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1623493 BIRD J. H.

1. FLIGHT 10 COURSE.

I. T. W.

HILLSIDE CAMP,

BULAWAYO.

PRIMARY. 1st. Jan. 1943 – 12th. Feb. 1943.

SECONDARY. 15th. Feb. 1943 – 19th. Mar. 1943.

24 E. F. T. S.

INDUNA.

STARTED COURSE 29th. Mar. 1943.

FINISHED COURSE 28th. June 1943.

21 S. F. T. S.

KUMALO

I.T.S. 12th. July 1943 – 10TH. SEPT 1943.

A.T.S. 20th. Sept 1943 –

NAVIGATION.

GEN. EXPLANATION.

Chap. 1. Scope of Navigation.

Par. 1–4.

" 5–7

Chap 1 Necessity of navigation. How to become a

Par 8–10 good navigator.

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Form of the Earth.

Chap I Par. 11. Earth is an oblate spheroid but for practical nav. the earth is considered as a sphere.

Polar diameter 7.900 miles (St).

Equatorial diameter 7.927 " "

Lines on the Earth

Chap I Par. 12 For the purpose of fixing position imaginary lines have been established on the earth.

DEFS. Great Circle

is a circle on the surface of a sphere the plane of which passes thro' the centre of the sphere and divides it into two equal parts. The shortest dist. between any two points on the surface of a sphere is the smaller arc of a great circle joining them.

Small Circle.

is a circle on the surface of a sphere the plane of which does not pass thro' the centre of the sphere.

Equator

The great circle whose plane is at right angles to the axis of rotation

Meridian

A semi-great circle terminating at the poles of the earth. The anti-meridian is the other half of the great circle.

Prime meridian

The meridian passing thro' the telescope at Greenwich observatory and is the 0° line of longitude.

Parallel of Latitude Small circles on the earth whose planes are parallel to that of the equator

Rhumb Line

A regular curved line on the surface of the earth cutting all meridians it crosses at the same angle.

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Direction on the earth

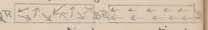
Chap. 1 The cardinal points are N. S. E. and W.

Par. 13-16. The quadrantal points are N.E, SE, SW, NW,
By convention in air navigation directions are measured to the nearest degree clockwise from north, which is 000°, through 360°. All directions are given as three figure groups.
There are three norths ① True or Geog. N. relative to north geographical pole and measured from the true meridian. All chart work is based on true north. ② Magnetic north relative to the north magnetic pole which is variable and not coincident with the true pole. ③ Compass north relative to the direction of a particular compass needle.

Theory of magnetism

Chap. 8 Molecular theory atoms in a magnetic
Par. 5+6. substance have planetory electrons which create lines of force extending outside the atom itself.

According to the nature of the substance an atom or combination of atoms is said to form a molecule which is the smallest tangible particle which can exist in a free state.
Each molecule has a magnetic field formed by the combination of the lines of force of its constituent atoms. 

The lines of force strain for red to blue (Polarity).
Pieces of magnetic material, such as steel, contain an infinite number of molecules, normally arranged in a haphazard manner — magnetically neutral 

un magnetised magnetised

If a force is applied which alines the molecules in one direction the magnetic fields combine and the bar becomes a magnet.

Par. 11 Magnetic Saturation

Par. 13. Poles of a magnet

" Law of attraction and repulsion Unlike poles

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attract. Like poles repel

E.S.P.9. Magnetisation (a) hard iron (b) soft iron

P.10. Methods of magnetisation (1) Induction (2) By stroking (3) Solenoid + 

P.12. Magnetic moment (1). dyne is the force required to produce an acceleration of 1 cm. per sec per sec in a mass of 1 gm.

Unit pole. When two exactly similar poles placed 1 cm. apart exert on each other a force equal to 1 dyne, each is said to be a unit pole.

Unit field. When a unit pole, [redacted] placed in a magnetic field, is acted on by a force equal to 1 dyne, unit field is said to exist at that point.

Couple. When two equal and opposite forces act on a body parallel to each other, the turning effect is said to be a couple.

P. 13. Moment of a magnet. is equal [redacted] to the moment of the couple necessary to maintain it at right angles to a magnetic field of unit intensity.

P. 13 & 14. Read only.

P. 15. Demagnetisation

P. 16. Read only

P.17-18. Terrestial magnetism

P. 21. Magnetic Dip is the angle of depression below the horizontal at an observer of the earths total magnetic force.

Magnetic Equator is a line joining all places where the direction of the earth's total magnetic force is horizontal. i.e where dip is zero.

Isoclinal is a line drawn on the map joining all places having equal dip.

P. 22 Magnetic Compass.

Variation and Deviation

P. 20. Variation

22-4. Magnetic meridian is the direction of the

C.I.P.17-24. axis of a freely suspended magnetic needle influenced only by the earths magnetic field

Variation is the horizontal angle between the direction of true north and magnetic north at a place. It is named E(+) or W(−) according to whether the direction of M. north is to the E. or W. of T. north. Its sign indicates how it is applied as a correction to magnetic directions to obtain true direcs.

Methods of indicating Variation of R.A.F. maps

① Isogonal. A line drawn on a map or chart between all places having equal magnetic variation

Agonic Line is the isogonal indicating zero variation

② Compass rose

③ Marginal diagram

④ Statement in words

Deviation

True	Var.	Mag.	Dev.	Comp.
200°	11°W	211°	3°E	208°
054°	9°E	045°	2°W	044°

The angle measured in the horizontal plane between the magnetic meridian and the direction of a particular compass needle influenced by magnetic fields in addition to that of the earth. It is named E(+) or W(−) according to whether the N. seeking end lies to E or W of the magnetic meridian. Its sign indicates how it is applied as a correction to compass readings to obtain magnetic

Compass Error. is the angle between a particular compass needle and the true meridian passing thro' its pivot, and is the algebraic sum of variation and deviation

Navigational terms

C.I.P. 25-27. Course is the direction in which an aircraft is heading. T. M. or C.

Track is the direction of the path of an aircraft over the earth

Drift is the angular difference between

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the Co. of an aircraft and its Track, - measured to port or starboard from the Co.

__Bearing__ is the direction of one place from another and can be measured T. M or C.

__Back bearing__ is the direction observed from an aircraft of a place over which it has previously passed without an intervening alteration of Co.

__Wind direction__ is always the direction from which the wind is blowing and is always given T.

__Position on the earth__ may be expressed in 4 ways ① Lat. and Long. ② Lettered coordinates ③ Military Grid system ④ Place names (Bearing and distance from fixed objects).

__Graticule__ is the network of lines formed on a map or globe by the meridians (of long) and parallels of latitude.

__Latitude__ of a place is the arc of the meridian intercepted between the equator and the place and is named N. or S. according to whether the place is N. or S. of the equator.

__Change of latitude__. The arc of a meridian between the parallels of latitude passing thro' the places and is named N. or S. according to the direction of change.

__Longitude__ of a place is the shorter arc of the equator intercepted between the prime meridian and the meridian of the place, named E. or W. according to whether the place is E. or W. of the prime meridian.

__Change of longitude__ from one place to another is the __smaller__ arc of the equator intercepted between the meridians of the places. It is named E. or W. according to the direction of the change.

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Measurement of distance

C.1. Speed is the rate of change of position

P.56-8 Knot is the speed of 1 nautical mile per hour.

Statute miles (st.M) = 5,280 feet by decree (Q.E)

Nautical miles (n.m) 6080 ft = average length of one minute of lat

Kilometre (km) = 3280 ft = 1/10,000 part of average distance between the equator and either pole.

Conversion ratio 66n.m: 76 st m 41nm: 76 Km
41 st m: 66K.M. 1 metre: 3·3 ft. (RATIO)

Recording position Position on the earth may be recorded in 4 different ways at the discretion of the captain of the aircraft.

① Latitude and Longitude. by convention lat. always

C.1 given first and figures below 10° are preceded by

P.38. a O.

② Lettered co-ordinate system. For the purpose of

P. 42 - 46 secrecy when reporting position by W/T in wartime, reference is never made to the lat. and long of the position.

The meridians and parallels (every whole °) are each given two code letters, which may be changed at intervals. The intersection of any parallel and meridian may be expressed by a group of 4 letters. The letters for parallel always given first.

R.A.F. method. Using the intersection to the S.W. of the position as an origin, and minutes of lat. and long. as co-ordinates. minutes of lat. given first

R.N. method. Using the same letter graticule the navy report position as a bearing ~~of~~ + distance from the nearest intersection of lettered co-ordinates.

③. Bearing and distance Some known object in the

P.52. vicinity of the position is chosen and the position reported as follows:- ① True bearing from fixed object to position. ② name of fixed object. ③ Distance in n.m. from fixed object to position

PLACE	R.A.F.	R.N
BEACHY HD	ABOP 43 15 ✓	150 CDOP 19 ✓
DOVER	CDRS 08 19 ✓	056 CDRS 14 ✓
EXETER	ABUV 43 28 ✓	231 CDEF 26 ✓
NEEDLES	ABGH 40 25 ✓	141 CDGH 25 ✓

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British modified grid system. In this system the
C.1. map is divided into squares of 500 K.m. sides
P.44-51. each of which is given a letter. Each of these squares is subdivided into 25 squares of 100 K.m. sides which are also lettered from A to Z. omitting the letter I. These squares are again subdivided each into 100 squares of 10 K.m. sides (see diagram 23 A.P. 1234).

On the ¼" to 1 mile map the lines of the 100 K.m squares are thickened and the appropriate letter printed in the square with the reference letter to the 500 K.m. square shown in smaller type in brackets. The 10 K.m squares are numbered. Report position as follows:-
(1) S.W. corner of square is reference point (2) Easting first northing second (3) The reference must always be an even number of figures (4) The reference may or may not begin with a letter.

Example. Report position of Andover aerodrome (1) 500 K.m. sq. (V) (2) 100 K.m. sq. (U) (3) Easting of 10 K.m sq. (7). (4) Easting of tenths sq (7) Northing of 10 K.m. sq (6) (5) Northing of tenths sq (6). =

(V) U7766

Maps and Charts.

C3. P.13. Projections A projection is an orderly system of representing the surface of the earth on a plane surface.

Representing the earth on paper. An exact reproduction of the earths surface on paper is impossible. Certain properties may be preserved however depending upon the purpose for which the map is required, and a general compromise is possible if only a small part of the earth's surface is taken at one time.

In air navigation projections are divided into two groups (1) topographical projections (for map reading (2) navigational (for plotting).

Topographical Projections. Designed to show features of the earth with minimum distortion — modified polyconic. — mostly orthomorphic (shape

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preserved), differing only in minor details which do not concern the navigator.

C.3 <u>Properties</u> ① Scale taken as constant over each P.7. separate sheet. ② Straight lines may be regarded as great circles ③ Bearing and distance may be taken as great circle bearings and G.C. distance. ④ A rhumb line appears as a curve convex to the Equator.

C.3 <u>Scale. Conventional signs</u>

P.8+9. Land aerodrome — Airship base

Landing ground. — Water aerodrome

Seaplane anchorage. — Airship hangar

L Airship mooring mast — Air navigation light

Track indicating light — marine light, lighthouse or buoy

Light vessel — Overhead power line & Teleferic

Aerial corridor — Prohibited area.

(250) Unlighted
OR
(250) "
" Lighted
" "

Obstruction to air navigation of a height above 60 metres or 200 ft.

X Explosives area — Danger area.

X

Aerodrome Controlled Area NAME ~~aerd~~ with customs facilities

airship base and land aerodrome — airship Base with mooring mast

Land and water aerodromes

T.N. aeronautical radioelectric station (comms with A/c) and non directional radiobeacon.

T. Land aerodrome with aerial light aeronautical radio-electric (comms. with A/c).

T.N. non - directional beacon.

CROYDON T.N. Customs land aerodromes with controlled zone. aeronautical radio-electric station (comms. with A/c) landing approach radio-beacon and aerial light

Recommended Air Route

Obligatory Air Route

Scale is the ratio between a given length C.3 P.8. on the map and the actual distance it represents on the ground. It may be shown in three ways ① Representative fraction, R.F. (natural scale) which expresses the ratio between a length on the map

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and the distance it represents on the earth expressed in the same units. (2) Statement in words, giving corresponding values in different units of maps e.g. 1 inch to 10 miles (3) Graduated scale lines showing actual lengths on the map corresponding to distances on the ground.
Usually three. s.m, n.m, and km.
Relief is indicated on maps and charts in one
P.10. or more of the following ways:- (1) Spot ht. is a record on a map of the exact height of a place above M.S.L. (2) Contours and form lines. a contour is a line drawn on a map joining all places of equal ht. above M.S.L. Form lines are approximate contours drawn in by interpolation. Vertical interval (V.I) is the diff. in level between two successive contours.
[illegible] Horizontal equivalent (H.E) is the distance in plan between two successive contours. Gradient $\frac{V.I}{H.E}$ (3). Layer tinting is the method of showing
P.13. relief on maps by colouring in different

shades those parts which lie between different levels. R.A.F. used purple as basic colour to assist reading by artificial light. (4). Hachures. short tapering lines drawn in the direction of the steepest slopes. (5) Hill shading.

Map reading

C.3 In good visibility Good mapreading is a
P.21-36. valuable asset since the ground, is never totally obscure.
The first essential is a knowledge of the types and properties of the maps and charts used and also the conventional signs.
To facilitate map reading the reference map should always be oriented.
The ground should be viewed as a collection of objects relative to each other and not as a collection of individual objects.
Since, at times, objects are only visible

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for a fleeting instance, there is a danger of jumping to conclusions which might be completely erroneous. Pinpointing should therefore be definite and accurate.
To facilitate pinpointing an idea of the approximate position of the aircraft is very helpful.
Intelligent anticipation is also very necessary

When approximate position of aircraft is known. is dependant on the presence of prominent land and sea-marks (usually to be found all over Europe). Time and speed scale may be used.

When position of aircraft is not known Calculation of position is necessary and then mapread from ground to map not vice versa.

In poor visibility
Look for pinpoints before E.T.A.

At night visibility is dependent on the moon, stars, season of the year and light on the ground. Visibility distance is greater at night and navigator must take this into account. Water shows up grey against black and is the most easily recognisable of all ground features. Smaller details cannot be picked up without a full moon. Low flying is helpful but dangerous, objects up-moon are easiest to see, cloud shadows are deceptive. Map reading should be practised at every opportunity.

Landmarks.
Railways: Good in U.K. not in Europe.
Water: Shape important, floods and drought misleading. Mountains. Contours noticeable, can be visible above fog. Peaks can be covered by cloud. Towns and villages. Size, shape, position and colour helpful; railways, roads and natural features should be used,

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towns can usually be indistinctly seen even in blackout. Roads difficult to identify because of number, secondary more prominent than main roads, concrete best also shows up at night. Woods size and shape important, clearings also helpful, if wholly or partly cut down may be confusing. Golf-courses good landmarks. can be used as emergency landing ground. Sea marks coastlines valuable by day and night, large lamp and lighthouses can be easily picked out, marine lights intended for nautical use but can be used from the air. Sea traffic useful when out of sight of land in peacetime.

Maps general. Mercators

C.3. The most important, designed for navigational
P.4. purposes.

Rhumb lines are straight lines which is a great advantage.

P.38&39. Read only.

Essential Requirements

① Meridians must be parallel straight lines so that a line cutting them at the same angle is a straight line i.e. rhumb line. Spaced equidistant from their original spacing at the equator.

41. ② Parallels cut meridians at right angles to preserve true direction and are parallel.

53. Scale Longitude scale is constant but does not represent earth distances correctly except at the equator.

Latitude scale varies in the same ratio as the map distance to earths distance (by construction) and is used for measuring physical

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distances.
57 &
56 Read.
57/4 N.B. longitude scale is used for vectors.
58/49 Properties of mercators ① Scale varies with lat. ② Straight lines are rhumb lines. ③ Bearings and distances are rhumb line bearing and distances ④ Great circle appears as a curve convex to the nearer pole.

Triangle of velocities

C.2.
P.1+2 Read.

P.3. Definition of velocity. Velocity is a rate of change of position in a given direction comprising both speed and direction.

4. Vector is a graphical representation of a velocity.

5. Acceleration is the rate of change of velocity.

6. Arrow convention ①. Vectors of all component velocities course and wind are marked with
22 a single arrow. ②. Resultant velocities (Track)
-25 are marked with a double arrow ③ Relative
27 velocities are marked with a cross together
-31 with an arrow.

37-9. Solution of triangles

40-6
C.12.

Hints on plotting N.B.

C.1
P.53. Ground position (G.P.) At any time the position on the earth directly beneath an aircraft is known as its G.P. or pin point or fix

54. Air position At any time the position of an aircraft whose progress is imagined to have been unaffected by the wind is called its Air posn.

55 Dead reckoning posn. At any time the G.P. of an aircraft deduced from a known Air Posn. and the estimated wind effect is called the D.R. Posn.

62. Ground speed G/S. is the speed at which an aircraft travels over the ground.

63. Wind speed.

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Airspeed Indicator 15th Feb. 1943

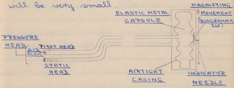
Purpose to measure speed of the aircraft through the air.

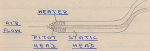
Principle. If a tube closed at one end has the other end open and pointing directly into a current of air, the pressure inside the tube will be greater than the pressure outside. This excess pressure will depend on two factors ① the velocity of the air current ② the density of the air.

Thus if a pressure gauge is attached to the closed end of the tube the pressure inside the tube can be measured and can be indicated in terms of speed per hours by means of an indicator needle registering against a suitably calibrated dial.

N.B. The relation between the speed of the airflow and the pressure inside the tube only holds good if the inclination of the tube to the airflow is zero.

The angle of inclination of the tube should never exceed 10° up to which the error will be very small.





A. S. I. Errors.

① Instrument error due to slight friction of parts and wear and tear. Corrected by checking instrument against another of known accuracy or using a mercury and water manometer. Correction when applied is known as Instrument Error Correction (I.E.C)

Position Error, due to position of pressure head not being entirely free from air flow disturbances although the best possible position has been selected. Position error is the same for all one type of aircraft and is corrected by reference to the correction card given in the air publication of that particular aircraft and is known as Position Error Correction (P.E.C.).

Total Instrument Error, This is the combination of I.E.C. and P.E.C. which makes Total Error Correction (T.E.C) which is placed in a correction card at the side of the A.S.I. concerned. Thus I.A.S + T.E.C. = Rectified air speed (R.A.S).

Height error

Due to decrease in density of the air with rise in height. This error is corrected approx. by formula to find the T.A.S e.g T.A.S. =

$$R.A.S + \left(R.A.S. \times \frac{1.75}{100} \times \frac{ht\ in\ ft}{1000}\right)$$

e.g $$T.A.S = 150 + \left(\overset{3}{\cancel{150}} \times \frac{7}{\underset{2400}{\cancel{10}}} \times \overset{3}{\cancel{18}}\right)$$

$= 181.5$ k.

Density error due to temperature and pressure changes in height not coinciding with those allowed for in the formula and is corrected for together with height error by using the airspeed computor attached to the navigational computor and a more accurate T.A.S is thus found.

Information required for finding T.A.S using A.S. Comp.

1. Ht above M.S.L.
2. Temp. surrounding the aircraft
3. R.A.S.

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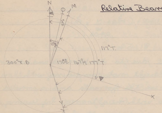
Position Lines

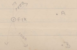
Relative Bearing.



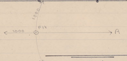
A position line is a line obtained from observation of a terrestial or celestial origin. The observer is known to be somewhere upon the line at the time of observation

Relative bearing is a direction measured clockwise from the heading of the aircraft from 0° to 360°. Added to the Co(T) it becomes a true bearing.

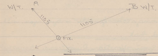
Two plan range



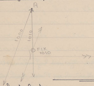
Plan and Range or Bearing and Distance



Simultaneous bearings of two origins



Transferred position lines



Cocked hat

By taking three successive position lines and transferring first two.

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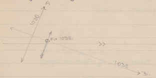
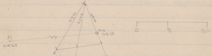
Running Fix of two or more origins



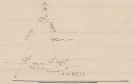
If another bearing is taken from another origin you will have a cocked hat.

Finding track from position lines



Ground speed can also be found by measuring distance from A to FIX which has been run in 40 mins

Doubling the angle on the bow.



Ground position is the position of an aircraft obtained by the visual observation of an object immediately below the aircraft that can be pinpointed on a map or chart

Fix is the position of an aircraft normally obtained by an intersection of two or more position lines. N.B. a range and bearing would be marked as FIX. as it is the intersection of a position line and a plan range. Only fixes obtained by first class bearings and plotted accurately can normally be considered accurate

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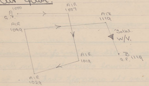
enough for commencing an air plot for finding wind speed & direction and setting course from.

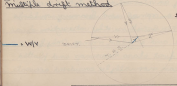
Finding W/V.

① Track and Ground speed
② Single leg air plot
③ Air plot.



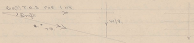
An air plot can be started from a G.P. but never a D.R. posn.

④ **Multiple drift method**



See Chap XII
Par. 39

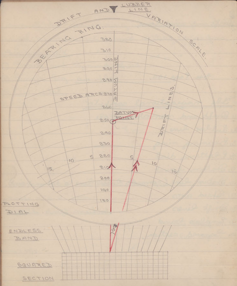
⑤ **Drift and wind lane**



See Page 100.

The navigational computor

1, Drift and variation scale
2, Lubber line
3, Bearing ring
4, Plotting dial
5, Datum point
6, Datum line (connects lubber line to datum point).
7, Speed arcs
8, Drift lines
9, Endless band
10, Squared section.



Ques no.	ANSWERS	CALCULATION
1)	a, T.A.S = 184 k. b, TRACK: 159°T. c, Co. = 180°C. d, DIST. = 140 n.m. e, E.T.A = 2101 hrs.	I.A.S = 160 k. R.AS = 164 k. T.A.S = 164 + (164 x 1/400 x 4) = 164 + 20 = 184 k. Co(T) 168° ∴ Co (C) 180°. S/C. 2000 hrs T.T. 61 mins E.T.A 2101
2)	a, FIX AT. 2026 hrs. = 5025N 0236W. b, W/V. 200°/34 k.	A.S. 15x60/26 = 34½ k.
3/	a, D.R @ 2035 hrs = 5002N. 0225 W. b, Co = 146°(C). c, E.T.A = 2104 hrs.	D.R. 2035 = 150/60 x 35 = 92 n.m. Co(T) 164. ∴ Co(C) = 146°
4,	W/V. 220°/30 k.	S.C. 2110. AIR. 2110 184/6 = 31 nm APR 2135 180/4 = 45. W/S = 25 x 60/50 = 30 kts.
5)	a, Co(C) = 289° b, E.T.A = 2250 hrs.	Co(T) 280 ∴ Co(C) = 289° S.C. 2205 T.T. 45 ~~[illegible]~~ mins ∴ E.T.A. 2250 hrs.

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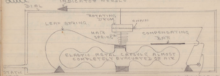
The altimeter.

Purpose: To indicate the height of an aircraft above M.S.L or ground level.

Principle An elastic metal capsule almost completely evacuated of air will expand with the decrease of density of air surrounding it and conversely will contract with the increase of the density of air surrounding it. The expansion or contraction of the elastic metal capsule due to the change of pressure surrounding it is magnified by a suitable system of levers and measured in terms of height by means of an indicator needle registering against a suitably calibrated dial.



MK XIII

Two calibration laws

(i) Isothermal law states (i) that M.S.L. pressure is 1013.2 millibars.

(ii) Temperature is constant from M.S.L for all heights at 10°C

(ii) I.C.A.N law, which states (i) that M.S.L pressure of 1013.2 millibars (ii) M.S.L. ~~pressure~~ temperature of 15°C.

(iii) Temperature decreases from M.S.L. at a rate of 1.98°C for each thousand feet rise in ht. up to 36,090 feet whereafter it remains constant at −56.5°C.

For calculation purposes only it can be considered that 1 millibar change in pressure equals 30 ft in height.

Altimeter errors.

1, Instrument error due to wear and tear and slight friction of parts. Corrected by checking instrument concerned with one of known accuracy or using a mercury barometer. Correction card is placed at the side of

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the instrument

Density error, due to the decrease in density of the air with rise in height not coinciding with that allowed for in the calibration law. Corrected by using height computer based on the same calibration law as the altimeter concerned.

Lag. This is a temporary error and due to rapid change of height. Corrected by flying straight and level for a short period of time.

Drift error. If the aircraft is drifting to the starboard in the N. Hemisphere or to the port in the S. Hemisphere precaution should be taken as the aircraft is flying into an area of low pressure thus the altimeter is reading higher than the aircraft actually is.

Mercator's Projection

It is the only projection emmenently suitable for plotting for the following reasons:-

1, A straight line on mercator's is a rhumb line [redacted] as all meridians are parallel straight lines and equidistant apart. It is normally far more convenient in most circumstances to follow a rhumbline track over the earth by steering a constant course by T. north, than saving a few miles distance by following a great circle track that requires frequent alteration of course in relation to true north.

2, Angles everywhere on the earth's surface are correctly represented on the chart as the equator and parallels of latitude cut all meridians on the projection at right angles as they do on the earth.

Construction of mercators projection

1, On the earth the meridians gradually

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converge until they all finally meet at the poles. The parallels of latitude on the earth cut all the meridians at right angles and to all intents and purposes are evenly spaced. The graticule thus formed is represented on mercators projection in the following way:

1) The meridians are drawn as a series of parallel straight lines longitudenly on the chart as agreed by practice.

2) Where the distance is expanded between any two meridians on either side of the equator, the distance between successive parallels of latitude must be increased in the same ratio on the projection.

3) Parallels of latitude are represented as a series of parallel straight lines cutting the meridians at right angles and spaced by calculation at ever increasing distances away from the equator going north and south

4) The spacing of parallels of latitude is calculated by using the tables of meridional parts given in Norrie's air tables or Inman's air tables.

A meridional part is the number of times the length of one minute of longitude which is constant on the projection, is contained in the projected distance between the equator and any particular parallel of latitude on the chart. e.g. 1 min. of long. on a mercators projection will equal 0.02 inches. Therefore the distance between the equator and the parallel 30° N equals 0.02" x m.p. for 30° = 0.02 x 1846.64" = 34.5334 inches.

Properties of Mercator's Projection

1) All rhumb lines are represented as straight lines

2) Great circles are represented on the chart as curves of varying radii convex to the

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nearer pole.
3. Angles on the earth's surface are correctly represented on the chart.
4) All bearings are rhumb line bearings
5) Meridians are equidistant apart and parallel.
6) The chart length of 1 min. of long. is constant
7) The equator and parallels of latitude are straight lines and rights angles to the meridians and parallel at ever-increasing intervals going north or south from the equator
8) The chart length of 1 minute of latitude is not constant but increases as the lat. increases.
N.B. As the scale varies as the latitude the navigator must always use the lat. sub-divisions for measuring distances that are immediately opposite the distance to be measured.
The navigator should only use the long. sub-division which are constant when construct-ing vector triangles.
9) The projection is true to shape over small areas but at high latitudes shapes are distorted and areas exaggerated.
10) The poles can never be represented.
11) The projection is not usually made of above 70° N. or S.
12) Conversion angles must be applied to great circle bearings and tracks where there is a change of longitude in order to convert them into rhumb lines.

Conversion Angles

Loop bearing	282°		098°
Q.E.C	−2°	C.A.	+3°
Relative bearing	280°	R.L.B.	101°
True Course	178°	plus	180°
	458°	Recip.	281°
Less 360°	360°		
G.C.B	098°		

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Gnomonic projection

Properties. ① The point of tangency appears as a straight line

2. The meridians are straight lines at ever-increasing intervals and and right angles to the point of tangency.

3. Parallels of latitude are represented by curves concave to the nearer pole. The concavity increases as the latitude increases

4. A straight line on the projection represents a great circle on the earths surface exactly

5. Shapes are distorted

6. Bearings are incorrectly represented except those drawn from the point origin of the projection

7. The projection has no proper scale ∴ distances cannot be easily measured.

Meade's diagram.

This is an equatorial gnomonic projection as its point of tangency is the equator. It is used as a means for plotting an accurate great circle which would appear as a straight line between any two places on the earth's surface on a chart drawn to mercators' projection or any other navigational projection.

Conversion Angle : is the angle between a great circle bearing and a R.L. bearing Its value can be calculated by formula

½ change long × sin mean lat.

or by using abac scale given at the side of mercators projection

Convergency.

Convergency angle = Ch. long. × sin mean lat.

= 2 × conversion angle.

It is the inclination between true meridians on the earths surface. There is no convergency between the meridians at the equator, and at the poles the meridians converge at the angles equal

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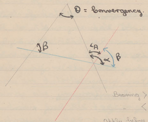
to the ch. long between them.

Convergency angle is normally only applied to D. F. W/T loop bearings obtained by an aircraft that are to be plotted on a projection where the meridians converge.



Bearing > 180° Subtract
" < 180° Add
Apply before taking reciprocal
Never to W/T bearings

θ = Convergency
$\hat{\theta} = \hat{A}$ (alternate angles)
$\hat{A} = \alpha - \beta \quad \therefore \angle\theta = (\hat{\alpha} - \hat{\beta})$

Convergency = the angular diff. between the G.C. bearing measured at each meridian

The compass.

29th Mar. 1943.

Differences between P. and O. type compasses

"P" TYPE	"O" TYPE
Graduated grid ring	Compass card with inverted
Magnetic needle.	figures. Azimuth circle
Two magnets (P.6 and P.8)	Four magnets (needs more
P.4. has four magnets	directive force as it is moved
Used for steering and	around and also due to its
reading courses	compass card). Movable.
P.6 and P.8 compasses fitted	Sights - take bearings
with syphon tubes.	Prism as magnifying glass
Fixed in aircraft	Sighting line

Function

Has four functions
1, Indicate direction of magnetic meridian
2, Indicate direction in which aircraft is travelling
3, Enable the aircraft to be headed in a given direction
4 To take bearings of various objects

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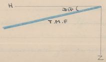
Requirements of an ideal compass

(1) Quick off the mark ∴ sensitive system ∴ large magnetic moment ∴ long powerful magnet.

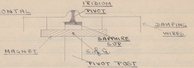
(2) Stop quickly ∴ aperiodic i.e. small moment of inertia ∴ several short magnets instead of one long one. Also damping wires immersed in liquid

(3) No friction. Because of iridium pivot in sapphire cup and balanced by bouyancy of alcohol

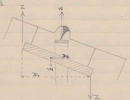
(4) Should remain horizontal ∴ pendulosity i.e. centre of gravity is below the pivot and ∴ system tends to swing back to horizontal. Counteracts effect of Z.



HORIZONTAL



When system is tilted a correcting couple is formed which brings it back to the horizontal e.g. Consider Z effect upsetting the system from the horizontal



Upsetting couple $\propto$ ~~as~~ as ZD_1

Correcting couple $\propto$ as WD_2

In construction it is determined that $WD_2 > ZD_1$ until about 2° from the horizontal

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when W.D.2 = Z.D.1. i.e. system is in equilibrium

Eight main component parts

1, Rotatable ~~ring~~ grid ring fitted above compass bowl, graduated in degrees and can be locked in any position

2, Lubber line - a small projection in bowl - fixed indicating mark lined up with fore and aft axis of aircraft

3, Magnet system. Two or four powerful bar magnets with eight radial damping wires

4, Damping liquid. Pure alcohol is used. Ideal qualities of liquid:-

a, Must be non-corrosive

b, Have large temperature range from -50°c to +50°C.

c, Have a low freezing point and a low viscosity and a low specific gravity.

d, Small coefficient of expansion

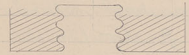
e, Be transparent.

f, must be cheap and easily obtained

N.B. Alcohol has all these properties except a.

5, Compass bowl. Made of brass coated inside with a special enamel as alcohol attacks most paints (if liquid becomes discoloured the compass must be watched for pivot friction which renders it U.S)

6, Expansion chamber - sylphon tube. Fitted to base of compass bowl, expands readily over alcohols temperature range.



SYLPHON TUBE

7, Outer container. Provides a means of mounting compass rigidly in aircraft

8, Antivibration suspension system. Compass bowl rests in outer container on four equally spaced springs. The springs isolate the bowl from vibration. The floating ring stops the compass bowl

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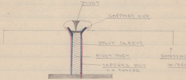
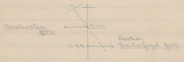
from turning but the slots allow it a little up and down movement.

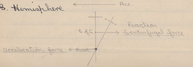


Acceleration errors.

N. Hemisphere



S. Hemisphere



Northern Hemisphere heading west, accelerating as aircraft accelerates C. of G. lags behind, thus causing the system to tilt. Z having a component in the plane of rotation rotates the system in the direction of acceleration thus showing an apparent turn towards north. ~~Centrifugal~~ acceleration force which always acts in the same direction as Z, also show an apparent turn towards north.

Deceleration heading west in N. Hemisphere is the opposite of the above and shows an apparent turn away from north.

S. Hemisphere, heading west, accelerating Aircraft accelerates and C. of G. lags behind tilting system to west. Z acting on the blue poles rotates system away from direction of acceleration as does also centrifugal force giving an apparent turn away from north. Deceleration is

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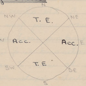
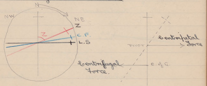
Opposite of above
N.B. Acceleration errors occur only on easterly or westerly courses

S. HEMISPHERE			N. HEMISPHERE		
Acc. W.	AWAY FROM	N.	Acc. W.	TOWARDS	N
E	..	N.	E	..	N
Dec. W.	TOWARDS	N	DEC W	FROM	N
E	..	N.	E	..	N

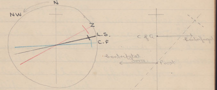
Turning errors



N Hemisphere turning towards N.E
corrected by undershoot



S. Hemisphere turning towards N.W.
& corrected by overshoot



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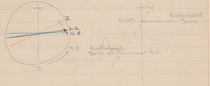
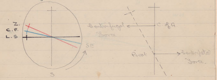
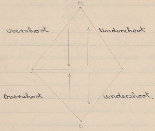
N. Hemisphere turning S towards S.E
Corrected by overshoot



S. Hemisphere turning S. towards S.E
Corrected by undershoot





Aircraft compass errors

A. Turning errors

When an aircraft turns other forces besides H affect the compass needle, causing it to move away from the meridian, thus giving turning errors. There are three different forces:-

1, Dip or Z effect
2, Centrifugal force
3, Liquid swirl

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All maximum on N. or S. heading, zero on E. or W.

① Dip

a, Cause ① As the aircraft banks to turn the magnet system remains in the same plane as the aircraft i.e. it tilts out of the horizontal

② The balancing effect, due to the position of the C. of G, is diminished

③. Magnetic system is now free to move in the vertical plane.

④ Vertical magnetic component Z causes rotation in a vertical plane.

b, Direction of error

① In N. Hemisphere – red pole is pulled down in direction of bank

On to northerly course – needle moves in direction of turn – undershoot when turning

On to southerly course – needle moves in opposite direction to turn, therefore overshoot when turning.

② In S. Hemisphere – blue end of needle is pulled down.

On to northerly course – needle moves in opposite direction to turn, therefore overshoot when turning.

On to southerly course – needle moves in same direction as turn, therefore undershoot when turning.

c, Magnitude of error.

Increases with ① Amount of bank. ② magnetic latitude.

② Liquid swirl

a, Cause

Inertia of liquid keeps it moving and carries compass system with it.

b, Effect.

① Deviation in direction of turn.

② Mechanic cause ∴ the same in both

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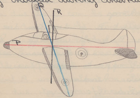
hemispheres
② Total magnitude very small compared with dip effect.
③ Centrifugal force
a) Cause of error
1, As aircraft turns centripetal force acts on the pivot of the compass
2, This forms a couple with centrifugal force acting on C. of G. of system.
3, This couple rotates magnet system.
b) Direction of error
In all cases the same as Z effect
c) Magnitude of error
① Decreases with amount of bank.
② Very small.

Analysis of aircraft magnetism
Aircraft magnetism can be classified under two headings ① hard iron - permanent magnetism ② soft iron - temporary magnetism i.e liable to magnetisation by the earth's field dependant upon a) direction of heading b) magnetic latitude
Hard iron magnetism
mostly induced during construction of A/c.



It can be resolved into three parameters P (fore and aft), Q (lateral), and R (normal). These three parameters will have a constant effect, as they are all permanent.

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Soft iron magnetism
Induction will cause different effects on every heading.
Coefficients
Parameter P. An aircraft flying N. or S. needle will lie in same direction as parameter P. Therefore no turning force. Also there is gain or loss of directive force, thus maximum deviation on east and west headings.

Coefficient B is deviation due to a, parameter P ~~&~~ soft iron effects. Deviation is zero on N and S and maximum on E and W but of opposite sign. Varies as sine of magnetic heading.

Calculation B: $\frac{E-W}{2}$.

Deviation due to P can be corrected. Any residual deviation is due to soft iron effect. Corrections are made on E. or W. headings

Parameter Q
Coefficient C. Deviation due to parameter Q and soft iron. It is zero on E. and W. and maximum on N and S. but of opposite sine It varies as the co-sine of the magnetic heading.

Calculation C = $\frac{N-S}{2}$

Deviation due to Q can be corrected and any residue is due to soft iron effects. It is corrected on N or S. headings

Parameter R. will have no turning effect but will supplement or cancel Z.

Coefficient A is constant on all headings and is due to 1, misplaced lubber line 2, incorrect assembly of magnet system i.e. apparent A. 3, induction in assymetrical horizontal hard iron i.e Real A: Calculation = $\frac{8 \text{ deviations}}{8}$

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may be corrected by moving the compass clockwise if positive, anti clockwise if minus

Coefficients D and E

These give rise to deviations on quadrantal headings. Only corrected in very large A/c.

Swinging a compass

Procedure

1, Check compass for serviceability
2, Ensure all equipment is as carried in flight i.e. tools, guns etc
3, Take aircraft clear of all unusual magnetism i.e. 100 yds from a hangar
4, Ensure all controls in flying position
5, Place aircraft head on magnetic north and note deviation N.B. magnetic headings may be obtained using a landing compass or compass base.
6, Turn on to magnetic east and note deviation
7, Turn on to magnet S. and note deviation Calculate coefficient C.
8, If correcting proceed as follows:-
a, change sign of C and apply this to existing reading.
b, This will give required new reading which is set against the lubber line
9, Place corrector key in hole at right angles to needle and turn until red is on red.
10, Place aircraft head on west and note deviation Calculate coefficient B and correct as for C. again with key in hole at right angles to the needle.
11, Carry out check swing on all 8 points starting with N.W.
12, Calculate coefficient A (average deviation) and correct if necessary. Permission of flight commander or navigation officer required
13, Record final deviations on Form 316, 316A

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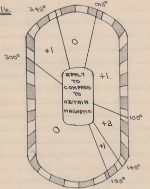
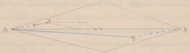
14) Fill in compass log book (Form 343) and sign Form 700.

FORM 316.



Pilot Navigation

① 5° Lines

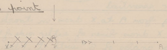


In a single seater aircraft without expert assistance of a navigator a pilot uses 3 methods for checking positions of a/c and making alteration of course. All are simple and speedy. However it is essential for an accurate compass course to be steered and track and G.S. to be checked frequently. Rapid and accurate map reading is a further essential.

① Flying from A to X draw in track. From A and X draw lines of either side of track making angles of 5° with it. Pilot sets off on calculated course but after 10 minutes flying finds himself at Z. It is obvious that he is 3° P. of track. If an alteration of 3° S is made a track parallel to the desired one will be made good. If however a further alteration of 3° S is made he will in 10 minutes time be approximately crossing his desired track. He then alters course back 3° P. and will now be steering the correct course to make good his desired track

Similarly if near the end of the flight he pinpoints J, it can be assumed that the line A J is parallel to the track so that a correction of 2° P. will bring him over his destination

(2). Two point



(1) Select conspicuous landmark on track that can be seen from base aerodrome

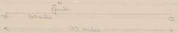
(2) Climb up to required height, turn on to aerodrome and fly plane so that it tracks over aerodrome towards landmark i.e A/c must make good required track.

(3) When directly over landmark set red on red on compass and course to make good track to A will be against the lubber line

(4). Between points X and P. a ground speed can be calculated and a time or distance scale should be put on track.

N.B. Landmark must be within visibility distance

Track error



Based on formula 1 mile off in 60 equals

error of 1°
Flying from P. to Q. we pinpoint at N. thus we are two miles off in thirty which equals an error of 4°. But we have 60 miles still to go, therefore 2 miles off in 60 equals error of 2°. Therefore total alteration of course = 4° + 2° = 6° S.

Procedure for cross country flights

Before take-off

1. Obtain the necessary maps and draw in tracks.
2. Study intended route noting danger and prohibited areas to avoid, and height of ground to be crossed.
3. Draw 5° or 10° from starting point along track.
4. Obtain weather report and route forecast.
5. Compute true airspeed, measure distances, and complete form 433A using met W/V.
6. From calculated G.S. construct time or distance scales.
7. Study map for important landmarks on track especially first 25 miles of each leg.
8. Ensure you have two pencils and a watch.
9. Fold map so that minimum of unfolding will be needed in the air.

In aircraft before take-off

1. See that compass has been swung in the last six weeks and calculate compass course to steer. Set this course on compass
2. Set altimeter to read height of aerodrome above sea level.
3. Ensure all equipment, cross country kit, topee, money, etc. is in the locker.

After take-off

1. Circle aerodrome, climbing to selected height
2. Note the time airborne.
3. At selected height, trim aircraft to fly

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a steady height and desired airspeed
④ Turn on to course to pass over centre of aerodrome, if above 3000', and to one side with the circuit if below.
⑤ Note departure time and E.T.A. in log.
⑥ Check course, height and airspeed and maintain until position can be checked.
⑦ If necessary, note track error and A/c. Check E.T.A. by time marks. Enter all a/c's and E.T.A's in log, and note position whenever possible
⑧ After landing, hand log to navigation officer for correction.

Pilot-navigator logs
Rules for log keeping
① All directions etc. to be expressed as 3 fig. groups followed by T, M, or C
② All place names to be written in block capitals
③ No alterations to be made, errors to be crossed out or erased.
④. Flight plan to be completed before flight
⑤ Units used stated clearly at head of columns
⑥ All courses flown and a/c's to be recorded followed by the reason for the alteration.
⑦ All E.T.A's entered on right hand side of log and underlined
⑧. All changes of weather conditions to be recorded
⑨ Positions recorded by approved systems of reference only.
⑩. Only standard abbreviations to be used.
⑪. Each sheet to be signed by the navigator
Special instructions to cadets
① Indicate whether log is dual, 1st, or 2nd cross country
② Have flight plan checked by instructor before flight
③ Have log countersigned by instructor

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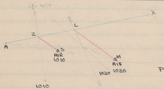
after flight
(4) Hand in to navigation officer as soon as possible

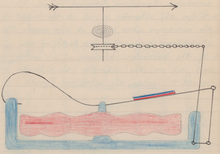
Fixing position with Tr. and G/S. unknown



Given
W/T. Station.
T.A.S.
Co

From last fix A draw in Co. A.P. Plot both bearings and their times. Using T.A.S. find air position at the times of the bearings From A draw in any line A X at any angle between A and the D/F station. Where A X cuts the first position line (Z) join Z to the first air position. Transfer the line Z S parallel thro' the second air position till it cuts A X at point L. Transfer 1st. pos. line through L thus obtaining fix at Y. A Y gives your T. M. G. and G. S. Y M gives you W/V.

THE ALTIMETER



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Special features of the I.C.A.N Kollsman sensitive altimeter

1, The altimeter can be set on the ground to read 0' or height above M.S.L.
2, When set at 0' on the aerodrome it also records aerodrome atmospheric pressure in mb.
3, When the altimeter is set at the height of the aerodrome above M.S.L. it also records the atmospheric pressure at sea level in mb.
4, If the barometric pressure at an aerodrome is known and set on the altimeter the altimeter will record 0' when the aeroplane lands.

COMPASS SWING

COL. I.	L/C.	A/C.	DEV.	L/C.	A/C.	DEV.	BEFORE A.	AFTER A.	FINAL
000	358	004 359	−6	358	359	−1	001	000	–
045				045	046	−1	046	045	–
090	092	089 093	+3	091	092	−1	091	090	–
135				135	135	–	135	134	+1
180	183	179 184	+4	182	183	−1	181	180	–
225				224	225	−1	226	225	–
270	268	273 269	−5	269	270	−1	271	270	–
315				316	314	−1	316	315	–

Coefficient C : $\frac{-6-4}{2} = -5$

Coefficient B : $\frac{+3+5}{2} = +4.$

Coefficient A : $-\frac{7}{8} = -1$

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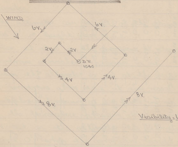
SQUARE SEARCH



Visibility = 10 N.M.

Navigational responsibilities of air-crew

Duties of navigator

1. Thorough preparation of each flight
2. Synchronises pilot's and W/Ops. watches with his own, checked against G.M.T.
3. Gives pilot courses to steer, written on message chits. He checks that the pilot sets the correct course on his compass
4. Keeps the navigation log
5. Keeps a plot of the flight
6. He makes all necessary observations to ensure accurate navigation. Notes all changes of height, temp. and T.A.S. Takes frequent drifts, pinpoints A/c. as necessary, checks W/V frequently especially near target using various methods
7. On request gives position and E.T.A to captain without undue delay.
8. Makes out all posn. signals for approval of captain
9. Notes weather conditions and changes in flight either in log or on Form 2330. On request advises captain on action to miss bad weather
10. When required, navigator keeps recco. report, supported by photographs.
11. Initiates requests for D/F bearings. When loop is used, the probable bearings of the best situated station should be given as a guide to the loop operator. The operator should also be informed which stations are most likely to perform satisfactory fixes
12. He informs pilot whenever drifts, sextant astro-compass and D/F loop installations begin and end.
13. He asks rear gunner for back bearings

14. Navigator co-ordinates efforts of other members of crew when map reading under difficulties or at night

Duties of Pilot

1. Pilot provides himself with topographical maps for flights and makes tracks thereon He prepares summary flight plan.
2. He checks watch with navigator
3. Before take-off he sets sensitive altimeter to aerodrome height
4. He keeps a brief log of the flight
5. He sets compass courses when directed by nav. and makes sure he continues on such courses until new ones are given
6. He informs nav. of all changes of course, height and I. A. S.
7. He maintains constant course and airspeed when drifts are being taken
8. If necessary he climbs to a layer free of bumps.
9. Assists navigator in map reading and reconnaissance

Duties of W/Op.

1. Prepares for each flight list of W/T D/F facilities, localities, times of op. frequencies, call-signs, ranges and procedure
2. On request he endeavours to call up those D/F stations indicated by navigator
3. He must be prepared to operate the loop
4. He advises navigator which stations are available at any time. He advises the navigator as to their identity

Duties of rear gunner.

1. On request takes back bearings of objects over which aircraft has passed.
2. He must be able to map-read in order to assist navigator

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Duties of bomb-aimer
1. Acts in close liason with navigator and pilot
2. If capable he obtains drifts and other readings.

Duties of the Captain of the aircraft.
1. He supervises navigational duties of crew on the ground and in the air.
2. He advises navigator in preparing flight plan.
3. He ensures all equipment is in order and all information taken on board
4. He qualifies himself by training and experience to take over from the navigator should the latter become a casualty.
5. He keeps a brief log.
6. He must be able to give an intelligent account of the trip

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1, a, I.A.S. : 120 kts
b, Tr. : 164°
c, Co(c) : 188°
d, G.S. : 113 kts.
e, Dist : 72 n.m
f, E.T.A. : 0838 hrs

T.A.S : $105\frac{1}{2} + \left(\frac{211}{8} \times \frac{7}{\cancel{400}\ 100} \times \cancel{8}\right)$

= 120 kts

W/V : 250°/30 kts

T	V	M	D	C
180°	11°W	191°	3°E	188°

2, a, W/V : 250°/34½ k
b, D.R. SHOT 5454

P.P. CLOT 3842 0817
A.P. 34 n.m
a.p. 0840 $\frac{23}{\cancel{60}} \times \frac{\cancel{60}}{17} \times \frac{63}{2}$

3, a, Tr. 040°
b, Co(c) 264°
c, G.S. 150 kts
d, Dist 164 n m
e, E.T.A. 0951 hrs

T	V	M	D	C
250°	10°W	260	4°E	264

4, FIX CLAM 1736.
ETA 0950 hrs

5, W/V 251°/

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PROCEDURE FOR COMPASS SWINGING.

(I) LANDING COMPASS.
(2) COMPASS BASE.

BEFORE SWINGING.

(a) SERVICEABILITY CHECK.

Oil or petrol stains or discolouration of external paint and rubber pads (if fitted).

(b) Test shock absorbers (no unusual metallic contact should occur)

(c) Test locking device and grid ring, if stiff apply vaseline and graphite.

(d) Inspect the liquid for bubbles.

(e) Inspect the liquid for discolouration, tap compass and notice any sediment present, and check discolouration of internal paint.

(f) Test for pivot friction.
Deflect magnet system 10° with a magnet. Remove magnet and take the reading of the compass. Deflect system opposite way 10°, repeat procedure. The difference of the two readings obtained should be less than 2°.

(g) Damping test.
Deflect magnet system 90° with a magnet held in that position for at least 30" to allow liquid to settle. Release magnet system by removing the magnet and time the swing of the needle back through 85°. The minimum and maximum times allowed for each type of compass are stated in the Instrument Manual (P6 is - 6.5 sec to 8.5.sec).
Compasses are guaranteed a minimum life of 6 months.

SWINGING.

(I) Check compass for serviceability.

(2) Take the a/c to the swinging base or a place removed from any magnetic disturbance.

(3) Remove all magnetic objects not normally carried in flight.

(4) See that everything carried in flight is in its normal position in the machine, and that the controls are central.

(5) Any electrical apparatus must be switched on.

(6) Place aircraft head on North and note deviation.

(7) Place aircraft head on East, and notedeviation

(8) Place aircraft head on South and note deviation.

(8a) Calculate Coeff C. be deviation $\frac{N-S}{2}$.

(8b) If correcting determine the new reading of compass by the following law.

LAW. Change the sign of Coeff C to apply it thus to the existing reading. The result will be the required new reading.

(8c) In the case of Grid ring Compasses set required new reading against the lubber line.

(8d) Insert the correction key in the athwartships and turn gently until the required reading is obtained.
N.B. Clockwise for -C. Anti-Clackwise for +C.

(8e) Remove the key.

(9) Place a/c head on West and note deviation.

(9a) Calculate Coeff B $\frac{E-W}{2}$

(9b) Correct for "B" if necessary by the same method as for "C". Key in fore and aft.

(IO) Carry out a check swing on all 8 points, noting deviation on each. Calculate Coeff "A" by Dev'nall 8 points.

(11) Fill in Deviation Card and Compass Log Book making a note of any Coeff "A" for the information of the Flight Commander concerned.

(12) If correcting for Coeff "A" change and sign and apply to existing deviation to correct turn container. Anti-clockwise for -A and Vice Versa.

NOTE.

Always give compass needle time to settle down on heading and ensure that aircraft is within 5° of each heading before correcting.

Take readings from directly above compass to avoid parellax.

Slight tapping is permissible and will be found of use.

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4,	a, 151½ kts b Tr 131° c, Co(C) 133° d, G.S. 183 kts e, E.T.A 1402½ hrs	T.A.S. = 120 + ($\frac{3}{120}$ × $\frac{1}{102}$ × $\frac{7}{19}$) = 150½ kts W/V = 350°/44 kts T V M D C 121° 11°W 132° 1°W 133° Distance = 99 n m E.T.A = 32½ mins
5	a, FIX. PTCE 1024. b, W/V 008°/35 kts c, G.S. = 164 kts d, E.T.A = 1405½ hrs.	A.P $\frac{3}{18}$ × 150 = 45 n.m W/S = $\frac{7}{21}$ × $\frac{530}{188}$ = 35 k G.S = 50 × 60/10 = 164 kts 183
6,	a, Tr 051° b, Co(c) 051° c, G.S. 118 kts d, E.T.A 1518½ hrs. e, Drift 9°S	T V M D C 042° 10°W 052 1°E 051° Dist = 145 n m E.T.A = 145 × 60/30 1859

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