04-102

ROYAL CANADIAN AIR FORCE

OPERATING INSTRUCTIONS

COMPASS INSTALLATION

COMPENSATION AND SWINGING

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PART 1

INTRODUCTION

1 The purpose of the magnetic compass in an aircraft is to enable the crew to determine the heading of the aircraft any time. The magnetic type compass for use on aircraft consists essentially of a liquid filled bowl containing a pivoted float element bearing a system of magnetized needles. The element is so suspended that the magnetized needles are free to align themselves with the horizontal component of the earth's magnetic field. In direct reading compasses, the position of the element and its graduations are visible, with reference to a lubber's line, through a glass window in the bowl. Direct reading compasses for use on aircraft are divided into two general types; namely, "B" type compasses designed for instrument board mounting and "P" type compasses designed for floor or table mounting.

2 In remote reading compasses, the position of the element is indicated by a repeater system which forms a part of the compass. Generally remote reading compasses are the more accurate since the magnetic element can be located in some portion of the airframe where magnetic influence from other components and/or circuitry is at a minimum.

3 Accuracy of navigation and flying safety depend directly on the function of the compass. The high standard of performance of this instrument can be maintained only by adequate servicing and careful calibration and adjustment. Aircraft swinging must never be rushed and attention must be given to the precautions which are outlined in this Engineering Order.

PART 2

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MAGNETISM

TERRESTRIAL MAGNETISM

1 The surface of the earth is surrounded by a weak magnetic field which culminates in two magnetic poles situated near the north and south geographical poles. As the earth's magnetic field is irregular, it is not possible to reproduce it by a simple distribution of magnetic material. Moreover, the magnetic field at any place on the earth's surface is continually changing, the changes being of both periodic and irregular nature. Some of the long period changes of the earth's field are of primary interest to the navigator, whilst the personnel responsible for the maintenance and calibration of compasses and compass systems will be concerned with annual and diurnal variations of the magnetic field. Sudden and simulataneous disturbances of the field, experienced from time to time are described as magnetic storms.

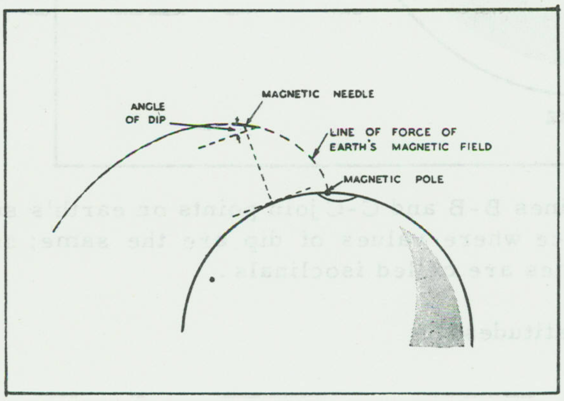


Figure 2-1 Angle of Dip

2 The lines of the earth's magnetic force are not in general parallel to the earth's surface as can be seen from Figure 2-1 and 2-2. An irregular imaginary line on the earth's surface joining points at which the field is horizontal is termed the magnetic equator. It coincides very roughly with the geographic equator. At all other places, the lines of magnetic force are inclined to the horizontal (angle of magnetic dip) and become perpendicular to the earth's surface at the magnetic poles. A line joining points of equal magnetic dip is known as isoclinal. When considering the effect of the earth's field it is convenient to split the total magnetic force into its horizontal and vertical components.

3 A freely suspended magnetic needle, if undisturbed by other magnetic influences, will align itself in the earth's field with its north seeking (or red) pole to the north. A plane passing through such a free needle and the center of the earth would trace on the earth's surface an imaginary line called the magnetic meridian, see Figure 2-3. The needle (or the magnet system) of a compass is so balanced on its pivot that it always remains practically horizontal and is affected only by the horizontal component of the earth's field. Such an arrangement is more suitable

for indicating the direction of the magnetic meridian than a freely suspended needle inclined at the local angle of dip.

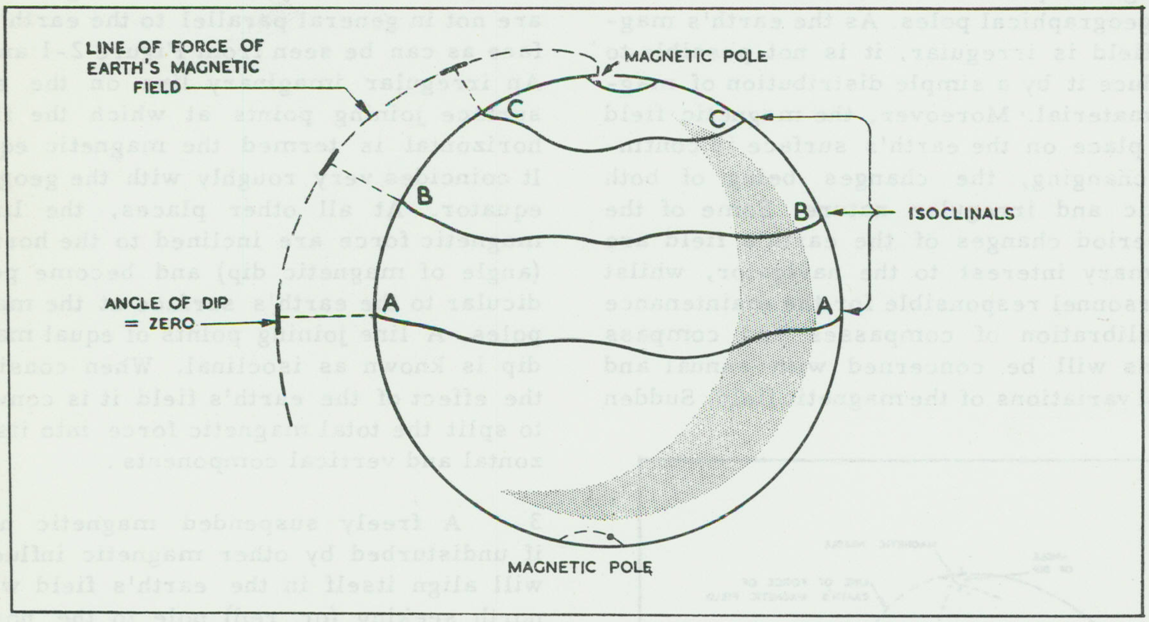
4 At any point on the earth's surface, the angle between the magnetic meridian and the true meridian can be measured. This angle does not remain constant for reasons mentioned in para. 3, but its changes can be accurately predicted. A compass needle can therefore be used as a datum from which the direction on the earth's surface can be measured. The angular difference between the magnetic meridian and the true meridian at any point is known as magnetic variation, see Figure 2-4. It is named easterly or westerly according to whether the red end of the magnetic needle lies to the east or west of the true meridian. Lines joining places which have the same magnetic variation are overprinted on navigational maps and charts. These lines are called isogonals, see Figure 2-5.

AIRCRAFT MAGNETISM

5 The ferro-magnetic materials contained in the structure of an aircraft, e.g. its engines, landing gear, armament and equipment, are potential sources of magnetism which is likely to interfere with the indications of the compass needle. The aircraft magnetism may be of a permanent or transient nature, depending upon the source from which it emanates. The sources of magnetism are classified conventionally as follows:-

Hard Iron

(a) Certain metals are not readily magnetized, but once magnetized, will retain that property for a considerable length of time unless an effort is made to demagnetize them. Since the horizontal component of the earth's magnetic field varies in strength over the earth's surface, the distorting effect of per-



Line A-A joining points of zero dip (i.e., where earth's magnetic field is horizontal) is called the magnetic equator.

Lines B-B and C-C join points on earth's surface where values of dip are the same; such lines are called isoclinals.

Figure 2-2 Magnetic Latitudes

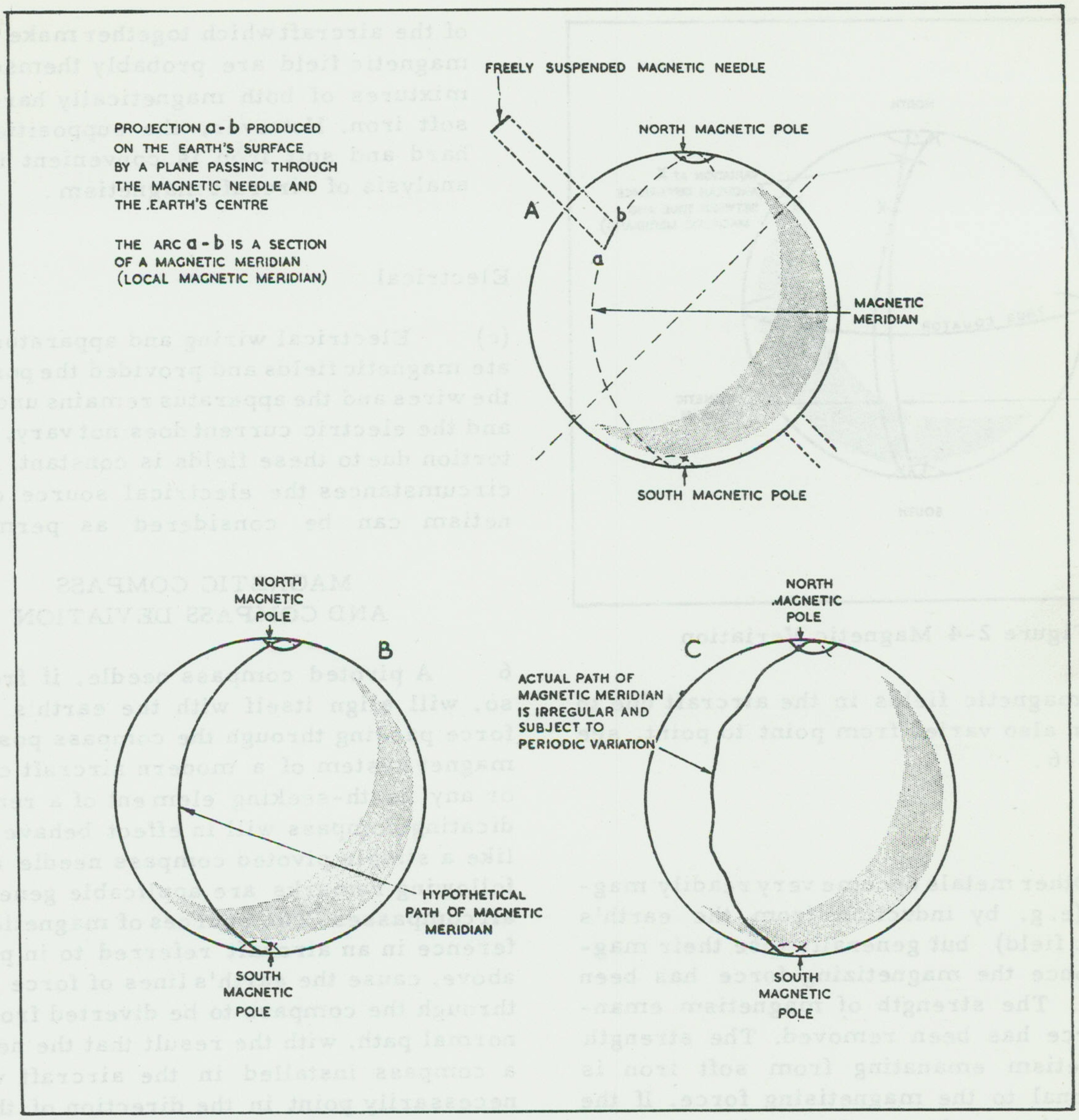


Figure 2-3 Magnetic Meridian

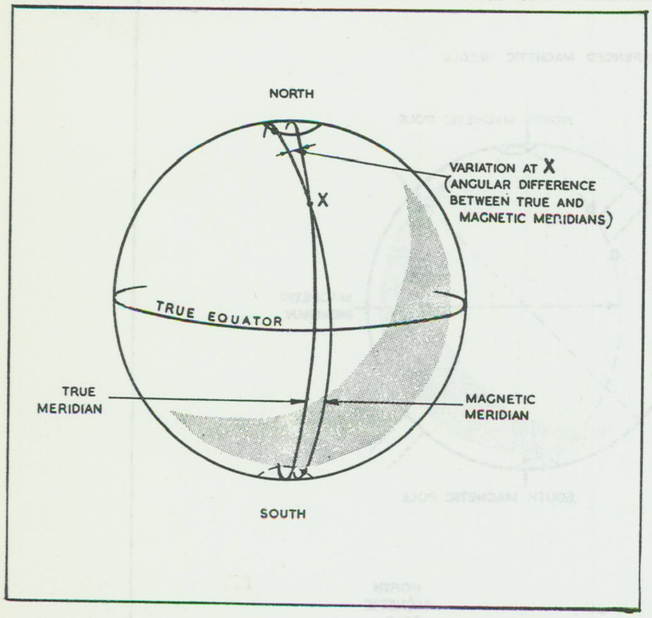


Figure 2-4 Magnetic Variation

manent magnetic fields in the aircraft due to hard iron also varies from point to point, see Figure 2-6.

Soft Iron

(b) Other metals become very readily magnetized (e.g. by induction from the earth's magnetic field) but generally lose their magnetism once the magnetizing force has been removed. The strength of magnetism emanating force has been removed. The strength of magnetism emanating from soft iron is proportional to the magnetising force. If the magnetization is due to the earth's magnetic field, the strength and polarity of the magnetic field due to soft iron will vary according to the position on the earth.

NOTE

It must be remembered that there cannot be a clear-cut differentiation between hard and soft irons, since some irons retain their magnetism longer than others. The terms hard and soft iron cannot be rigid. The various components of the aircraft which together make up its magnetic field are probably themselves mixtures of both magnetically hard and soft iron. However, the supposition of hard and soft iron is convenient in the analysis of aircraft magnetism.

Electrical

(c) Electrical wiring and apparatus generate magnetic fields and provided the position of the wires and the apparatus remains unchanged, and the electric current does not vary, the distortion due to these fields is constant. In these circumstances the electrical source of magnetism can be considered as permament.

MAGNETIC COMPASS AND COMPASS DEVIATION

6 A pivoted compass needle, if free to do so, will align itself with the earth's lines of force passing through the compass position. A magnet system of a modern aircraft compass or any north-seeking element of a remote indicating compass will in effect behave exactly like a simple pivoted compass needle and the following remarks are applicable generally to all compasses. The sources of magnetic interference in an aircraft referred to in para. 5, above, cause the earth's lines of force passing through the compass to be diverted from their normal path, with the result that the needle of a compass installed in the aircraft will not necessarily point in the direction of the local magnetic meridian. The magnetic field of the aircraft structure and equipment exerts a deviating force on the compass needle.

7 The angular difference between the actual magnetic heading of the aircraft and that indicated by the compass (compass heading) is known as compass deviation. Deviation is easterly or positive, if the compass is reading low, and westerly, or negative, if the compass is reading high, i.e. the sign and the value of the deviation is obtained by subtracting the compass heading from the magnetic heading ($d = M - C$).

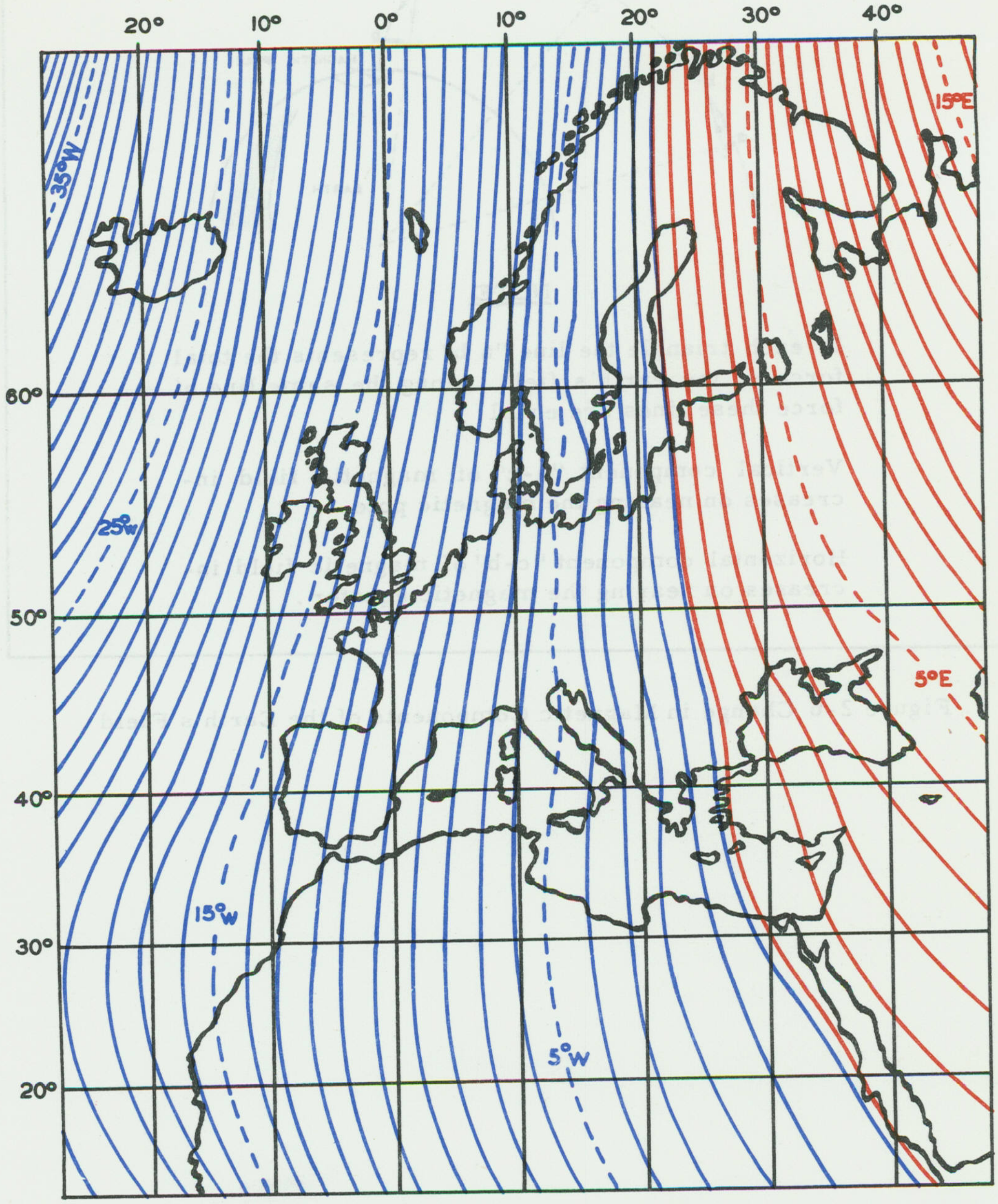
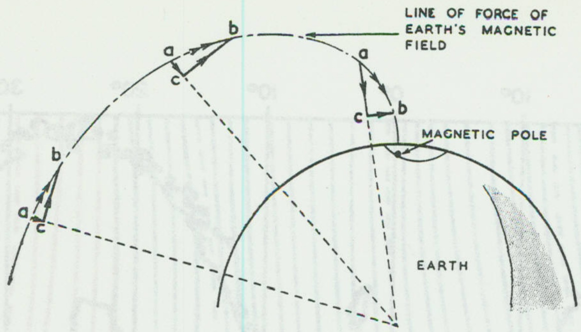


Figure 2-5 Isogonal Lines



NOTE

In each triangle the line "a b" represents the total force of the earth's field. Along the same line of force these lines are equal.

Vertical component "a-c" of magnetic field increases on nearing the magnetic pole.

Horizontal component "c-b" of magnetic field increases on nearing the magnetic equator.

Figure 2-6 Change in Magnetic Components of the Earth's Field

PART 3

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DEVIATION CO-EFFICIENTS AND COMPENSATION

PURPOSE

1 The object of compass compensation is to introduce magnetic forces equal and opposite to those inherent in the aircraft, so that the magnetic interference is cancelled out and the earth's lines of force can pass through the compass position unhindered. Complete correction is rarely possible and the remaining deviation (residual deviation), as measured during a compass swing, is recorded on a deviation card which is kept in the aircraft near the compass.

2 The deviating effect upon a compass varies from time to time and from place to place for the following reasons:-

(a) As the horizontal component of the earth's field decreases in strength towards the magnetic poles, see Figure 2-6, so the directive force on the compass decreases and hence the effect of the deviating forces due to hard iron becomes proportionately greater.

(b) The soft iron magnetism may change its strength and polarity as referred to in Part 2, para. 5(b).

(c) Airframe components may become magnetized from outside sources, e.g., magnetism induced through standing on one heading for a considerable time, magnetization in the course of servicing and repairs, magnetization due to hammering effect produced by firing of guns, magnetism induced by lightning discharges, etc.

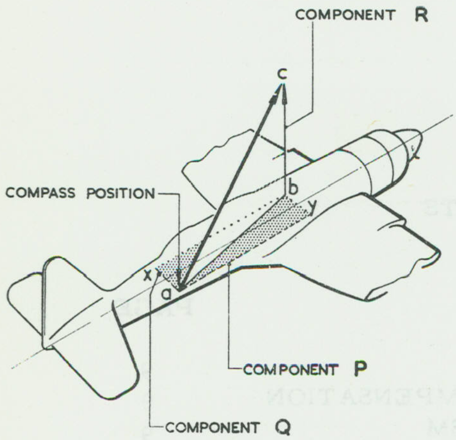
OCCASIONS FOR SWINGING AND COMPENSATION

3 Compasses are swung and compensated whenever conditions, which are deemed likely to cause erroneous indications of the compass, have taken place. Among various causes, those of flying through thunderstorms or storm clouds can be considered as special conditions calling for a calibration of the compass.

4 The periods at which compass swinging and compensation should be carried out are detailed in Part 6 of this Engineering Order.

ANALYSIS OF AIRCRAFT MAGNETISM

5 The factors which constitute the compass deviation are termed deviation co-efficients A, B, C, D and E. Co-efficient A can be allowed for as far as it affects courses, by rotating the compass bowl in relation to the aircraft. The corrector box fitted close to the compass will compensate for co-efficients B and C. Co-efficients D and E are the effect of horizontal soft iron (soft - in magnetic sense, denoting



a-c	Resultant Force of Total Aircraft Magnetism at Compass Position "a".
c-b	Vertical Component of a-c.
a-b	Horizontal Component of a-c.
a-x	Athwartships Component of a-b.
a-y	Fore and Aft Component of a-b.

Figure 3-1 Resolution of Aircraft Magnetism

that it readily assumes or loses magnetism when moving about in a magnetic field.) No provision is normally made for correcting for the effect of co-efficients D and E in the aircraft, and it is generally the error due to these co-efficients (sometimes of the order of 5°) that should appear on the deviation card of the compass which has been carefully adjusted.

6 For the purposes of consideration of compensation of the effects of aircraft magnetism on the compass the total distorting magnetic field is theoretically represented by a number of horizontal and vertical magnets, the individual fields of which contribute to the measured deviation according to the aircraft heading.

7 During normal flight the aircraft and the compass needle are both horizontal. Therefore, except in special circumstances it is necessary to consider only that part of the permanent magnetism in the aircraft which is horizontal in effect.

8 The horizontal effect is further resolved into two components, viz., fore and aft component known as P component and athwartships component known as Q. The resolution of the aircraft magnetic field is demonstrated in Figure 3-1 and the representation of horizontal fore and aft and athwartships components as equivalent magnets in the aircraft is shown in Figure 3-2.

9 The vertical component, known as R component see Figure 3-1, will be discussed in para. 14.

NOTE

It must be remembered that in the present treatment of the subject components P and Q represent total fore and aft and athwartships fields respectively and hence include both permanent magnetic field and their allied fields due to soft iron.

10 The effect of aircraft magnetism on the compass needle is shown in Figure 3-3. In Figure 3-3a the compass pointer (represented by the arrow) is seen to be correspondingly deflected on east and west headings and unaffected on north and south headings i.e., compass deviation exists on east and west headings, and is absent on north and south headings, when component P is considered.

11 The reverse is the case, see Figure 3-3c when component Q is considered. Here the maximum deviation is when the aircraft heading is north and south.

12 The curves shown in Figure 3-3b and 3-3d represent the change in deviation due to P and Q respectively, when the compass heading is changed. It is seen that for P the true curve is a "sine" curve, whilst for Q it is a "cosine" curve.

DEVIATION CO-EFFICIENTS

13 The meaning of the co-efficients and the causes which give rise to them are as follows:-

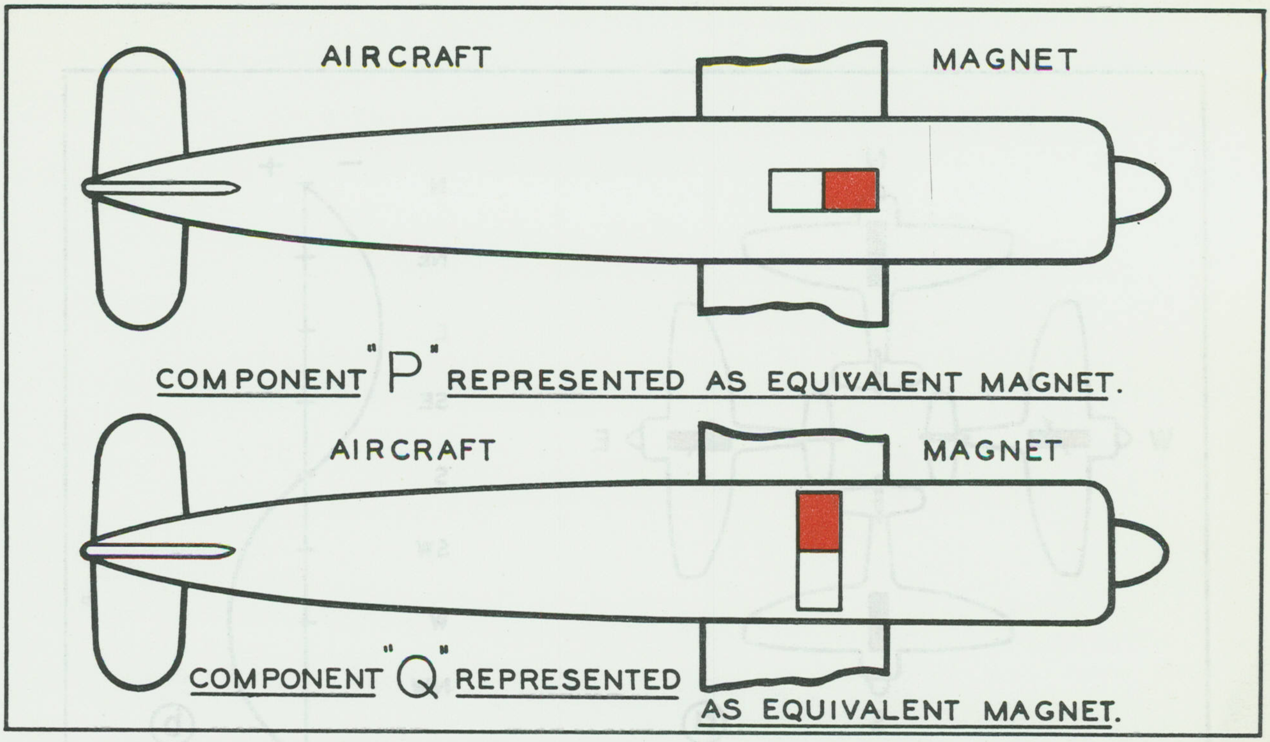


Figure 3-2 Effect of Components P and Q and their Allied Soft Iron

Co-efficient A

(a) This is a constant deviation on all headings and is a mean of all deviations recorded during the swing. It has several causes among which are:-

(1) The lubber's line may not be parallel with the fore and aft line of the aircraft. This applies only if the deviations were obtained by using the lubber's line to read the course.

(2) Some stationary source of interference may have been unduly close to the aircraft during the swing.

(3) Certain arrangement of horizontal soft iron may be present.

NOTE

The condition mentioned in para. 13(a)(1) is the only source of true co-efficient A but is seldom present in aircraft, and is nearly always accompanied by co-efficient E. If E is small, A should also be small. Co-efficient A as found, can usually be assumed to be apparent A, which is allowed for by rotating the compass bracket through the required number of degrees (clockwise if A is positive and vice versa if negative).

For causes of co-efficient A due to changes in voltage and frequency in the case of remote indicating compasses. reference should be made to the relevant Engineering Order.

Co-efficient B

(b) This co-efficient is caused by the fore and aft permanent magnetism in the aircraft (component P shown in Figure 3-1 and 3-2 less the contributory soft iron effect) and is overcome by the fore and aft corrector magnets. Co-efficient B is zero on north and south and

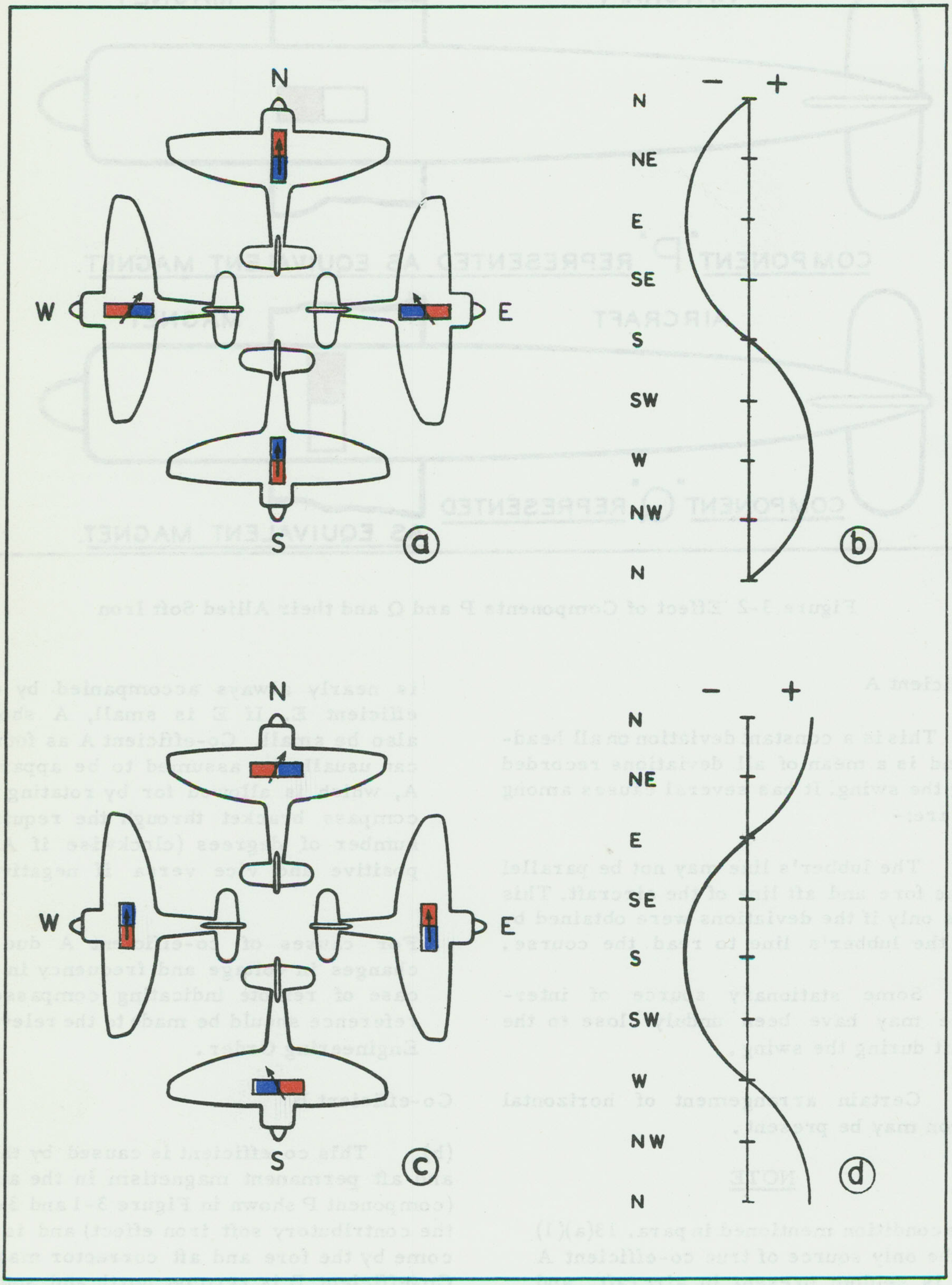


Figure 3-3 Equivalent Magnets Representing Longitudinal and Lateral Fields

is maximum on east and west. This can be appreciated from Figure 3-3a. Co-efficient B is the mean of deviation found on east and west with the sign changed on west.

Co-efficient C

(c) This co-efficient is caused by the athwartships permanent magnetism in the aircraft (component Q shown in Figure 3-1 and 3-2 less the contributory soft iron effect) and is overcome by the athwartships corrector magnets. Co-efficient C is maximum on north and south and is zero on east and west. This becomes evident from study of the effect of the component Q in Figure 3-3c. Co-efficient C is the mean of deviations found on north and south with the sign changed on south.

Co-efficient D

(d) This co-efficient is caused by symmetrical horizontal soft iron about the compass position. The co-efficient D causes maximum deviation on the quadrantal points, and is the mean of deviations on NE, SE, SW and NW; signs change on SE and NW.

Co-efficient E

(e) This co-efficient is caused by horizontal soft iron placed unsymmetrically about the compass position. It causes maximum deviations on the cardinal points and is the mean of deviations found on north, south, east and west; signs change on east and west.

NOTE

For causes of co-efficients D and E due to transmission systems (changes in voltage and frequency) in the case of gyro-magnetic compasses, reference should be made to the relevant Engineering Orders.

Higher Co-efficients

(f) There are other co-efficients (harmonics of higher order) but they should be negligible in effect on a normally well-placed compass. Higher co-efficients are uncorrectable.

INFLUENCE OF VERTICAL COMPONENT R (TILT OR HEELING ERROR)

14 The magnetic fields due to normally vertical iron in an aircraft have a varying horizontal component in relation to the compass position dependent upon the attitude of the aircraft. Hence deviations obtained by swinging the aircraft tail down may not apply when the aircraft is in the flying attitude. Further, in overload conditions or in high-altitude flight, the aircraft flies nose high to a certain extent. If there is a large vertical component of the aircraft's magnetism, the compass may be seriously affected when flying in such an attitude.

15 The error due to component R is at a maximum on east and west, and zero on north and south. Consequently, this error combines with that due to co-efficient B.

16 The effect of the vertical component is demonstrated in Figure 3-4 which shows the horizontal component which will effect the fore and aft component (co-efficient B), appearing when the aircraft attitude is changed from level flight to tail down.

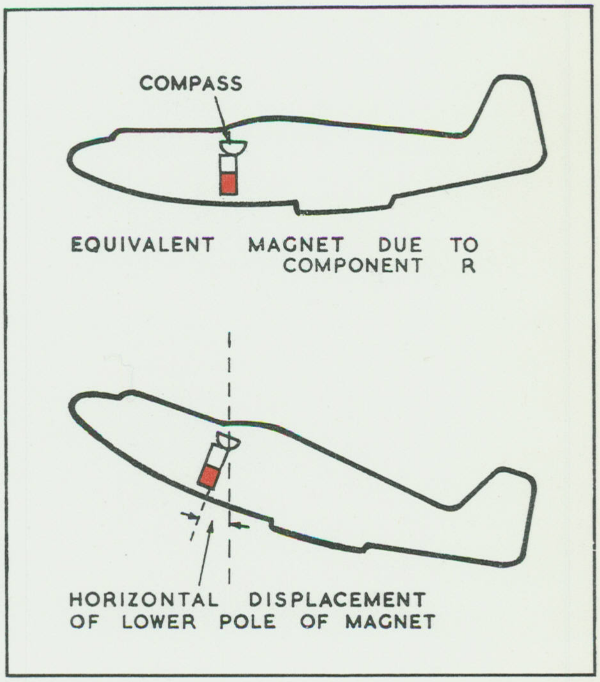


Figure 3-4 Effect of Component R

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COMPASS SWINGING BASE

GENERAL

1 Since the swinging of aircraft compasses is undertaken to determine the compass deviations due to the magnetism in the aircraft, it is necessary to undertake the swinging at a place where only the aircraft and earth's field can affect the compass reading. This requirement is met ideally when the compass is calibrated in the air but for a number of reasons, calibration is usually undertaken on the ground at a suitable compass base where the aircraft can be swung. A compass base, therefore, is an area used for compass swinging and compensation. It may consist of a specially laid down concrete circle, marked with magnetic directions in some instances, or, more usually, it will be an area of the airfield set aside for the purpose.

REQUIREMENTS FOR A COMPASS BASE

2 The requirements for a compass base are as follows:-

(a) It must be accessible to the type of aircraft under consideration.

(b) It should be located where it will not interfere with normal airfield operation.

(c) It must be of a size suitable for the type of aircraft borne at the unit. In estimating the working area required for the base, the calculations must include the minimum distance from the aircraft of the datum instrument used for the establishment of the correct magnetic direction.

(d) The surface, when of grass, should be such that it will not preclude swinging in wet weather. This is particularly important when dealing with heavy aircraft.

(e) The area must be free from magnetic fields, other than that of the earth, which might affect the compass and magnetic structure of the aircraft. This is the most important requirement. Disturbing magnetic fields may be due to the proximaty of underground power lines, lighting circuits, metal re-inforcing of concrete, pressed steel plate covering for grass strips, drainage systems or fuel installation pipe lines etc. For these reasons, runways or taxi tracks are not ideally suited for swinging aircraft without making a careful preliminary survey.

SELECTION OF SITE

3 When a compass base has to be selected,

the first step is to scrutinize a detailed plan of the airfield site in company with the Station Construction Engineering Officer, bearing in mind the requirements listed in para. 4, above. Air Traffic Control should be consulted also regarding aircraft movement on the airfield etc. A suitable site, or sites, having been selected, it will then be necessary to conduct a survey to ascertain the presence or otherwise, of unwanted magnetic fields. This can be done using one of the following two methods.

THE RECIPROCAL BEARING METHOD

4 For this method, two sighting compasses or other magnetic datum instruments are required together with two observers. The observers should be stationed at a distance of 30 to 40 yards apart and should take bearings of each other. Successive instrument stations should be chosen, so as to cover the whole of the surveyed area, and the instrument or the central leg of the tripod, depending on the aspect, is a suitable sighting mark. The two bearings should then be compared and, within fine limits, each should be the reciprocal of the other. The reference compasses must then be moved round the area and bearings taken at every 15 or 20 degrees and comparisons made; approximately 20 sets of such readings will suffice. Too much care cannot be exercised when reading the reference instruments. The bearings should be read to the finest limits possible with the particular instrument in use. Acceptance of the site will depend on the consistency of the readings, and provided the differences throughout them are insignificant, compared with observational errors, the site may be accepted.

THE DISTANT BEARING METHOD

5 This method has an advantage in that one reference instrument and one observer are required, but its use is restricted to conditions of good visibility. The first step is to select as a datum point a distant but clearly defined landmark, such as a church spire, approximately 10 miles from the site. Bearings of the datum point should next be taken from different stations around the site, chosen so as to cover the whole area, and the readings compared with each other. Within limits, depending upon the accuracy to which the reference instrument can be read, the readings should be constant. If they vary considerably, the site is unsuitable.

EXTRANEOUS MAGNETIC FIELDS

6 The existence of undesirable magnetic fields in the vicinity of the selected site is a possibility which must be borne in mind when making the survey. Observers using the reciprocal bearing method should note and communicate to each other, at the time of making the observation, any serious deviation which they suspect to be due to such influences. Immediate investigation, prior to taking further readings, may establish the presence of pressed steel plate, etc., the removal of which, if possible, might save an otherwise ideal site from being rejected. This applies also to the observer using the distant bearing method, but in this instance he will form his own conclusions and act upon them as he proceeds.

COMPASS BASE SURVEY LOG

7 Due to constructional work, the laying of cables etc., it is possible that the magnetic properties of a chosen compass base may not remain constant over a long period. For this reason, it is desirable that the base should be surveyed at intervals. To facilitate this, the compilation of a "compass base survey log" preferably by the Senior Navigation Officer is recommended. It should contain the dates of surveys, notes on instruments used, differences between readings, the names of the observers and a large scale plan of the area surrounding the base, including all installations likely to affect the surrounding magnetic field.

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SIGHTING COMPASS

GENERAL

1 The compass provided to be used when swinging compasses is the Ref. 6B/532, compass, datum, hereinafter referred to as a sighting compass. It is comparatively small and is fixed to a handle which is held vertically. The sighting devices are simplified and a lamp and dry battery are fitted in the handle to illuminate the scale when the compass is used in the dark.

DESCRIPTION

2 The sighting compass is illustrated in Figure 5-1. The construction of the compass whilst following the general principles of aircraft magnetic compasses, differs from them in that it is used on the ground. It is not provided with anti-vribrational suspension incorporated in other types of aircraft compasses.

3 The compass card consists of a white mica ring with the scale markings in black, the letters and figures being reversed laterally for viewing in a reflecting prism. The bowl is filled with compass fluid and a sylphon tube allows for expansion of the fluid due to temperature variations.

4 A prism is mounted on a bracket attached directly to the verge ring. It turns on horizontal trunnions in rigid bearings and spring washers provide the necessary friction. Only one sight is fitted; it is a "V" sight and is attached at the top of the prism. The sloping face of the prism forms a mirror and the front surface is curved to magnify the image of the scale. An index line is fitted in the bowl immediately below the prism, and the scale is read from this line.

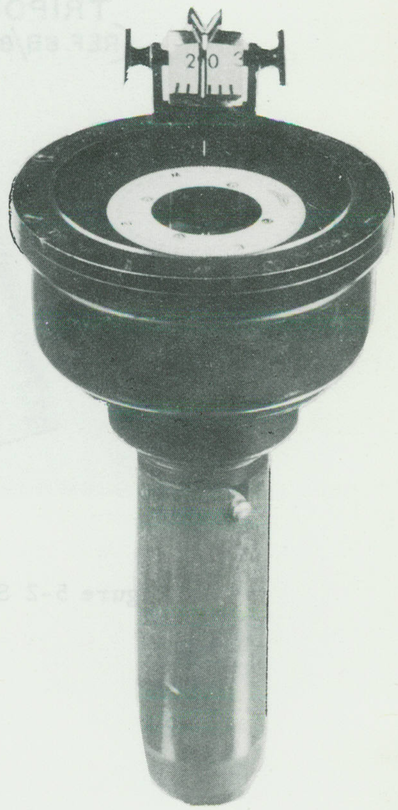

Figure 5-1 Sighting Compass

5 The handle is of wood and carries the lighting system which consists essentially of a 2.5 volt bulb operated by a dry battery. Illumination is passed from the bulb through a frosted glass plate carried by the sylphon tube to the interior of the bowl. By removing the handle, and using an adaptor (Ref. 6B/465) the compass can be fitted to a tripod (Ref. 6B/87). Refer to Figure 5-2.

OPERATION

6 It is strongly recommended that the sighting compass be used with a tripod, however, it can be held in the hand by means of the handle, to take bearings. It must be held with the verge glass horizontal. The object is viewed through the "V" sight while the compass is turned so that the object, the sight and the

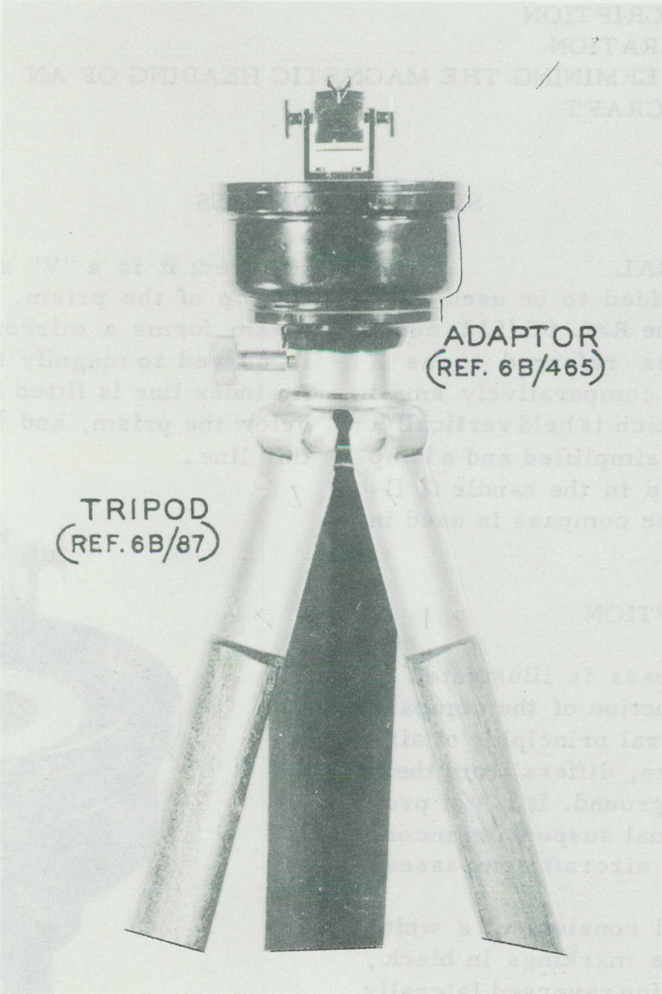

Figure 5-2 Sighting Compass Fitted to Tripod

image of the index line as seen by reflection in the prism are all in line. The bearing is then read off on the card against the index line.

DETERMINING THE MAGNETIC HEADING OF AN AIRCRAFT

7 Standing at least 50 feet from the aircraft, the observer aligns himself with its longitudinal axis by Reference to a radio mast and fin, row of central fuselage rivets, or any suitable line or pair of objects on the aircraft and using the sighting compass, sights one of the objects used for alignment as shown in Figures 5-6, 5-7, 5-8. The sighting compass is read when steadied. The reading obtained is the magnetic heading of the aircraft, if the observer is behind the aircraft. If the observer is in front of the aircraft, the magnetic heading is obtained by adding or subtracting 180° from the reading obtained from the sighting compass.

Figure 5-4 Side View of Correct Method of Holding the Sighting Compass

Figure 5-3 Front View of Correct Method of Holding the Sighting Compass

Figure 5-5 Side View - Observer Using Sighting Compass Fitted to Tripod

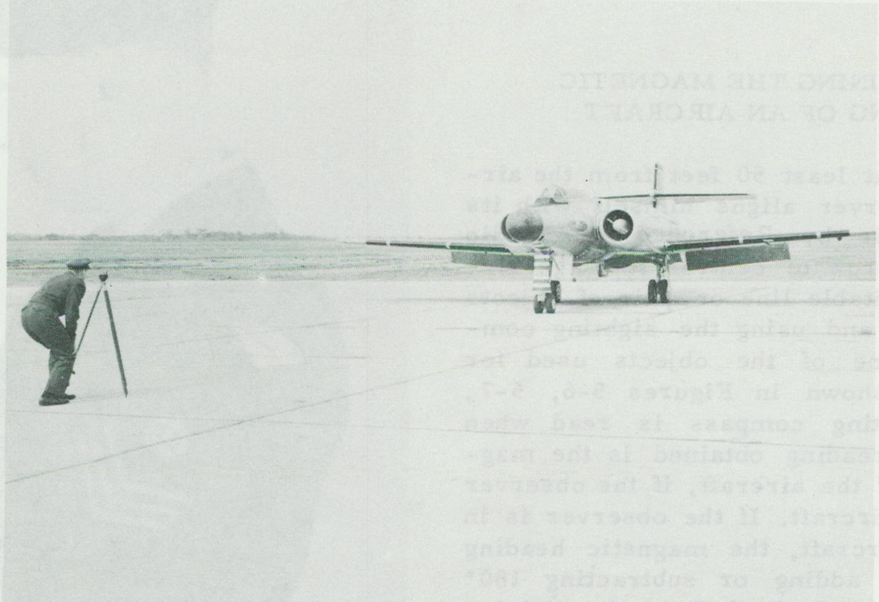

Figure 5-6 Sighting an Aircraft with Sighting Compass fitted to Tripod

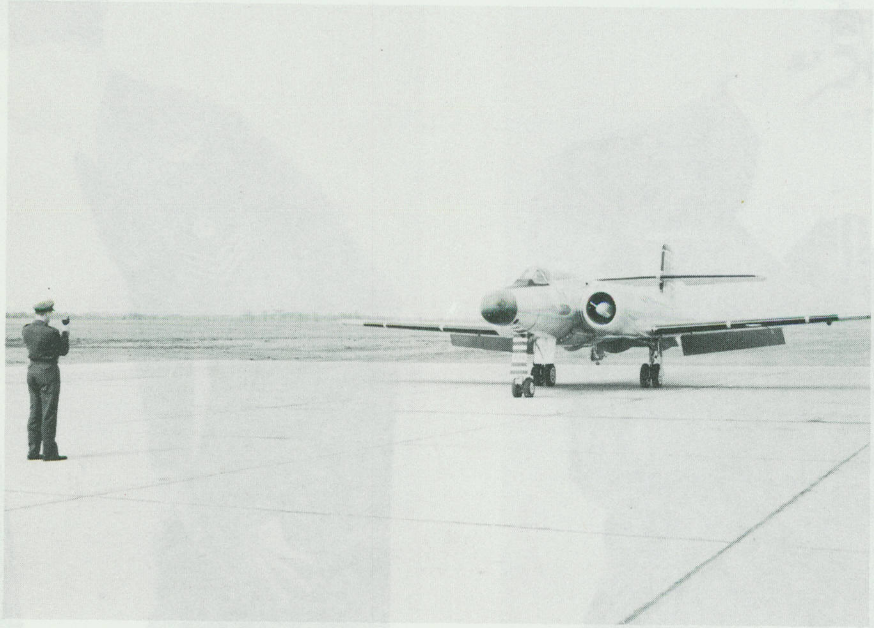

Figure 5-7 Sighting an Aircraft with Sighting Compass

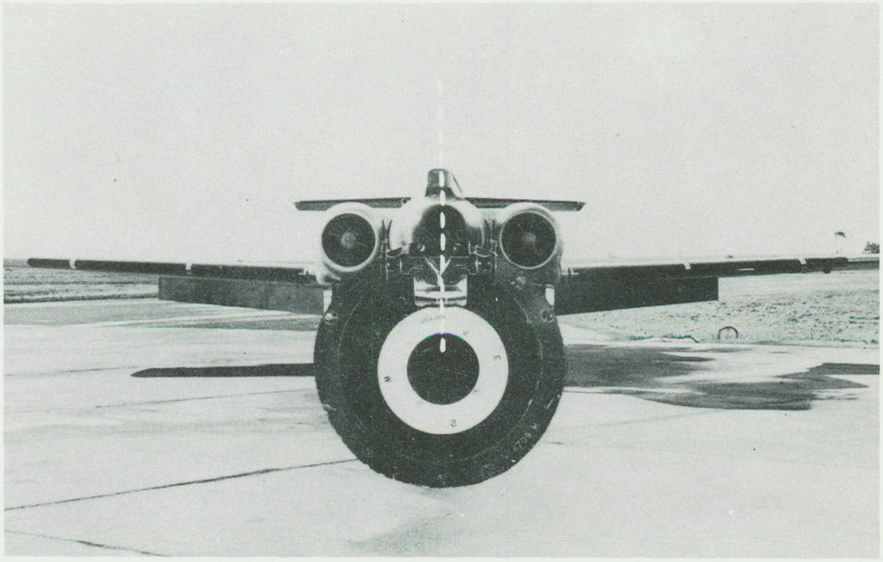

Figure 5-8 Pictorially Illustrating Alignment of Aircraft with Sighting Compass

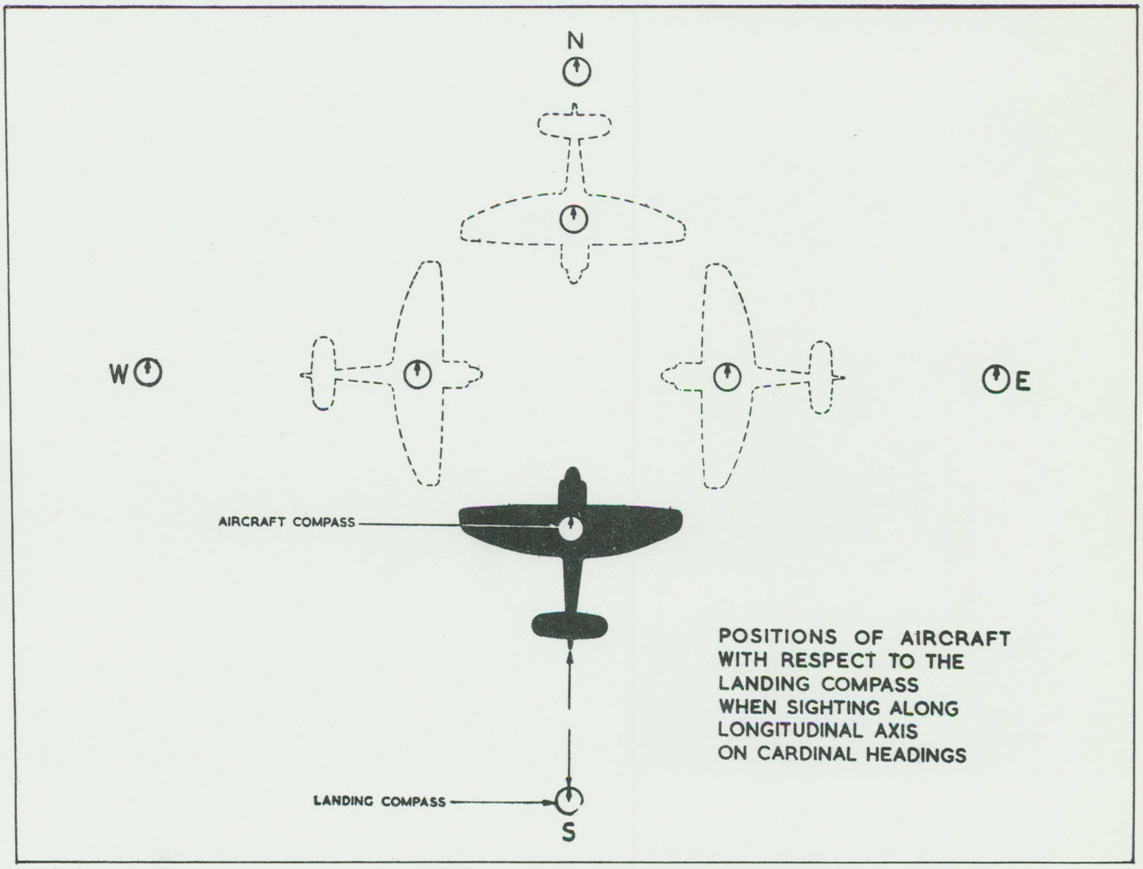

Figure 5-9 Some Relative Compass Positions During a Swing

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FREQUENCY AND REQUIREMENTS FOR SWINGING

TYPES OF COMPASSES

1 For the purposes of this Engineering Order, aircraft compasses will be classified as follows:-

(a) Remote indicating compasses.

(b) Direct reading compasses.

FREQUENCY OF SWINGS

2 All installed compasses are to be swung when one or more of the intervals and/or conditions listed below are present:-

(a) Prior to acceptance of an aircraft by the RCAF.

(b) Prior to issue of an aircraft from an RD or overhaul contractor.

(c) On completion of a major aircraft inspection.

(d) On completion of an engine change.

(e) When an aircraft has been standing in one position, i.e., facing in the same direction, for four weeks or more.

(f) When 60 days have elapsed from previous compass swing.

(g) When the accuracy of the compass is in doubt.

(h) When there is any considerable change in magnetic latitude.

(j) When the compass and/or any major component of a compass system has been replaced.

(k) When magnetic materials have been added to the aircraft or when wiring circuits, components or parts thereof have been altered or replaced, which may affect the magnetic characteristics of the aircraft.

(l) After the aircraft has been loaded with magnetic materials which may influence the compass.

REQUIREMENTS FOR SWINGING

3 The following conditions are requisite when swinging remote indicating and/or direct reading compasses with the exception of compasses installed for standby reference only:-

(a) The aircraft engines must be running with the generators charging and inverters operating.

(b) All electrical, instrument and radio circuits and components (not including landing lights and equipment used for emergency purposes) required in the normal operational role of the aircraft must be switched on.

(c) Fighter and bomber type aircraft must have had all guns fired and bombsight, gunsight, gun turret and a bomb selector circuits operated prior to commencing compass swings, however, these circuits are to be switched "off" during the swing.

4 The following conditions are requisite when swinging compasses installed for standby reference only:-

(a) The aircraft engines must be operating with the generators charging and the inverters switched off.

(b) All other electrical, instrument and radio circuits are to be switched off.

NOTE

All compasses are to be swung with the aircraft in normal cruising attitude, i.e., in a tail-up position.

5 Ground swinging can generally be considered satisfactory for most types of aircraft, however, it is recommended that, if possible, a check air swing be carried out to verify the results of the ground swing.

PRESWINGING

6 Insofar as possible, all fixed or movable items containing ferrous materials should be placed in positions they will occupy in flight before beginning the swing.

7 The compass should be inspected for general serviceability.

CAUTION

Remove the compensator drawer or assembly of the aircraft compass before beginning the swing. If removal of the compensator assembly of the compass is impractical, the compensator must be set for zero effect by matching the dots on the instrument. Compass systems fitted with variation setting facilities must be reset to zero variation prior to commencing the swing.

NOTE

Personnel engaged in compensating compasses must take care to remove all magnetic materials from their persons before beginning the compass swing. Have available a nonmagnetic screwdriver.

PART 7

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COMPENSATION AND SWINGING

GROUND COMPENSATION AND SWINGING

1 Having selected a suitable area for swinging, NEUTRALIZE THE COMPENSATOR by matching the dots on the compensator screws with those on the instrument case. It is essential that the following precautions are taken prior to commencing the swing:-

(a) The compass must be tested for serviceability.

(b) Personnel engaged in compass swinging are to ensure that they have no magnetic material on their person and that only non-magnetic tools are used for adjustments.

(c) In the case of remote reading compasses it must be ensured that the power requirements of the system are available and correct within the specified tolerances.

(d) The accuracy of the sighting compass must be verified.

(e) It must be ensured that the actual equipment carried in flight is in position in the aircraft and that no additional items, likely to affect the compass, are fitted or lying loose in the cockpit in the vicinity of the compass or remote transmitter.

NOTE

The methods of compass swinging and adjustment discussed in this Part apply specifically to compasses and compass systems which have their compensating mechanisms attached directly to the case of the magnetic element. It may be desirable when swinging compasses, whose compensators are fixed to the mounting bracket, to remove "A" or index error after correcting for co-efficients "B" and "C". For instructions relative to compensation of the Flux Gate Compass System refer to EO 20-25BB-2.

COMPENSATION FOR CO-EFFICIENT "A" (INDEX ERROR)

2 To determine the "A" or index error of a compass or compass system proceed as follows:-

(a) Place aircraft on a heading within 5° of magnetic east.

Date: Aircraft Type and No.: Harvard Compass Type and No.: P 11 014 Adjusted by:

CORRECTING SWING

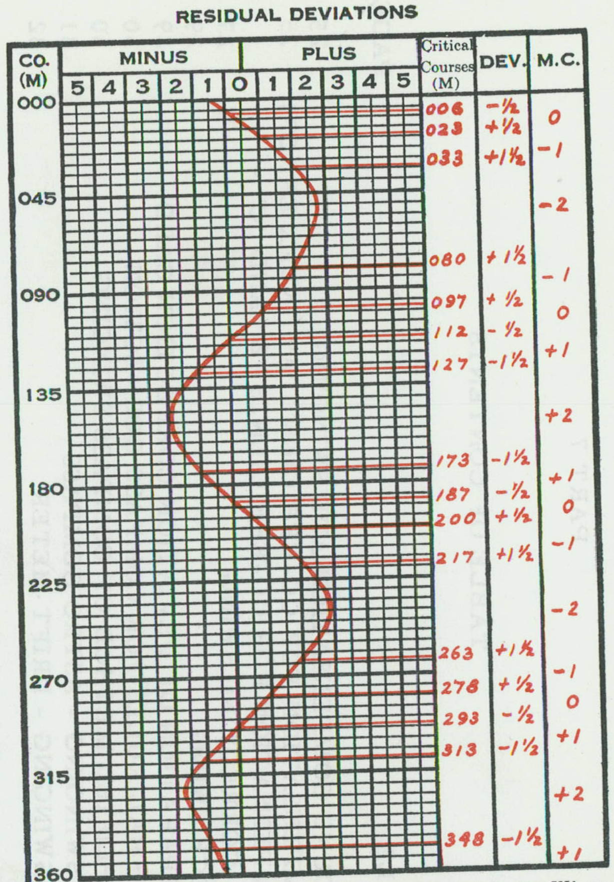
(i) Approx. Course (M)	(ii) Astro Compass Course* (T)	(iii) Variation*	(iv) Actual Course (M)	(v) Aircraft Compass reads	(vi) Deviation (iv) − (v)	Coefficients
North	—	—	359	003	−4	$C = \frac{\text{Dev. on N} - \text{Dev. on S.}}{2}$
East	—	—	091	085	+6	$= \frac{-4-8}{2} = -6$
South	—	—	178	170	+8	
Coefficient C (with sign changed)				+6		
Make Compass read..........				176		
West	—	—	267	265	+2	$B = \frac{\text{Dev. on E} - \text{Dev. on W.}}{2}$
Coefficient B				−2		$= \frac{+6-2}{2} = +2$
Make Compass read..........				263		

BY SIGHTING COMPASS

CHECK SWING

(i) Approx. Course (M)	(ii) Astro Compass Course* (T)	(iii) Variation*	(iv) Actual Course (M)	(v) Aircraft Compass reads	(vi) Deviation	(vii)	(viii) Residual Deviations
N.W.			317	316	+1	+3	−2
North			000	358	+2	+3	−1
N.E.			047	042	+5	+3	+2
East			093	089	+4	+3	+1
S.E.			135	134	+1	+3	−2
South			179	177	+2	+3	−1
S.W.			225	220	+5	+3	+2
West			273	269	+4	+3	+1
				Total:	+24	÷ 8 = +3	

To remove + A, turn Lubber Line clockwise.
To remove − A, turn Lubber Line anti-clockwise.
*For use when swinging by Astro Compass.



It will be noted that example shown in Figure 7-1 is for a Type P-11 compass in which co-efficient A was removed last. When compensating remote indicating compasses co-efficient A MUST be removed prior to correcting for co-efficients B and C. Columns (vii) and (viii) of Form E174 will not be used in this instance, as column (vi) will actually indicate the residual deviation.

Figure 7-1 Form E174

(b) Allow the aircraft compass time to settle and record its reading. (This may require several minutes, particularly when swinging a Gyrosyn compass system in order to allow the system to slave to the heading sensed by the uncompensated flux valve).

(c) With the sighting compass, determine the magnetic heading of the aircraft and record this reading.

(d) Repeat sub-paras (a), (b) and (c) on magnetic headings south, west and north.

(e) Calculate the differences in readings between the aircraft compass and the sighting compass, for each heading, as plus (+) or minus (-) depending on whether the readings are greater or less than the correct headings.

(f) Add the errors algebraically and divide by four. The result is the index error.

(g) Loose the mounting screws and rotate the compass or remote transmitter to cancel out the index error. If the error is positive, the compass or remote transmitter should be rotated in the minus (-) or clockwise direction, as observed from above the instrument. If the error is negative, rotate the compass or remote transmitter in the positive (+) or counterclockwise direction. The amount of rotation should equal the index error.

(h) Tighten the mounting screws and re-check the readings at the four cardinal headings. Recalculate the index error to ensure that it is zero. If it is not zero readjust the compass or remote transmitter until this error is cancelled. Any remaining errors in excess of $\pm$ 1° are due to extraneous magnetic fields and should be compensated for as discussed below.

COMPENSATION FOR CO-EFFICIENTS "B" AND "C" - CORRECTING SWING

3 Compensation for co-efficients "B" and "C" is to be effected as follows:-

(a) Place the aircraft on a heading within 5° of magnetic north, allow the compass time to settle, and enter its reading in the appropriate column of Form E174, see Figure 7-1. When swinging a Gyrosyn compass system allow a minimum of five minutes for the system to slave to the heading sensed by the uncompensated flux valve.

(b) With the sighting compass determine the actual magnetic heading of the aircraft and enter this reading in the appropriate column of Form E174.

(c) Repeat the procedure as outlined in sub-paras (a) and (b) above, for the approximate heading of magnetic east.

(d) Repeat the procedure as outlined in sub-paras (a) and (b) above, for the approximate heading of magnetic south.

(e) Calculate co-efficient C from formula,

$$\frac{\text{Deviation North - Deviation South}}{2} = \text{Co-efficient C}$$

shown on the Form E174, Figure 7-1, and compensate in the following manner:-

(1) Change the sign of the co-efficient C (since the aircraft is now heading south) and add it algebraically to the aircraft compass reading on south. In other words, increase the aircraft compass reading by the amount of co-efficient C if C is negative, or decrease the aircraft compass reading by co-efficient C if C is positive. The figure obtained is what the aircraft compass must read after correction.

(2) Using a corrector key or non-magnetic screwdriver, as applicable, gently turn the athwartships or N-S compensating screws until the required reading is obtained.

(f) Repeat the procedure as outlined in sub-paras (a) and (b) above, for the approximate heading of magnetic west.

(g) Calculate co-efficient B from formula,

$$\frac{\text{Deviation East - Deviation West}}{2} = \text{Co-efficient B}$$

shown on the Form E174, Figure 7-1.

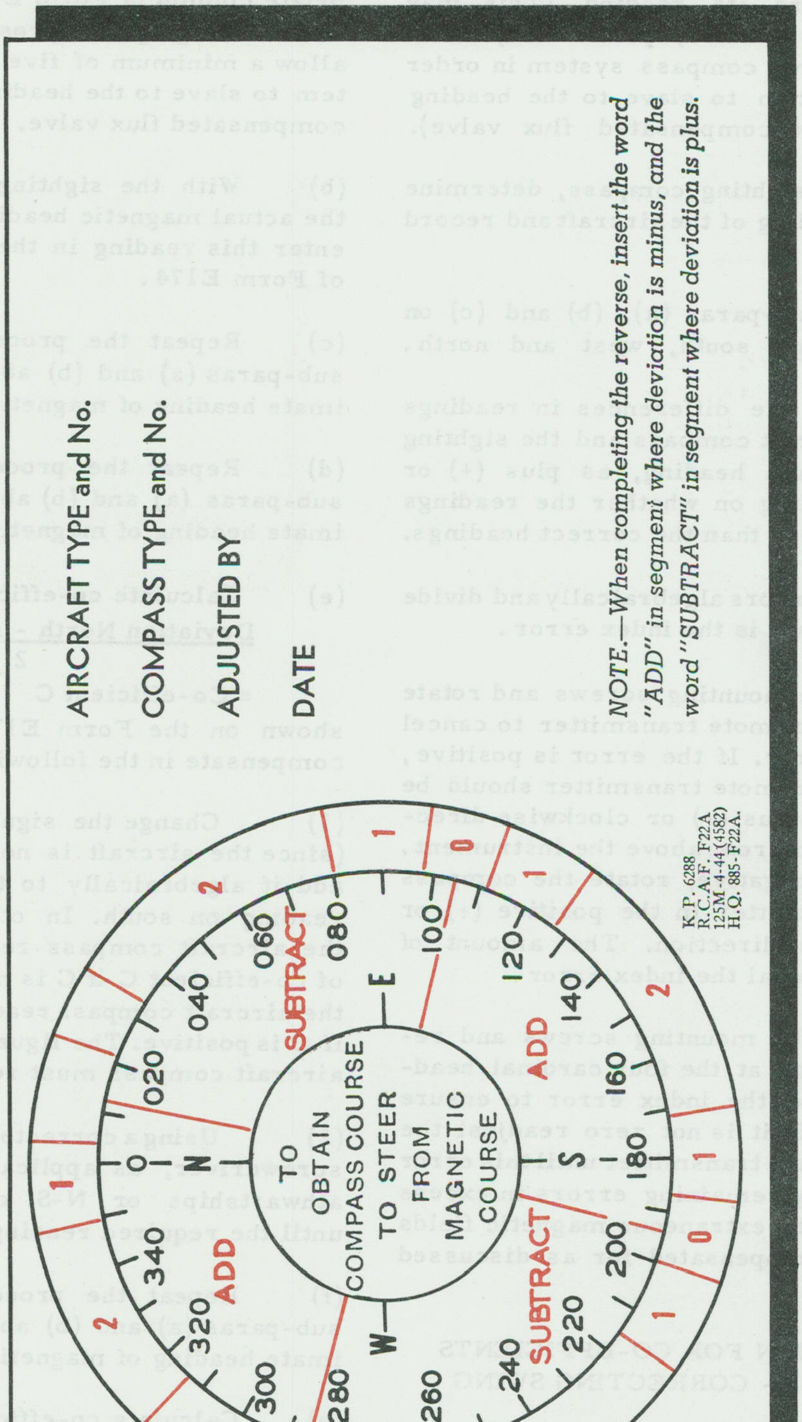
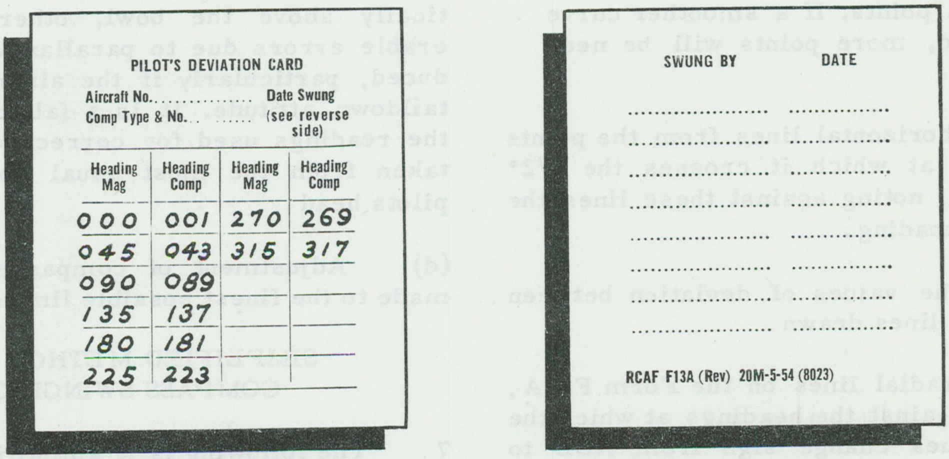


Figure 7-2 Form F22A



PILOT'S DEVIATION CARD

Aircraft No. .... Date Swung

Comp Type & No. .... (see reverse side)

Heading Mag	Heading Comp	Heading Mag	Heading Comp
000	001	270	269
045	043	315	317
090	089		
135	137		
180	181		
225	223		

SWUNG BY	DATE
....	....
....	....
....	....
....	....
....	....
....	....
....	....

RCAF F13A (Rev) 20M-5-54 (8023)

Figure 7-3 Form F13A

(h) Using a corrector key or non-magnetic screwdriver, as applicable, gently turn the fore and aft or E-W compensating screws until the required reading is obtained.

CHECK SWING

4 On completion of the compensating swing a check swing is to be carried out as follows:-

(a) Manoeuvre the aircraft successively on the magnetic headings NW, N, NE, E, SE, S, SW and W, allowing the compass time to settle before noting its reading and that of the landing compass on each heading. (Allow a Gyrosyn compass system a minimum of two minutes on each heading before recording its reading).

(b) Enter these readings in the columns (iv) and (v) of the Form E174 under Check Swing and calculate the residual deviations by subtracting algebraically the readings entered in column (v) from the readings entered.

(c) Calculate the residual deviations by subtracting algebraically the readings entered in column (v) from the readings entered in column (iv) for each heading.

PREPARATION OF DEVIATION CORRECTION CARD

5 The procedure for recording the residual deviations and the preparation of a deviation correction card (Forms F22A or F13A as applicable) shown in Figures 7-2 and 7-3 is outlined in the following steps:-

(a) Enter the residual deviations, as calculated in para. 4(c) above, in column (viii) on Form E174.

(b) Plot on the graph the values given in column (viii) against the cardinal and quadrantal headings as indicated by the aircraft compass.

(c) Join the plotted points by a smooth curve.

NOTE

Some practice is necessary for drawing a smooth curve, and it must be remembered that the maximum and minimum values need not necessarily occur at the plotted points. If a smoother curve is required, more points will be necessary.

(d) Draw horizontal lines from the points on the curve at which it crosses the 1/2° vertical lines, noting against these lines the approximate heading.

(e) Note the values of deviation between the horizontal lines drawn.

(f) Draw radial lines on the Form F22A, Figure 7-2, against the headings at which the deviation values change sign from ADD to SUBTRACT and vice versa (see note on the reverse of Form F22A).

(g) Fill in the values obtained from the graph in the outer ring on Form F22A.

(h) Fill in the particulars on the reverse side of the Form and insert the Form in the appropriate holder.

GENERAL RULES FOR COMPASS CORRECTION

6 In addition to the instructions given above, the following rules must be observed:-

(a) Where large corrections for co-efficients B and C have to be made, it will seldom be possible to remove all the error due to these co-efficients in one correcting swing. A second swing should be carried out when necessary.

(b) THE COMPASS ADJUSTMENT SHOULD NEVER BE RUSHED. A compass requires at least two minutes on each heading and after each correction in which to settle down. Slight tapping on the bowl will aid the settling down process. A distant reading gyro-magnetic compass (DRC) usually requires considerably longer than two minutes before a steady reading is indicated, and it must not be assisted by tapping. Reference as to adjustment of a specific type of compass, should be made to the relevant Engineering Order.

(c) When reading a "P" type compass during a swing the eye should be kept vertically above the bowl, otherwise considerable errors due to parallax will be introduced, particularly if the aircraft is in the taildown attitude. It is a fallacy to assume the readings used for corrections should be taken from the most usual position of the pilots head.

(d) Adjustment of compasses should be made to the finest possible limits.

SIMPLIFIED METHOD OF COMPASS SWINGING

7 The following is a simplified method of compass swinging which is quite accurate and if carried out carefully can be effected in much less time:-

(a) Remove the "A" or index error as detailed in para. 2 of this Part.

(b) Align aircraft on a heading within 5° of magnetic north, allow the compass time to settle and record its reading. (Allow a Gyrosyn compass system a minimum of five minutes to slave to the heading sensed by the uncompensated flux valve).

(c) Determine the actual magnetic heading by means of the sighting compass and record this reading.

(d) Calculate the deviation as plus (+) or minus (-) depending on whether the readings of the aircraft compass are greater or less than the correct headings.

(e) By means of the athwartships or N-S compensating screw remove all of the error.

(f) Repeat sub-paras (b) through (d) above, with the aircraft heading magnetic east.

(g) By means of the fore and aft or E-W compensating screw remove all of the error.

(h) Repeat sub-paras (b) through (d) above, with the aircraft heading magnetic south.

(j) By means of the athwartships or N-S compensating screws remove one-half of the error.

(k) Repeat sub-paras (b) through (d) above, with the aircraft heading magnetic west.

(l) By means of the fore and aft or E-W compensating screws remove one-half of the error.

(m) Carry out a check swing, completing Forms E174 and F22A or F13A as previously described.

AIR SWINGING - ASTRO COMPASS

8 The practical requirements of swinging an aircraft in flight by astro compass are:-

(a) Calm air conditions and a visible sun whose attitude is preferably less than 45°.

(b) Sufficient view of the ground to locate the aircraft within 10 miles.

(c) Positions for the astro compass in the aircraft which provide an adequate view of the sun on all cardinal and quadrantal courses.

(d) A watch keeping GMT.

(e) A navigator or observer in addition to the pilot.

(f) Automatic pilot.

9 Air swinging using an astro compass is to be carried out as follows:-

(a) Check the alignment of the astro compass mountings on the ground. This may be done by placing the aircraft on a known true heading (a known magnetic heading corrected for variation) and checking that heading by means of the astro compass on the sun or a distant object whose true bearing is known. Rotate the astro compass so that the true heading as determined by it agrees with the actual true heading of the aircraft.

(b) From the air almanac, prepare a graph of GMT against LHA for the selected flying area for a period covering that during which the swing is to take place. The graph is drawn as a straight line between the values of LHA and the GMT for the start and finish of the swing.

(c) Take-off, and using the automatic pilot, fly straight and level at normal cruising speed, landing gear retracted, over the area for which the LHA's were calculated (within 10 miles) on compass headings, north east, south and west (within 5°). Using the graph of LHA sun and the GMT, the aircraft's true course is determined by astro compass on each of the four headings. To these true courses apply the local variation (which should be taken from the latest local air map, corrected for date, if necessary) to obtain the magnetic headings. The mean of a number of astro compass readings on each heading should invariably be taken.

(d) Land, calculate co-efficient "A" and correct same as described in para. 2(g) and (h), of this Part.

(e) Having corrected co-efficient "A", take off again and using the astro compass as before, determine the true headings on compass headings, north, east, south and west. To these true courses apply the local variation as before.

(f) Land, calculate co-efficients "B" and "C" and compensate for same as described in the applicable sub-paras of para. 3, this Part.

(g) Having compensated for co-efficients "B" and "C" conduct a check swing, taking readings on north, northeast, east, southeast, south, southwest, west and northwest (flown within 5°).

(h) Land, convert the true headings to magnetic by applying the variation and complete the Forms E174 and F22A or F13A.

AIR SWINGING - DRIFT METER

10 The practical requirements of swinging an aircraft compass in flight by means of a drift meter are:-

(a) Calm air conditions.

(b) A straight railroad, road, pipe line, or the like whose magnetic direction is known, and sufficient visibility to locate it.

(c) A type B-3 or B-6A drift meter.

(d) A navigator or observer in addition to the pilot.

Procedure

11 Air swinging using a drift meter is to be carried out as follows:-

(a) Check the alignment of the drift meter in accordance with the relevant Engineering Order.

(b) Take-off, and using the automatic pilot, fly straight and level at normal cruising speed, landing gear retracted, over the known land mark within 5° of compass headings; north, east, south and west. Align the drift wires of the drift meter parallel with the ground reference when over it and read the compass immediately. Determine the magnetic headings flown by adding the azimuth angles read from the drift meter to the known magnetic direction of the ground reference.

(c) Land, calculate co-efficient "A" and correct same as described in para. 2(g) and (h), this Part.

(d) Take-off again and using the drift meter as before, determine the magnetic headings on compass headings north, east, south and west.

(e) Land, calculate co-efficients "B" and "C" and compensate for these errors as described in the applicable sub-paras of para. 3, this Part.

(f) Having corrected the co-efficients, and using the drift meter as before conduct a check air swing, taking readings on compass headings, north, northeast, east, southeast, south, southwest, west and northwest (flown to within 5°).

(g) Land and complete the forms E174 and F22A or F13A.

PART 8

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FAULTY INSTALLATIONS

COMPASS DEVIATION REQUIREMENTS

1 Where the strength of the earth's horizontal field is .18 gauss and the vertical field .54 gauss, the maximum deviation on any heading with corrector magnets removed, and with all equipment in cruising condition shall not exceed the following:-

(a) 10° spread for remote indicating compasses.

(b) 20° spread for standby and other magnetic compasses.

2 Requirement for remote indicating compasses is one-half that for direct reading compasses. This is as measured with a direct reading compass at the remote compass location and does not include the transmission error of the remote compass.

3 After the deviations have been reduced by the use of corrector magnets, the maximum deviation remaining on any heading shall not exceed 3° for any compass.

EXCEPTIONS

4 In places where the earth's field differs from the field mentioned in paragraph 2 of this Part, the maximum uncorrected deviation shall be altered accordingly, for example, where the earth's field horizontal component is .28 gauss, the maximum allowable deviation is $\frac{.18}{.28}$ of 20° or 13° spread, and where the earth's field horizontal component is .14 gauss this figure would be $\frac{.18}{.14}$ of 20° or 26° spread. The above example applies for standby or other magnetic compasses, however, maximum uncorrected deviation for remote indicating compasses may be determined in a similar manner.

5 While the above requirements will apply for aircraft projected after the date of this Engineering Order, many aircraft now in existence will not meet them.

6 If it is decided that the compass performance in a particular aircraft or type of aircraft is faulty, an unsatisfactory condition report should be submitted.

7 When an unsatisfactory condition report on faulty compass operation is made, data necessary for an analysis to enable corrective measures to be taken shall be submitted with the report. A form as shown in Figure 8-1 will be used for reporting faulty compass installation. Such data shall be obtained as follows:-

NOTE

The compensator drawer or the compensator assembly MUST BE REMOVED when gathering the data even if removal of the compass is necessary for such purpose.

(a) Start the engine(s).

Aircraft Type and No.		Compass				Date		
	Actual Head (M)	Aircraft Comp.	Aircraft Compass with Switches Operating					
			Gen.	Radio	Pitot	Heater	Land Light	Gun Sight
N. 000								
NE. 045								
E. 090								
SE. 135								
S. 180								Add
SW. 225								Other Columns
W. 270								When
NW. 315								Necessary

Figure 8-1

(b) Place the aircraft's head on magnetic north (within 5°), chock the wheels, and with engine(s) idling, read the compass. Record both the compass reading and the actual magnetic heading of the aircraft.

(c) With engine(s) idling, record the aircraft compass readings as each switch, excepting the generator, is operated in turn (radio; pitot heater; gunsight; cockpit heater; gun solenoids; landing, navigation, instrument, passing lights, etc.). Allow the compass time to settle before reading.

(d) Run up the engine until the generator is charging and turn on the generator switch. Record the compass reading.

(e) Repeat the above steps, (2) to (4) inclusive, on magnetic headings of northeast, east, southeast, south, southwest, west and northwest.

(f) Arrange the recorded data for submission to Air Materiel Command Headquarters, in a form similar to that shown in Figure 8-1.

(g) With the aircraft in level cruising flight on each of the cardinal and quadrantal compass headings, north, northeast, east, etc., record the compass reading, wheels extended and wheels retracted. Submit the results of this test with the data above.

8 While analysis of the above data will supply considerable information regarding magnetic characteristics of an aircraft, it must not be construed that it constitutes a complete magnetic investigation.