PART 2: SECTION 5

CHAPTER 2

ARTIFICIAL HORIZONS

Mk. 3

1. The size, dial presentation, and operating principles of the Mk. 3 artificial horizon are basically similar to those of the air-driven Mk. 1B described in Section 1.

2. **Construction.** Constructional details are given in A.P. 1275A. From the pilot's viewpoint the salient feature is that when at rest the slightly pendulous gyro assembly assumes a position within 30° of its spinning attitude, thus ensuring rapid erection after starting up. Erection is achieved and maintained by mercury-operated levelling switches. The rotor spins at 22,000 r.p.m. clockwise (viewed from above).

3. **Power Supply and Consumption.** This instrument operates on 115 volts A.C., with a voltage tolerance of ±10 per cent., and consumes about 15 watts. Power is supplied through a D.C./A.C. inverter, the source being the aircraft main electrical system (D.C.). Many aircraft have an additional inverter with a manually controlled or automatic changeover switch to bring the second inverter into operation if the first should fail. A second changeover switch is sometimes incorporated to enable an alternative D.C. supply to be selected in the event of the fuse blowing in the normal circuit supplying the inverters.

4. **Compensation for Turning Errors.** Rate One turning errors at 220 knots are fully compensated. At other speeds and rates of turn errors of up to 15° may occur. Compensation is achieved by mounting the erection control switches so as to erect the rotor with its axis inclined 1·2° to starboard and 1·6° forward of the true vertical. The horizon bar setting is modified in such a manner that during level flight, when the rotor axis top is tilted as described, the instrument indicates level flight.

5. **Compensation for Acceleration Error.** During take-off, acceleration causes the mercury in the pitch erection control switch to apply a precessional torque which maintains precession at 5° per minute throughout the acceleration period in such a sense as to indicate a NOSE UP attitude. In other than high-performance aircraft this false nose-up indication is, however, unlikely to exceed 2½°, *i.e.* only slightly in excess of the horizon bar width during a normal take-off. Pendulosity causes a slight roll error to port, not exceeding 2°, during take-off. Correct indications are given after a time lag of the same duration as the acceleration period. In high-performance aircraft the horizon bar may become so displaced during take-off and overshooting as to render the instrument unsuitable for use during these manœuvres.

6. **Limitations.** The Mk. 3 artificial horizon is suitable for use at any cockpit temperature from −20°C. to +50°C. It has complete freedom in roll but is limited to 80° in climb and dive; if these limits are exceeded the gyro precesses from its datum reference position, and a few minutes in a normal flight attitude must be allowed before the instrument can again be used to give correct flight indications. The accuracy of the Mk. 3 artificial horizon is almost unaffected by high altitude since it is electrically operated.

7. **Operation.** During the initial erection period, after the power has been switched on, the horizon bar may be seen to oscillate slightly. This is quite normal and of brief duration.

> WARNING. If the horizon bar swings round in a random manner when the power is switched on there is a fault either in the power supply or in the connections, and the power must be switched off *immediately*, otherwise serious damage to the instrument will result.

The artificial horizon is installed so as to indicate level flight when the aircraft is in the level flight attitude. On the ground, therefore, the indications vary according to the ground attitude of the aircraft. If the aircraft has a tail wheel the horizon bar will assume a position below the miniature image aircraft, as though the aircraft were in a climb. If the aircraft has a nose-wheel undercarriage the horizon bar will be approximately in line with the miniature aeroplane. In tail-wheel aircraft with a ground attitude of about 15° nose up, the readiness time of the artificial horizon is 3 minutes; but in tail-wheel aircraft with a ground attitude of

5° or less, and in nose-wheel aircraft, the readiness time is 1½ to 2 minutes. The reason for the discrepancy between this time and that given in A.P. 1275A is that the latter is the time laid down in the Air Ministry specification as considered necessary for the gyro to pass the fine limits required under *calibration* conditions. If the operating limits are exceeded during flight, the gyro topples and up to 10 minutes may be necessary for complete re-erection.

8. **Pilot's Serviceability Checks.** Before flight, pilots should check that the horizon bar takes up a laterally level position in the correct pitch relationship to the image aircraft within the specified time limit and retains this position when the aircraft is turned during taxying. In the air, check that the artificial horizon gives an immediate and correct indication of any changes in the pitching and rolling attitude of the aircraft.

Mk. 3B

9. The Mk. 3B is basically similar to the Mk. 3 model, but the dial presentation and erection system have been improved, and a fast erection button embodied.

10. **Presentation.** The gull-wing presentation, of thinner wing section than the Mk. 3 image aircraft, permits the inner ends of the horizon bar to be seen. Coupled with the gull-wing presentation this permits greater accuracy of alignment of the image aircraft with the horizon bar. In addition, the wing sections of the gull image, which are at 30° and 45° to the horizontal when the instrument is indicating level flight, assist bank angle estimation. The bank angle pointer is larger than that of the Mk. 3 model and is reshaped to allow more accurate alignment with the zero bank graduation at the dial bottom centre.

11. **Erection System.** During a turn the centrifugal effect on the roll mercury switch and the gyro pendulosity cause the gyro to seek a false vertical. This effect is greatly reduced in the Mk. 3B model by a roll cut-out which operates automatically whenever the aircraft banks more than 10° in either direction. Operation of the cut-out disconnects the normal erection voltage supply to the roll erection system, thereby preventing the rotor axis from erecting to a false vertical. As the roll cut-out is fitted to this instrument, no tilt compensation for erection error is necessary, *i.e.* the gyro axis top is not tilted forward, and since the gyro assembly pendulosity is relatively low (for the reasons given in the following paragraph) the compensating tilt for pendulosity is only 0·6°. Thus during operation the gyro axis is more nearly vertical than that of the Mk. 3. Owing to the function of the roll cut-out, no roll erection occurs if the instrument is switched on when the bank pointer is more than 10° from the vertical *unless the fast erection button is pressed.* The Mk. 3B is affected by acceleration to the same extent as the Mk. 3.

12. **Fast Erection Button.** A push-button switch marked "Fast Erection—PUSH" is fitted at the bottom left-hand corner of the dial. Operation of this switch increases the erection rate from 5°/minute to 180°/minute and bypasses the roll cut-out switch, restoring the roll erection voltage supply whenever this has been terminated by the roll cut-out. If the bank pointer is more than 10° from the vertical at the time of starting it is essential to bypass the roll cut-out switch by using the fast erection button *otherwise the gyro will not erect at all.* It is important to note that, although the fast erection button will erect the instrument, the gyro readiness time (see para. 7) must be allowed to elapse before reliable indications are given. When the fast erection button is used it must be released as soon as the horizon has erected; if the button is held in for longer than necessary, arcing occurs across the erection switch and damages the instrument. After the instrument power supply has been switched on, the fast erection button must not be used *until* 10 *seconds have elapsed,* otherwise the horizon bar will oscillate violently and damage the instrument. If the instrument is toppled during flight the fast erection button may be used to re-erect the gyro. *During flight the fast erection button must only be used in unaccelerated level flight, otherwise the horizon bar will erect to give a false indication of level flight.* Less pendulosity of the gyro is needed when a fast erection button is fitted, therefore the turning and acceleration errors are reduced.

13. **Operation and Pilot's Serviceability Checks.** Paras. 7 and 8 may be taken as applying to the Mk. 3B instrument, except that the time required for initial erection may be reduced by operating the fast erection button. The readiness times for aircraft having different ground attitudes remain the same as stated in para. 7.

Mk. 3C

14. This model is similar to the Mk. 3B except that a power failure indicator is embodied. This indicator is in the form of a flag with a fluorized "OFF" marking, which is out of sight during normal operation. When the flag appears the instrument has been switched off or the power has failed.

Mk. 4 Series

15. The Mk. 4 artificial horizon, which has a power failure indicator and a fast erection button, is of similar presentation to the Mk. 3C but embodies certain improvements.

16. **Construction.** Constructional details are given in A.P. 1275A. The salient pilot-interest features are the interconnection of the pitch and roll mercury switches, and in the later models in this series the automatic temporary provision of an above-normal initial voltage to build up the rotor speed quickly after switching on. The rotor spins at 23,000 r.p.m. clockwise (viewed from above) and the instrument case is sealed to exclude dust and moisture.

17. **Power Requirement and Consumption.** Mk. 4 series artificial horizons operate on 115 volts A.C. with a voltage tolerance of $\pm$10 per cent. and consume 12 watts.

18. **Turning and Acceleration Errors.** The erection system, known as the "pitch bank" system, has a cross-connection between the pitch and roll mercury switches which functions automatically during turns involving bank of over 10°. The cross-connection transfers the control of the roll axis torque motor to the pitch axis switch during turns, greatly reducing turn errors. A pitch cut-out which operates automatically during take-off and other forward accelerations virtually eliminates acceleration errors.

19. **Limitations.** The Mk. 4 artificial horizon operates efficiently at cockpit temperatures from -55°C. to $+70$°C. It has complete freedom in roll but is limited to 85° in climb and dive. The accuracy of this instrument is unaffected by high altitude since it is electrically operated.

20. **Operation.** If the bank pointer is less than 10° from the vertical when the power is switched on, the gyro will erect within not more than 20 seconds. As for the Mks. 3B and 3C, if the bank pointer is more than 10° from the vertical at the time of switching on, the fast erection button must be pressed, *otherwise the gyro will not erect at all ;* however, the button should not be used until ten seconds after switching on. The button must be released as soon as the instrument has erected; if held in for longer than necessary, arcing across the erection switch will damage the instrument. If the fast erection button is operated before ten seconds have elapsed after switching on, violent horizon bar oscillations occur and may damage the instrument. Although initial *erection* occurs rapidly, rotor speed is not high enough to give reliable indications until $1\frac{1}{2}$ minutes after starting up, but on later models, on which the initial voltage supply is boosted, reliable indications are obtained 20 seconds after switching on. *During flight the fast erection button must only be used in unaccelerated level flight, otherwise the horizon bar will erect so as to give a false indication of level flight.*

21. **Pilot's Serviceability Checks.** The pilot's serviceability checks for the Mk. 4 artificial horizons are as detailed in para. 8.