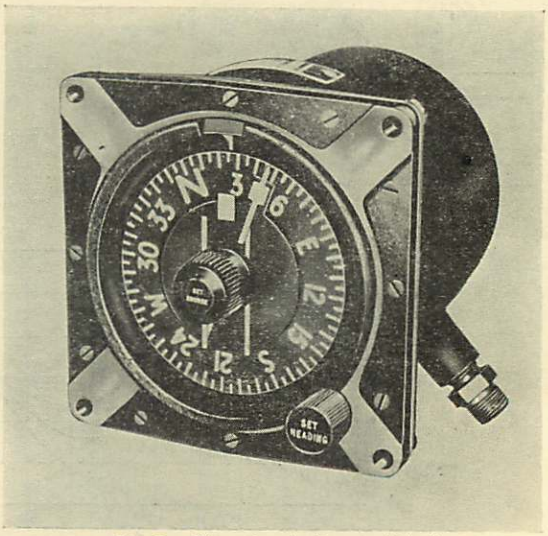

Fig. 7. Direction Indicator, Mk. 2.

Implementation

32. The requirements are fulfilled by using the gyroscopic principle of rigidity. Presentation is similar to that of the G.4 type compasses, showing aircraft heading in the natural sense.

Description

33. The D.I. Mk. 2 is air-driven and operates at a rotor speed of 20,000 r.p.m. provided by a suction of 3½ inches to 4 inches of mercury. An adjustable course-setting pointer is provided and can be set to any desired heading by pressing and turning a knob in the centre of the dial (Fig. 7). Operation of the SET HEADING knob at the bottom right-hand side of the dial permits the compass card to be reset *without caging the gyro*. Constructional details are available in A.P. 1275A.

Errors

34. **Drift.** The Mk. 2 model is subject to mechanical and apparent drift. By accurate manufacture mechanical drift, which has already been explained in para. 11, is reduced in this instrument to 3° per 15 minutes, *i.e.* a lower figure than that permitted for the Mk. 1 series. Apparent drift caused by the earth's rotation is nullified by the precessional counter effect of a drift nut as in the Mk. 1 series instruments. Apparent drift caused by change of longitude is experienced in polar regions, for the reasons explained in para. 18.

35. **Gimballing Errors.** The D.I. Mk. 2 is subject to gimballing errors during turning, but the extent of the gimballing error on a particular heading at a specific angle of bank is not necessarily the same as that experienced with a direction indicator of the Mk. 1 series. This is because the relationship between the position of the gyro axis and that of the compass card is not constant, as it is in the Mk. 1 series instruments. For example, the scale of many Mk. 1 direction indicators reads either north or south when the rotor axis is athwartships, and east or west when the rotor axis lies fore and aft; but the compass card of a D.I. Mk. 2 can indicate any heading from 000° to 359° when the rotor axis is athwartships, owing to the absence of a fixed rotor-axes/compass-card relationship. Similarly, the rotor axis can be at *any angle* relative to the athwartships axis of the aircraft when the compass card is reading 000°. Thus during a turn through 360° at, say, 50° bank angle, although the graph of the indicated heading error is similar to that for the Mk. 1 series instruments, it does not necessarily reach the two zenith and the two nadir points on the same headings as with the Mk. 1 series instruments as illustrated in Fig. 6.

Limitations

36. The limitations of the D.I. Mk. 2 are 85° in roll and pitch. If these are exceeded the stop-pin bears against one or other of the stop-screws and topples the gyro. Under certain conditions, however, these limitations can be exceeded without causing toppling. Complete rotation of the aircraft in the rolling plane will not topple the gyro if the aircraft heading is at right angles to the plane of rotation of the gyro. The aircraft can be looped without toppling the gyro when the gyro axis lies athwartships ; but, as can be appreciated from the foregoing paragraphs, performance of these manœuvres cannot be related to definite readings of the D.I. compass card. If the gyro topples, the rotor axis does not normally move more than 10° from the horizontal, and owing to the fast re-erection rate of the instrument, *i.e.* 20°/minute, there is only a brief time lapse before complete re-erection.

Pilot's Serviceability Checks

37. Before starting the engine the serviceability of the adjustable course-setting pointer mechanism should be verified through movement of the pointer in both directions by manual operation of the course-setting knob. If it is desired to pre-set the required heading, it should be done at this stage to avoid any subsequent waste of fuel. After starting the engine the correct suction must be applied to the direction indicator, Mk. 2, for seven to ten minutes for the rotor to reach full rotational speed ; but reliable indications are obtainable after five minutes' running at the correct suction. After this time the compass card should be watched during taxying for correct indication of turns and to ensure that it stops dead when the aircraft stops turning. Before taking off, a further check should be made to ensure that the compass card agrees with the magnetic compass.

Air Procedure

38. The following procedure should be adopted in the air :—

(*a*) The compass card should be synchronized with the magnetic compass reading every 15 minutes.

(*b*) When synchronizing, the pilot should ensure that the aircraft is laterally level and in steady flight ; this eliminates incorrect settings due to magnetic compass acceleration, deceleration, and turning errors. Compass deviation must be taken into account.

(*c*) To turn on to a pre-set heading, the aircraft should be turned until the course-setting pointer is aligned with the centre block on the grid and with the lubber mark.


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