SECTION 3

CHAPTER 1

COMPASS ADJUSTMENT

CHAPTER I

COMPASS ADJUSTMENT

TERRESTIAL MAGNETISM

Introduction

1. The earth is surrounded by a weak magnetic field, which could be represented as if produced by a bar magnet, lying between the magnetic north and magnetic south poles. The direction of this magnetic field is such that the lines of force run from the magnetic south to the magnetic north pole. It can be said that the magnetic north pole has the property of a south seeking (blue) magnetic pole, since with a normal bar magnet, the lines of force run externally from the Magnetic North to the Magnetic South Pole. The north seeking pole is termed the "Red Pole" and the south seeking pole the "Blue Pole".

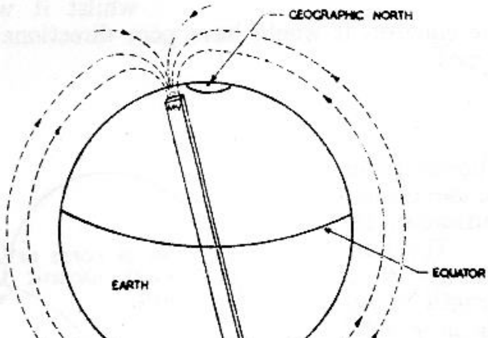
2. Should a freely suspended magnet be placed in any position on the earth's surface, it would always align itself (unless prevented by some external force) with the earth's field, so that its north seeking pole will point to the magnetic north.

3. This magnetic field is not uniform in shape, direction or strength, and varies on account of the following factors :—

(a) The magnetic poles rotate slowly around the True Geographic Poles.

(b) There are large iron ore (loadstone) deposits near the earth's surface.

(c) Magnetic storms.



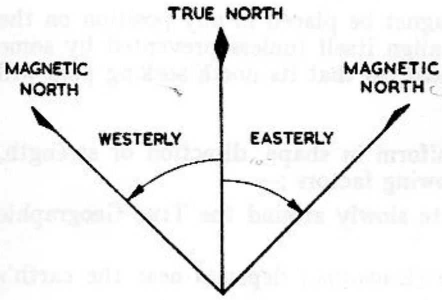
THE EARTH'S FIELD

Variation

4. It is necessary when navigating to use fixed positions, and all charts are drawn up with positions fixed in relation to Geographic North and

South, the axis around which the earth rotates. Normally the Geographic North position is used, and is termed True North. As the compass needle points to magnetic north, to find this true position a correction must be applied to the magnetic reading. This correction is known as correcting for the angle of Variation, and is found from a chart which indicates the amount of variation which occurs at different positions on the earth's surface.

5. On these charts, lines are drawn indicating places of equal variation, these lines being termed ISOGONALS, the red lines indicating easterly, and the blue lines westerly variation. The line joining places of no variation (usually drawn in black) is known as the AGONIC line. Variation may be defined as the angle between the true and Magnetic North meridians. It is measured easterly or positive, when the Magnetic meridian is in a clockwise direction from the True meridian and westerly or negative when in an anti-clockwise direction.

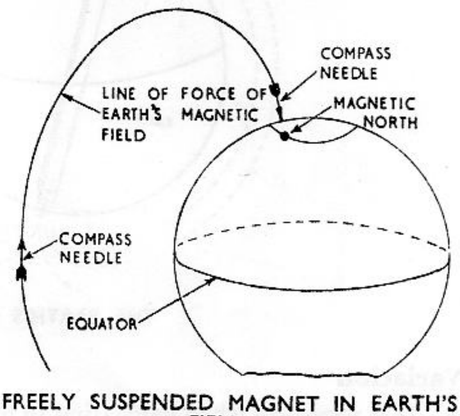


VARIATION

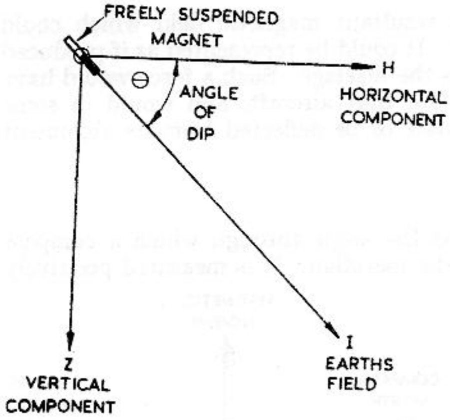
Earth's Field

6. At the geographic equator the earth's magnetic field is approximately parallel to the earth's surface, but at the magnetic poles it is at right angles to the surface. This would be of little use if a measure of direction was required, as a compass needle will align itself with this field, and whilst it would be quite accurate at the equator, it would have poor directional qualities near the magnetic poles.

7. The field, however, can be divided into two components, one horizontal, the other vertical. The horizontal component is of maximum strength at approximately the geographic equator and minimum strength at the magnetic poles. It will be seen later that the horizontal component is used for navigational purposes, although the vertical component does have an effect on a compass needle.



FREELY SUSPENDED MAGNET IN EARTH'S FIELD



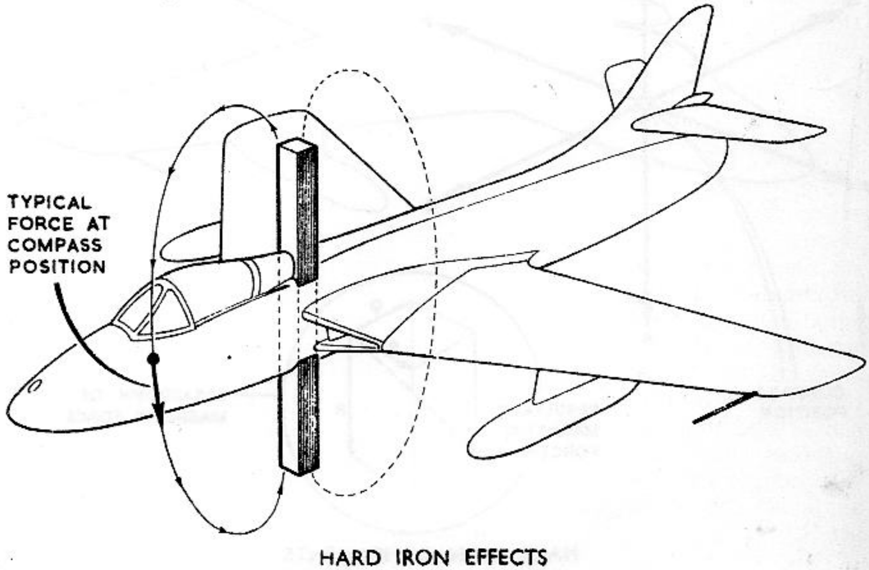
ANGLE OF DIP

8. As the compass needle would normally align itself with the earth's field, the angle between the horizontal component and that field is known as the Angle of Dip. Charts are produced indicating positions with various angles of dip, and positions with the same dip are joined by lines known as ISOCLINALS, the red lines joining places of equal northerly dip and the blue lines, places of equal southerly dip. The line joining positions of no magnetic dip is known as the ACLINIC line or Magnetic Equator ; it coincides approximately with the Geographic Equator.

AIRCRAFT MAGNETISM

Hard Iron

9. During manufacture an aircraft is subject to many types of processes, which will induce magnetism into that aircraft. For example an aircraft may stand on one heading in an assembly shop for some considerable time, which in itself will allow the earth's field to magnetise the "hard" components of the aircraft. It will further be magnetised by such operations as riveting, grinding, or polishing, all of which allow the molecules



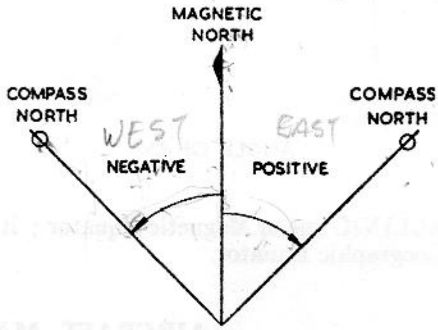
HARD IRON EFFECTS

to align themselves more readily with the earth's field. In addition when certain items of equipment are installed which have their own magnetic fields, additional "hard" magnetism is present.

10. This resolves itself into one resultant magnetic field which could act in any direction in an aircraft. It could be represented as if produced by a bar magnet positioned across the fuselage. Such a force would have an effect on a compass installed in that aircraft, and would in some instances cause the needle to deviate or be deflected from its alignment with the earth's magnetic field.

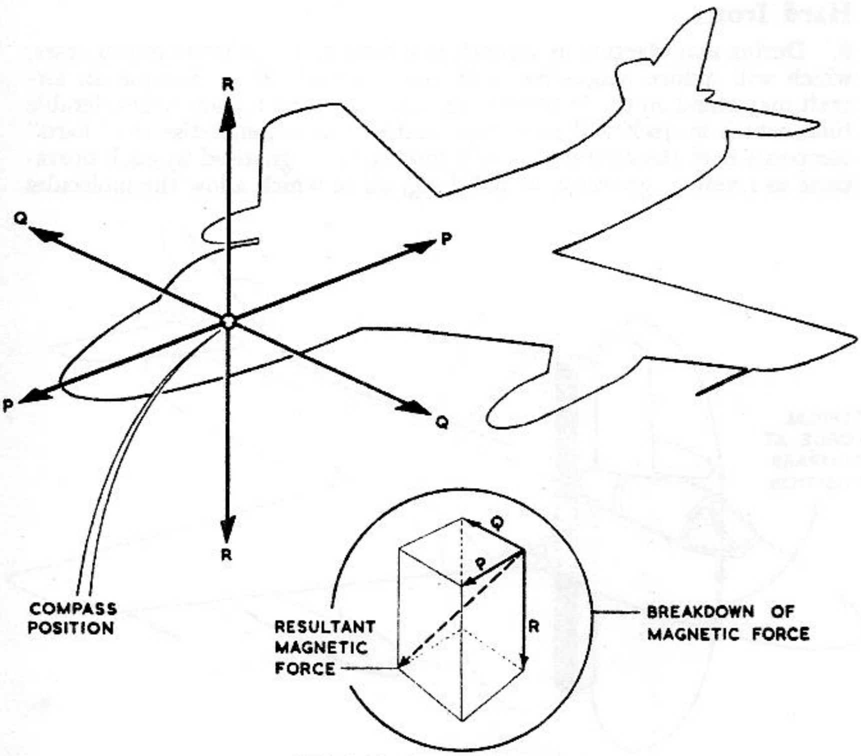
Deviation

11. Deviation may be defined as the angle through which a compass needle is deflected from its magnetic meridian. It is measured positively when the needle is deflected in a clockwise or easterly direction, and negatively when deflected in an anti-clockwise or westerly direction.



DEVIATION

12. It is necessary to be able to calculate the amount through which the compass needle would deviate on various headings, namely N, S, E and W (the Cardinal), and NE, SE, SW and NW



HARD IRON COMPONENTS

(the Quadrantal) headings. To achieve this, it is first necessary to break down the resultant magnetic force on the compass needle into three components. By using the parallelogram of forces, the force can be resolved into fore and aft, athwartships and vertical components.

These components are termed.

(a) Component P—fore and aft.

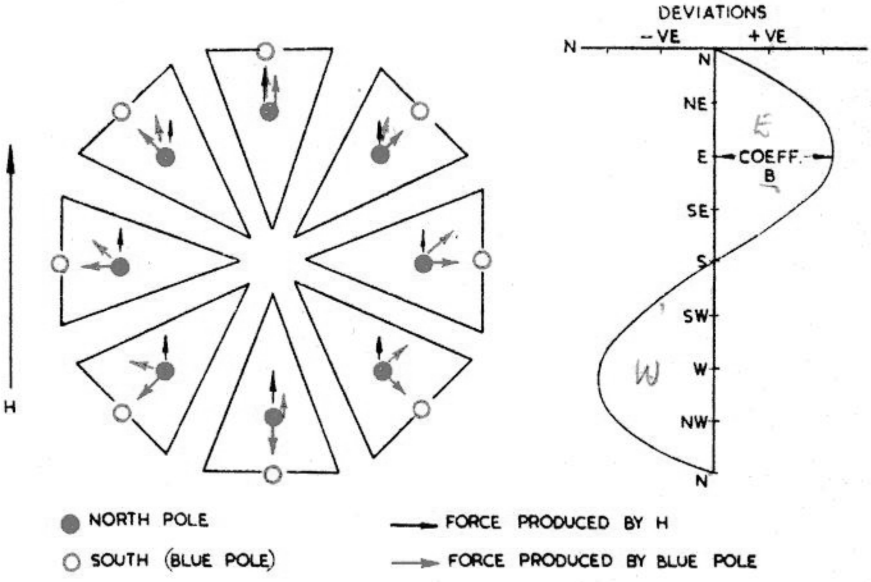
(b) Component Q—athwartships.

(c) Component R—vertical.

P. Q. and R. are considered to be positive when the blue pole (effective pole) is forward, starboard or below the compass position.

Consideration of P, Q and R

13. In the ensuing diagrams, consider the triangle to represent an aircraft. The base of the triangle being the nose, and its apex, the tail. An arrow drawn at the side of the diagrams will indicate the direction of the earth's horizontal component. In all cases, consideration will only be given to the force acting on the north seeking pole of the compass needle, and the component will be considered as produced by the effective blue pole acting on that compass needle, e.g., a plus P component will be considered as the blue pole acting forward of the compass position.



COMPONENT P.

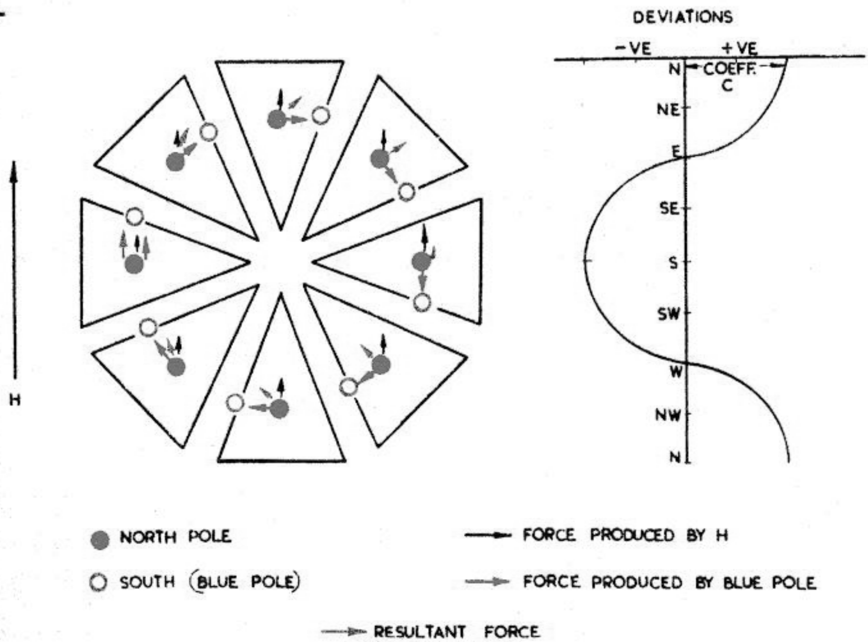
Component P.

14. A +P Component will give rise to :—
   - (a) Maximum deviations on easterly and westerly headings.
   - (b) Partial deviations on the quadrantal headings.
   - (c) Gain in directive force on a northerly heading.
   - (d) Loss in directive force on a southerly heading.

A —P component will produce similar effects but the deviation will be in the opposite direction, together with a loss in directive force on the northerly and a gain on the southerly headings. The graph of these deviations plotted against aircraft heading produces a sine wave, the amplitude of which is known as Coefficient B.

Coefficient B is calculated from the formula :—

$$\text{Coeff. B.} = \frac{\text{Deviation on East—Deviation on West}}{2}$$



COMPONENT Q.

Component Q.

15. A +Q component will give rise to :—
   - (a) Maximum deviations on northerly and southerly headings.
   - (b) Partial deviations on the quadrantal headings.
   - (c) Loss in directive force on the easterly heading.
   - (d) Gain in directive force on the westerly heading.

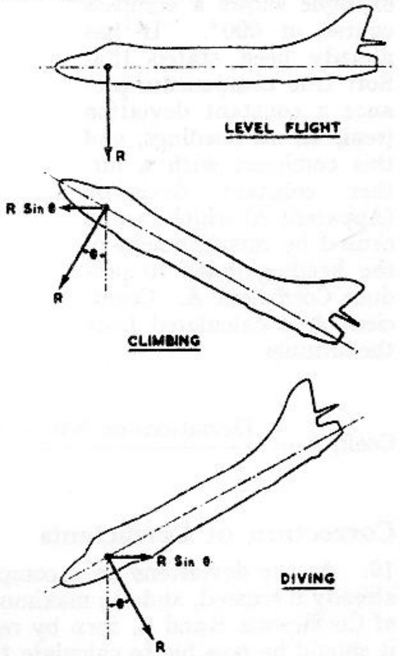
A —Q component will produce similar effects, but the deviation will be in the opposite directions, together with a gain in directive force on the easterly and a loss on the westerly heading. The graph of these deviations plotted against aircraft headings, produces a cosine wave, the amplitude of which is known as Coefficient C.

Coefficient C is calculated from the formula :—

$$\text{Coeff. C} = \frac{\text{Deviation on N — Deviation on S}}{2}$$

Component R.

16. During flight, this component is normally acting vertically through the compass position and has no deviating effect. Should the aircraft climb or dive it produces a fore and aft component on the compass which has the same effect as component P. Similarly should the aircraft roll, then R will combine with component Q to produce maximum deviations on North and South headings. As the majority of present day aircraft have tricycle undercarriages, it will be appreciated that on the ground or in level flight, component R can have no effect on the compass.



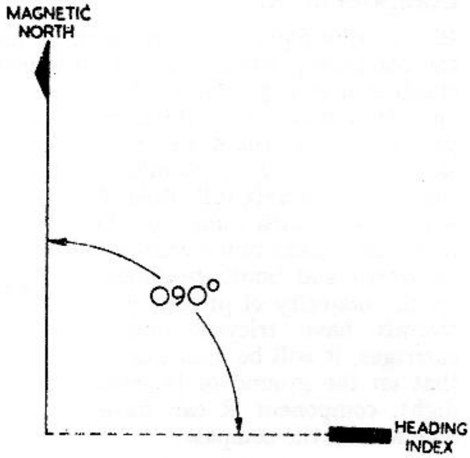
COMPONENT R.

Soft Iron

17. Some parts of an aircraft are permanently magnetised (Hard Iron), other parts may more easily be magnetised by induction, and lose their magnetic effect once the magnetising force has been removed. The most common of these forces is the earth's magnetic field, whose strength varies with change of latitude and aircraft heading, and which produces a force, termed "Soft Iron", which can be resolved into various components, again producing deviations on the compass needle. The "fore and aft" and "athwartships" components produce Coefficients D and E, which are usually small and are left uncorrected in aircraft, plus a small constant deviation known as Coefficient "Real A," for which correction is made mechanically. The Vertical Components of this "Soft Iron" are affected by the earth's vertical component Z, and will only change polarity with change of hemisphere. They are treated as semi-permanent magnets, which combine, and are corrected, with Components P. Q. and R.

Coefficient A.

18. Compass needles are subject to deviations caused by both "Hard" and "Soft" Iron. A compass heading or course is measured in a clockwise direction from the compass needle to a heading index or lubber line. The example shows a compass course of 090°. It has already been stated that Soft Iron components produce a constant deviation (real) on all headings, and this combines with a further constant deviation (Apparent A) which can be caused by misalignment of the heading index to produce Coefficient A. Coefficient A is calculated from the formula



A COMPASS COURSE

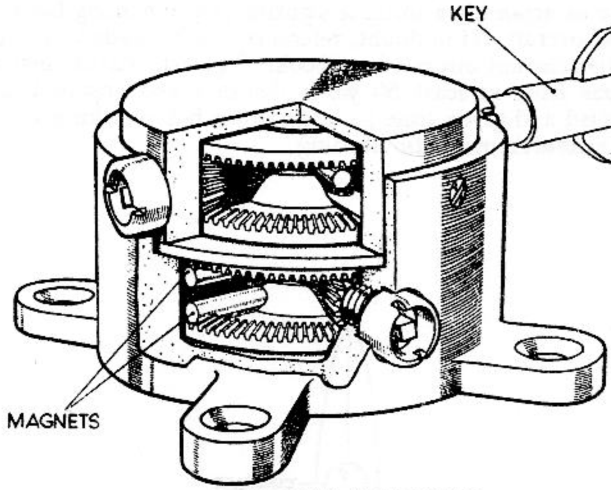
$$\text{Coeff. A} = \frac{\text{Deviations on NW} + \text{W} + \text{SW} + \text{S} + \text{SE} + \text{E} + \text{NE} + \text{N}}{8}$$

Correction of Coefficients

19. As the deviations on a compass are produced by the components already discussed, and are maximum on the Cardinal headings in respect of Coefficients B and C, then by replacing an aircraft on these headings, it should be possible to calculate the amount by which they deviate the compass needle. The method of determining the magnetic heading of the aircraft as opposed to the compass heading will be determined later. By introducing a force which will make the compass needle deviate in an opposite direction to that produced by the Components, it is possible to almost entirely eliminate the deviations caused by Components P and Q (Coefficients B and C). These forces are contained in an adjustable corrector box, which consists of a container housing four small magnets, each mounted on a bevel gear. The gears are arranged in pairs with operating pinions between them, the pinions being operated from external heads by means of a key.

20. When the gears are midway between their respective limit stops, the magnets lie one pair fore and aft, and the other pair athwartships The magnets of each pair neutralize one another. By rotating the magnets a resultant magnetic field will be produced, the strength and polarity of which will depend on the amount and the direction of displacement.

21. Rotation of the magnets will if required, produce fields in both the fore and aft, and athwartships directions. It is extremely important that this corrector box be fitted rigidly to the aircraft, just above or below the compass position, and, once set, it must not be altered until the compass is again recalibrated. A datum mark on the corrector box indicates the aft position and enables it to be installed correctly ; the two keyways to each pair of bevelled gears are for ease of operation.



ADJUSTABLE CORRECTOR

Occasions on which a compass must be calibrated

21. Compasses will require calibration on the following occasions.

(a) After any change of compass or corrector box.

(b) On the receipt of the aircraft into the R.A.F.

(c) After a major inspection.

(d) After every change of a major component (tail plane, oleo leg, engine).

(e) After any great change in latitude.

(f) After being struck by lightning, or flying through violent magnetic storms.

(g) After the aircraft has been standing on any one heading for more than four weeks.

(h) Every three months.

(j) At the discretion of the Flight Commander.

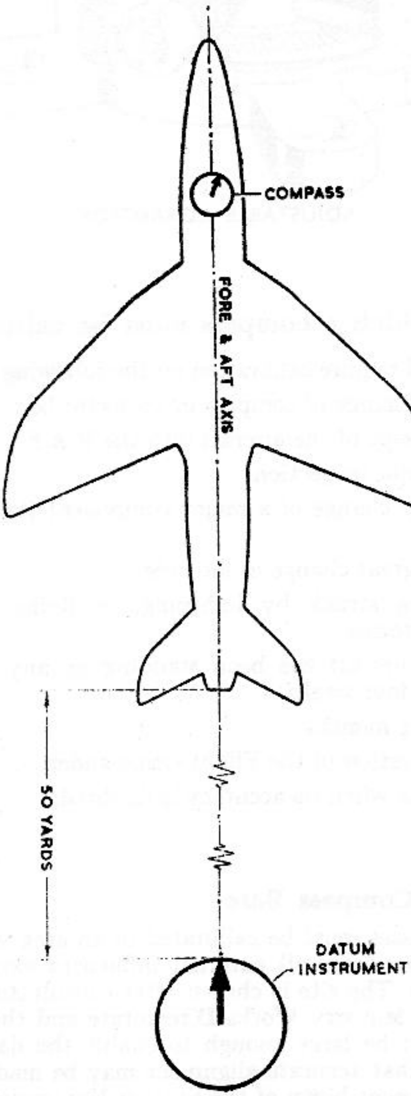
(k) At any time when its accuracy is doubted.

Suitability of a Compass Base

22. Aircraft compasses must be calibrated in an area where the earth's magnetic field is free from all external influences except that of the aircraft's magnetism. The site is chosen after consultation with a representative of the Air Ministry Works Directorate and the Senior Airfield Controller, and must be large enough to enable the datum instrument to be positioned so that accurate alignment may be made. The position of this site is the responsibility of the Station Navigation Officer, and it should be tested periodically.

A Method of Obtaining an Aircraft's Magnetic Heading

23. The alignment of an aircraft is checked by using a datum instrument which is free from the effects of the aircraft's magnetism. This can be carried out by ascertaining a suitable sighting position along the fore and aft axis of the aircraft. If in doubt, reference can be made to the rigging diagram in the relevant aircraft handbook. Sight the datum instrument along this axis from at least 50 yards distance and ensure that it is properly levelled and given time to settle down before taking a reading, which is the aircraft's magnetic heading.



OBTAINING A MAGNETIC HEADING

24. There are now two readings, one the aircraft magnetic heading, the other the aircraft compass reading. The difference between the two will indicate the amount by which the compass has deviated on that magnetic heading.

Conditions to be observed prior to Compass Calibration

25. Before carrying out any calibration, the following conditions must be observed

(a) The compass must be tested for serviceability.

(b) All equipment normally carried in flight must be in its correct position.

(c) All aircraft controls must be centralised and all doors shut.

(d) No magnetic material to be carried on the person near to the aircraft compass or datum instrument (screwdrivers, knives, torches, etc.).

Calibration Procedure

26. This is normally divided into three phases :—

(a) Correction for Coefficient A.

(b) Adjustment of Coefficients B and C (correcting swing).

(c) Calibration or Check Swing.

Note 1. After initial installation of a compass, corrector box, or detector unit, adjustment of Coefficient A is always made before correcting for Coefficients B and C. In the case of periodic swings, B and C are normally corrected first. Should a large Coefficient A be removed (more than 2°) adjustment for B and C must be repeated.

Note 2. Always allow sufficient time for both instruments to settle down. Light tapping is permissible and assists in overcoming any friction present.

Note 3. Ensure that the aircraft compass always indicates within 5° of the Cardinal or Quadrantal headings, as it will not be possible to correct the errors satisfactorily if this margin is exceeded.

Note 4. Always read both the datum and aircraft compasses with the highest degree of acccuracy, remembering always to view the instrument from the same position, thereby avoiding parallax errors.

27. The following explanation of the adjustment of a liquid compass should be read in conjunction with the illustrated Forms 343 and 316C. The columns (ii) and (iii) on the Form 343 are used when the Astro Compass is the datum instrument. The value of the variation in column (iii) is then either added to, or substracted from, the readings in Column (ii) depending on whether it is an easterly or westerly variation. Remote compasses are swung in a similar manner.

(a) Head the aircraft North, and note the readings of the aircraft and datum compasses. Enter these in Column (iv) and (v) of the F.343. Complete Column (vi).

(b) Head the aircraft East, again noting both readings. Repeat the procedure as at (a).

(c) Head the aircraft South and repeat procedure as at (a).

(d) Calculate Coefficient C using the formula as on the F.343.

(i) Change the sign of Coefficient C and apply it to the existing compass reading.

(ii) Set this corrected reading against the lubber line (heading index) and lock the grid ring.

(iii) Insert the corrector key in the athwartships keyway, at right angles to the compass needle, and rotate it until the compass needle aligns itself with the North of the grid ring, i.e., "Red on Red."

Note. It is necessary to change the sign of Coefficient C on South and likewise later on West, as, to find the mean of the deviations, it was first necessary to subtract the deviation, e.g. $\frac{2 + -3}{2}$ would be $-\frac{1}{2}$ when in fact the average deviation is $2\frac{1}{2}°$ irrespective of its direction.

(e) Head the aircraft West and carry out procedure as at (a).

(f) Calculate Coefficient B from the formula as shown on the Form 343. Change the sign of Coeff. B and apply it to the existing reading. Correct as for Coefficient C but this time using the fore and aft keyway of the micro adjuster, which is again at right angles to the compass needle.

(g) Head the aircraft on NW. N. NE. E. SE. S. SW. and W. completing columns (iv) and (v) of the check swing each time. Complete column (vi) and calculate Coefficient A.

(i) Apply Coeff. A with its sign unchanged to the existing compass reading.

(ii) Set against the lubber line the corrected reading, loosen the securing screws and rotate the compass bodily until North is on North. Re-tighten the screws.

Note 1. The sign is unchanged as the lubber line is being moved in relation to the compass needle.

Note 2. In the example, Coefficient A is so small it will not be removed.

Note 3. When removing Coefficient A from remote-indicating compasses, it is always carried out at the Detector Units.

Note 4. The check swing ensures that corrections for Coefficients B and C have been applied correctly and it is also a double check to ensure that pivot friction is not excessive.

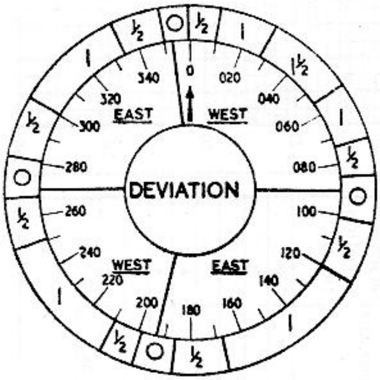
(h) Plot the graph of the residual deviations against aircraft heading.

Obtaining Critical Courses

28. It will be seen that the graph cuts the thick lines and moves from one unit of deviation to another. In the example, the residual deviation values have been doubled and the unit of deviation is $\frac{1}{2}°$. The magnetic headings have also been amended to compass headings. Draw horizontal lines from the points on the curve at which it cuts the $\frac{1}{4}°$ vertical lines, noting against these lines the aircraft heading. These headings are known as the critical headings, on which the value of the deviation changes.

Compilation of Form 316

29. Draw lines in the outer margin (border) on the appropriate Form 316, against the headings on which the deviation values change, and radial lines against the headings on which the values change from positive to negative. Between the outer lines put the values of the deviations and between the inner radial lines in the appropriate quadrants thus formed put WEST where deviations are negative and EAST where they are positive. The necessary information is then conveyed to the pilot or navigator, enabling him to use the Compass accurately.



AIRCRAFT TYPE and No. VALIANT B.X. 343.

COMPASS TYPE and No. P.10 G 569829

ADJUSTED BY: J/TECH. J. JONES

DATE: 19-7-57.

METHOD OF USE

When completing the reverse, insert the word "West" in segments where deviation is minus and the word "East" in segments where deviation is "Plus".

Remote Indicating Compasses

Apply deviation EAST or WEST direct to V.S.C.

Direct Indicating Compasses

Where deviation is WEST, ADD to HDG.(M) to obtain HDG.(C) and vice versa.

FORM 316C

DATE:	AIRCRAFT TYPE AND No: VALIANT BX 343	ADJUSTED BY: J/TECH. J.JONES.
19-7-57	COMPASS TYPE AND No: P10. G 569829	

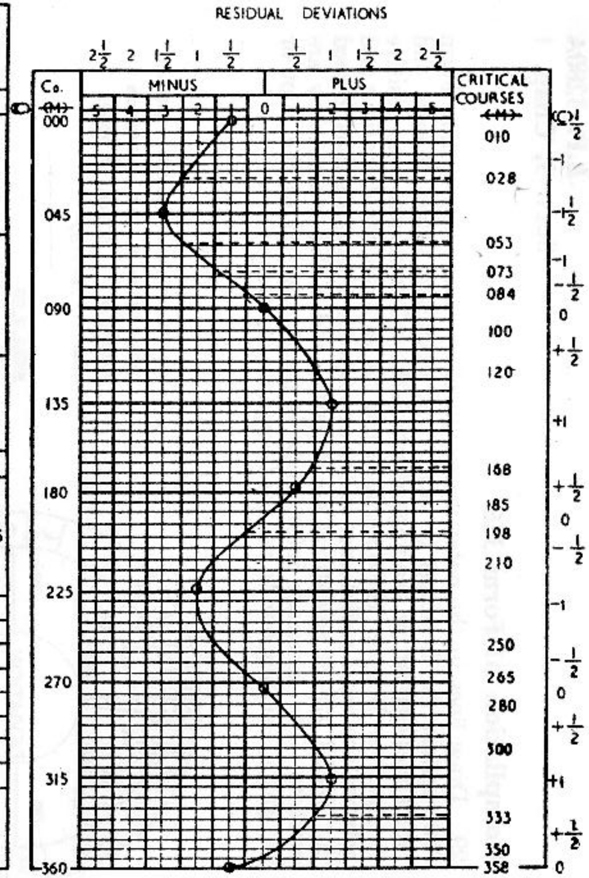
CORRECTING SWING

(i) APPROX. COURSE (M)	(ii) ASTRO COMPASS COURSE* (T)	(iii) VARIATION*	(iv) ACTUAL COURSE (M)	(v) AIRCRAFT COMPASS READS	(vi) DEVIATION (iv—v)	COEFFICIENTS
NORTH			003	001	+ 2	$C = \frac{\text{DEV. ON N} - \text{DEV. ON S}}{2}$
EAST			088	090	− 2	$= \frac{2-(-3)}{2} = +2\frac{1}{2}$
SOUTH			180	183	− 3	
COEFFICIENT C (WITH SIGN CHANGED)				− 2·5		
MAKE COMPASS READ				180·5		
WEST			271	269	+ 2	$B = \frac{\text{DEV. ON E} - \text{DEV. ON W}}{2}$
COEFFICIENT B (WITH SIGN CHANGED)				+ 2		$= \frac{-2-(+2)}{2} = -2$
MAKE COMPASS READ				271		

CHECK SWING

(i) APPROX. COURSE (M)	(ii) ASTRO COMPASS COURSE* (T)	(iii) VARIATION*	(iv) ACTUAL COURSE (M)	(v) AIRCRAFT COMPASS READS	(vi) DEVIATION (iv—v)	(vii) COEFFICIENT A	(viii) RESIDUAL DEVIATIONS (vi—vii)
N.W.			316	315	+ 1		+ 1
NORTH			001	001·5	− ·5		− ·5
N.E.			046	047·5	− 1·5		− 1·5
EAST			090	090	0		0
S.E.			137	136	+ 1		+ 1
SOUTH			178	177·5	+ ·5		+ ·5
S.W.			224	225	− 1		− 1
WEST			272	272	0		0
				TOTAL:	− ·5 ÷ 8	= − ·06	

TO REMOVE +A, TURN LUBBER LINE CLOCKWISE.
TO REMOVE −A, TURN LUBBER LINE ANTI-CLOCKWISE.
* FOR USE WHEN SWINGING BY ASTRO COMPASS.



FORM 343.