Part 8 Aircraft Instruments

Leaflet 8-1 Compass Base Surveying

1 Introduction

In carrying out a swinging procedure for direct-reading and remote-reading compasses, the primary object is to determine the deviations caused by the magnetic field components of an aircraft. It is, therefore, necessary for swinging to be undertaken at a location where only these aircraft field components and the earth's magnetic field can affect the readings of compasses. The location must be carefully chosen and surveyed to prove that it is free from any interfering local magnetic fields and also to establish it as the base on which all aspects of swinging procedures are to be carried out. The effect of interfering fields is to cause distortion of the direction and intensity of the earth's field. The effects on direction are the most critical and therefore, it is necessary for these to be determined during a survey. Any significant effects on the horizontal intensity will be detected as a change in direction, if suitable procedures are employed. The purpose of this Leaflet is to outline the basic requirements of a compass base, to define the accepted base classifications and also to outline the procedures which may be adopted for surveying selected locations.

1.1 The CAA does not carry out surveys or approve compass bases, but its interest in surveying procedures lies in the fact that the accuracy of a base is a significant factor in meeting British Civil Airworthiness Requirements relevant to the overall accuracy of compasses installed in aircraft. Surveys may be carried out by an operator or by an airport authority and in this connection, the standards set by QinetiQ, formerly the Ministry of Defence agency Defence Evaluation & Research (DERA), are recognised by the CAA. QinetiQ has the responsibility under the MoD's Long Term Partnering Agreement for surveying compass bases for military aircraft world wide, where the UK MoD have an interest, in addition to this QinetiQ also provides a technical and scientific advisory service to the MoD on all aspects of compass bases and compass calibration and testing. All aspects of these services can be commercially contracted by airline operators and airport authorities by contacting QinetiQ:

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2 Base Requirements

A compass base must meet the following minimum requirements:

a) It must be accessible, reasonably level in all directions and its use should not interfere with normal aircraft movements on the airport.

b) It must be free from magnetic fields, other than that of the earth, which might cause aircraft compass errors. Most surface causes of errors are obvious, i.e. buildings and installations containing ferromagnetic components such as wire fences, drain and duct covers, picket points and lighting installations. The most likely underground causes of magnetic interference are:

   i) Buried scrap metal and old brickwork.

   ii) Reinforced concrete.

   iii) Pipelines including drainage systems.

   iv) Magnetic soil and rocks.

   v) Electrical cables, conduits and airfield lighting transformers.

   vi) Ferromagnetic pipes.

   If such items are found at the selected location they should be removed if possible. Even though the area may be within permitted maximum limits of deviation (see paragraph 3) it is recommended that any ferromagnetic material present should still be removed as its magnetic effect may change with time and thereby down-grade the accuracy of the base. Where electrical cables cannot be avoided, their effects, with and without current flowing, must be checked at intervals along their length, especially around known joints. If a new base is being manufactured great care must be taken to ensure that the area is not magnetically contaminated after survey and during manufacture. Steel reinforcing must obviously be avoided and any aggregate or hardcore used in the foundations must not be magnetic or contain magnetic items such as steel wire or drums, bricks, boiler clinker, blast furnace slag or magnetic rock. All steel shuttering and associated pins used when laying concrete must be removed. On completion of all work a full survey must be repeated.

c) A base should be sited so that its datum circle (see paragraph 2 f) iii)) is at least 46 metres (50 yards) away from hangars and other steel-framed buildings and at least 91 metres (100 yards) away from buildings containing electrical power generation and distribution equipment and also from overhead or underground power cables.

NOTE: Proposed building programmes should be examined to ensure that the site is not scheduled for other work.

d) A base must be large enough and of such load-bearing strength as to take all types of aircraft for which it is likely to be used. In this connection, some important factors to be considered are:

   i) Whether an aircraft will be towed or taxied during the swing.

   ii) The radii of the turning circles of the aircraft.

   iii) The position of sighting rods and target fixtures on the aircraft and their likely path during the swing.

   iv) The likely positions of flux detector units of remote-reading compass systems.

e) The surface of the base should not preclude its use in wet weather.

f) The base should be clearly and permanently marked to show:

i) The base centre.

ii) The central area in which a direct-reading compass, or flux detector unit of a remote-reading compass system, should remain during the swing.

iii) The datum compass circle, i.e. the circle around the central area showing where the datum compass should be placed.

iv) Areas of magnetic anomalies which cannot be removed.

v) Nose wheel turning circles.

vi) If the base is to be used for carrying out 'electrical' swings a North-South line should be painted on the base, together with markings to indicate the locations of the compass calibrator monitor and turntable and the bearing of the reference target used when sighting the monitor (see also paragraph 5.6).

NOTE: Paint is the best medium for marking concrete. The datum compass circle, which may be on grass, must be marked permanently with a narrow continuous path of non-magnetic material such as tarmac or gravel.

3 Base Classifications

Compass bases may be established as either Class 1 or Class 2, the difference between them being only in the limits of permitted maximum deviation to be found anywhere within the base area as follows:

a) **Class 1.** The maximum permissible deviation is ±0·1°. Bases of this accuracy are required for carrying out refined swings, e.g. swinging of aircraft in which remote-reading compasses are used as magnetic heading reference systems, in conjunction with such equipment as Doppler Systems.

b) **Class 2.** The maximum permissible deviation is ± 0·25°. Bases of this accuracy are suitable for carrying out standard swings, e.g. swinging of aircraft in which the primary heading reference is provided by a remote-reading compass system, with a direct-reading compass serving as a standby.

NOTE: A location, the permissible deviation of which is greater than ±0·25° may be used where a direct-reading compass is used as the primary heading reference (see paragraph 5.5).

4 Types of Survey

The following types of survey are normally carried out to assess the suitability of a location at which a compass base is to be finally established:

a) **Initial Survey.** This is the first assessment survey of a location to determine gross errors and should be carried out by the aircraft operator or airport authority but, where appropriate, it is recommended that the certified services of QinetiQ be contracted (see paragraph 1.1). If the deviations obtained appear to be within the permissible limits laid down for Class 1 and Class 2 bases there is justification for carrying out an establishment survey.

b) **Establishment Survey.** This survey is of a more detailed nature in that measurements are taken at a greater number of more closely spaced points. The survey may also be carried out by the aircraft operator or airport authority, but, where appropriate, it is recommended that the certified services of QinetiQ be contracted (see paragraph 1.1).

c) **Periodic Re-survey.** After a base has been established a detailed re-survey must be carried out at the following intervals, in order not to compromise QinetiQ:

i) Class 1, every 5 years.

ii) Class 2, every 2 years. In addition, bases of this accuracy should, where possible, be surveyed by QinetiQ every 6 years.

d) **Annual Check.** All bases should be checked annually to ensure that markings and boundaries are clearly defined and that no work has been done which might affect their magnetic properties and also to take into account changes in magnetic variation. If any doubt exists, the suspect area should be given a detailed magnetic survey.

e) **Area Survey.** An area survey (see paragraph 5.6) is normally confined to the selection of a location which is to be used for carrying out a more specialised form of compass calibration procedure known as an 'electrical' swing.

5 Survey Methods

There are two principal methods which may be adopted for the surveying of a compass base:

a) the reciprocal bearing method (see paragraph 5.3), and

b) the distant bearing method (see paragraph 5.4). In both methods, the use of accurate magnetic bearing compasses of either the medium landing type or the high-precision datum type will be required to determine the effects of interference from local magnetic fields. There is also a third surveying method (see paragraph 5.5), but being of a lower order of accuracy its adoption should be strictly limited. For the area survey referred to in paragraph 4 e) units of a specially designed compass calibrator set are used (see paragraph 5.6).

5.1 Checking and Correction of Survey Instruments

Before carrying out a survey the appropriate survey instrument(s) should be given the full serviceability checks prescribed in the relevant operating manual, paying particular attention to checks which affect the repeatability of readings, e.g. pivot friction. Reference should also be made to any associated instrument test certificates to ascertain any instrument errors requiring correction. When the reciprocal bearing method (see paragraph 5.3) is used, bearings should be taken on a distant object with both compasses to establish a correction which can be applied to every reading taken from one of the compasses.

5.2 Positioning of Survey Instruments

In order that the deviation limits of a chosen location may be accurately assessed for base classification purposes from an establishment survey, the survey instrument(s) should be set up at close regular intervals, e.g. every 6 metres (20 feet), to cover the area quadrant by quadrant. The instrument(s) should be at the maximum height of its tripod which is approximately 1·5 metres (5 feet). In most types of aircraft, direct-reading compasses and flux detector units of remote-reading compasses are above this height. If a base is also to be used for an aircraft the compasses and detector units of which are below 1·5 metres (5 feet), assessment should then be made closer to the ground.

NOTE: At certain stages of an area survey procedure, assessments are made with the tripod set at both minimum and maximum heights (see paragraph 5.6).

5.3 **Reciprocal Bearing Method**

This method is the most accurate and may be adopted for an initial assessment survey, a detailed establishment survey and a periodic re-survey. It requires the use of two precision datum compasses, one being designated the master compass and the other the mobile compass. The procedure is as follows:

a) Following the checks for serviceability, both compasses should be aligned to a common magnetic datum. This is done by setting them up, in turn, on a tripod positioned as near to the anticipated centre of the base as is practical and sighting the compass on a distant object and noting, for each compass, the average of several determinations of the magnetic bearing. This produces the correction referred to in paragraph 5.1 which is subsequently applied to the readings of the mobile compass. Frequent checks on the accuracy of this correction should be made throughout the subsequent stages of the survey procedure.

b) The master compass and tripod should be kept in its original position and the mobile compass and its tripod should be positioned at various points around the area to give good coverage (see paragraph 5.2). At each point, the two compasses are aligned on each other's sighting telescope object lenses.

c) When the compasses are aligned, bearings should be taken from the bearing plates of the compasses and the magnetic deviation between the two compass positions should be obtained by taking the difference between bearing plate readings and subtracting 180°. The sign convention used for the deviation is that, if the reading of the mobile compass is greater than that of the master compass, the deviation is negative. Conversely, the deviation is positive if the master compass reading is greater than that of the mobile compass.

d) The deviations should be recorded on an observation log, which should take the form of a scaled diagram of the area. The positions of any objects in the area such as drains, cable duct covers, lights, picketing points, etc., should also be indicated on the log. Areas in which deviations are in excess of the limits permitted by the appropriate base classification, should be investigated and, where possible, the source of magnetic interference should be eliminated. Where magnetic interference cannot be eliminated the area should also be indicated on the observation log as a prohibited area, i.e. an area which must be avoided when positioning an aircraft and datum compass for the purpose of swinging.

e) Care should be taken to ensure that there are no obvious magnetic objects near the chosen centre of the base. If the deviations are such that their mean is more than half the deviation limits for the class of base being surveyed, it should be assumed that there is a buried object near the base centre.

5.4 **Distant Bearing Method**

This method should be used only for initial surveys and for gross error checks of Class 2 bases carried out because of doubts raised during annual checks. The procedure to be adopted is as follows:

a) Select a distant object at least 2 nautical miles away and accurately locate its position and the position of the compass base on a larger scale map and measure the distance between them. Mark the line of sight from the centre of the compass base to the distant object.

b) Calculate the angular correction to be applied to bearings taken away from the base centre using the formula:

$$\text{Correction Angle} = \frac{\text{Lateral distance from line of sight} \times 180}{\text{Distance to the object} \times \pi} \text{ Degrees}$$

c) After ensuring that there are no objects in the area of the base centre likely to have a magnetic influence, the bearing compass, which may be of the medium landing type or precision datum type, should be set up and a datum bearing obtained by measuring the bearing of the distant object.

d) Take bearings of the distant object from selected points around the base area and after applying the calculated corrections, compare the bearings with the datum bearing. Any difference obtained will be due to deviations present, assuming that the base centre is free from deviation. The deviations should be recorded on an observation log (see paragraph 5.3 d)).

5.5 **Surveying Pole Method**

This method is simpler than those already described and requires the use of two poles similar to those used by a land surveyor and in addition, a medium landing compass. Its survey accuracy is, however, of a lower order, principally because it does not utilise magnetic bearings of distant objects as a datum. The use of this method should, therefore, be restricted to the surveying of locations at which deviation limits outside those permitted under Class 1 or Class 2 (see paragraph 3) are acceptable; for example, a location for swinging aircraft using direct-reading compasses as the primary heading reference. It may also be used in such cases as the initial assessment of gross errors prior to a detailed establishment survey of a base and where, in the absence of an established Class 1 or Class 2 base or more accurate surveying equipment, a swing is necessary to enable an aircraft to undertake a positioning flight. The procedure for carrying out this method is as follows:

a) One surveying pole should be placed in the centre of the area chosen and the medium landing compass should be positioned and levelled 9.1 metres (30 feet) to the south of the pole. A plumb bob should be suspended from the centre of the compass to the ground and the sighting device should be set to read due North. The second pole should be positioned 9.1 metres (30 feet) to the North of the centre pole, so that, when viewed with the compass sights as set, the two poles are in alignment.

b) The plumb bob position should be marked with a peg or a painted mark and the position of the second pole and the compass should be interchanged. The compass reading with the poles as now positioned should be checked and should be within ±1° of the reciprocal of the initial reading.

c) A further check should be made by moving and sighting the compass along a line between the North and South points already obtained, taking at least four readings at approximately equidistant intervals. The compass should not deviate by more than 1° from the original reading at any position.

d) The same procedure outlined in paragraphs a), b) and c) should be followed for determining the East and West positions.

e) The geometric location of the cardinal points should be proved by checking the chord distances between the points, as indicated by pegs or painted marks. If they are equal then the North-South and East-West lines are at right angles. In any case, the measurements should agree within ±76 millimetres (3 inches).

f) The whole of the foregoing procedure should be followed for determining deviations in the inter-cardinal areas and in the area around which the compass is to be positioned during the swinging procedure.

5.6 **Area Survey**

This survey is carried out using the monitor and console control units of a compass calibrator set which is also designed for the 'electrical' swinging of remote-reading compass systems. In this type of survey the principal objectives are

a) to determine the direction and strength of the earth's magnetic field at the locations of aircraft flux detector units (detector unit location check);

b) to select the point at which the compass calibrator monitor unit should be located in order to carry out an 'electrical' swing (monitor location check), and

c) to mark out the monitor and turntable location points and also a North-South line over which an aircraft must be positioned during a swing. The full setting-up procedures and operating instructions are detailed in the calibrator operating manual and reference to this document should, therefore, always be made. The information given in the following paragraphs is for general guidance only.

5.6.1 **Detector Unit Location Check**

The purpose of this check is to determine the uniformity not only of direction, but also the strength of the earth's field at points of the compass base which will correspond to the locations of detector units, e.g. in the vertical stabiliser, or wing tips of an aircraft. The strength of field is determined in order to obtain certain voltage values which must be set up in the calibrator control console unit, during an 'electrical' swing procedure, to simulate the earth's field. The monitor and console control units are electrically interconnected by the appropriate cables and are set up within 3 to 4·6 metres (10 to 15 feet) of each other. Magnetic direction and strength is measured in both the vertical and horizontal planes.

a) Measurements in the vertical plane are taken with the monitor mounted on its tripod, adjusted firstly to the minimum height position and then to the maximum height position. Direction is determined in each position of the tripod by setting the monitor on each of the four cardinal headings and noting the difference between these headings and the headings recorded on the control console unit. The average of the errors (the algebraic sum divided by four) is recorded as the monitor index error. The difference between the index errors at the minimum and maximum height positions is then calculated. If the difference exceeds the specified value (6 minutes is a typical value) the area surveyed is unsuitable. Field strength is determined at the minimum and maximum height positions of the monitor tripod, by setting the monitor to a heading of zero degrees and obtaining voltage values from settings made on the control unit.

b) Measurements in the horizontal plane are carried out to determine the uniformity of the earth's field direction and strength over a circle of 1·5 metres (5 feet) radius, the centre of which is at the location of the flux detector unit on the aircraft. The readings are taken at the centre of the circle with the monitor tripod at its normal operating height and with the monitor set, in turn, on each of the four cardinal headings. The differences between monitor and control console unit headings are then noted and a monitor index error obtained in the same manner as that described in a). Readings are then taken on the cardinal headings with the monitor and tripod positioned, in turn, at four equidistant points on the perimeter of the circle and corresponding monitor index errors are obtained. The algebraic difference between these errors and the index error at the centre of the circle is then calculated and should be within the limits ±6 minutes. Field strength is determined by setting the monitor to a heading of zero degrees and obtaining voltage values with the monitor at the centre of the circle and at the four equidistant points on its perimeter.

5.6.2 **Monitor Location Check**

The purpose of this check is to select the location for the monitor in order to measure the earth's field during the 'electrical' swinging procedure. The location selected should be such that with an aircraft positioned on the base, the monitor readings will not be influenced by magnetic effects of the aircraft itself. A distance of 23 to 30 metres (75 to 100 feet) is normally sufficient. The direction and strength of the earth's field is determined at the selected location and corresponding monitor index error and voltage values, calculated. The bearing of a reference target at least 800m (one-half mile) distant from the location is also obtained. As this target is to be used during a compass swing it should be ensured that it will be visible from the monitor location when an aircraft is positioned on the base. The suitability of the selected monitor location is then determined by re-positioning the monitor at the flux detector unit location and measuring the direction and strength of the earth's field and then calculating the algebraic difference between values at each location. The readings at each location should be taken within a time of 30 minutes of each other to lessen the possibility of a change in the earth's field.

5.6.3 **Marking of Base**

On completion of the foregoing checks, markings must be permanently set out on the base to indicate the following:

a) **Location of Flux Detector Units.** For aircraft the flux detector units of which are installed in the vertical stabiliser, the marking is made on the North-South line (see c)) and for aircraft the flux detector units of which are installed in each wing tip, the markings are made each side of the North-South line at distances corresponding to those from the aircraft centre line.

b) **Location of Monitor.** In addition to this marking, the bearing of the reference target used during the survey should also be marked at the monitor location.

c) **North-South Line.** This line should be marked out from a point which is used as a reference in determining the flux detector unit location. The monitor is set up over this point and by lowering the monitor telescope so that its graticules are observed against the base, several other points are marked out; firstly, with the monitor on a corrected zero degree heading and then on a heading of 180° degrees. The points are then joined by a painted line.

Leaflet 8-2 Compasses

1 Introduction

This Leaflet gives general guidance on the installation of compasses which are used as either primary or standby heading indicators, and also on the methods of compensating for deviation errors. Brief details of the operating principle of compasses are also included, but as there are so many variations in application to systems in current use such details are only of a fundamental nature. It should be read in conjunction with Leaflet 8–1 Compass Base Surveying, relevant compass and aircraft Maintenance Manuals, and approved Maintenance Schedules.

1.1 **Contents**

Paragraph

1.2 Deviation is the angular difference between magnetic and compass headings, and is caused by magnetic influences in or near the aircraft. It is called Easterly (positive deviation) or Westerly (negative deviation) dependent on whether the North-seeking end of the magnet system is deflected to the East or the West of the magnetic meridian.

1.3 The technique of deviation compensation is known as 'swinging' and consists of:

a) observing the relevant compass system indicator readings on different headings of the aircraft,

b) calculating the deviation errors and determining coefficients,

c) neutralising the aircraft's magnetic fields by adjustment of compensator devices, and

d) recording any residual deviations on a deviation or 'Steer-by' card.

NOTE: This Leaflet describes one of the methods used for swinging, calculating deviations and applying corrections. There are other procedures in use which adopt different calculation sequences.

2 Direct Reading Compasses

There are two types in use, the card type and the grid-steering type. The major differences between the two are in the magnet system arrangement, the method of heading presentation and the arrangement of the deviation compensator devices.

2.1 Card type compasses, which are designed for mounting on an instrument panel or on a coaming panel, indicate magnetic headings by means of a graduated card affixed to the magnet system and registering against a lubber line in the front of the bowl. The deviation compensator device is usually secured directly to the compass bowl.

2.2 Grid steering type compasses, employ a needle and filament type magnet system which is referenced against a grid-ring located over the compass bowl. The grid-ring, which may be rotated and clamped in any position, has a graduated scale and two pairs of parallel grid wires in the form of an open T. Magnetic headings are indicated by the number of degrees read against a lubber line in the compass bowl, when the needle and filaments lie parallel to the grid wires, and the North-seeking filament points to the North mark on the grid ring. These compasses may be designed for mounting on a bracket below an instrument panel or for inverted mounting in a cockpit roof. In the latter case, heading indications are observed by means of a mirror attachment. Deviation compensator devices are normally separate and are mounted on the compass supporting bracket.

3 Compass Errors and Methods of Compensation of Direct Reading Compasses

In connection with the compensation of direct-reading compasses, the following principal errors have to be taken into account:

a) **Index Error.** This error, which is also known as Coefficient 'A' error, results from misalignment of a compass in its mounting and has the same magnitude on **All Headings**. The error is calculated by averaging the algebraic sum of the deviations on each of the cardinal and quadrantal headings. Compensation is effected by rotating the compass in its mounting through the number of degrees calculated, and relative to the longitudinal axis of the aircraft.

b) **One-cycle Errors.** These refer to the deviations produced in compass readings as a result of the effects of components of permanent or hard-iron magnetism of the aircraft's structure. The deviations vary as sine or cosine functions of the aircraft's heading, the maximum deviations being termed Coefficients 'B' and 'C' respectively. Other sources of these errors are components of soft-iron magnetism induced by the earth's field, the hard iron itself, and the effects of electric currents from cables or equipment which may be mounted in the vicinity of the compass.

The Coefficient 'B' error is calculated by averaging the algebraic difference of the deviations on the East and West headings, while the Coefficient 'C' error is calculated by averaging the algebraic difference of deviations on the North and South headings. Compensation is effected by a permanent magnet type compensator unit, which, depending on the type of compass, is either secured direct to the compass bowl or is mounted separately on the compass support bracket. The unit contains two pairs of magnets, the axes of which are so disposed that their fields neutralise the effects of the magnetic components producing 'B' and 'C' deviations. Each pair of magnets can be rotated by a shaft provided with either a screwdriver slot or a shaped end requiring the use of a key.

4 Remote-Reading Compass Systems

The principal component of any system is a flux detector unit, sometimes called a flux valve or fluxgate. It is located in an area relatively free from any disturbing magnetic fields of the aircraft itself (e.g. a wing tip or vertical stabiliser) so that the horizontal component of the earth’s magnetic field can be more accurately detected by the sensing element within the unit. The sensing element forms part of a synchro type of transmission system which, in most compasses, is coupled to a horizontal-axis directional gyro contained within either a heading display indicator mounted on the main instrument panel, or a master gyro unit from which heading data is transmitted to a separate indicator. In some aircraft using an inertial navigation system, the flux detector sensing element is connected to a compass coupler unit instead of a directional gyro, the purpose of the unit being to develop a stabilised magnetic heading reference from both sensing element and inertial navigation system signals. The sensing element is pendulously suspended in such a way that it has a limited amount of freedom in the pitching and rolling planes, but has no freedom in the yawing plane. In one currently used system the element is stabilised by a vertical gyro.

4.1 The sensing element is made up of material having high magnetic permeability wound with an exciter or primary coil and three pick-off or secondary coils. The exciter coil is supplied with a low-voltage single-phase a.c. at a constant frequency (typical values are 26 V, 400 Hz) and this produces an alternating flux in the sensing element material. In addition to this flux, the horizontal component of the earth’s magnetic field is also introduced; its effect being to change the total flux cutting the pick-off coils in such a manner that an e.m.f. is induced in them which, in terms of amplitude and phase, represents the magnetic heading.

4.1.1 The induced e.m.f. causes current to flow to the stator windings of a receiver synchro within either the display indicator, master gyro unit or compass coupler, as appropriate, and a field is set up across the stator in a direction determined by the current flow in windings. If the detector sensing element and receiver synchro are in synchronism, the synchro rotor is in its 'null' position and no signal voltage is induced in its winding by the stator field cutting it. When a change in aircraft heading takes place, however, the position of the detector sensing element with respect to the earth’s field also changes with the result that the current flow in the receiver synchro stator changes, causing the stator field to rotate. This, in effect, is the same as a rotor displacement from the 'null' position, and although the rotor itself always tends to rotate with the stator field it is restrained momentarily by the mechanical coupling between it and the gyro. Thus, an error voltage is induced in the rotor winding; the phase and amplitude of which being dependent on the direction and magnitude of displacement of the rotor from the 'null' position. The voltage is fed to an amplifier and finally to a slaving system which produces a torque to precess the gyro and its indicating element to indicate the heading change. At the same time, the synchro rotor rotates in synchronism with the stator field.

5 Compass Errors and Methods of Compensation of Remote Reading Compass

In connection with the swinging and compensation of remote-reading compasses, the following principal errors have to be taken into account:

5.1 **Index Error**

This error, which is also known as Coefficient 'A' error, results from misalignment of the flux detector unit and has the same magnitude on All Headings. The error is calculated by averaging the algebraic sum of the deviations on each of the cardinal and quadrantal headings.

5.2 **One-cycle Errors**

These refer to deviations produced in compass readings as a result of the effects of components of permanent or hard-iron magnetism of the aircraft's structure. The deviations vary as sine or cosine functions of the aircraft's heading, the maximum deviations being termed Coefficients 'B' and 'C' respectively. Other sources of these errors are, components of soft-iron magnetism induced by the earth's field, the hard iron itself, and electric currents from cables or equipment which may be mounted in the vicinity of the flux detector unit. The error due to Coefficient 'B' is calculated by averaging the algebraic difference of the deviations on the East and West headings, while the Coefficient 'C' error is calculated by averaging the algebraic difference of deviations on the North and South headings.

5.3 **Two-cycle Errors**

These errors result from imperfections in the transmission of heading data and are usually referred to as transmission errors. They can be caused by impedance or voltage unbalance in the flux detector sensing element or in the synchros of the compass system. Another source of two-cycle error is soft-iron magnetism.

5.4 **Crosstalk Errors**

These errors occur particularly during an 'electrical' swinging procedure (see paragraph 13.2) when the d.c. signals simulating the earth's field are applied. They are caused by different sensitivities of the flux detector unit coils and by unequal air gaps separating the flux collector horns; the overall effect being to produce quadrature components which offset the field from that originally intended.

5.5 **Methods of Compensation**

Typical methods of compensating errors are described in the following paragraphs:

a) **Index Error Compensation.** The error to be compensated is calculated from the Coefficient 'A' formula (see 5.1). In the most commonly used method, compensation is effected by rotating the flux detector unit in its mounting through the number of degrees so calculated, relative to a datum parallel to the longitudinal axis of the aircraft. The flux detector unit is rotated clockwise (when viewed from above) for a +A error and anti-clockwise for a -A error. In some compass systems the flux detector is first aligned with the centreline of the aircraft, and the 'A' error is removed by providing an electrical differential by means of a differential synchro between the flux detector unit and its synchro.

b) **One-cycle Error Compensation.** The errors to be compensated are calculated from the Coefficient 'B' and Coefficient 'C' formulae (see 5.2). Depending on the type of compass system installed, compensation may be effected by one of the methods described in i) and ii):

i) **Mechanical Methods.** In several types of compass systems, a permanent magnet type compensator unit secured to the top of the flux detector unit. The compensator contains two pairs of magnets, the axes of which are so disposed that their fields neutralise the effects of the magnetic components producing 'B' and 'C' deviations. Each pair of magnets can be rotated by a shaft containing a screwdriver slot, and associated gearing. In one particular type of compass system, mechanical compensation is effected by screws, a metal cam and cam follower; the complete device being incorporated within the compass indicator. For details of this method of compensation reference should be made to the relevant Maintenance Manuals.

ii) **Electrical Methods.** Electrical compensation is normally effected by a compensator unit connected to, and located remote from, the flux detector unit. A compensator unit contains two adjustable potentiometers, one for each coefficient. Depending on the compass system installed, the potentiometers can be adjusted to vary either the electromagnetic fields produced in two coils mounted on top of the detector unit, or they can be adjusted to produce the correcting electromagnetic field within the flux detector pick-off coils, by supplying direct current to the coils themselves. In this latter case, the coils have the dual and simultaneous function of picking-off voltages resulting from heading changes and of deviation compensation. In certain types of compensator unit, test points are provided to permit measurement of the d.c. voltages across the two potentiometers.

5.6 **Crosstalk Error Compensation**

Compensation is effected during an 'electrical' swing procedure, by applying d.c. signals to the flux detector unit coils and generating fields which oppose the quadrature components in the North-South and East-West directions.

6 Compass Location

The location of a compass or detector unit in an aircraft is important and factors such as angle of observation, illumination, vibration, and in particular, the effect of magnetic disturbances, require careful consideration. The location is determined during the aircraft's design stage and should not be altered unless authorised by the Airworthiness Authority.

6.1 Compensation may be made for a reasonable amount of permanent magnetism, but variable sources of deviation must be kept distant in order to minimise their effects.

6.1.1 Where practicable, magnetic steel parts, especially movable parts, should not be positioned near the compass.

6.1.2 Electrical cables carrying uni-directional current produce a magnetic effect on the compass magnet system which is governed by the current and distance from the compass. All such cables should be positioned, if possible, at least 2 feet away from the compass. If double pole cables are used (i.e. supply and return cables run closely together) the magnetic effects of the cables are usually insignificant.

6.1.3 To minimise the effect on the compass of items of equipment with magnetic fields, such items should not be located closer to the compass than the relevant compass safe distance specified for each item by the manufacturer.

NOTE: Compass safe distance is defined as the minimum distance from a compass at which an item of equipment may be located to produce a maximum deviation of 1° under all operating conditions. This distance is measured from the pivot of the compass magnet system to the nearest point on the surface of the equipment.

6.1.4 The possibility of magnetic fields generated by electric currents passing through windscreen pillars and frames, or through instrument mountings, should not be overlooked.

6.1.5 The effect of modifications to instrument installations, radio installations, electrical control panels or wiring in the vicinity of the compass must be considered, and tests should be made to determine whether any deviation will be caused under operating conditions.

NOTE: The most adverse combinations of electrical loads must not cause deviation in excess of 2° (5° for light aircraft).

6.1.6 In some instances, particularly in light aircraft, certain components and parts of the structure, e.g. control columns, control arches, tubular frames, may exhibit residual magnetism in varying amounts which cannot be corrected by compass deviation compensating devices. The origin and cause of such magnetism must be investigated and the appropriate remedial action must be taken. A simple practical detection method is to position a small pocket compass near suspect components or parts and to note any deflections of the needle.

7 Inspection and Tests Before Installation

Direct reading Compasses are particularly susceptible to damage in transit and to deterioration during storage. They should be stored in the transit boxes supplied by the manufacturer, and should be handled carefully to avoid shocks which might impair the pivot action or cause other damage. Compasses should not be stored on steel racks or shelves, or in steel cupboards. Each compass should be inspected for serviceability before installation as follows:

a) The compass glass, anti-vibration devices and all movable or working parts, where appropriate, should be inspected for condition.

b) In grid steering compasses, the grid-ring locking device should function correctly and the grid-ring should rotate freely when unlocked. The grid wires should be undamaged and the graduations should be legible.

c) The compass bowl must be free from dents, and the card and liquid must not be discoloured.

d) The liquid must be free from sediment and bubbles. There should be no sign of leakage from the bowl as indicated, for example, by staining of the bowl exterior.

e) In compasses in which the deviation compensator devices are built in, the magnet adjusting screws or spindles should be slowly rotated through their full range of movement to check for roughness, 'hard spots' and backlash in the gearing. There should be sufficient inherent friction to prevent disturbance of compensator settings by shock or vibration. On completion of these checks, the compensators should be returned to their magnetic neutral positions as indicated by the alignment of indicator lines or dots engraved on the spindles with their fixed datum marks.

f) Compasses with integral lighting should be tested to ensure that no deflection of the magnet system is caused when the lighting is switched on.

7.1 **Pivot Friction**[1]

This should be checked with the compass in a level position. The magnet system should be deflected through approximately 10° and held for 30 seconds by placing magnetic material near the compass. The magnetic material should then be removed and the settling position of the magnet system noted. The system should then be deflected approximately 10° in the opposite direction, held there for 30 seconds, then released and the settling point noted. The angular difference between the two settling positions should not exceed the limits specified in the relevant manuals. During this test no tapping of the compass bowl is permissible.

7.2 **Damping Test**[1]

The magnet system should be deflected with an external magnet through 90° and held for 1 minute. The deflecting force should be removed. The time taken for the magnet system to return through 85° should not exceed the limits specified in the relevant manuals.

7.3 **Defect Rectification**

The rectification of defects, such as might be revealed by the inspections and tests referred to in paragraph 5 may only be undertaken by an organisation approved by the CAA or JAA to carry out such work.

8 Installation

The compass should be so mounted that a line passing through the lubber line and the vertical pivot support is either on, or parallel to, the longitudinal axis of the aircraft. The lubber line in grid steering type compasses should always point forward. With the card type compasses the lubber line faces aft. Compasses provided with adjustment slots and scale for index error (coefficient 'A') correction, should be positioned so that the centre zero mark on the scale is aligned with the datum mark on the compass mounting.

8.1 When not integral, the compass deviation compensator device should be mounted as close as possible to the compass, and should be centrally disposed about the magnet system pivot support with the AFT engraving positioned aft.

8.2 Brackets, or other forms of compass supporting structure, should be made of non-magnetic materials; this also applies to all nuts, screws, washers and the tools used for mounting.

NOTE: In aircraft employing a direct-reading compass as a standby heading indicator, the instrument is usually installed adjacent to the central support frame of the windscreen panels. In such cases the retaining nuts and bolts used in this frame should also be of non-magnetic material.

8.3 The compass deviation or 'steer by' card should be positioned so that it may be easily read during flight.

8.4 If the compass has an integral lighting system the wiring should be properly connected to the appropriate terminals. The lighting circuit should then be switched

1. These paragraphs deal only with pre-installation checks on compasses which have passed their schedule of tests. The tolerances given are general and vary in accordance with the type of compass, the compass specification, the latitude at which the test is made, temperature variation and the strength of the earth's magnetic field.

on and a check made to ensure that this does not cause a deflection of the magnetic system.

9 Preparation Before Swinging

A check should be made to see that all airborne equipment is installed in the aircraft. Loose items or tools made from magnetic materials should not be left in the aircraft or carried by the personnel engaged in the swinging procedure. Any detachable cockpit mechanical control locks which might be magnetic should be removed and placed in their flight stowages. Where towing arms and towing vehicles are to be used for manoeuvring the aircraft, their possible magnetic effect should be investigated, and if significant they should be disconnected and moved clear before taking any compass readings.

NOTE: Throughout the serviceability test and other preliminary checks, and also subsequent swinging procedures, it is most important that power supplies to systems be continually monitored to ensure that voltage and frequency values remain constant within their prescribed limits.

9.1 Carry out a serviceability test of the system in accordance with the procedure prescribed in the relevant Maintenance Manual.

9.2 Ensure that all equipment required for the swing is available, e.g. appropriate datum compass, sighting equipment, test voltmeters and milliammeters, non-magnetic tools for adjustment of deviation compensators, and external power supply equipment.

9.3 Where appropriate, landing gear ground locks should be in position and landing gear shock struts should be checked to ensure that they are properly inflated. In some types of aircraft, a landing gear lever latch is employed which is solenoid-operated. The solenoid is normally energised in flight, and since its magnetic field may have an effect on the accuracy of the standby direct-reading compass, it should also be energised during the swinging procedure. Check that brake system pressure is normal for the appropriate type of aircraft.

9.4 The flying controls should be in the normal straight and level flight positions when taking the readings, and should then be operated to ascertain that the movements have no adverse effect on the compass readings. Flaps, throttles, etc., should also be set to the 'in flight' positions.

9.5 Electrical equipment, e.g. radio, instruments and pitot tube heaters, should be switched on to ascertain that there are no adverse effects on the compass. In this connection, reference should always be made to the relevant aircraft manuals for details of the electrical loads to be selected appropriate to the aircraft operating conditions, e.g. normal day or night operation, or operation with emergency power.

9.6 Deviation compensator devices should be set to their magnetic neutral positions after installation, or after replacement of a compass or deviation compensator device where this is a separate unit.

9.7 Obtain appropriate clearance to tow the aircraft to the compass base.

10 Aircraft Sighting Points

In all swinging procedures it is necessary to determine the position of the longitudinal axis of the aircraft with respect to a magnetic heading reference datum, and for this reason, two datum points on the aircraft (e.g. the aircraft nose and tip of the vertical stabiliser) and directions from which they are to be sighted, must be carefully selected. If the datum points are at different heights above the ground, and if the aircraft is rolled out of a level plane as a result of the compass base not being level, then an error can occur in the measured datum heading. In several types of large transport aircraft, sighting is facilitated by the provision of sighting devices which are attached to the aircraft prior to carrying out the appropriate swinging procedure. Some examples are described in the following paragraphs.

10.1 **Sighting Rods**

In this example, front and rear sighting rods are attached to corresponding points provided along the centre line at the underside of the fuselage. An extension rod is also provided for attachment to either the rear sighting rod, if datum compass sightings are to be taken from the front of the aircraft, or the front sighting rod, if sightings are to be taken from the rear.

10.2 **Telescopic Target Fixture**

a) A typical fixture is shown in Figure 1. It is attached to the bulkhead of a main landing gear wheel well so that the scale and cross hair are on the inside of the turning circle of the aircraft. The setting of the fixture with respect to the longitudinal axis of the aircraft, is determined by sighting the telescope on a target mark located at the underside of the front fuselage, in this case at the forward jack pad position. The scale is of the centre-zero type, angles to the right being positive and angles to the left being negative, when sighted from the datum compass. Magnetic heading of the aircraft is determined during the swinging procedure by sighting the datum compass on the crosshair and scale of the target fixture, and calculating the difference between the scale reading and the datum compass reading, the latter being the bearing of a pre-selected reference target located at some distance from the base.

b) Another example of a target fixture is shown in Figure 2. In this case the fixture is attached to the underside of the front fuselage, and its telescope is sighted on a target ball mounted on a cable, the ends of which are secured to the up-lock rollers of each main landing gear strut. When the cable is in position, the ball is situated to the left of the aircraft centreline. Magnetic heading of the aircraft is determined in a similar manner to that described in a).

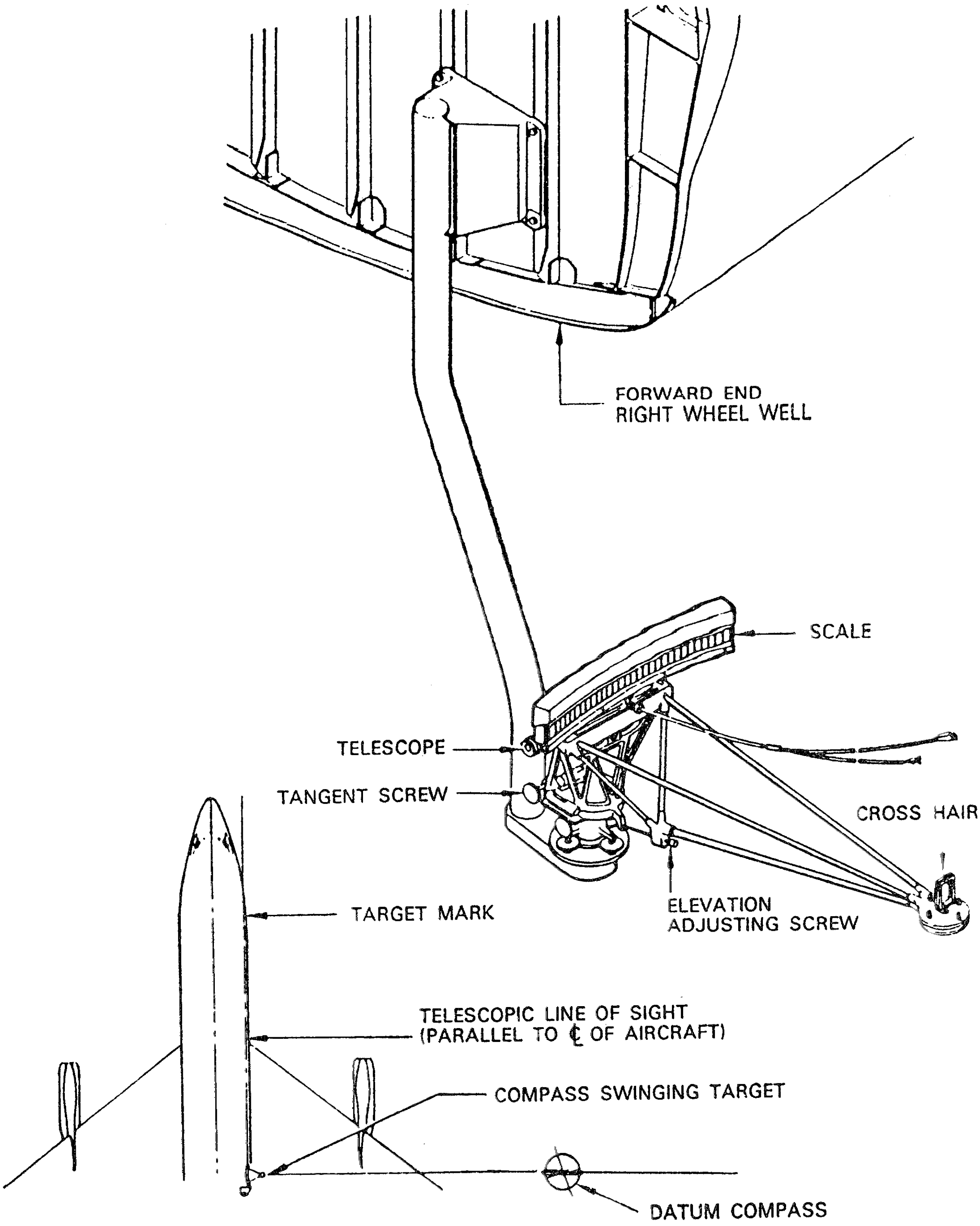

Figure 1 Telescopic Target Fixture

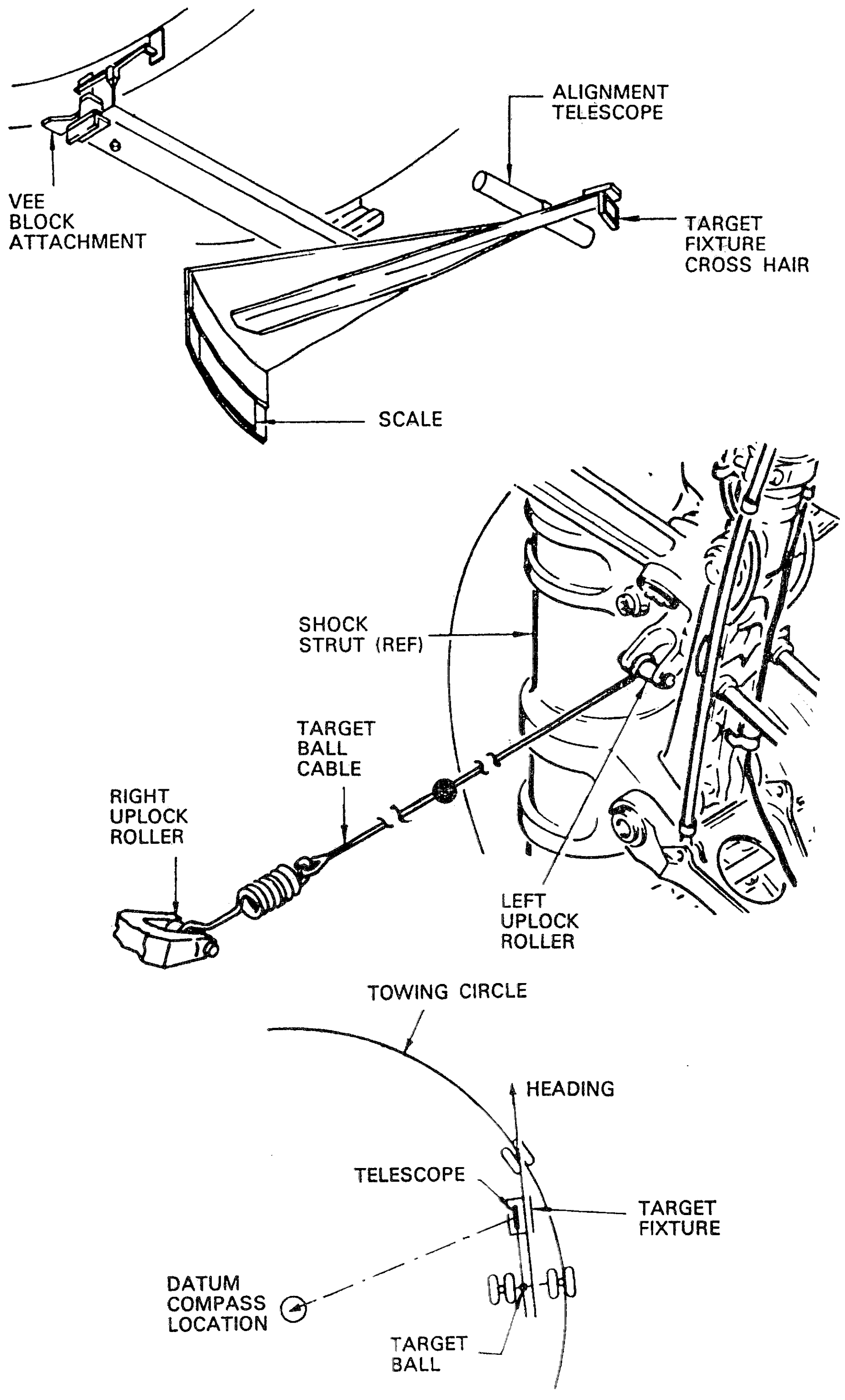

Figure 2 Target Fixture and Ball

10.3 Plumb Line Sighting

In this method, the longitudinal axis of an aircraft is indicated by the alignment of two plumb bobs suspended individually from fore and aft points at the underside of the fuselage. The use of the plumb bobs as a means of sighting depends on the compass swinging procedure adopted. If a swing is carried out on a base on which cardinal and quadrantal heading lines are marked out, the aircraft heading is determined by the position of the plumb bobs with respect to the marked lines.

a) In case of an 'electrical' swinging procedure, the plumb bobs are used only for ensuring that the aircraft is aligned with the North-South line marked out on the base. Malalignment should not exceed a specified amount, usually 1°, and this is calculated from a nomograph comprising three scales corresponding to the separation between plumb bobs, to plumb bob displacement from the North-South line, and to aircraft malalignment. An example based on an aircraft in which the plumb bob suspension points are 76 ft 2 in apart is shown in Figure 3.

   i) When the aircraft is positioned over the North-South line, with its nose pointing North, the points where the plumb bobs come to rest are marked on the ground and the lateral displacement of each from the edge of the line is measured. If the displacement is West of the line it is negative, and if it is East it is positive. The algebraic difference between the two values is then obtained as a reference point on the plumb bob displacement scale, and aircraft malalignment is read off the appropriate scale at the point intersected by a line projected through the known points on the plumb bob separation and projection scales. Thus, in the example shown, the known points are 76 ft 2 in and 4 in, and a projected line intersects the malalignment scale at a value of 18 minutes. In the event that malalignment is greater than the maximum specified for the aircraft, the aircraft should be repositioned.

11 Compass Swinging Area

Since the swinging procedure determines deviations caused by the magnetic fields of an aircraft, it is necessary for it to be undertaken at a location where only these fields and the earth's magnetic field can affect the compass readings. The location must, therefore, be carefully chosen and surveyed to prove that it is free from any interfering local magnetic fields (see Leaflet 8–1 Compass Base Surveying).

12 Compass Swinging Procedure (Direct Reading)

Where compasses are to be compensated on a base with marked headings, the longitudinal axis of the aircraft must be aligned either on, or parallel to, the markings, usually with the aid of plumb lines dropped from points fore and aft along the axis. A datum compass such as the medium landing compass may also be used, whether or not a concrete or tarmac base is available. The datum compass should be aligned with the aircraft's longitudinal axis and positioned on the datum circle, or if this is not marked, at a specified distance from the aircraft (typical distances are 50 to 150 feet). In order that the longitudinal axis of the aircraft may be accurately determined, datum points on the aircraft and directions from which they are to be sighted, must be carefully selected. Some aircraft have provision for the fitment of sighting rods to aid determination of the longitudinal axis. Details of the procedure appropriate to a specific system and aircraft type are given in the Maintenance Manuals, and reference must, therefore, always be made to such documents. The information given in the following paragraphs is intended to serve only as a general guide to procedures and to certain associated important aspects. The most straightforward direction for sighting is from the rear; the heading then corresponds to the datum compass reading. If the view from this aspect is unsatisfactory the view from ahead of the aircraft should be considered, bearing in mind that reciprocal headings will be indicated. It is not advisable to take sights from positions at angles to the longitudinal axis.

NOTE: When using a datum compass to position an aircraft, it is not necessary for the aircraft to be set exactly on the cardinal and quadrantal points; settings within 5° are acceptable.

13 Compass Swinging Procedure (Remote Reading)

The procedure to be adopted depends primarily on the type of compass and the method by which magnetic heading reference datum is obtained, i.e. from a base having headings marked out on it, from a datum compass, or from a base established for carrying out 'electrical' swinging as outlined in paragraph 13.2. Details of the procedure appropriate to a specific system and aircraft type are given in the Maintenance Manuals, and reference must therefore always be made to such documents. The information given in the following paragraphs is intended to serve only as a general guide to procedures and to certain associated important aspects.

13.1 Conventional Swinging Procedure

The term 'conventional' is used here to signify a procedure in which the magnetic heading reference datum is obtained, either from a compass base with heading alignment marks painted on it, or from a datum compass. In the former case, and with the aid of plumb line sighting, an aircraft can be aligned precisely on the cardinal and quadrantal headings. When using a datum compass, such precise alignment is not essential since the compass is always positioned to sight on the aircraft. It is usual, therefore, for positioning of both aircraft and datum compass to be within certain permissible limits. Limits commonly specified are within the range ±3° to ±5°. A typical swinging sequence is outlined in the following paragraphs.

13.1.1 When the aircraft has been towed onto the base, the appropriate sighting equipment should be fitted (see paragraph 4.2) and the aircraft positioned so that it is heading North.

13.1.2 Compasses installed in aircraft with fuselage-mounted engines should be compensated with engines running. If this is not practical then they should at least be re-checked on four equally spaced headings with the engines running, on completion of the swinging procedure.

13.1.3 External power supply should be connected to the aircraft, and after the compass systems have been energised and their gyros allowed to run up to normal operating speed, carry out the preliminary checks specified in the appropriate Maintenance Manuals. The following checks are typical of those normally required for systems in current use:

a) Synchronising of heading indicators against annunciator devices to ensure that magnetic monitoring by flux detector units, has ceased before taking readings. In certain types of compass system this check is effected by plugging a centre-zero milliammeter into 'monitoring current' sockets provided in a unit (e.g. an amplifier) of the system. If the gyro has no drift, monitoring has ceased when the meter oscillations are evenly balanced about the indicator 'null' position within the tolerances specified for the particular system. In some cases, a monitoring meter forms part of a compass indicator, thereby obviating the need for a centre-zero milliammeter.

b) Slaving of compass system indicators, e.g. radio magnetic indicators.

c) Check heading signals to auto-pilot and other associated navigational systems after selection of appropriate system switch positions.

d) Operational check of power failure warning and other indicating flags on all heading indicators.

e) Drift rate check of gyros.

f) Setting of deviation compensators to their neutral positions. This is normally only done during an initial swing procedure, and whenever a new flux detector unit or a deviation compensator is installed (see also paragraph 15). If a compensator is of the permanent magnet type, the slots of the adjustment screws should be aligned with datum marks on the compensator body. In the case of a potentiometric type compensator the potentiometers should be adjusted until a 'null' position, as indicated by a test meter plugged into the compensator, is obtained. If a new flux detector unit has been installed its index error scale should also be aligned at the zero datum.

NOTE: It is recommended that if no new components have been installed, compensators should remain at their previous settings so that with each subsequent adjustment procedure, some indication of how coefficients change with time can be obtained.

13.2 'Electrical' Swinging Procedure

An 'electrical' swinging procedure is one in which the earth's magnetic field is simulated by electrical signals in such a way that it is unnecessary to rotate the aircraft onto the various headings as in the conventional forms of swinging. The aircraft is positioned heading North with its fore-and-aft axis co-incident with a North-South line marked on the selected compass base, and with its flux detector units positioned over marked location datum points (see also paragraph 10.2.3 and Leaflet 8–1). The electrical signals are in the form of varying d.c. voltages, the values of which are determined during the appropriate compass base survey procedure (see Leaflet 8–1) and also during the swinging procedure. The signals are designated as E1 and E2 voltages and are applied respectively to the A-leg pick-off coil and the B-leg and C-leg pick-off coils of the flux detector sensing elements, by adjusting the controls of a console unit forming part of a special calibrator set which can be connected into the flux detector circuit. The electromagnetic fields produced by the E1 and E2 voltages alter the effective magnitude and direction of the earth's field passing through the legs of the detector sensing element, resulting in a magnetic vector which rotates to various headings, thereby simulating rotation of the aircraft and detector unit relative to the earth's field. These simulated headings are compared with the actual headings indicated by the aircraft compass system to determine the deviation errors to be compensated.

13.2.1 Compass Calibrator Set

It is beyond the scope of this Leaflet to go into the complete details of the compass calibrator set and its use in the 'electrical' swinging procedure, reference should, therefore, always be made to the relevant manufacturer's operation manual. The information given in the following paragraphs serves only as a general outline.

a) A compass calibrator set consists of a turntable, magnetic field monitor, field tester, console, power supply and optical alignment unit. The magnetic field monitor (which is a theodolite with a 22x telescope and a magnetic sensing element) is used, in conjunction with a console unit, to measure the strength, and determine the direction, of the horizontal component of the earth's field. It is used for the magnetic survey of areas required for swinging (see Leaflet 8–1) and also to monitor changes in magnetic conditions during a compass swing. The magnetic sensing element is similar to that employed in a remote indicating compass flux detector unit, except that it is nonpendulous.

b) The turntable is also a theodolite but without a telescope and magnetic sensing element. It is used for calibrating and aligning certain types of flux detector unit (see paragraph 13.2.2 b)) with magnetic North, and for determining the index or Coefficient 'A' error before installing a unit in the aircraft.

c) The console unit is the central control unit of the calibrator and contains all the switches, controls and indicators for programming the E1 and E2 voltage signals and for determining the errors in aircraft compass system indications to be compensated. The console also provides interconnection of the magnetic field monitor, turntable and power supply unit. The power supply unit is a solid-state inverter which converts a 28V d.c. input into a 115V 400 Hz a.c. output required to operate the calibrator.

d) An optical alignment unit consists of a fixed-focus 8x telescope and appropriate adjustment devices, and is used for aligning certain types of flux detector unit in an aircraft during its transfer from the turntable, thereby ensuring that the index error compensation is maintained (see paragraph 13.2.2 e)).

13.2.2 **Swinging Procedure**

The procedure for carrying out an 'electrical' swing depends primarily on whether a flux detector unit is of the pre-indexed type, or of the master type (pre-calibrated and pre-indexed). Basically, however, the procedure consists of the following sequence of operations:

a) **Check on the Direction of Magnetic North.** This is done to determine whether there has been any shift from that obtained when the base survey was carried out. The check is carried out by sighting the calibrator monitor, from its location point on the base, on the pre-determined reference target, and then determining errors on the cardinal headings, and thus obtain an area compensation value for setting on the console control unit.

b) **Magnetic Alignment of Detector Unit.** The purpose of this operation is to check the Index or Coefficient 'A' Error, and thereby the amount by which the detector unit is to be offset in its mounting with respect to magnetic North. If the detector units are of the pre-indexed type, the check is done with the unit mounted on the calibrator turntable at its location on the base, and before the aircraft is towed onto the compass base. In the case of master type detector units, the aircraft can be towed onto the base at the outset of the swing procedure, since the units, being pre-calibrated on the four cardinal headings for a specific compass system and aircraft installation, are already installed and the use of the turntable is thereby eliminated.

c) **E_1 and E_2 Voltages Check.** The purpose of this check is to determine the voltages required to simulate the earth's field effects which would be obtained if the aircraft and its detector units were rotated onto various headings. The check also determines the adjustments which are necessary to compensate for one-cycle errors, i.e. Coefficients 'B' and 'C', during the compass swing operation.

The check applies to both pre-indexed and master type flux detector units, except that in the former case, voltage values are obtained by selecting headings on the calibrator turntable, while for master units selections are made on the calibrator monitor.

d) **Determination of Crosstalk Errors.** These errors (see paragraph 5.4) are measured at headings of 90°, 180° and 270°. Crosstalk error does not occur at 0 degrees since no voltages are applied to the flux detector unit to simulate this heading.

e) **Optical Transfer of Flux Detector Unit.** This operation is applicable only to flux detector units which have not been pre-indexed or pre-calibrated. It is carried out by means of the calibrator optical alignment unit, and is necessary in order to ensure that a detector unit will be installed in the same position with respect to magnetic North, as that determined by the calibrator turntable magnetic alignment check. The aircraft is towed onto the base and positioned so that not only is the longitudinal axis coincident with the North-South line with the nose pointing North, but also the flux detector unit access location is directly over that of the calibrator turntable. The optical alignment unit is then attached to the detector unit and a reference bearing is obtained by sighting the telescope on a target which is at least half-mile distant from the base.

The values of aircraft malalignment and the flux detector unit index error, are then set into the optical alignment unit, and the detector unit, with equipment attached, is transferred to its mounting bracket in the aircraft and is rotated until the telescope is again aligned with the distant reference target. At this setting the detector unit is secured to its mounting bracket and electrically connected to its compass systems. The optical alignment unit is then removed.

NOTE: Optical transfer is a critical operation in 'electrical' swinging procedure, and extreme care should be taken to prevent the telescope from being jarred or knocked out of adjustment before a flux detector unit is fully secured in its mounting bracket.

f) **Compass Swinging.** This operation, which applies to all compass systems irrespective of the type of flux detector unit employed, is the one in which compensations are made for one-cycle (Coefficients 'B' and 'C') and two-cycle (transmission) errors. Before compensating, a final check on E1 and E2 voltage values should be made, and adjustments should, where necessary, be carried out to allow for any possible changes in the earth’s field strength. On completion of all adjustments, a final swing through increments of 15° should be carried out.

NOTE: Variations between compass system compensation can occur depending principally on the type of compensator used. Reference should, therefore, always be made to the relevant system and aircraft Maintenance Manuals.

13.3 Swinging by Inertial Navigation Systems

With the introduction of Inertial Navigation Systems (INS) into certain types of public transport aircraft, the use of system display unit heading information, as the datum for compass swinging, became a possibility. The swinging procedure, although basically similar to that employing an external magnetic datum, does however, require that the effects of diurnal changes in local magnetic variation be taken into account in order to minimise compass deviation errors.

13.3.1 Variation is the horizontal angle between the true and magnetic meridians, and in the United Kingdom it normally increases Westerly during the morning and decreases during the late afternoon. These diurnal changes, as they are called, are in the order of 0·1 degrees in the winter, and 0·3 degrees in the summer. During periods of high sunspot activity however, the changes become random and may increase in amplitude to 0·5 degrees, and have been known to be as large as one degree. In the case of a compass swing using an external magnetic reference datum, the diurnal changes do not affect the swing since both the datum compass and the aircraft compass are affected by the same changes and the correct deviations are calculated. Furthermore, as long as the compass base has a constant value of variation over it, an accurate compass swing can be carried out irrespective of the value of local variation. In using INS heading information as a datum, diurnal changes will, however, affect only the aircraft compass, thereby giving rise to false deviation errors which require the application of variation corrections. An outline of a method of applying the corrections, based on that prescribed for a particular type of aircraft using three inertial navigation systems, is given in the following paragraphs:

a) The aircraft is positioned within 2° of North using the readings of the INS display units, and the average of the three readings is noted. The aircraft's magnetic heading is then determined by applying the value for the local magnetic variation to the average of the display unit readings. For Westerly variation the value is added and for Easterly variation it is subtracted.

b) The heading indications of the compass systems are then noted, after allowing each system to synchronise, and the deviations of each system on the North heading are calculated.

c) The foregoing procedure is repeated on the other three cardinal headings, and the deviation coefficients are calculated and compensated in the manner prescribed for the particular compass systems.

13.3.2 Although the method described in paragraph 13.3.1 takes into account local variation on all cardinal headings, it should be noted that it is still possible for false deviations to occur as a result of diurnal changes taking place, for example, during the time required for compass systems to synchronise. Unless continuous calculations are made, or the aircraft headings are checked with the aid of an external datum compass, it is unlikely for local variation to be known accurately for the duration of the swing. Serious consideration should, therefore, be given to the maximum compass error which might occur during an INS datum swing compared with one using an external magnetic datum, and whether such error can be accepted for the aircraft compass systems concerned.

14 Compensating and Recording

When taking compass readings a brief pause should be allowed after placing the aircraft on each heading and the direct reading compass should then be tapped gently while the magnet system is allowed to settle. If compensating a remote compass, allow time for the compass to synchronise. A check should always be made on each heading to ensure that interference from each individual item of electrical equipment and its associated wiring, or the interference from the most adverse combination of the possible electrical load, has not been increased. For card type compasses, the readings are taken against the vertical lubber line. If the compass is of the grid steering type, the grid wires should be aligned parallel to the magnet system, North on North, and the reading against the lubber line should be observed. In both cases observations should be such that parallax errors are avoided.

NOTE: When more than one direct-reading compass is fitted in an aircraft, or when a direct-reading compass serves as a standby to a remote-reading compass, all readings and subsequent adjustments should be made simultaneously on each heading.

14.1 All observed readings and associated deviation calculations obtained during swinging should be recorded on properly prepared record forms. The layout of forms varies for different compensation methods but, in general, their composition follows that associated with the method described in this Leaflet and as set out in Table 1.

Table 1

Points	(1) Datum Compass or Base* Reading	(2) Aircraft Compass Cardinal Readings	(3) Deviation	(4) Deviations Corrected for C or B, as applicable	(5) Aircraft Compass Quadrantal Readings	(6) Deviation	(7) All Deviations Corrected for A	(8) Finally corrected Readings for Card
N	000	006	-6	-4	-	-	-2	002
E	090	088	+2	+1	-	-	+3	087
S	180	182	-2	-4	-	-	-2	182
W	270	270	0	+1	-	-	+3	267
NW	315	-	-	-	317	-2	0	315
NE	045	-	-	-	048	-3	-1	046
SE	135	-	-	-	138	-3	-1	136
SW	225	-	-	-	227	-2	0	225

*A compass base was used in this example.

$$C = \frac{\text{Deviation on N-Deviation on S}}{2} = \frac{(-6)-(-2)}{2} = \frac{-6+2}{2} = \frac{-4}{2} = -2°$$

$$B = \frac{\text{Deviation on E-Deviation on W}}{2} = \frac{(+2)-(-0)}{2} = \frac{+2}{2} = +1°$$

A = The sum of the Deviations on

$$\frac{\text{N E S W NW NE SE SW}}{8} = \frac{-4+1\ -4+1\ -2\ -3\ -3\ -2}{8} = \frac{-18+2}{8} = \frac{-16}{8} = -2°$$

14.2 The aircraft should first be headed N and the compass reading should be noted in column 2 of the Table, e.g. 006°. The deviation is the difference between the compass reading (column 2) and the magnetic heading indicated by the datum compass or compass base (column 1); the sign is plus or minus according to whether it is necessary to add the deviation to, or subtract it from, the compass reading in order to obtain the magnetic heading. In this example it is –6° and this should be recorded in column 3.

14.3 The compass reading on E should next be checked, and the deviation obtained and recorded, e.g. 088° and +2°.

14.4 The aircraft should now be headed S and the compass reading and deviation also recorded, e.g. 182° and –2°. Coefficient 'C' should be calculated algebraically from the formula shown in the Table; thus, from the example readings, 'C' is –2°. This should be applied, with its sign unchanged, to the deviation noted on S and the result recorded in column 4, i.e. –4°. The sign of the coefficient should then be changed and applied to the deviation on N, the result being –4°, which should also be recorded in column 4. The appropriate adjusting spindle of the compensator device should be rotated until the compass indicates the corrected reading, i.e. 184°. The compass should be tapped gently whilst making the adjustment.

14.5 The compass reading on W should be checked next, and the deviation recorded, e.g. 270° and 0°. Coefficient 'B' should be calculated algebraically from the formula shown in the Table; thus, from the example readings, 'B' is +1°. This should be applied, with its sign unchanged, to the deviation noted on W and the result recorded in column 4, i.e. +1°. The sign of the coefficient should then be changed and applied to the deviation on E, the result being +1°, which should also be recorded in column 4. The appropriate adjusting spindle of the deviation compensator device should be rotated until the compass indicates the corrected reading, in this case 269°. The compass should be tapped gently whilst making this adjustment. This completes the compensation of deviation on the cardinal headings.

14.6 The aircraft should again be headed on each cardinal heading and any residual deviations noted. A check should then be made on the compass reading, and deviation, at each quadrantal heading and these should be recorded in column 5 and column 6 respectively.

14.7 Coefficient 'A' should be calculated from the formula shown in the Table (after correction for coefficients 'C' and 'B'). It will be noted from the example readings that coefficient 'A' is –2°. Corrections should be made by adding this coefficient (sign unchanged) to the compass reading on any aircraft heading, and by adjusting the mounting position of the compass (e.g. rotating it about bolts in slotted mounting lugs) through the appropriate number of degrees until the lubber line is aligned with the corrected heading.

14.8 After correction for coefficient 'A', residual deviations should be calculated in order to obtain corrected readings for entry on the deviation card (column 8). The deviations, which should not exceed 3° (5° for light aircraft) on any heading, are calculated by subtracting coefficient 'A' from the deviations noted in columns 4 and 6, recording the values as in column 7, and then finally subtracting these values from the datum compass or base readings (column 1).

14.9 **Deviation Card**

A deviation or 'steer by' card (see Figure 4) should be compiled to show deviations related to standard headings at intervals of 45° (30° for light aircraft) and should be secured in a position adjacent to the respective compass. The card readings are those which the compass must indicate in order that the aircraft may be flown on correct magnetic headings, e.g. in order to fly on a magnetic heading 000 (North) the compass must indicate 002°. In cases where radio equipment is installed in instrument panels, it should also be stated whether the compass was swung with the equipment switched on or off. Details should be given on the back of the card to indicate aircraft type and registration, compass type and serial number, place and date of swing, signature and authority of the compiler. A record of the swing should be entered and certified in the aircraft Technical Log Book

For Magnetic Heading		Steer by Compass
N	000°	002°
NE	045°	046°
E	090°	087°
SE	135°	136°
S	180°	182°
SW	225°	225°
W	270°	267°
NW	315°	315°

Figure 3 Typical Deviation Card

15 Compass Swinging In Service

15.1 Direct Reading Compass

Swinging and compensation as detailed in paragraph 14 must be carried out whenever a direct-reading compass or separate deviation compensator device, if appropriate, is installed. On other occasions a check-swing is sufficient. A check-swing consists of placing the aircraft on four headings 90° apart, and comparing the deviations with those on the existing deviation card. If there is any difference between these deviations it will be necessary to carry out a complete swing.

15.2 Remote Reading Compass

The swinging procedures described in paragraph 14 should normally be carried out after installation of a complete compass system, and whenever standard type, or pre-indexed type, flux detector units are changed. Changing of a master type detector unit does not usually downgrade the performance of its associated system unless alignment of the unit in its mounting bracket, or alignment of the bracket itself, has been altered. Normally, a complete swinging procedure should also be carried out after a deviation compensator device has been changed, although in some systems this may not be necessary provided that compensating voltage settings are properly transferred to the replacement unit. On all other occasions it is sufficient only to carry out a check swing by placing the aircraft on four headings 90° apart, and comparing any deviations with those recorded on the previous calibration swing. If there is any difference between these deviations, a complete swinging procedure should be carried out.

15.3 Occasions for Check Swing of Compass:

a) After a check inspection if required by the approved Maintenance Schedule.

b) Whenever inaccuracies in heading indications are reported.

c) After any modification, repair or major replacement involving magnetic material, particularly in aircraft the engines of which are mounted in the fuselage or wing nacelles.

d) Whenever a compass has been subjected to shock, e.g. after a heavy landing.

e) After the aircraft has passed through a severe electrical storm, or has been struck by lightning.

f) Whenever the aircraft has been subjected to a magnetic crack detection examination.

g) Whenever the sphere of operation of the aircraft is changed to one of different magnetic latitude.

h) Whenever a significant change is made to the electrical or radio installation, particularly to circuits in the vicinity of the compass.

i) Whenever a freight load is likely to cause magnetic influence and thereby affect compass readings.

j) After the aircraft has been in long term storage.

16 Routine Inspection

The security of the mounting of each compass and deviation compensator device should be checked, and any adjustment or tightening should only be done by an organisation approved by the CAA for such work or by an engineer licensed in the appropriate category. The compass should be inspected for bubbles in the liquid, discoloration, sediment, clarity of scale, liquid leakage, cracked glass and the effectiveness of the anti-vibration mounting where fitted. In compasses of the grid steering type, the functioning of the grid-ring locking device should also be checked, and when in the unlocked position it should permit complete rotational freedom of the grid-ring. The deviation card must be legible and secure in its holder.

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