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### PART 2 : SECTION 3

#### CHAPTER 2

## G.4 GYRO-MAGNETIC COMPASSES

### Introduction

1. This chapter provides information on gyro-magnetic compasses of the Mk. 4 series, which at present consists of two models :—

- (a) Mk. 4F (for fighter aircraft).
- (b) Mk. 4B (for heavy aircraft or for light aircraft in which additional repeaters or automatic dead-reckoning instruments are fitted).

2. These instruments are also known colloquially as the G.4F and the G.4B. This chapter deals with the general principle of operation, which is similar in the two types. There is a third model, the Mk. 4FT, in use in the Fleet Air Arm, but it is not described in this manual.

### Purpose

3. The purpose of the G.4 Gyro-Magnetic Compass is to provide an aircraft compass which, having all the advantages of gyroscopic stabilization, gives a stable, dead-beat directional reference related at all times to the earth's magnetic meridian.

### Implementation

4. The purpose is implemented by the employment of an electrically-driven gyroscope, monitored by a detector unit which controls the gyro in such a manner that it is constantly maintained at a pre-set angle relative to the earth's magnetic meridian. By this arrangement the compass indication is dead-beat ; northerly turning and other errors associated with purely magnetic compasses are reduced to a minimum, while the slow drift of the gyro is eliminated.

### Construction

5. The gyro unit is mounted on the pilot's instrument panel and provides the compass indication. The detector unit is usually mounted either in the wing tip or tail fin of the aircraft ; a position where local magnetic disturbances are at a minimum. This greatly reduces the amount of correction required for magnetic deviation. Both marks of compass utilize an amplifier unit, the purpose of which will be seen later in this chapter.

6. The Mk. 4F compass is for use in aircraft where no repeaters are needed and/or no heading information is required for ancillary equipment ; it comprises the minimum number of components, namely, a gyro unit, detector unit, amplifier unit, and a small deviation corrector control box. It provides a dead-beat indication of aircraft magnetic heading on the gyro unit.

7. The Mk. 4B compass is a more comprehensive instrument, for use in aircraft which carry navigators and/or ancillary equipment requiring heading information, *e.g.* automatic dead-reckoning instrument system (A.D.R.I.S.), automatic pilot, etc. Hence, in addition to the gyro unit, detector unit, and amplifier unit, the Mk. 4B contains a navigator's master indicator which provides :—

- (a) A large-scale, easily-read indication of aircraft heading for the navigator.
- (b) A control for setting local magnetic variation so that indications of the compass and monitored equipment are given in relation to true north.
- (c) A special signal system for monitoring the Mk. 9 auto-pilot.
- (d) A power repeater system for providing heading information in such equipment as A.D.R.I.S., radio compass, etc.
- (e) A Selsyn-type synchronous transmission system for monitoring ancillary equipment.

The Mk. 4B compass also makes provision for the incorporation of a second gyro unit for mounting on the second pilot's instrument panel.

8. Since, for certain operations, it may be desirable to use the gyro unit as a directional gyro only, provision is made for switching off the monitoring of the detector unit by the inclusion of a D.G./compass selector switch. In the Mk. 4F this selector switch is mounted in the top left-hand corner of the gyro unit instrument face. In the Mk. 4B, however, since two gyro units may be used, the D.G./compass selector switch is mounted on a separate control panel. When two gyro units are fitted, only one of them can be controlled from the magnetic detector at any one time ; the other then functions as a directional gyro. Provision is made for both

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gyro units to be operated as directional gyros if desired; therefore the D.G./compass switch of the Mk. 4B has three positions. When the switch is centralized, neither gyro is controlled, *i.e.* both units function as directional gyros. With the switch moved to port, only the port gyro is controlled; when the switch is moved to starboard, only the starboard gyro is controlled.

9. If only one gyro unit is fitted in a Mk. 4B installation, a similar control panel is provided, but with the third position blanked off. In aircraft where space prevents the control panel being accessible to the pilot, it can be mounted remotely and controlled by a simple on/off switch mounted near the gyro unit.

10. Constructional details of both types of compass are given in A.P. 1275B, Instrument Manual (Navigation Instruments).

### GENERAL PRINCIPLES OF OPERATION

11. The principles of operation detailed in the following paragraphs refer to *both* the Mk. 4F and the Mk. 4B except where otherwise stated.

12. The gyro-magnetic compass, Mk. 4 series, should not be confused in any way with the Distant Reading Compass, Mk. 1. The Mk. 4 differs basically in that the detector unit is not in the same assembly as the gyro element and that it detects the direction of the lines of force of the earth's magnetic field *electro-magnetically*, and not by the use of bar-magnets.

### Detector Unit

13. The detector unit (Fig. 1) comprises a pendulous sensitive element, free to move up to 25° in pitch and roll but fixed to the aircraft in azimuth. This element is suspended from the terminal plate and the assembly is hermetically

sealed in a case which is partially filled with oil to dampen oscillations. On top of the terminal plate, but not shown in Fig. 1, is mounted the deviation corrector assembly.

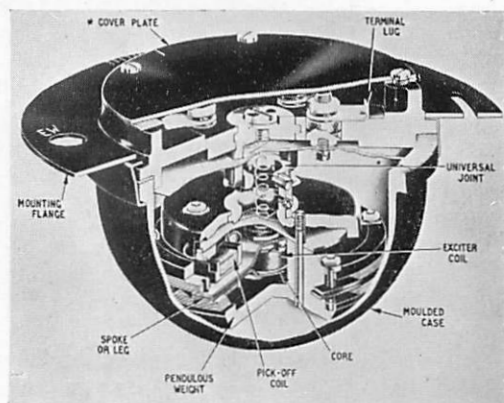


Fig. 1. Detector Unit.

14. The pendulous detector element resembles a three-spoke wheel slit through the rim between the spokes, which are 120° apart. The rim thus forms a collector horn for each spoke, as shown in Fig. 2. The horns and spokes are made up of a series of laminations of metal having a high magnetic permeability, and each spoke (Fig. 1) has two strips or legs, top and bottom, separating to enclose the central hub core. This core has an exciter coil wound round it on a vertical axis, and each spoke has a coil wound round *both* legs on a horizontal axis.

15. The exciter coil is fed with an alternating current sufficient to induce a magnetic flux to saturate the spoke and collector-horn elements. Thereby a signal is induced in each of the three collector-horn coils, the amplitude of each signal being proportional to the component of the earth's magnetic field in line with that

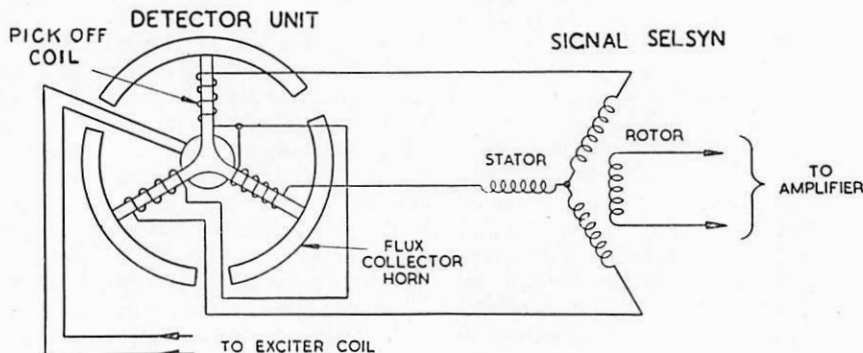


Fig. 2. Detector Unit System.

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particular spoke. The detailed theory of the detector unit is beyond the scope of this manual, but for those pilots wishing to investigate it a full explanation is given in the Instrument Manual, A.P. 1275B, Volume 1, Section 3, Chapter 14, Appendix 2.

### Selsyn Units

16. As shown in Figs. 2 and 3, the detector unit output is fed to the stator of a signal Selsyn. Thus a magnetic field is produced in the stator of this Selsyn, *the vector of the field being directly related to the aircraft magnetic heading*. This signal is fed to the precession amplifier where it is amplified, rectified (*i.e.* changed to D.C.), and applied to the precession coil on the gyro. The gyro is thereby precessed so as to synchronize the compass card and signal Selsyn rotor with the detector unit, *i.e.* the gyro unit card is maintained in alignment with the aircraft heading. The similarity between the detector unit signal Selsyn system and a signal generator type of Selsyn transmission can be followed by a study of Selsyn transmission as described in the previous chapter.

17. The basic principle of operation of the G. 4B is identical to that of the G. 4F, but the disposition of the units in the system differs because of the introduction of the master indicator. The signal from the detector unit is again fed to the stator of the signal Selsyn, which in this compass is located in the *master*

*indicator* with its rotor coupled to the master indicator pointer; thus any misalignment between this pointer and the magnetic heading of the aircraft causes a signal to be induced in the Selsyn rotor, and this signal, after passing through the amplifier, is applied to the precession coil of the gyro unit. To ensure that there is no discrepancy between the indications of the gyro unit compass card and master indicator pointer, data Selsyns in each of these units virtually interlock their indicating mechanisms.

### Summary of Basic Features

18. To summarize, the compass has the following basic features :—

- (a) It is a stable direction indicator under all conditions of air turbulence.
- (b) It is a north-sensing instrument without the disadvantages of northerly turning error and oscillation.
- (c) It does not drift, and is self-synchronous, and when synchronized gives non-ambiguous indications.

### Presentation of Compass Indications

19. The presentation of the gyro units in both the Mk. 4F and Mk. 4B compasses is identical. However, a D.G./compass selector switch is included in the top left-hand corner of the gyro unit of the Mk. 4F, whereas in the Mk. 4B this switch is mounted on a separate control panel.

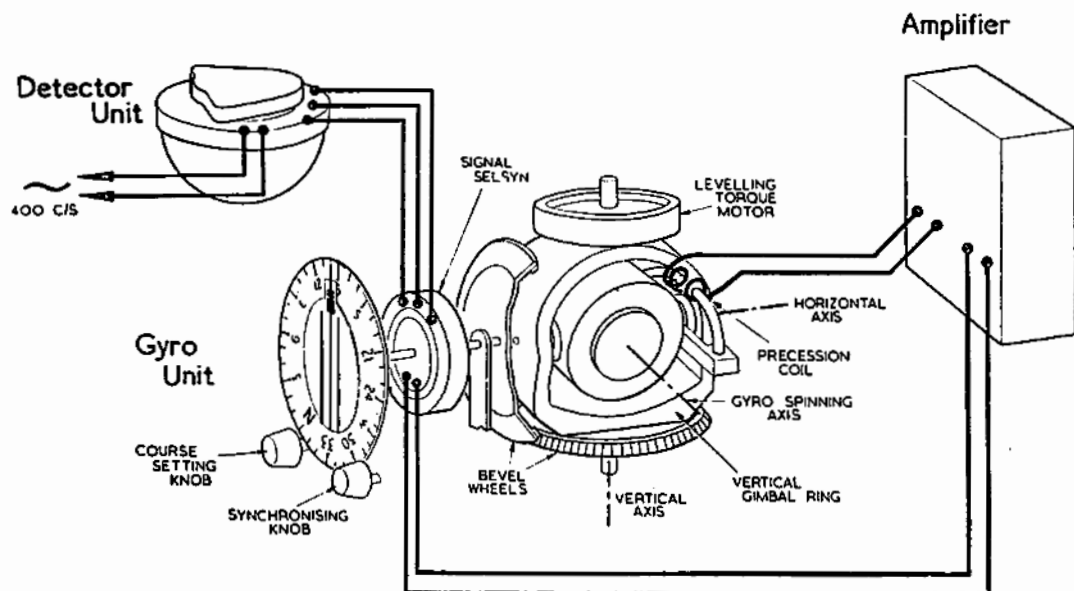


Fig. 3. Schematic Diagram of the Mk. 4F.

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20. The indication of aircraft heading is given to the pilot by a moving card presentation on the gyro unit. This is shown in Figs. 4 and 5.

21. The two parallel grid lines (Fig. 4) and the aircraft heading (inner) rectangle, are engraved and painted on the glass front of the instrument. The lubber mark is fixed to the instrument case. The course pointer and course rectangle are engraved and painted on a circular plate which is normally friction-loaded to the compass card, and therefore remains fixed in relation to the compass card. When the knob marked "SET COURSE" is pressed in and rotated, however, the plate carrying the course pointer and course rectangle is released from the compass card and rotates relative to it and to the instrument case.

22. In Fig. 4 the compass indicates the aircraft heading as  $330^{\circ}$  C, and a new course of  $045^{\circ}$  C selected. Aircraft heading is always indicated by the lubber mark against the compass card. The new heading of  $045^{\circ}$  C has been selected by the pilot using the SET COURSE knob, and is indicated by the course pointer. The two parallel grid lines and the inner rectangle enable the pilot to check accurately whether or not the aircraft is on the selected heading. To turn onto the new heading the aircraft is flown so that the heading rectangle aligns with the course rectangle. It is apparent that a turn to starboard is

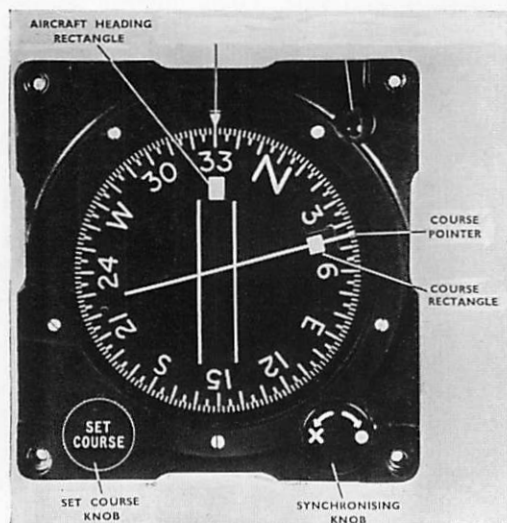


Fig. 4.

Compass Showing Aircraft Heading  $330^{\circ}$  and Course Pointer Set to New Course ( $045^{\circ}$ ).

necessary in this instance to bring the aircraft onto the new heading of  $045^{\circ}$  C, since the course rectangle is to starboard of the aircraft heading rectangle.

23. During the turn onto the new heading, the course pointer and course rectangle, being friction-loaded to the compass card, remain fixed in relation to the compass card. Fig. 5 shows the indications when the aircraft has reached the new heading of  $045^{\circ}$  C. The course rectangle is now opposite the aircraft heading rectangle, and this new heading can be held by reference to these two rectangles, which should be kept aligned. Any discrepancy can be corrected by manoeuvring the aircraft until the aircraft heading rectangle coincides again with the course rectangle. (Attention is drawn to A.M.O. A.161/53, Standard Terminology—Navigation Terms.)

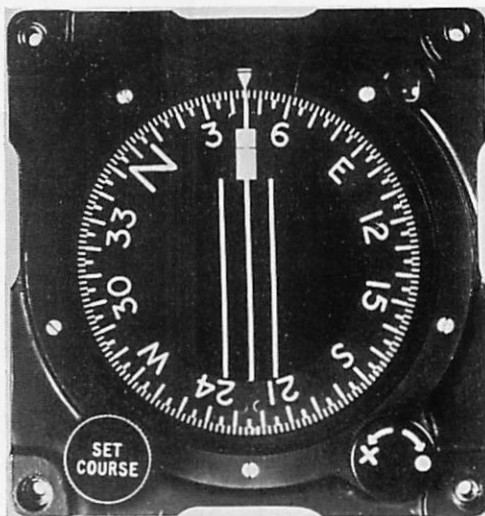


Fig. 5.

Compass Showing Aircraft Heading  $045^{\circ}$  after Turning onto New Course.

### Master Indicator

24. The navigator's master indicator (Fig. 6), which is only fitted to the Mk. 4B, is normally mounted on the navigator's instrument panel and provides a moving pointer indication.

### Annunciator

25. When the compass card indication is not synchronized to the aircraft heading, *i.e.* when the signal Selsyn rotor is not in line with the magnetic vector in its stator and thus not in line with the detector unit signal, the gyro is precessed by the application of a D.C. signal to

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the precession coil, as explained previously. A small indicator known as an annunciator is included in the gyro unit to show the pilot when the compass is not synchronized.

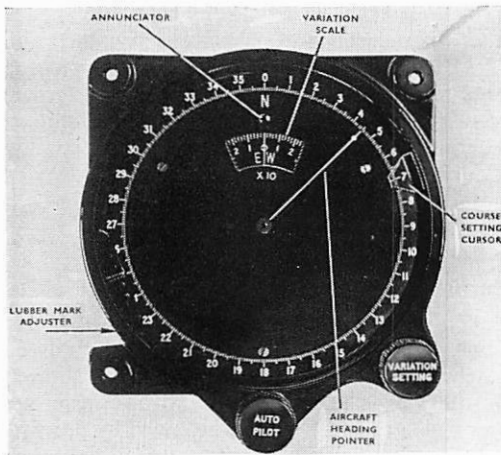


Fig. 6. Master Indicator (Mk. 4B only).

26. This annunciator (Fig. 7) consists of a small flag visible through a window in the top right-hand corner of the gyro unit face. The flag is marked with a dot and cross and is carried on one end of a pivoted staff, the other end of which carries a small permanent magnet. The magnet swings between two soft iron cores, each wound with a coil. These coils are connected to the precession coil on the gyro so that when the precession coil is energized, *i.e.* when the compass

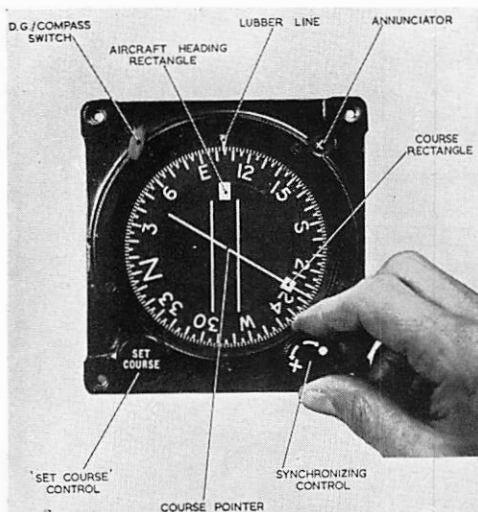


Fig. 7. Gyro Unit Synchronization Control Knob.

indication is not in synchronism, the annunciator's permanent magnet is attracted to one of the coils, causing either a dot or cross to appear in the window, depending on the direction of precession, *i.e.* the direction of misalignment. During flight, except under very smooth conditions, the pendulous element of the detector unit swings, and an alternating signal is transmitted. Thus either a dot or cross appears alternately in the annunciator window. The stability of the gyro is such that this fluctuating precessing signal is averaged out and a dead-beat indication is given by the compass card.

*Note:* After a prolonged turn the annunciator indication may be a steady dot or cross for a short period.

27. **Annunciator Indication in Jet Aircraft.** In jet aircraft the annunciator flag indication may *not* alternate, or may do so at a very slow rate. This is quite normal owing to the vibration-free location of the detector unit and the smooth flight characteristic of jet aircraft.

### D.G./Compass Selector Switch

28. Under certain operational conditions a directional gyro only may be required; therefore, as stated in para. 8, a switch is provided so that the detector unit monitoring signal may be switched off. When this switch is operated, "D.G." appears in the annunciator window instead of a dot or cross.

### Synchronizing Knob

29. Since the maximum rate of precession of the gyro to synchronize the compass card with the detector unit signal is arranged to be low (about 2°/minute), under certain circumstances, particularly when switching on, there would be considerable delay in the automatic synchronizing of the compass. The time would in fact depend on how many degrees the compass card was offset from the aircraft heading. To eliminate delay a manual synchronizing knob is fitted.

30. The synchronizing knob is located at the bottom right-hand corner of the gyro unit face (Fig. 7) and must be pushed in to cage the gyro. The knob shaft is spring-loaded outwards so that it cannot be left in the caged position.

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31. The effect of manually rotating the synchronizing knob is to synchronize the compass card indication with the aircraft heading. *On some instruments it is possible to rotate the compass card while the gyro is not properly caged. If this is done the gyro may be toppled. To prevent this happening it is important to press the knob fully home during synchronizing.*

32. Should the gyro topple, *e.g.* during aerobatics, the synchronizing knob should be pushed fully home to erect the gyro, which can then be used, immediately as a directional gyro. The compass should be re-synchronized as soon as level flight has been regained. It should not be synchronized during turns or linear accelerations, as the detector unit does not indicate the correct heading during these manoeuvres.

33. The synchronizing knob is marked with a dot and cross and corresponding arrows to indicate in which direction the knob is to be turned to synchronize the compass. When the annunciator window is showing a steady dot the knob should be turned in the dot direction and vice versa. If the knob is turned in the opposite direction from that indicated, the compass may appear to be synchronized when it is in fact indicating the reciprocal. When this occurs, the dot and cross do not alternate about the central position when the knob is pulled out, but either a steady dot or cross appears. A check against the stand-by compass reveals this error immediately.

### Deviation Corrector

34. The deviation corrector is mounted on top of the detector unit in place of the cover plate shown in Fig. 1. The general arrangement is shown in Fig. 8. Two pairs of two coils each are mounted in a horizontal plane at 90° to each other to correct for deviation coefficients B and C. The D.C. for these coils, which provide for a range of  $\pm 15^\circ$  compensation, is supplied from the 24-volt aircraft supply. Compass calibration instructions, including the elimination of coefficient A, are given in A.P. 1275B.

### PREPARATION FOR FLIGHT

#### Starting the Mk. 4F

35. To start the compass, the aircraft power supply and the compass switch should be switched on. Half a minute should be allowed for the valves in the equipment to warm up, after which the gyro should be caged by pressing in the setting knob. The knob should then be rotated in the direction indicated by the annunciator cross or dot until the cross and dot appear alternately or until the window is clear. The setting knob should then be released, after which the compass should indicate the correct magnetic heading. The cross and dot will also appear alternately if the gyro is aligned 180° out of phase with the magnetic detector, but when the gyro is uncaged only the cross or dot will appear

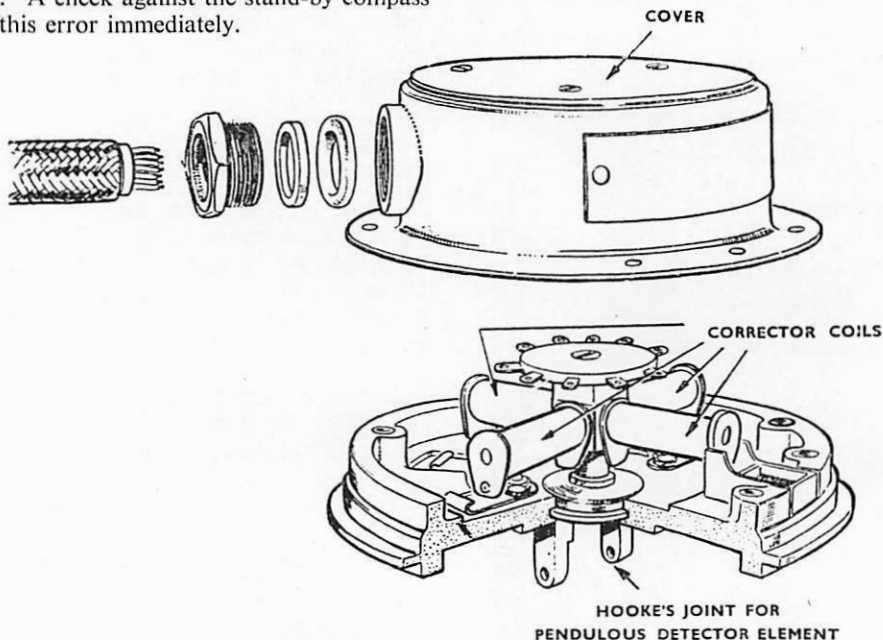


Fig. 8. Deviation Corrector.

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until without further adjustment the gyro comes into correct alignment. This takes a considerable time, however, and it is recommended that in these circumstances the gyro should be recaged and reset.

#### Starting the Mk. 4B

36. The Mk. 4B compass is started in the same way as the Mk. 4F, but if true headings are to be steered the required local variation must be set at the master indicator before starting up. The indicator(s) will then display true headings. If the variation control knob is set to zero the master indicator and compass card will indicate magnetic headings.

#### Pre-Flight Checking of Mk. 4 Compasses

37. The gyro motor windings and internal wiring of both Mk. 4B and Mk. 4F compasses may be damaged if an attempt is made to start them after failure of one of the protecting fuses.

38. This can be prevented by checking that the compass starts immediately when it is switched on, or, if no separate compass switch is fitted, that the compass starts when the engine is started. The check should be done as follows:—

- (a) Depress and turn the course-setting knob.
- (b) Check that the compass card does not rotate with the course-setting pointer.
- (c) If the compass card rotates with the course-setting pointer, it indicates that the gyro has not started. In this event the engine and/or compass should be switched off immediately and the cause of failure investigated.

#### Pilot's Serviceability Checks

39. When the compass has been synchronized the reading should be cross-checked with the stand-by compass. During turns on the ground and in the air the pilot should note that the compass card indicates the degree of turn in the correct sense.

#### OPERATING LIMITS

40. The gyro has 85° freedom in roll and pitch. If the gyro is toppled, or if the annunciator persistently inclines in one direction, the aircraft should be flown straight and level, and the indicator caged and reset until the annunciator is centralized.

#### MONITOR AND A.C. SUPPLY FAILURE

##### Magnetic Monitoring Failure

41. If the magnetic monitoring fails the compass can be used as a direction indicator by turning the D.G./compass selector switch to D.G.

##### A.C. Supply Failure

42. If the A.C. supply fails (a warning light or voltmeter is usually fitted to indicate this), a second inverter can then be selected by means of the A.C. change-over switch. On some installations the change-over takes place automatically. If this fails to re-establish the A.C. supply, a failure in the main D.C. supply circuit to the inverters is the probable cause and the D.C. change-over switch should be set to the alternative position to complete the stand-by D.C. circuit to the inverters.

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