SURVEY OF INDIA

PROFESSIONAL PAPER NO. 20.

RECONNAISSANCE SURVEY FROM AIRCRAFT

BY

Lt.-Col. G. A. BEAZELEY, D.S.O., R.E.

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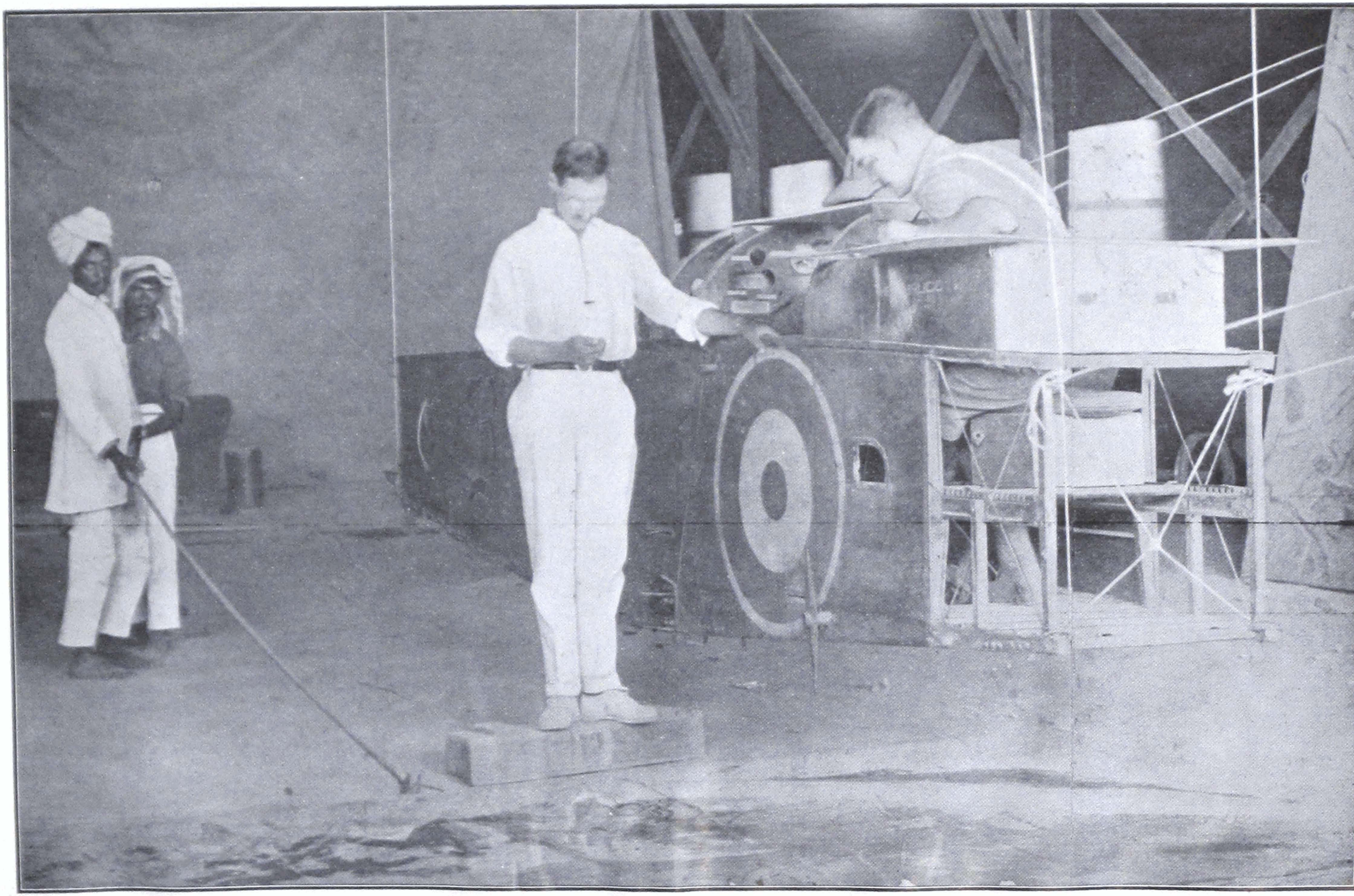

INDOOR TRAINING.

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INTRODUCTION

1. The system described in this paper provides a means of supplying in a rapid manner topographical information about unmapped country. The resulting map is much easier to read than a mosaic of air photos. At the same time useful information can also be collected regarding the enemy's disposition.

2. No fixed points are necessary over the unmapped area, the instruments required are simple and easily made and the system can be learnt by any officer with a bent for the work, and who is fairly quick at freehand drawing. An observer trained in these methods should be able to produce something vastly superior to the ordinary eye-sketch, but only a highly skilled surveyor can be expected to compile a reliable sketch-map.

3. The system was actually used over enemy territory during the Great War, in Mesopotamia, by the author and later on in that country to fill up some gaps in the mapping where ground survey and air-photography were not feasible and thus proved its usefulness.

4. It is possible to sketch in about a hundred square miles in 1 to 1½ hours according to the nature of the country, excluding the time spent in flying to the ground and returning to the aerodrome; in a few hours after landing, it is possible to produce a sketch-map of the country and write a report on the area and of any enemy dispositions within it. The time taken to do a larger area will be in proportion.

5. It is not claimed for this system that it will produce accurate survey, it is therefore designated as sketch-survey. It should only be resorted to when other better methods of survey such as air-photography are not feasible.

The resulting sketch-map will be useful for bombing operations and to the air-photographer for laying out his "strips".

6. *Reconnaissance Report*—The sketch-map should be supplemented, in war time, by a reconnaissance report. The principles of air-reconnaissance are laid down in official

manuals on the subject where all necessary information can be obtained. It is important, however, that the pilot should cooperate in collecting information as he has more leisure to observe than has the air sketcher.

7. Reconnaissance and survey from air-craft comes under the following main headings, i.e.:—

(a) Sketching in of an unmapped area.
(b) Route-traverse sketching.
(c) Supplementary sketching over partly surveyed areas.

All of which may be accompanied by a reconnaissance report. (b) would only normally be used for the sketching in of a long route about which it was important to collect information, or for sketching in the details of valleys in an area sketch where the high ground enclosing the valleys might possibly render normal methods difficult or dangerous.

The system can be used in conjunction with tie-lines run in by means of a reliable continuous film camera.

Vertical and oblique stereo photos can be taken where the terrain is of sufficient importance, the latter are of great use to the commander of the forces in giving a vivid idea of the main valleys up which the troops will have to operate. A simple form of camera can be used and can be operated by hand, no expensive or complicated apparatus is necessary. Experiments in India have already been tried in oblique photos with success.

The camera can be operated by the observer at the time of carrying out the sketch.

Vertical photos of important tactical points are useful.

SECTION I

Fundamental Principles

8. Unlike "ground" survey, when in the air we have a pictorial representation of the ground below us similar to a map spread out on a table, and as the country passes under us we can draw in the detail freehand, given the scale we are to work to, much in the same way as we could draw in the features of a map while being slowly dragged along the floor close to our chair.

9. Taking air-sketching in its simplest form, all we want to know is the speed the machine is travelling at and the true bearing of the track made good. In fact we work entirely on a time basis in the air as opposed to a linear basis in "ground" survey.

10. Speed in the air is made up of 3 factors, i.e.:—

(i) True air speed.
(ii) Indicated air speed.
(iii) Wind factor.

(i) and (iii) invariably go together unless there is a dead calm aloft. Now it is evident that as long as there is any wind at all and we fly in one direction and then return in the opposite way the effect of the wind in one direction will have the opposite effect the other way and the wind factor will therefore cancel out.

Once therefore we know the air speed, our times up and down the course added together and divided by 2 will enable us to calculate out the true distance run on a time scale, and knowing the number of miles flown in a minute we can plot the distance run on our board to the scale we are to use, straight away.

In actual practice the speed indicator never gives the true air speed but is always subject to an "index" error the elimination of which will be reserved for another section.

Conditions necessary to *ensure success* in air-sketching

11. (a) Pilot must try and keep a constant "air" speed. But he may find it necessary to vary the "air" speed from time to time in order to keep the

machine in "trim" and all he has to do in that case is to keep a record of the air speeds and the times the changes occurred, the observer can then work out the distances run over each change in the speed.

Differences in ground speed due to wind can be calculated out and corrected for.

(b) *Pilot should keep the same height above the ground level*; any very large variations in the height makes it difficult to judge the correct scale of features on the ground and their distance to a flank. At about 5,300 feet above the ground 1 mile to a flank subtends an angle of about 45°, 2 miles 63½°, to the horizontal any considerable difference in this height throws the observer's calculations out but this can sometimes be corrected for to a certain extent in joining up the grid strips of an area sketch; the height above the ground should not exceed 6000 feet.

(c) *Pilot should make good the track set.*

In its simplest form the observer has no control over the course, he must trust the pilot to make this good and any good pilot, accustomed to steering a set course, can be counted on to do his part in this respect. The problems set up in fulfilling this condition may conveniently be studied at this point. It will readily be understood that if we are accurately to sketch in the ground that passes under the machine the line drawn representing the track on our sketching board must be drawn parallel to the track made good, otherwise all the detail drawn in will be distorted, see also paras 13 to 15, 60.

12. Fig. 1 shows the machine making good course A—B, no wind; line a—b on sketching board parallel to course A—B, then all detail drawn in at an angle to A—B will be shown at the same angle to a—b and there will be no distortion.

13. But suppose there is a cross wind from the observer's right or port side as in Fig. 2. To make good the course laid down pilot must put the nose of his machine up into the wind till the direction his machine travels in is parallel to

the course laid down. Directly this happens the line a—b moves with the machine and both a—b and the longitudinal axis of the machine c—d are inclined at the same angle to the course laid down. Observer is not yet provided with any means of checking this angular turn and it naturally follows all the detail he sketches in will be inclined at the angle it appears to make with the side of the machine i.e., a—b and not the actual track made good; this will be evident from Figs. 1 and 2. We must therefore provide some means of correcting for this angular displacement for the pilot is doing his part and making good the track laid down.

14. Again supposing the wind is blowing from the port side and the pilot, relying solely on his compass, does not correct for the wind but allows his machine to drift, then the machine instead of making good the track laid down will drift further and further off the track according to the strength of the wind as shown in Fig. 3. and the ground sketched in will be shown in the figure with the village E to port not starboard, but the observer does not know this and mistakes A—F for A—B and G for E.

15. Referring to figures 4 and 5 and taking the case presented in Fig. 2 again, when the observer passes over object A (say a prominent village) he sketches it in as it passes under his right shoulder (the observer being seated facing astern); on reaching "á" on the track he finds A instead of being dead astern is to the right of him and again at b′ or c′, still to his right at the same angular distance.

Either of two things has happened i.e.:— (a), the pilot has corrected for wind on his left and put the machine at an angle to the track to counteract the wind as in fig. 4, or (b), he has allowed the machine to drift to his right off the track as in Fig. 5. The observer has no means of detecting what is actually happening even if he were in a position to cut in back points O, P, say, already fixed, the angles they make with the track line on the board would be much the same in each case vide Figs. 4 and 5.

16. Now suppose we provide the observer with some means of always keeping his board parallel to the course set, then the moment the machine puts its nose up into the wind the sketching board can be moved round its pivot till it is again parallel to the track. One can easily ascertain the

track line being flown by the machine by looking over the country astern.

In "ground" survey we can orient our board by aid of a magnetic compass. In the air we cannot use a compass fixed to the board owing to its inertia and this is made worse by vibration, and circular motion set up in the liquid.

But if we instal a quick-setting compass in the observer's cockpit with a horizontal dial, independent of the sketching board and we know the true bearing of every point of that compass and can keep the true N. and S. line on the sketching board parallel to the same line on the compass, we are on an equal footing with the "ground" surveyor and can sketch in the ground in its true position and proportion.

In Fig. 8 No. 1 we have a representation of the observer's cockpit and the direction of the track made good by the pilot, there being no wind and the machine's longitudinal axis is kept parallel to the track line being made good. Here magnetic N. and S. line M′ N′ on movable dial is set parallel to the compass needle by eye, then as long as M″ N″ on board is parallel to M′ N′ and the compass needle, the track line on the board is parallel to the track line on the ground. We can do this most conveniently by fitting a movable ring to the compass and setting the line M′ N′ parallel to magnetic N & S line and keeping M″N″ on board parallel to its equivalent on the movable ring. It will be evident that any angular movement of the axis of the machine will at once be shown up by a similar movement of the compass needle as shown in Fig. 8, No. 2. Then all we have to do is to turn the movable ring till the line M′ N′ is again set parallel to the magnetic N & S line and then turn the board till the corresponding line is again parallel, or simply turn the board till M″ N″ is parallel to the compass needle. The track line on the ground and on the board will now be parallel again, vide No. 3.

17. If we find the movement is due to the pilot correcting for wind, and the track laid down is being made good (see Fig. 6.), all the observer has to do is to take care that he draws in his detail with reference to the track line on the board and *not with reference to the side of the machine*, which is now at an angle to the track being made good, see also paras 23 and 64 and Fig. 22.

18. If however he finds that detail cut in when verti-

cally below him, later on appears to one flank or the other, and, on resecting with his sight-rule, he finds his position is off the track laid down (see Fig. 7, position No. 1) he at once knows the pilot has allowed the machine to drift and should be directed by the observer till he makes good the original track line laid down. (vide Fig. 7 position No. 3). The way this is done will be explained later on in paras 21 to 23. From the above it will be seen that merely keeping the board parallel to the track line will not "orient" the board, and detail cut in will only be correct with regard to the track line followed and not with reference to the N. and S. line.

19. We have referred in para 16 to using a magnetic compass and to its disadvantages, there is always a certain amount of uncertainty about the "variation" and the stresses set up by the electromotive forces in the machine itself, and any attempt to rectify these takes an appreciable time, and much important detail may be missed which cannot be picked up subsequently, the aeroplane moves too quickly in the air.

Given however a needle stuck vertically in our sketching board and the sun shining on it we at once have a means of instantly detecting any change in the direction of the longitudinal axis of the machine and if we protract a series of rays with needle as centre we can at once turn our board on its pivot till the shadow cast by the sun on the board coincides with the same ray before the change in direction took place. Here we have the application of the "sun" compass in its simplest form. Conversely if we mark down the line of the shadow at any time and note down the correct local "mean" time we can always calculate at our leisure afterwards what the true bearing of any particular shadow line was at any moment and so calculate what the true bearing of our track line was at that instant. This will be fully explained and examples worked out further on in this paper.

20. The sun compass however has these disadvantages, i.e., the sketching board must be kept level and the sun must be actually shining on the board where the needle is stuck in the board. Otherwise recourse must be had to a magnetic compass.

21. Now referring to Fig. 7, suppose we have directed the pilot to fly along course A—B, A being a point we can

easily recognise on the ground such as a prominent village, and before A is reached the pilot will have got on to the prolongation of A—B, i.e., A—A′ and will have steadied down to the course set.

He will have put his machine's nose up into the wind to counteract any tendency of the latter to blow the machine off the course before he has reached A.

Here it would be just as well for the observer to satisfy himself that the pilot is making for A and not for some other point that he has mistaken for the former.

22. By this time the machine is nearly over A′ so that the observer can just see village A under his right shoulder (it must be remembered he cannot see vertically under him as the fuselage and the air blast prevent this). He will have to get ready to commence work and will have remembered to have numbered off his minute grid lines 0,1,2,3 and so on. He will have oriented his board by magnetic, or sun compass, or have aligned the track line on board along track line made good. He now sketches in village A which is his starting point at zero, and as he moves along he sketches in the detail.

23. When he gets to "á" he cuts in A with his sight-rule and finds he is at "a″" and not at "á" on the track laid down as he expected to be, observer knows at once the pilot has not allowed sufficiently for the wind and that the machine is drifting to starboard. He immediately taps the pilot on his left shoulder, which is the signal to turn slightly to port (at "b′") the observer again cuts in A and finds he is near enough to the track line for all practical purposes and carries on his work as long as the pilot makes good the track laid down. If on reaching "b" the observer finds he is still off the course, he again taps the pilot on the left shoulder till the machine regains the track line laid down as in position No. 3.

24. If no compass is available and there has not been enough time to work out a sun compass and local true mean time, all one has to do is to note down the track followed by the machine, place sight-rule against the track line on the board and turn board till sight-rule is parallel to track line on the ground. If there is any drift successive detail passing vertically under observer will not remain in the same straight line vide Fig. 9 as shown by chain-dotted line

from small hill. Drift will at once be noticeable as the hill will move to the left of the other detail previously cut in instead of remaining in the same vertical plane. Without a compass the direction of the track is not known to the observer as he has no means of checking the bearing the pilot is flying on.

25. Fig. 10 shows the cumulative effect of not correcting for drift and providing observer with some practical means of orienting his board. It would be impossible to fit the figure together and on finishing up at B after doing diagonal course the position of D would now be at D″.

26. In all air-sketching and reconnaissance the pilot should keep a straight course on a given bearing and eliminate drift. He should also take an interest in the work. One that has himself been trained in the work makes the best pilot as he knows from personal experience what is expected of him and the effect of drift on the accuracy of the work. If the pilot and observer have both been trained in air-sketching the best results will be obtained.

A beginner always finds one of his principal difficulties is in explaining to the pilot what he is to do.

Once a pilot knows exactly what is expected of him he will take much more interest in his own share of the work and anticipate the observer's requirements.

27. The bulk of the air-sketcher's work will be (a) filling in gaps left in the surveyed area, or (b) breaking off from surveyed ground and sketching in entirely unmapped country where the positions of some of the more important towns are more or less accurately known.

In every case it is best to break down the areas into blocks that can be completely sketched in in one flight.

For instance a D.H. 9a can keep the air for 5 hours: allowing say one hour for outward and return journey and half an hour as a margin this leaves $3\frac{1}{2}$ hours and this at say 90 miles an hour will enable the machine to run 315 linear miles, in other words to cover an area of about 250 square miles.

Tie-lines would first of all be run in along the sides of the area then a grid would be run over it to sketch in all the ground. The difference between "tie-line" and "grid" is that in the former the observer flies up and down the same course to get rid of the wind factor. He utilises these for laying out the figure. The grids are then adjusted on this figure and the detail, after adjustment, filled in from these.

The best way to sketch in a large area is to break it up into triangles by means of tie-lines and then "grid" each triangle.

In hilly country it will generally be better to run route-traverses up each valley instead of the usual grids as the form of the ground lends itself better to this.

SECTION II

Instruments used

28. The outfit required is:—

(i) Sketching Board, with Tee Level fitted to it for levelling purposes.

(ii) Stand or Pedestal for (i)

(iii) Attachment for (ii) to fix it firmly into the aeroplane.

(iv) Set of "Ground" Speed Scales.

(v) Sight-rule.

(vi) Holdall to take a few simple drawing instruments required in the air such as pencils, sight-rule, spectacles, scales, and a few simple tools and accessories.

(vii) Stop-watch.

(viii) Suitable Seat.

(ix) Clothing, i.e.:—Warm coat, suitable form of gloves, goggles, airman's cap or helmet.

(x) Water Bottle and some food.

(xi) Sun Helmet for use on the ground, in a hot climate.

(xii) Small tin case for holding maps rolled up.

29. *Sketching Board.* In actual practice the best form of board is one made up on the lines of a Cavalry sketching board modified to suit conditions in the air. The rollers should be strongly made to stand the rough usage to which they are subjected. They should also be provided with larger milled-headed ends to give more purchase to the fingers, weight is of little importance in a light fitting of this description. Size should not exceed more than $9\frac{1}{2}'' \times 9\frac{1}{2}''$, a bigger board gets in the way in the cramped space of the observer's cockpit. The Tee Level is an essential fitting when using a sun-compass. An ordinary board is only suitable for supplementing small areas of partly mapped ground, it cannot be used for tie-lines or grids as the area of paper available is small and soon gets used up; fitting on a fresh piece takes time and the change might have to be made in the middle of sketching resulting in a large gap being left in the strip which could not be made good. On

the other hand the long strip on the roller type of board gives ample margin even after 5 hours work in the air.

Fig. 24 shows a suitable attachment for sun-compass needle, to throw a shadow on the sketching board.

30. *Pedestal for Board.* This must be so constructed as not only to permit of the sketching board being turned round its centre but to allow of its being levelled if a sun-compass is used. A ball and socket head to the pedestal is the most suitable (vide Fig. 11). A screw boss is fitted to the underside of the board to enable the latter to be fixed on to the head. Fig. 14 shows a simple form of universal joint, easily made, which can be used instead of a ball-and-socket joint but is not so convenient to use in actual practice.

31. *Transom Attachment for Pedestal.* Figs. 12, 13 and 14 show suitable types for a Bristol Fighter and 14a for a D.H. 9a.

32. *Ground-Speed Scales and Sight-rule combined.* These can be made up at any time and sights fitted to them at the same time for use as a sight-rule as well, the formula for these scales is:—

For linear distance in inches covered by an aeroplane in a minute, on the 1-inch scale,

$$D = \frac{\text{ground speed in miles per hour}}{60}.$$

Example:—Suppose we want the linear distance in inches covered in one minute at 75 m.p.h. on the $\frac{1}{2}$-inch scale, the distance D will be $75/60 \times \frac{1}{2} = 0{\cdot}625$ inch.

The best way is to have these made up in boxwood rules like an architect's scale with the speed scales most likely to be used engraved on them (75, 80, 85, 90 and 95 m.p.h. will be found to be the speeds most commonly used) and sockets fitted to them to take the sights, see Figs. 15 and 16.

The intermediate speeds if required can easily be worked out and drawn on cardboard strips.

33. *Holdall.* This should be big enough to take everything one requires for work in the air, a separate pocket is necessary for folded maps in order to prevent their being dragged out and lost in this way.

The actual fittings which are usually required are:—

Speed scale, sight-rule, red and blue, green, brown, and yellow chalk pencils; hard and soft lead pencils, India rubber, knife, protractor, hairspring dividers, proportional compasses, sun-compass needles, scissors, screw-driver, spanner, small wooden mallet for sun-compass needles, and maps as required.

34. *Stop-watch.* One showing 5, 10, 15, 20, 25, 30 minutes preferable to one showing 3, 6, 9, 12 etc.

It is very important that the stop-watch action should synchronise with the main mechanism of the watch itself. If the mechanism is examined 2 small finely milled wheels will be seen which intermesh. The jolts and jars these get very soon tend to wear down the fine milling and cause them to get out of mesh and in consequence no longer synchronise with the main mechanism. Very little causes a slip. If this occurs the watch is useless for air-survey work and should at once be changed and sent for repairs. A good stock of watches and spare milled wheels should therefore be kept.

A mechanic whose trade is that of watchmaker should be consulted and the watch, if out of order, sent to him for repairs.

35. *Seat.* The best seat of all is the swivel seat fitted to the R.E. 8 machine, failing which a small shallow box and cushion, high enough to suit the observer, strapped on to the seat of the machine to be used will give sufficient command over the side of the fuselage to give a clear view of the ground to be sketched in. The seat must be shifted forward for the observer must sit facing the tail to do his work.

36. *Clothing.* Warm leather gloves are necessary in cold weather, the tips of the fingers should be cut off to enable the pencil to be handled properly. It is strongly advisable to wear goggles to save the eyes, the rush of the air is a great strain on them.

SECTION III

General instructions

37. In this section the general instructions for Air-sketching will be explained in detail separately in their right order as far as possible.

38. A list of the equipment required has been given in the previous section, but the paper has not been dealt with yet. This should be cut up into long strips to fit the rollers of the sketching board, the best paper to use is the linen-backed paper on which maps are printed.

Unmounted paper is apt to get torn by the blast from the propeller. Long strips are best as it gets used up quickly, and saving of time and delay is important.

39. In actual practice we never do know what the actual "ground" speed is going to be on any course, so we adopt some arbitrary speed equivalent to the average working "air" speed of the machine, and reduce or enlarge as required after landing and when compiling the map.

Having selected the speed we intend using we rule up the "minute" lines at right angles to the length of the paper (see Figs. 17 and 18). At right angles to these we draw lines one mile apart to assist us in placing detail to a flank the correct distance from the centre line on the scale of the sketch. From para 11 (b) we know that if we are a mile above the ground 1 mile to a flank subtends 45° and 2 miles $63\frac{1}{2}$°; with a little practice we can easily judge these angles and draw in the detail in its correct position to a flank. If we get the lines printed by machinery it saves a lot of labour. In addition we can have the "minute" lines subdivided into $\frac{1}{4}$-minutes as shown in Fig. 18.

40. The 1-inch and $\frac{1}{2}$-inch scales will be found the best to work on.

41. It must be remembered that we cannot see vertically underneath the machine so there will always be about a quarter of a mile of dead ground which will have to be left blank and drawn in when sketching the adjoining strip.

42. Pencils should always be kept sharp. Blue should be used for water forms such as canals, water in streams, and rivers, etc. Red for communications, buildings, forts,

bridges. Green for forests, woods and trees; yellow for cultivation. Black for all other features. Brown may be used with advantage to represent hill formations on the way back to the aerodrome while the memory is fresh.

To save time in using chalk pencils the colour may often be added to pencil lines with the left hand immediately the feature has been marked up in pencil.

43. A list of conventional signs should be drawn up.

44. Very few signals are necessary once the machine has left the ground, the following are suggested as being suitable and sufficient, i.e.:—

(a) 1 tap on $\frac{\text{left}}{\text{right}}$ shoulder = "turn slightly to $\frac{\text{port}}{\text{starboard}}$".

(b) 2 taps on shoulder = "turn at right angles in the direction of the shoulder indicated".

(c) 2 or more taps on shoulder and hand directed downwards = "pivot point reached, re-pass it after circling and steadying down to next course".

(d) 2 or 3 taps on shoulder and hand circled round 2 or 3 times = "sketch finished, return to aerodrome".

Or headpiece telephones may be used.

45. It is a very good plan to give the pilot a watch set to run at the same rate as the observer's and to the same minute and second. The reason for this is that the pilot may find it necessary to alter the air speed to keep the machine in trim, this will enable the observer to locate the position on his sketch where this took place and adjust the scale accordingly.

46. Compass bearings if given to the pilot should be in terms of his compass which has probably been swung and the deviations from the true bearing at various points of the compass entered up on a card, in his cockpit.

47. Given the following:—

g_1 = ground speed on outward trip.
g_2 = ground speed on return trip.
a_1 = true air-speed on outward trip.
a_2 = true air-speed on return trip.
w = wind factor.

then vide para 10, $g_1+g_2= a_1+w)+(a_2-w)$ and when "w" is constant $g_1 + g_2 = a_1 + a_2$ ....(1).

In other words the sum of the "ground" speeds is equal to the sum of the "true" air speeds.

Now "ground" speed in miles per hour is equal to

$$\frac{\text{distance flown in miles}}{\text{time taken in minutes}} \times 60 \quad\text{.............................(ii).}$$

Let t_1 = time in minutes taken on outward trip,
and t_2 = time taken on return trip,
d = distance run in miles,
then from (ii) we get—

$$g_1 = \frac{d}{t_1} \times 60 \text{ and } g_2 = \frac{d}{t_2} \times 60 \quad\text{..........................(iii).}$$

$$\text{and } g_1 + g_2 = \frac{d\,(t_1+t_2) \times 60}{t_1 \times t_2}$$

and by (i) $g_1+g_2=a_1+a_2$

$$\therefore a_1 + a_2 = \frac{d\,(t_1+t_2) \times 60}{t_1 \times t_2}$$

$$\text{whence } d = \frac{(a_1+a_2) \times t_1 \times t_2}{(t_1+t_2) \times 60} \quad\text{..................................(iv).}$$

48. To arrive at the distance run all we have to do is to fly up the course at air speed "a_1", take time "t_1" on outward course, then fly back again on same course at say air speed "a_2" and take the time "t_2". Then distance "d" can be computed out by formula (iv) given above.

49. Unfortunately air-speed indicators do not always register the actual, or true, air-speed, so we must find out the "index" error of the dial, and we can arrive at this as follows:—

Select two points on the earth's surface whose distance apart in miles is known or can be measured from a map, then fly over these two points and back again over them, taking the times t_1 and t_2 and arrive at the ground speeds by formula (iii) as before.

But $g_1+g_2=a_1+a_2$ vide formula (i) and suppose the "index" error to be "e", then if the indicated "air" speeds were b_1 and b_2 :—

$$g_1 + g_2 = (b_1+e) + (b_2+e) = a_1+a_2$$

hence $b_1 + b_2 + 2e = a_1 + a_2$

$$\text{and } e = \frac{(a_1+a_2) - (b_1+b_2)}{2}$$

and is $\frac{\text{positive}}{\text{negative}}$ if the sum of a_1

and a_2 is $\frac{\text{greater}}{\text{less}}$ than that of b_1 and b_2.

Having found "e" we can obtain "d" from formula (iv). Owing to the jars the speed indicating instrument receives every time the machine lands and takes off it is strongly advisable to find the value of "e" every time the machine goes up on an air-sketching trip.

50. *Example of calculations for Tie-line.*

Using formula (iii):—

given d = 5·3, t_1=4·3, t_2=3·6

$$g_1 = \frac{5\cdot3}{4\cdot3} \times 60 = 74 \text{ m.p.h.}$$

$$g_2 = \frac{5\cdot3}{3\cdot6} \times 60 = 88\cdot5 \text{ m.p.h.}$$

2) 162·5 sum.

81·3 m.p.h. = average true air speed.

Indicated air speeds are 85 out and 86 back, mean 85·5. So that the average index error=85·5−81·3=4·2 "e".

Air speed on run out on Tie-line No. 1	=86
True do. do.	=86−4·2
	=81·8
Air speed on run back	=87
True speed on run back on Tie-line No. 1	=87−4·2
	=82·8

Time out was 17·6 minutes.

Time back was 16·1 minutes.

Then using formula (iv) distance run, d=

$$\frac{(81\cdot8+82\cdot8)\ 17\cdot6\times16\cdot1}{60\ (17\cdot6+16\cdot1)} = \frac{164\cdot6\times17\cdot6\times16\cdot1}{60\times33\cdot7} = 23 \text{ miles}$$

In other words the linear distance between the initial and final points on the half-inch scale=11·5 inches, the strip must be reduced or enlarged accordingly to bring it to the correct scale.

51. It will be a good plan at this stage to deal with the action we intend taking on receiving our orders say to sketch in a bit of unmapped country beyond the limit of the survey area. The first thing to do is to get 3 copies of the latest edition of the map of the surveyed portion. From one copy we cut a strip about 2 inches wide of the margin

of the surveyed portion beyond which we have to sketch the ground, (it is understood we are to survey the area on the $\frac{1}{2}$ inch scale and the maps provided are on that scale) and paste it on to our paper as has been shown in Fig. 18. The observer then consults the pilot then makes up his mind how he is going to tackle the work, gives the pilot one of the maps with the surveyed margin he intends basing his work on, marks on it 2 pivot points as the end of his base (see Fig. 18 A and B) and completes his preparations to carry out the sketch.

Referring to Fig. 19 it is evident that a 4-sided figure approximating a square will give us the maximum area for a given time. This we can build up with 2 triangles ABC, BCD. We can run in an extra diagonal AD if we like and there is time, it helps to pull the figure together better. We can run along AB (see Fig. 18) and back again to get our index error and at the same time glance over the area we are about to sketch in, it also gives the pilot a chance to do this.

We will have to run tie-lines along AB, BC, CA, BD, CD, and also along AD if we intend running in this diagonal: we then grid the area by running lines parallel to AC or BD and can return to the aerodrome.

52. The left side is easiest to sketch from (the observer is seated sitting facing the tail), less blast from the propeller, the right arm does not get in the way. When gridding we must however work from alternate sides in order to sketch in the dead ground of the previous grid-line.

Suppose we intend gridding from and parallel to side AC and we have to get in 7 grid-lines to cover the area.

Suppose we tie our first grid-lines on to AB then along ab we must sketch from our left so as to get in all the detail between ab and AC. On reaching DC we overshoot it and then run down cd parallel to ab. It will be evident from the figure that we must now sketch in from our right side if we are to get in the detail between ab and cd. We now get a clear view of the dead ground underneath ab so we need not worry about this when running along ab. When we run down the next strip ef we must sketch from our left side and so on alternately for each grid-line. We shall find that we cannot sketch in more than about 2 miles of ground in depth to a flank and that it is better to do so from one side only especially as we have a strip of dead ground under us, but it pays us to follow up the more important features such as rivers, streams and roads and sketch their continuation on the opposite side, it helps to piece the sketch together better. It also pays to run these features beyond the two miles on the side we are sketching, sometimes. It all depends what time we have available: we must not do this however at the expense of the detail along our 2-mile strip. The smaller features such as villages, railway stations, bridges will not be visible from the adjoining grid-line, whereas we can trace rivers and communications that run across our track for some distance to either flank. It is better to run our grids at 2-mile intervals to ensure no detail being left out.

On the supposition that the machine can keep the air for 5 hours and that it takes 1 hour to reach the ground and return to the aerodrome and deducting $\frac{1}{2}$-hour as a factor of safety this leaves us with $3\frac{1}{2}$ hours available for sketching.

53. If A is the nearest point pilot would be directed to fly to the left of it, straighten out and then fly along A—B then circle round and fly along B—A. While doing this observer can obtain data for "index" error, and both he and pilot have time to look at the ground to be sketched in, observer can also cut in a good deal of detail along the edge of the unmapped portion and run in any important features running into the area and roughly fix a few prominent points by resection with his sight-rule which will be useful in piecing the sketch together afterwards. He can also draw in any features omitted on the surveyed strip, this was done in Mesopotamia and added to the usefulness of the map.

Having passed A, pilot will next fly to B, then turn and fly along B—C, then back again C—B, then B—A. Then fly along A—C, C—D and D—B and then back via B—D, D—C and C—A. We have now done all the tie-lines we require and can take up the gridding. We have at this stage flown beyond A. Suppose our Base A—B is 16 miles long then at 2-miles intervals we require 7 grid-lines and fly over these in the following order and direction i.e. :— a—b, c—d, e—f, g—h, i—j, k—l, m—n and the last brings us to the neighbourhood of D; if we want to do tie-line DA and have time now is the opportunity.

54. We must now see how long the sketch is going to take us, it is no good attempting more than we can do in one trip. This we can arrive at from the following tabular statement:—

miles	omitting AD 8 grid-lines.	omitting AD 6 grid-lines.
(a) Side of square 16 miles		
4 sides 18×2×4	144	114
1 diagonal 26×2	52	52
8 grid-lines 18×8	144	
6 grid-lines 18×6		108
taking working air speed of machine as.............85)	340 total	85) 304 total
	4 hours	$3\frac{1}{2}$ hours
(b) Side of square 14 miles		
4 sides 16×2×4	128	128
2 diagonals 23×2×2	92	{ 1 diagonal 23×2 46
6 grid-lines 16×6	96	96
	) 316 total	85) 270
	$3\frac{1}{4}$ hours	$3\frac{1}{6}$ hours

Note.—1 mile has to be added to the ends of each course to allow for overlap and turning round to straighten out on to the next course so that 2 miles has to be added to each course given above.

From the above we see that we can complete the 16-mile square if we omit diagonal AD and use only 6 instead of 7 grid-lines.

If we want to include the above diagonal we must reduce our square to one of 14 miles a side.

In using 6 instead of 7 grid-lines in square (a) we must sketch in a strip of 14/6 or $2\frac{1}{3}$ miles wide instead of 2 miles.

If time is of importance (a) using 6 grid-lines is the best.

55. When running in a tie-line, on the return flight the observer can easily get in what detail he has not had

time to cut in on his outward run. It is important on the return journey to take the time of re-passing some of the detail he cut in on the outward run as the ground speed may vary a little if the wind happens to be gusty. By doing this it will be possible to plot the positions of some points more accurately and adjust the remainder of the detail on to these.

56. When flying on a tie-line with a strong wind abeam the inclination of the longitudinal axis of the machine to the track-line should be cut in as the "ground" speed varies in proportion to the strength of the wind and the wind factor does not cancel out as it does up and down wind. Referring to Fig. 20 if BC is the actual track-line and ABC the inclination of the machine to it make AB equal to the average air speed of the machine up and down the tie-line as before and drop a perpendicular on to BC from A then AC is the wind factor and BC the corresponding air speed along the track made good in terms of AB. It will thus be readily seen that unless we know the angle B we cannot arrive at the value of BC and the true length of our tie-line cannot be worked out.

On a grid-line this is not necessary as this is adjusted straight on to the sides of the square and reduced or enlarged accordingly.

57. A wide circle at the end of each course or lap is necessary in order to give the pilot time to straighten out for the next course and also to give the observer time to (a) stop his watch, note time of passing final point of course, just completed, re-start watch on reaching initial point of next course expose a fresh piece of paper for his next course, (b) look out for his next initial point and get in detail round it before it passes vertically under him (c) sharpen his pencils and get some momentary relaxation from his strenuous duties amongst other things, see Fig 21.

If the pilot banked straight away on to the next course the machine would be well down the new course before the observer was ready to start work and it would involve his having to tell the pilot to turn back again and begin the course all over again.

58. When vertically over the initial point of the course the observer begins to sketch, as a matter of fact he should begin directly he can see the point and before it comes

vertically under him because it is a good thing to get in all the detail he can round it. The observer, sitting facing the tail cannot see his initial point nor can he direct the pilot on to it. He is dependent on the pilot entirely for this. When he estimates he has reached the end of his course he must let the pilot know because the latter does not know when the end of the course has been reached. The pilot should take care to pass to the right or left of the point as the observer cannot see vertically under the machine.

The sketcher cannot do his work facing the propeller as the body of the machine and the wings get in the way and once detail has passed, he cannot see it any longer. On the other hand it is quite easy to go on sketching in detail after it has passed the observer, when seated facing the tail in fact the bulk of the detail will be got in after it has passed him. It is of course important to cut in detail at intervals to get these points in their correct position, but having done that the intermediate features can easily be sketched in freehand after it has passed. One will therefore be doing quite a lot of work at an oblique angle.

59. Observer should be careful not to forget to number his minute lines 0, 1, 2, 3, 4, and so on, and to do this before he reaches his initial point. Also not to forget to start his watch directly he is vertically over his initial point.

The watch should be hung up in a position where he can easily read, stop, and re-start it.

60. It must be remembered that the observer has no time to use a drift indicator or course director as he would not have sufficient time to sketch in detail if he did and his map would be useless for war purposes, the instrument is therefore not included in his equipment, at the same time it is essential to keep the track line on the board parallel to the track made good and this can best be effected by fixing a simple sight-rule made out of a piece of wood, pivotting it in the centre and fixing one on each side of the machine keeping this aligned on the track-line made good and keeping the line on the board parallel to this. But the actual track-line made good can easily be judged by eye and the line on the board swung parallel to it.

61. It is very important to make sure of detail common to 2 or more courses and giving them common letters so that the strips can be pieced together. This can best be

effected when on the return trip to the aerodrome while the memory is fresh and there is time to turn the rollers to get at the strips concerned, there is no time to do so while at work.

62. To help to visualise the work of sketching in a strip see Fig. 17, the pilot will have warned one that he was nearing the mark and the sketcher, directly he can see it (a village at 0) starts getting in what detail he can see at zero which happens to be the road and river to his right a mile or so away, by the time he has got in the initial point a village passes under him at 0·32 which he dots down at 0·5 on his minute scale and he will have to work quickly to get in the tracks running SE. and the form of the low ridge running WNW. and the rest of the track and the road and stream to his right.

By this time the big village to his left at 1 minute 45 seconds will be visible quickly followed by the village to the right and the observer will be busily employed getting these in as well as the river and road to his left and similar detail to his right. The machine will in the meantime have arrived at 3 and he will have to get in the small hill to his left where the road makes a bend and all the detail to his left besides. He will have got to 3m. 4os. by now and will have to get in the pond and the villages and the streams and river and tracks to his right. By this time the big village at 4m. 50s. will have caught the corner of his eye and all the roads radiating from it and he will have to draw in the continuation of the main road to his left with its avenue of trees and then the village to his right and the stream.

By this time he will find he is crossing over a canal and by the time he has got this in he will be at 6m. 15s. and he will have to draw in the small village to his right and the two streams and then pay attention to his left and the canal crossing under the main road and another road coming into view running SSE. by S. and the detail between these and his track line. By this time he will be at 7m. 30s. and he will find plenty of work to do getting in the detail on both sides and will find probably at 8m. 25s. that the pilot thinks he has gone far enough and is beginning to make a wide circle preparatory to running on the next course and the observer must stop work (he will find it impossible to sketch in any detail while circling) and get ready for his next course. In the sketch detail has been cut in on both sides and any blanks left over dead ground will have to be filled in from the adjoining grid or if a tie-line, on the return run, for arrangements would have been made beforehand with the pilot to fly along a parallel course to avoid having the same dead ground twice.

63. Great care must be taken to consult the watch frequently so as to get the detail cut in at the correct time and corresponding position on the time scale along the track line on the board. If there is a lot of detail to cut in one is apt to outstrip one's watch and get the detail into wrong positions on the paper in advance of the time.

64. Care must be taken constantly to keep the line on the paper parallel to the track-line and to draw the detail with reference to the former and not with reference to the side of the machine so mark this by a thick line so as to catch the eye as shown in Fig. 22. The road passing through the village to the right appears to be perpendicular to the side of the machine whereas it is at an angle of about 40° to the track-line and the railway line appears to be at 40° to the side whereas it is parallel to the track line, in this figure the line on the board is shown turned parallel to the line on the ground as it ought to be.

64(a). When using a sun-compass solar time must be used instead of local mean time so as to get the sun on the meridian at solar midday.

64(b). Traverse lines can be run across grid-lines to eliminate any "bulge" in the latter if time permits.

SECTION IV

Example of a Tie-Line

65. Plate II shows a tie-line up the River Indus at Attock, copied from an actual sketch, a check run for index error was first made over 2 points whose distance apart was 6·7 miles (beyond the limits of the sketch), the pilot then flew on, straightened out on the course indicated to him beforehand, ran straight up and then back again on much the same line. The course was checked by resection on back points and shadow cast by a needle stuck vertically into the board to enable a straight course to be maintained, the pilot kept a very straight course except in the Attock gorge itself where it was a bit gusty.

The compass bearings given was taken from the pilot's compass.

Over the measured distance—

$$g_1 = \frac{6\cdot7}{5\cdot92} \times 60 = 67\cdot9 \text{ miles per hour}$$

$$g_2 = \frac{6\cdot7}{5\cdot23} \times 60 = 76\cdot9 \text{ miles per hour}$$

$$2)\overline{144\cdot8} \text{ total.}$$

$$\text{average air speed} = 72\cdot4 \text{ miles per hour}$$

Indicated air-speed was 63·0, index error = 9·4

$$d = \frac{(72\cdot4 + 72\cdot4) \times 20\cdot65 \times 17\cdot73}{(20\cdot65 + 17\cdot73) \times 60} = 23 \text{ miles.}$$

For formulae see para 47.

The actual distance according to the map was 23·72 miles. It is important in all tie-lines on the return journey to take the time of re-passing some of the detail already sketched in as the "ground" speed may vary from time to time if the wind is at all irregular or gusty. By doing this it will ensure a more correct position for points at intervals along a tie-line.

SECTION V

Route-Traverses

66. Route-traverses are used to sketch in long stretches of important features such as a river, road or railway, or may be used instead of tie-lines in mountainous country where the height of the hills render it inadvisable to use the ordinary "grid" system in filling in an area, or where it may be easier to get in the detail of a valley by flying up and down it than by the normal methods.

As the bearing of the track-line will vary with each turn to follow the feature some means of measuring these angles must be used. This may be effected by magnetic or sun-compass bearings or a combination of both. In any case the track-line on the board must be kept parallel to the track made good on the ground and the bearings deduced from readings noted down by the pilot from his compass at each change in the course.

It greatly assists the observer if the pilot taps him on the shoulder every time he has to change course, he can see ahead and determine when it is necessary to do this. The observer, sitting as he does facing the tail, does not know when a change in the course becomes necessary, but he should always let the pilot know which side of the main feature of the route he should fly as it is no good keeping it under the machine where it cannot be seen.

If there is a wind abeam the longitudinal axis of the machine will be at an angle to the track followed and the tail will obstruct the view on the side opposite to which the wind is blowing and he has no choice of sides in that case and must sketch from the side the wind is blowing. The pilot must be careful to remember this and on straightening out to pass over the initial point of the sketch must select the windward side.

67. Plate I shows the actual detail sketched in on a route-traverse between Peshāwar and Attock.

Before straightening out to fly over the route 2 points were chosen on the Peshāwar-Jamrūd road 5·3 miles apart for the purpose of checking the air speed as indicated by the "pitot" or indicator dial (air speed).

The pilot then straightened out on to the traverse line and finding the wind on his left kept the road and railway on his left so that the observer could sketch from his right quite clear of the tail which was to his left.

A certain amount of detail was followed up under the machine to the left hand side and one or two villages sketched in. The track-line on the board was kept parallel to the track made good by resection and the board was levelled whenever a sun-compass reading was taken.

On the return journey the board must be turned round on its pivot as one starts getting in the detail from the end of the sketch. Work in the detail over the detail already cut in and finally finished up at the starting point, in this case at Peshāwar.

68. In a route-traverse a pilot should have no difficulty in following up the features to be sketched in whether a road, railway or river etc., and the observer can leave this entirely to him, but the pilot must tap the former whenever a change in the course becomes necessary, this the pilot can easily foresee as he can see ahead of him.

69. Pilot must keep as constant an air speed as possible and fly about the height named by the observer but need not increase the height if a range of hills has to be passed over provided the height the machine happens to be flying at is sufficient to clear the feature, the observer must however remember that as the tops of the hills are comparatively close to the machine, para 11 (b) will not apply and that detail subtending $45°$ and $63\frac{1}{2}°$ is less than 1 and 2 miles to a flank respectively.

70. The needle may be stuck into the board anywhere where the sun is actually shining on it and the line of the shadow rapidly marked but the observer must level the board and see that the track-line on the board is parallel to the track on the ground, and must not forget to remove the needle before shifting the paper when exposing a fresh piece. If the shadow moves the observer will at once know that the direction of the course is being changed or that the pilot is slewing the machine round to counteract an increase in the strength of the wind and must shift his board round its pivot in proportion.

71. On the return journey it is important to take the

time of re-passing some of the detail cut in on the outward journey, see para 55.

72. The computation for the sun-compass bearings is based on the following formulae:—

$$\tan\frac{A+B}{2}=\frac{\cos\frac{a-b}{2}}{\cos\frac{a+b}{2}}\times\cot\frac{C}{2}\quad . \quad . \quad . \quad (1)$$

$$\tan\frac{A-B}{2}=\frac{\sin\frac{a-b}{2}}{\sin\frac{a+b}{2}}\times\cot\frac{C}{2}\quad . \quad . \quad . \quad (2)$$

Taking the figures for Lap No. 1

where C = (12hrs – 9hrs. 32mts.)
= 2 hours 28 minutes.
= 37° 0′

$$\frac{C}{2} = 18^\circ\ 30'$$

$$b = 90^\circ - \lambda^* = 90^\circ - 34^\circ = 56^\circ\ 0'$$

$$a = 90^\circ - \delta\dagger = 90^\circ - 1^\circ\ 14' = 88^\circ\ 46'$$

$$a-b = 32^\circ\ 46',\ \frac{a-b}{2} = 16^\circ\ 23'$$

$$a+b = 144^\circ\ 46',\ \frac{a+b}{2} = 72^\circ\ 23'$$

$$\log\cos\frac{a-b}{2} = \bar{1}\cdot 98200$$

$$\text{,,}\ \cot\frac{C}{2} = 0\cdot 47548$$

$$\text{Sum} = 0\cdot 45748$$

$$\log\cos\frac{a+b}{2} = \bar{1}\cdot 48094$$

$$\text{Diff.} = 0\cdot 97654 = \log\tan\frac{A+B}{2}$$

$$\text{whence}\ \frac{A+B}{2} = 83^\circ\ 58' \quad . \quad . \quad . \quad (1)$$

* λ = latitude = 34°, taken off published sheet.

† δ = declination of Sun = 1° 14′, taken from Nautical Almanac.

$$\log \sin \frac{a-b}{2} = \bar{1}\cdot 45035$$

$$\text{,,} \quad \cot \frac{C}{2} = 0\cdot 47548$$

$$\text{Sum} = \bar{1}\cdot 92583$$

$$\log \sin \frac{a+b}{2} = \bar{1}\cdot 97914$$

$$\text{Diff.} = \bar{1}\cdot 94669 = \log \tan \frac{A-B}{2}$$

whence $\frac{A-B}{2} = 41^\circ\ 30'$. (2)

Sum of (1) and (2) = $A = 83^\circ\ 58' + 41^\circ\ 30' = 125^\circ\ 28'$

This is the sun's bearing, that of the shadow line marked on the board = $180^\circ - A = 54^\circ\ 32'$ reckoned West from North.

73. The bearings deduced from the sun-compass angles are as follows:—

No. 1 Lap, 1st reading, computed out as an example sun's shadow, A,		54° 32′
Angle between shadow of needle and track-line, S		35 15
True bearing of track-line, T		89 47
No. 1 Lap, 2nd reading	A	53 01
	S	37 30
	T	90 31
No. 1 Lap, 3rd reading	A	50 21
	S	41 20
	T	91 41
No. 2 Lap,	A	131 52
	S	26 00
	T	105 52
No. 3 Lap,	A	132 43
	S	4 00
	T	136 43
No. 4 Lap,	A	133 52
	S	47 10
	T	181 02

74. COMPARATIVE TABLE

No. of Lap	Angle by sun-compass	Angle by magnetic compass	Difference.
No. 1 (i)	$89\frac{3}{4}°$ }		$-2\frac{1}{4}°$
do (ii)	$90\frac{1}{2}°$ }	92°	$-1\frac{1}{2}°$
do (iii)	$91\frac{3}{4}°$ }		$-0\frac{1}{4}°$
No. 2	106°	110°	− 4°
No. 3	$136\frac{3}{4}°$	140°	$-3\frac{1}{4}°$
No. 4	181°	185°	− 4°

75. COMPUTATIONS FOR INDEX ERROR

Ground speed out, g_1 on measured distance $= \frac{5 \cdot 3}{4 \cdot 05} \times 60$

$= 79$ miles per hour

Do. back, g_2 on do. $= \frac{5 \cdot 3}{4 \cdot 52} \times 60$

$= 70$ miles per hour

True air speed $= \frac{79 + 70}{2}$ $= 74 \cdot 5$ miles per hour

Average air speed indicated $= \frac{79 + 80}{2} = 79 \cdot 5$ miles per hour

True air speed from above $= 74 \cdot 5$ miles per hour

Index error $= 5 \cdot 0$ miles per hour

76. COMPUTATIONS FOR DISTANCE RUN

Distance run $d = \frac{(a_1 + a_2)\, t_1 \times t_2}{60\,(t_1 + t_2)}$

where $a_1 = 78 - 2 = 76$

$a_2 = 79 - 2 = 77$

Sum $= a_1 + a_2 = 153$

$t_1 = 34$ minutes.

$t_2 = 36 \cdot 72$ minutes.

$\therefore d = \frac{153 \times 34 \times 36 \cdot 72}{60 \times (34 + 36 \cdot 72)} = 45 \cdot 0$ miles

Actual distance by mile-stones = 43·3 miles.

Note (a)—The mean latitude of the observer's area can always be obtained from the published map, to the nearest minute of arc.

Note (b)—The sun's declination can always be obtained from page II of the month in the Nautical Almanac.

SECTION VI

Sketching in hilly ground

77. This is undoubtedly the more difficult task, especially when one takes into account the speed with which an aeroplane travels and the distorted appearance of the hill features as they pass under and away from the observer. The sketching in of the main streams or rivers, and ridges, is not difficult; but the side valleys and more important minor hill features have to be sketched in very rapidly. Complicated ground as found in the neighbourhood of Attock calls for more physical and mental effort on the part of the air-sketcher than the more regular and parallel valleys and ranges, which do not present so much difficulty. Undoubtedly the best way is to do a traverse up a main valley getting in what one can on the way up from both sides, and amplifying and filling up gaps on the way back. Supplementary survey afterwards on an area board is generally necessary in hilly ground.

The relative height of the hills can easily be estimated when seen obliquely or in profile and when passing over the ridges. "Dhamans" or Fans are easily recognisable, but a sharp look-out must be kept for undulating ground and minor hills in flat country.

78. Colour and form will often indicate the relative height of the hills above the general ground level.

79. It is a good plan to run in by eye at least one level contour in and out of the valleys.

80. The relative height above a predetermined estimated and datum level should be given to all the more important features and entered on the sketch while in the air.

81. The sketching in of hills requires more practice than that of features in the level ground.

82. Sketching in hilly ground should always be divided into two operations:—(i) Tie-lines, route-traverses and grid-work. (ii) Adjusting sketch as it stands, inking it up and then transferring it to an area board and going over the ground again and filling up all blanks and omissions. It is generally impossible to fill in all the essential features

in complicated hilly ground without going over it twice, i.e , by supplementary survey.

83. Hill formations as viewed from the air assume entirely different shapes as compared with the same hills viewed from the ground. The best way to teach pupils how to sketch in hills can undoubtedly be effected by means of coloured models of various forms of hills made of cardboard which can be separated so as to expose the dominant contours. It is essential to sketch in rapidly from the air in order to furnish enough data to contour the hills when compiling the sketch. A series of well thought-out, carefully made cardboard models painted so as to represent actual hills and placed on the floor so that a pupil can view them from his chair and rapidly draw them in, will teach him how to contour a similar type of hill when he flies over it, and familiarise him with the dominant characteristics of the various forms of hills met with in different parts of the world.

SECTION VII

Indoor Training

84. A good deal of useful preliminary training can be carried out indoors in a spare hangar or large drill hall by means of square canvas screens coloured up to represent what the ground looks like from an aeroplane and an old fuselage suspended from the roof some 2 or 3 feet above the floor.

The pupil sits in the observer's compartment of the fuselage with the instruments etc., he actually takes up with him in the air and sketches in the ground as represented by the canvas screen as it is dragged slowly under him at approximately the pace the ground would appear to move when actually seated in a machine in the air at 5,000 feet or so above the ground.

Given the scale of the map on the screen as 2 feet to the mile, suppose the air speed to be 85 miles per hour, the screen would have to be moved at the rate of $\frac{85}{60} \times 2 = 2{\cdot}8$ feet per minute.

To obviate the setting up of expensive machinery to move the screen at this rate, all that is necessary is to mark on the floor marks at 2·8 feet intervals and drag the screen that distance every successive minute of time.

The speed can be varied as required, a scale of feet can be marked on the floor and the distance the screen would travel each successive minute indicated by stops.

With the aid of this apparatus which is quite easy to construct, a pupil can acquaint himself with the use of the instruments required and accustom himself to depicting the ground to the required scale in the correct conventional signs and colours before actually going up into the air.

This form of apparatus was actually used to train pupils at Risālpur and Baghdād.

At the latter place the officers under training were also taught the use of a theodolite and how to work out local time and a true bearing so as to be able to lay the true North and South line on the ground for testing their sun-compasses etc.

Geod. Br., P.O.-1927-350.