SURVEY OF INDIA

HAND BOOK OF TOPOGRAPHY

CHAPTER V

SEVENTH EDITION

PLANE – TABLING

PUBLISHED BY ORDER OF
SURVEYOR GENERAL OF INDIA

CHAPTER V

PLANE – TABLING

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When any correction to this Handbook is considered necessary, the _____, should be addressed.

Subsequent procedure will be as laid down in Chapter I (Seventh Edition, 1966), para 3.

Record of Correction Slips to Chapter V, Plane-Tabling

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PREFACE TO THE SEVENTH EDITION

Surveyor General of India

LIST OF CHAPTERS OF THE HANDBOOK OF TOPOGRAPHY

GENERAL REMARKS

I. Topography may be defined as the graphical representation of any portion of the surface of the earth in a horizontal plane. In the Survey of India this is effected among other methods, almost exclusively, by means of the plane-table in its simplest form. The plane-table is the instrument best adapted for rapid and economical topography, and it has the advantage of being the only surveying instrument which admits of a rapid solution of the three-point problem. The plane-table can be used to the best advantage in open and hilly country, and to the least in flat and heavily wooded tracts. In America, and on the continent of Europe, plane-tables of elaborate constructions are used, but a simplified version has been adopted in India to suit local conditions.

The following appears in " Maps and Survey " by A. R. Hinks:–

"The discovery of the right use of the plane-table is of comparatively modern date, and its credit belongs to the Survey of India. The instrument itself is ancient; but so long as it was employed only for fixing points by intersection or so long as it was set up by compass, and resections were made by two rays only, it was not a very valuable instrument. The introduction of the method of resection by the solution of the triangle of error, made it at once an instrument of precision, unexcelled for convenience and rapidity of work".

In topographical surveys, carried out by the method of plane-l tabling, the errors due to the imperfection of the plane-table and to the inaccuracy of the human eye are limited and controlled by theodolite triangulation or traversing, by which the detail survey is invariably preceded. This instrumental "control" is supplemented by plane-table or graphical triangulation or traversing, which require technical skill and extreme care on the part of the surveyor. The representation of the features of the country, in detail, by sketching, is however, the most difficult part of a surveyor's work ; it is essentially an art, and one for which, although general principles can be taught, no definite rules can be laid down.

The amount of detail which can be shown on a map is limited, to a certain extent, by the scale ; but, whatever the scale, it may be conceded that there must be, on every topographical map, a certain amount of generalization ; it is on judicious generalization, as well as on the true expression given to the natural features, that the quality of a map depends; these call for experience, as well as natural ability, on the part of the surveyor.

SECTION I.–USE AND CARE OF INSTRUMENTS

This chapter has been prepared mainly for topographical surveys on the 1:50,000 scale. The same principles apply to similar surveys on other scales.

2. The plane-table.—The plane-table was first used.in India for the topographical survey of Mysore in 1799.

The pattern adopted for general use in the Department is illustrated on page 96, Appendix I. The table measures 750 mm x 600 mm and the legs of the tripod are usually 1,200 mm long. The instrument is made entirely of well-seasoned wood except for the metal-plate, bolts, nuts and screws, which are of brass, and the shoes to the legs, which are of iron.

When taking over a plane-table, the following points should be noted:—

(i) The table-top (Fig.1) should be truly flat, not warped, and be free from knots and indentations.

(ii) The butterfly nuts (Figs.3 and 4), which clamp the legs to the clamping-head, should not be free over the screws threads.

(iii) The clamping assembly (Fig.2) should fit the plate at the bottom of the plane-table (Fig.1).

(iv) None of the screws which hold the brass annular ring (Fig.1), cross-battens (Fig. 1) and iron shoes (Fig. 3), should be missing.

(v) The rigidity of the table and tripod, when set up and clamped, spreading the legs well apart, should be tested.

(vi) The zinc sheet on which cloth-mounted drawing paper is mounted should be as least 5 mm less in length and width than the plane-table.

3. The sight-rule.—The sight-rule, in use like the plane-table, is in its simplest form. The sight-rule, illustrated in Appendix I, page 95 should not be shorter than the longest side of the plane-table ; it is important that it should not be warped, that the sight-vanes should be perpendicular, and that the line joining their centres should be parallel to the edges of the rule. As a precaution, the same sight-rule should be used on any one plane-table, and the same edge used throughout the work for setting and drawing rays ; errors due to the faulty construction of the instrument will in this way be minimized. When the elevation of the object is more than can be embraced by the sights, intersection can be effected by stretching a thin thread tightly between the sight-vanes. The sight-rule should occasionally be tested, both by the surveyor and the camp officer. For this, draw a line along the edge, reverse the sight-rule, place it against the ends of the line and again draw a line—the two lines should coincide.

The sight-rule should not be washed nor allowed to remain outside, exposed to damp, or to the direct rays of the sun. The sight-rule is apt to dirty the paper, and, to avoid this, paper should be pasted on the under side of the rule and renewed when necessary ; in the case of a metal sight-rule it is advisable to use fish glue instead of ordinary paste ; the glue should be fairly thickly applied and should be allowed nearly to dry before putting on the paper. Before applying the glue, any lacquer should be removed by methylated spirit. The sight-rule should never be moved by sliding it on the board; it should be lifted and again set down in its new position. No surveyor should be allowed to use a curved, bowed, or broken edged sight-rule, as it will give bad results. A surveyor is often apt to attribute bad results, due to this cause, to an indifferent fixing, and very often rejects a good fixing and accepts bad intersections and so gets hopelessly involved and eventually sends in an indifferent section. By thus losing confidence in himself, he gradually becomes an inaccurate workman. The necessity for the systematic inspection of a surveyor's instruments by his camp officer is therefore apparent.

4. The box compass.—The box (or magnetic) compass should be fairly sensitive and should "play" freely; one of 15 cm hi length is used for ordinary work. To guard against rough usage and damage, the surveyor should be instructed not to take his compass out of its box, but to wedge it securely therein with pads of paper, so that its position in the box may not be altered. In the new pattern, the compass is so secured to the box that the wedging in with pads of paper is dispensed with. The needle, when not in use, should be thrown off its pivot by the lever provided for this purpose ; this should always be done before the compass is taken off the plane-table. Compasses should be stored in a horizontal position and should always be tested by an officer before being issued to surveyors. Each camp officer should keep several spare compasses for use in case of emergency. The most important sources of error in the box compass, as used by the plane-tabler, are a bent pivot, imperfect balance, and insufficient magnetism in the needle, coupled with friction between it and the pivot on which it swings. The dip can be temporarily adjusted by tying thread round the elevated end and dropping sealing wax on the thread, or even by affixing a little stamp paper. The needle, if sluggish in its movements, can be re-magnetized by means of bar magnets, the pivot and the agate being cleaned and freed from grease before the needle is replaced. When compasses work unsatisfactorily, owing to the agate having become worn or perforated through friction, new agates should be got fitted.

5. Re-magnetizing compass needles.—A good compass, that is fairly sensitive and plays freely is a great aid to rapid plane-tabling, in as much as it usually enables the surveyor to set his plane-table so correctly that the intersections of the rays from the surrounding points give him at once his true position, without the necessity of a second approximation. In order to magnetize needles, when a pair of magnetic bars is available for the purpose, draw the southern pole of one bar along the northern pole of the needle from the centre outwards (taking care to keep the bar moving continuously in one direction, that is, the bar should not be rubbed backwards and forwards along the needle) and simultaneously, in a similar manner, draw the northern pole of the other bar along the southern pole of the needle. The needle must be held down by a second person whilst this is being done. After giving twelve strokes to one side, the needle should be turned over, and the reverse side similarly treated. No needle will work well unless the pin is sharp, the agate bearing dry and clean, and the balance properly adjusted.

The magnetizing bars, when not in use, should be so placed as to have the north pole of one toward the south pole of the other, and the armatures attached to them.

6. Survey of India clinometer.—The Survey of India clinometer is intended for determining differential heights. The instruments is illustrated in Appendix I, page 95 ; it stands on three buttons and is placed on the surface of the plane-table. A small level is attached to the frame carrying the vanes and the instrument is so adjusted that, when made truly level, a line through the sight-vane to the zero of the object-vane is horizontal. Above and below this zero, there is, on both sides of the object slit, a scale of natural tangents. The scale of natural tangents can be read by estimation to three places of decimals. In using the clinometer, care should be taken that the vanes are upright and parallel, and that they have not been bent. The clinometer should never be lifted on or off the plane-table by either of its vanes, to avoid bending them. The vanes are usually graduated for a horizontal distance, between vanes, of 20**.**32 cm ; that is, the distance between the eye-hole and the zero of the graduations should be exactly 20**.**32 cm; also the distance from the eye-hole to the extreme graduation, + **.**40 above, or — **.**40 below the zero on the tangent scale, should be 21**.**88 cm. In observing, the eye should not be too close to the eye-hole, but about 5 to 10 cm away from it. To obtain the difference of height between his own position and any other object in view, the observer looks through the hole in the sight-vane, after levelling the clinometer by means of the level on the base-plate, and notes what figure on the tangent scale is cut by the ray to the object. This

figure, multiplied by the distance in metres, gives the difference of height in metres between the observer and the object. Ordinary unchecked observations for heights should never be taken for distances exceeding three kilometres, but, when several points are visible and when the conditions are favourable, observations can be taken up to about 15 kilometres. When employing the clinometer at distances exceeding three kilometres, it becomes necessary to correct the resulting heights for curvature and refraction*. When the distances are great, errors will occur unless the readings are very accurate and the clinometer is very well adjusted; when the clinometer readings are large, considerable errors will occur, unless the distances are very accurately determined. The principles laid down in Appendix II, paras 8-10 should be understood by all surveyors.

A surveyor can either deduce the height of his own-position by observations to two or more points, the heights of which are known, adopting the mean value ; or, on the other hand, if his own height is known, he can obtain the height of any other point hi view within a reasonable distance. The difference in height is obtained either by multiplying the observed natural tangents by the distance as measured by an accurate scale, or directly by means of a height indicator, see para 11.

Clinometer observations are usually recorded and worked out in the field on form 17 Topo.

7. Telescopic clinometers and Alidades.—These are not| described in this Handbook because they are not in use**.**

8. Testing of clinometers.—With the Survey of India pattern clinometer, the essentials are (*a*) that the front vane be truly straight and at right angles to the zero line of sight, and (*b*), that the distance from the eye-hole on the inside of the back vane to the zero mark be equal to the distance from the -f- -40 mark to the — -40 mark, added to the distance from the zero to either of the 0-20 marks (i.e., equal to a length of 1-00 of the tangent scale).

The following is a good method of testing and adjusting the instrument:—

For (a), rule two lines on a mounted plane-table at right angles to one another; place the clinometer on its side with the vanes erected, so that the zero line is parallel to and vertically above one of the lines; the front vane (which should be propped up so as to lie horizontally) should then be parallel to the other line. If

* See Appendix-II, Computation of clinometric heights.

not, make it so by bending the vane near the hinges while keeping or making it quite straight between its extreme marks.

For (b), mark off the first distance while the clinometer is on its side on the paper and ascertain the second distance with dividers. Make the two equal by bending the back vane.

An alternative method of testing is to check the clinometer against a specially constructed template which can be prepared in any workshop. This can conveniently be made to show the position of the eye-hole, the zero line of sight, lines for every five degrees of elevation and depression, and several alternative lines for the position of the front vane at approximately 20 cm from the eye-hole.

These preliminary measurements and adjustments should invariably be made before testing and adjusting the level of a clinometer.

9. Testing level adjustment.—*The level adjustment of all clinometers must be carefully tested by the camp officer at the commencement of every field season, before they are issued to the surveyors.* The surveyor should satisfy himself that the screw for level adjustment is neither too tight nor too loose. Where, however, the camp officer certifies in writing that the surveyor is capable of doing the adjustment of the clinometer himself, he may be permitted to do so.

There are several methods of testing the level adjustment of a clinometer, and the following are as simple as any ; the first two require a theodolite, and are suitable methods at the commencement of a field season before the clinometers are issued, whilst the third can be adopted whilst a surveyor is at work plane-tabling :—

(a) Place the clinometer on the edge of a plane-table, or any other tripod stand higher than a plane-table stand, if available, and set up a theodolite alongside of it, so that the eye-piece of the telescope, when clamped at zero, is level with the eye-hole of the clinometer. Level the theodolite carefully, ascertain its vertical collimation error, if necessary, and clamp the telescope to zero on the vertical arc, plus or minus the collimation error, so that the axis of the telescope lies in a horizontal plane. Then fix a small piece of paper about 10 cm square on a tree or staff, at a distance of about 100 metres, at such a height from the ground as to intersect the horizontal wire of the theodolite thus clamped ; then, by means of the milled-headed screw on the clinometer, make the mark read zero on the tangent scale, and bring the bubble of the level

into the middle of its run by the bubble adjusting screws attached to the level.

(b) Observe the natural tangent to a distinct object about two kilometres away, with the clinometer placed on the plane-table in the usual way, and record the reading. Set the theodolite up alongside the plane-table and observe the vertical angle to the same object on both faces. Look up the natural tangent of this angle and compare it with that observed with the clinometer. If a difference is found, by means of the milled-headed screw, make the clinometer read the correct natural tangent, and then, by the bubble adjusting screw, bring the bubble into the centre of its run. Verify by reading to another object in a similar manner.

(c) Place the clinometer on a plane-table set up at a Point A ; take a measurement of the height of the eye-hole of the clinometer above the ground, and mark the spot with a small heap of stones. Tie a strip of white cloth or handkerchief round a bamboo at the same height as the eye-hole of the clinometer above the ground and have the bamboo held by a *khalasi* at a Point B about 100 metres off; observe the reading of the cloth on the bamboo on the tangent scale of the clinometer. Then proceed to B, and set up the clinometer at the same height above the ground as it was at A. Send the flagman to A, and again observe the reading of the cloth on the bamboo. If an elevation at A, the reading at B should show an equal depression, if the level is in proper adjustment; otherwise there will be a difference, half of which will give the correction to be applied. Then, by means of the milled-headed screw, make the reading of the mark on the tangent scale equal to the corrected reading and bring the bubble of the level into the middle of its run by means of the capstan-headed screws. Then return to A, send the flagman back to B, and verify this reading.

(d) Most of the clinometers have been made reversible by piercing an eye-hole at zero of the front vane and marking graduations on either side of the eye-hole in the back vane. If the level is correctly adjusted the readings to a point from either end of the clinometer are the same. If not, the level can be adjusted as in other methods.

Whenever the surveyor changes level adjustment of his clino-. meter in the field, he should make a definite report about it to his camp officer.

10. Test in the field.—A surveyor must take the first opportunity to test his clinometer by going to the nearest hill station and taking a reading to two or three of the best trigonometrical heights nearest to it; he then deduces the height of his station of observation, and, if that agrees with its recorded height, his clinometer is in adjustment; otherwise it is not, and should be at once exchanged for another.

11. Height Indicator.—The difference in height can also be obtained without computation by the "Height Indicator" designed by Colonel Wahab, R.E., revised and improved by Sir Edward Tandy, which is so arranged as to give the horizontal equivalents for given vertical intervals, and vice versa for any inclination. The improved height indicator is designed for the scale of 1 : 50,000, and, by multiplying or dividing the heights obtained, can be used for other scales. The results obtained should be entered in form 17 Topo. under item 5. Clinometer observations should, as a rule, be computed in the field.

12. Holdall, etc.—In addition to the instruments mentioned above, the surveyor should have a holdall containing dividers, proportional compasses, bow pen, ruling pen, pricker, protractor, pen-knife, pencils and India rubber. He should have a box containing colours, Indian ink, and palette, with a sufficient supply of spare pencils, brushes and nibs. He should be provided with a suitable umbrella to protect the plane-table from the drip from trees and to prevent glare ; also, where necessary, with cloth for flags and a few light poles or bamboos. He should also be provided with a supply of stationery and forms, and with a note-book, in which he should enter the co-ordinates and heights of all the points on his board ; this note-book should contain a list of all the instruments, camp equipment, etc., served out to him at the commencement of the field season ; it will also be of use to him for jotting down notes of any description whilst at work.

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13. Allotment of areas.—The allotment of areas for survey to individual surveyors should be carried out with due regard to :—

(a) Keeping down the number of plane-table sections, thus reducing overlaps, minimizing movements in the field and simplifying preparation of blue prints. This is, however, qualified by *(b)* below.

(b) The date on which the survey is required to be finished. Usually it is required that some sheets should be completed before others so that they will be ready for fair mapping at the commencement of recess. Climatic or health conditions may also necessitate areas being taken up in rotation.

(c) The configuration of the ground and how features such as large rivers, hill ranges, etc. fall with reference to the limit of each man's work. Usually the surveyor's edge will conform to parallels and meridians. In mountainous country, however, it is sometimes an advantage to apportion the work between plane-tablers by physical features rather than by hard-and-fast meridians and parallels. It is manifestly more economical to allot to one surveyor a valley with its two slopes up to the summit of the bounding ridges, rather than to give him a ridge with its two slopes down to the bottom of the flanking valleys.

If, for any reason, a surveyor has to leave his section unfinished, he must be careful to make the edges conform to parallels and meridians, or to some feature, and not to an indefinite or broken line. Such a boundary as this latter makes the subsequent joining up difficult and uncertain.

14. Mounting plane-tables.—If drawing paper is mounted direct on the plain wooden board, which forms the ordinary plane-table top, the drawing paper will expand and contract with the board, according to the humidity of the atmosphere. A wooden board will shrink across the grain more than it will with the grain : if a square figure is drawn with truly equal sides in the month of October in a damp place like Mussoorie, it will be found that the square has been seriously distorted by the month of May, especially if the plane-table has been moved to a dry zone.

For accurate survey work in countries, where there is considerable change in humidity during the course of survey, some method of mounting a plane-table must be used to minimize the effect of this distortion.

PLANE-TABLING

If the Surveyor's field section is allowed to become distorted, the Surveyor will find it impossible to make accurate interpolations ; accurate enlargement or reduction of the distorted section by photography is impossible, and elaborate adjustment is necessary before the fair map can be started.

Cloth-mounted drawing paper or only drawing paper mounted on zinc is valuable for accurate work. This mounting is done in printing offices.

Drawing paper mounted on stiff cloth can also be used, which can be prepared and mounted on the plane-table section in either of the following ways. It is customary in some parties to back the mounted drawing paper with fairly stiff cheap paper.

The paper to be mounted on cloth should be cut about 13 mm shorter each way than the plane-table, and, when possible, passed through a press after mounting and allowed to dry. It may then be projected and plotted and can be rolled up and carried about, until actually wanted for work.

It is fixed to the plane-table board by pasting strips of cloth along the upper edges of the drawing paper, and along the under edge of the plane-table board. It is particularly necessary to avoid dropping any paste along the upper surface of the plane-table; for, if the cloth or drawing paper is allowed to stick anywhere to the upper surface of the board, the paper is certain to cockle.

Alternatively, the drawing paper may be mounted on cloth large enough to leave about 10 cm free round the edges of the paper, this fringe of cloth being pasted down on the under edge of the board. This is very convenient, except that the edges of the paper are apt to be torn away from the cloth. This can be obviated by sewing the paper to the cloth, along the edge, by means of a sewing machine.

In all these methods, as the wood of the plane-table contracts the spare cloth along the edges will become loose, and it may be necessary, as the season proceeds, to remove the cloth from the under side of the board and to stretch and refix it. If fastened down with too tight a cross-pull at the corners, slight cockles often appear.

It often happens in the early morning that the paper expands from moisture, and lies very loose on the board, but the weight of the sight-rule keeps it down and the paper tightens, as soon as the sun gets up.

SECTION–II. PREPARING BOARDS FOR THE FIELD

15. Mounting direct on to board.—When plane-tabling is to be done in countries of equable climate, where there is no fear of distortion, the plane-table may be mounted as follows.

Choose a plane-table whose board has been well seasoned and has an even surface free from warp. Expose the board to the sun for a week or two before mounting, so that it may be well shrunk.

Take a sheet of drawing paper cut just smaller than the surface of the board; wet it thoroughly without injuring the surface by rubbing.

Then cut a piece of fine white cloth to a size that will overlap the board about 8 cm all round and wash it thoroughly.

Damp the board with a sponge, and spread the cloth, while wet, evenly over the board. Cut the projecting cloth into strips! about 10 cm wide.

Then rub a thin paste of fine flour into the cloth, pasting down the strips under the board with stronger paste mixed with sulphate of copper.

Place the damp paper over the pasted cloth, and press it carefully down, working from the centre outwards. Any rubbing action will destroy the surface. Then leave the board to dry slowly for two days. When dry, paste strips of brown paper along the edges of the plane-table to hold the drawing paper down.

The mounted board should be exposed to the sun for as long a period as possible, before the graticule is plotted on it.

When survey is completed, the field section can be removed from the board by cutting through cloth right round the edges, and stripping cloth and paper off together.

The disadvantages of this method are as follows :—

(a) The survey is burdened with any distortion arising from the unequal shrinking of the board.

(b) The method takes several days, if properly done.

(c) No projection or plotting can be done until the board is thoroughly dried.

(d) No preliminary work can be done without the plane-table board. Either such work has to be done at field headquarters, or all plane-table boards have to be taken to and from recess headquarters.

(e) The field section, thus mounted and projected, is very cumbersome to carry about, and the issue of second and third boards to plane-tablers, already in the field, is difficult. Instances have occurred of a plane-table board being sent to a surveyor, who had no screw or stand that would fit it.

Cloth-mounted drawing paper can also be obtained from the printing offices and then it is only necessary to fix this on the plane-table by cutting the projecting cloth into strips and pasting them down under the board with strong flour paste mixed with copper sulphate.

16. Plotting a graticule.—A graticule is a four-sided figure contained by parallels of latitude and meridians of longitude.

Two modes of plotting the graticule of sheets are in use in the Survey of India. The first by means of the lengths of the sides and diagonals of certain geographical sections, as described in Auxiliary Tables (8th Edition), Part I; this is used when a survey is being carried out by triangulation, and the positions of all points are in spherical terms.

The second mode of projection is used when the positions of the stations are given in rectangular or grid co-ordinates, parallel and perpendicular to the meridian of origin.

When co-ordinates are given in rectangular terms, the latitude and longitude of the origin being known, Auxiliary Tables 2 Sur., and 4 Sur., of Part III (7th Edition) enable the rectangular coordinates of the corners of a graticule to be computed. Table 12 Sur., which gives the rectangular co-ordinates of J degree squares referred to the centre of a degree as origin, will be found useful whenever the centre of a degree has been adopted as the origin of a survey, the operations of which are based on rectangular co-ordinates. Rectangular co-ordinates of the spherical corners can also be computed on form 8 Trav.

When grid co-ordinates are given, the grid co-ordinates of the corners of degree sheets are calculated from 9 Grid, Auxiliary Tables Part V. Grid co-ordinates of spherical corners can also be computed on form 1 Lamb.

(*i*)—*By spherical co-ordinates*

For surveys on the 1 : 200,000 and larger scales, where the area comprised in each little square is that of a plane-table section, the graticule will be plotted in the following manner from the dimensions given in Auxiliary Tables Part I, according to scale of survey:—

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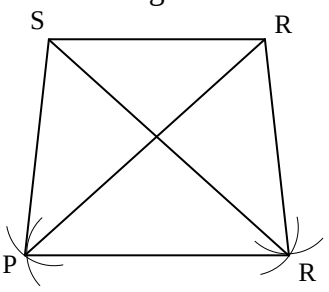
Draw a line parallel to the top edge of the plane-table section and lay off *SB* the upper parallel, the distance being taken from the tables. Then with *S* and *B* as centres, and *SP* and *RP* (as obtained from the tables for meridian and diagonal respectively) as radii, describe two circles cutting each other in *P ;* and two others with the same centres, but with *SQ* and *RQ* as radii, cutting in *Q ;* the lines *SP*, *PQ* and *RQ* are then joined up to form the graticule; the practical test is that the length of *PQ* shall be equal to the length of the lower parallel, as given in the tables.

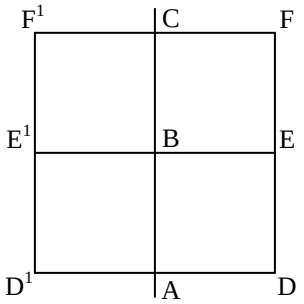
Fig. I



For surveys on the scale of 1/250,000 and smaller scales, the graticule will be projected in the following manner from Auxiliary! Tables, Part I, according to scale of survey :—

A line is drawn down the centre of the paper, and on it *AB* and *BC* are laid off, the distances being taken from the tables. With *A* and *B* as centres, and the corresponding distances on the lower parallels and diagonals as radii, circles are described cutting in *D* and D^1 ; and with *C* and *B* as centres, and the corresponding distances on the upper parallels and diagonals as radii, circles are described cutting in *F* and F^1; *DF* and D^1F^1 are joined, *DE* and D^1E^1 are each made equal to *AB*, and the graticule completed by joining the various points.

Fig. II



When several field sections have to be projected along the same parallels of latitude, time can be saved by plotting the graticules on a sheet of drawing paper and pricking through the corners on to the plane-table.

(*it*)—*By rectangular or grid co-ordinates*

Suppose the scale of survey is 1 : 50,000. Draw a rectangular grid of 1,000 metres by a co-ordinatograph or with beam compasses. Draw a diagonal scale to read metres in one of the squares of this mesh. Plot the four corners of the graticule with the help of this diagonal scale. Join the four corners of the graticule and test the lengths of the sides with beam

compasses from Auxiliary Tables Part I. Sub-divide the graticule and ink in with fine black lines. Enter the values of the spherical co-ordinates in black ink near the margins of the board. The triangulated or traverse stations and points are, however, plotted from the rectangular grid lines.

In the case of rectangular co-ordinates, no ambiguity can arise as regards points which fall within the limits of the area allotted to any one origin of survey ; when, however, it is necessary to plot, on the same section, points and traverses computed from more than one origin, reference should be made to Chapter IV, paras 58 and 68 (3rd Edition).

17. Selection and placing of graticule.—The size of the plane-table in normal use, viz.:—75 cm X 60 cm, or on active service 60 cm X 50 cm, allows that plane-table sections on the scale of 1: 50,000 should be projected for an area of 15 minutes of latitude) by 15 minutes of longitude; similarly, for surveys on other scales, the area projected should embrace the largest area pf paper available.

The plane-table itself is considerably larger than the graticule to be plotted on it; this is necessary to enable the surveyor to plot a certain number of trigonometrical points outside his work, thereby ensuring greater accuracy of fixing towards the edges of the section ; and the section or graticule should be so placed on the board, as to include the most useful of these. It is often extremely convenient to have one well defined, very distant point, such as a sharp hill peak in the work, as it enables the plane-tabler to orient his board with great accuracy. The best way of doing this is to cut out a sheet of tracing paper of the exact size, that the plane-table would be when reduced to the same scale as the reconnaissance chart of triangulation. This piece of paper is laid on the chart, and shifted about over the allotted section, so as to embrace the best outside points ; the graticule is then outlined on the tracing paper in pencil. Measurements from the corners of this outline to the points where the lower parallel of latitude of the section produced cuts the edge of the board, will now enable the surveyor to place this line in its proper position, and then, by similar means, to find points on it corresponding to the lower corners of the graticule. In placing the section on the board as described above, its edges should be parallel to those of the table, but they should nowhere be so close as to leave less than 4-cm margin.

It should be noted that the graticule selected for projection need not necessarily correspond to that of the map. Where the area covered by a 1: 50,000 sheet is allotted to two or more surveyors, each may have a different graticule plotted on his board, in order that each section may be most favourably placed having regard to outside points.

SECTION–II. PREPARING BOARDS FOR THE FIELD

18. Sub-division of graticule and inking.—After being projected, the sections should be sub-divided into smaller divisions of 6' for 1 : 50,000, 2' 30" for 1 : 25,000 scales, and so on. This sub-division should invariably be done with a beam compass, the value of one part being computed from Auxiliary Tables and its measurement taken from a diagonal scale. After checking to see that the length of each sub-division is identical, the lines should be neatly inked up and their values marked near the edge of the board. Special care should be taken in inking up to see that the line does not deviate from the true. The graticule should be inked up and checked before plotting is commenced.

19. Plotting points.—Printed scales of latitude and longitude can be procured for plotting. Owing to expansion and contraction of the paper, the length of a sub-division of the graticule seldom agrees with its theoretical value, and scales which exactly fit the projection on the plane-table section should be chosen.

Whenever possible, printed scales are to be used for plotting trigonometrical data and measures of length, in preference to scales constructed by hand on plane-table sections. Departmental latitude and longitude-plotting scales are available for all latitudes in India, and also scales of metres, for most normal scales of survey.

All trigonometrical stations and points which fall within the area covered by the plane-table section, and all prominent points lying within the area of the board, are then plotted by spherical co-ordinates; stations, which are or will be treated as intersected points in the triangulation pamphlets, will be entered as intersected points. Points should always be plotted from the nearest graticule line. Testing should always be carried out by two men ; one should measure the position as plotted by co-ordinates and read out the result as found from the scale, which is then checked by the other against the list of stations and points. The necessity for extreme accuracy in projecting and plotting cannot be too strongly insisted on. Nothing tends so much to shake the confidence of the surveyors as errors due to carelessness in these respects, and many hours may be wasted in the field, if this preliminary work is found to be unreliable. The projection and a percentage of the plotting should, therefore, invariably be tested independently by an officer not below the rank of Surveyor or Survey Assistant, the remainder of the plotting being tested by a reliable surveyor, preferably the one who will carry out the survey.

When rectangular co-ordinates are being used and a co-ordinatograph is available, it should be used in preference to a beam

compass, both for projection and plotting, as giving absolute accuracy and a saving in time.

Stations and points are plotted by rectangular co-ordinates with reference to the squares which have been ruled up in blue in accordance with the procedure laid down in para 16 (*ii)*, and tested by distance.

The practice of plotting such points on separate paper, and pricking through, without the squares appearing on the plane-table section, is unsound as the plotting cannot be tested in the field in the event of points being found wrong.

The method of computing rectangular from spherical co-ordinates and vice versa, and of changing rectangular co-ordinates from one origin to another, is described in Chapter IV, para 58 (3rd Edition).

20. Overlaps.—A sufficiently wide overlap must always be surveyed, in order to ensure a proper junction with adjoining plane-table sections or maps. The whole scheme for marginal overlaps for a season should be drawn up on an index map before leaving recess headquarters, and the limits of the overlap, allotted to each section, should be marked thereon, in blue, as soon as it has been plotted. It will generally be sufficient to survey an overlap on two adjacent sides in each plane-table section (usually on the northern and eastern side), but, when a section adjoins an unsurveyed area not in the season's programme, an overlap must invariably be surveyed on the edges adjoining such unsurveyed area. No overlap need be surveyed on the edges adjoining an area which has already been mapped, but the previously surveyed overlap should be traced and inked up in blue on the section. The surveyor will of course check this, and, if found correct, will ink it up in its proper colours. Prominent points outside the overlap should also be pricked off on to the section. Unless otherwise ordered, the overlap should be 5 mm wide for surveys on all scales.

When a river forms the limit of any surveyor's work, both banks must be surveyed, and, when a ridge, at least one contour on the reverse slope should be surveyed.

It is important that surveyors working on adjoining sections should exchange the marginal detail while in the field; it will be generally found sufficient if the surveyor, who first completes the work, supplies his neighbour with a tracing of the edge of his work about 5 mm in width.

21. Preliminary accessory work.—It is usual hi most parties for the record slip, tabular forms for list of triangulation or traverse stations and name reference list, to be printed on the plane-table sections beforehand.

If this is not done, the record slip will have to be pasted on, and the tabular forms ruled up, where they will not interfere with the work which will appear on the section, or with the border which will be subsequently drawn.

(a) *Records slip*. This constitutes a record of the various stages of the execution and examination of a plane-table section, and each operation should be vouched for by the signature, with date, of the member of the party who is responsible for it.

(b) *Table of trigonometrical stations and points*. The trigonometrical points plotted within the area of the work should be given serial numbers, which should be entered on the plane-table section (see para 70 a), and on the table, which should contain the name, coordinates and height of each point in descending order of latitude. The heights should be entered hi the appropriate column in black, according to whether they are top or ground heights. The letter 'P' should be entered in black in the table against those stations and points which are of fairly permanent character.

(c) Reference table. This table will be prepared for the entry of reference numbers, names, etc. (see para 62).

(d) Surveyors will also be furnished with the following :—

(i) Triangulation and traverse data of the points falling on their plane-table sections, both within and outside the area allotted for survey, on forms 9 Topo. and 16 Traverse. Great care should be exercised that no points are omitted, and it should be remembered that the area of a map is touched on by eight other map areas which may contain points for plotting.

(ii) Particulars regarding the positions and heights of all bench-marks falling in their work.

(iii) Forms 17 and 22 Topo. and the necessary tracing cloth for preparation of field traces described in paras 50--52.

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SECTION III. — PLANE-TABLING METHODS

22. General principles.—The plane-table should be levelled. This is specially important in hilly ground and in large scale surveys. When some of the fixed points are situated high above the observer, and some on the same level, or below him, a slight dishevelment of the plane-table will throw out the position of the fixing very considerably. It can be roughly ascertained whether a plane-table is level or not by dropping a pencil on the board a few times and noting the direction in which it tends to roll. A small spirit- level can be used to level the plane-table.

In soft and marshy ground, a firm footing may be obtained for the plane-table by driving in stout wooden pegs flush with the surface of the ground for the legs to rest on ; in loose sand, a certain amount of stability can be effected by inserting each leg of the plane-table stand into a block of wood with a hole drilled through it.

The pencil should be a hard one, and should be kept very sharply pointed, as fineness of line is absolutely essential to accurate intersection and "clean" sketching of detail; a small piece of fine grained sandpaper is useful for renewing the point of the pencil.

When making a fixing or intersection, rays should be drawn through the centre of the fixed point, and not tangentially to it. The blunt end of the pencil (with a little of the lead removed, so as to prevent smudging) should be used as a pivot for the sight-rule ; a pin should not be used, as pin holes photograph, and are also apt to cause blots when the section is inked up.

When taking a ray, the pencil should be held as upright as possible, and at the same angle throughout, the point being kept pressed close to the edge of the sight-rule. If the sight-rule is at all bowed, special care must be taken to prevent the pencil running under its edge, and so deviating from the straight line. After checking with the pencil point that the sight-rule is directly over the pivoting point, a short ray should be drawn at the estimated position of the object aligned, which should be marked lightly with a small circle or with the appropriate symbol; it is sometimes also convenient to draw a third line at or near the edge of the board ; at this third line, a note of the object, or a slight sketch of it, should be entered.

23. Cleanliness.—In order that the plane-table section may be kept clean, the following precautions should be taken :—

(a) A clean piece of white paper should be pasted at the bottoms of the sight-rule and magnetic compass box.

(b) All pencil lines should be rubbed out as soon as they are finished with. It is, however, useful to leave pencil rays to intersected points, etc., which fall outside the surveyed area.
(c) When not in use, the board should be covered with a piece of white muslin or cloth.
(d) The plane-tabler should make sure that his hands and arms are clean and dry before commencing work at each fixing.
(e) Protect the board from drippings, etc., when working under a tree.
(f) When inking in, keep the board covered, leaving exposed only the area actually being worked on.
(g) Lift the sight-rule clear off the board, when moving it.

24. Work at first station.—When commencing work, the surveyor should set up his plane-table on a prominent hill station, or well-fixed trigonometrical point situated in as commanding a position as possible, placing it level, and nearly over the station mark. He should then truly orient his board, by placing his ruler so that its edge passes through the point at which he is standing and the most distant visible point plotted on his board, and turning the table bodily round in azimuth until the true distant point is intersected by the sight-rule. This is commonly called "setting" the plane-table. He should next test the accuracy of all the trigonometrical points on his board by laying his sight-rule in their direction in succession ; if any found to be wrong, the plotting of them should be examined and corrected, if necessary, by reference to the data in his note-book.

The necessary condition for the true orientation of a plane-table is that it should be in such a position that the north and south line on it shall correspond with the meridian, or, what amounts to the same thing, that the line drawn between any two stations on the plane-table shall be parallel to the line joining the same stations on the ground.

He should now place the compass, in its box, on some convenient part of the table outside the graticule, and shift it till the needle reads 0°, and then mark on his board with a firm pencil line the edge of the box. This position of the box should always be used subsequently for all ground nearly in the same meridian as that of the station at which the compass was set up.

He should next draw rays to prominent and well-marked objects for the purpose of fixing them as auxiliary points (see para 28). He should determine the height of his station from other close by triangulation stations and intersected points to check their heights and

his own clinometer. He should throw heights to the auxiliary points to which he has drawn rays. Normally clinometric readings when taking such heights should not exceed .05.

25. "Setting" by the back ray.—One of the methods of Betting the plane-table is by the method of back ray. The surveyor draws a ray from the plotted point or fixing to any forward point which he considers suitable to visit for the purpose of sketching. This ray should be produced, and its extremities marked on both edges of the table. On arrival at the forward point, he will place himself accurately on the ray from the last station, and will "set" his board by laying his ruler on the ray, and turning it round with the board until it intersects the last station. This is termed "setting by the back ray". It is independent of abnormal compass variations, but it is essential that the same edge of the sight-rule be always used. Rays now drawn from any other *near* trigonometrical points, if possible, on both sides of the setting ray, so as to intersect it, and preferably nearly at right angles, accurately determine the position of the surveyor.

26. Interpolation or Fixing.—The method most commonly used for setting the plane-table is by interpolation, or fixing by resection from known points; it is essential that the surveyor should be thoroughly familiar with this method, as most of his work is carried out by means of it; it has the great advantage of avoiding any accumulation of error, as each fixing is made independently, and depends solely on the triangulated or other fixed points.

(a) Interpolation from two points after orientation by compass is not satisfactory, owing to the possibility of error due to any abnormal magnetic declination and inaccuracy of setting by a magnetic compass; and, when this method is unavoidable, it should only be used for the purpose of sketching detail, in the vicinity of the fixing, and not for extension.

A satisfactory check can be got if a ray is drawn from the first interpolation to some object D (see diagram opposite) in a direction nearly parallel to the line joining the two fixed points, A and B and at a distance approximating to the distance between them. The surveyor then proceeds to *D* and, setting by the back ray, draws rays from the two points, A and B.

These rays will, if the board has been truly oriented, intersect on the line drawn towards D from his first station. If they do not intersect on this line, accept; for the time being, the position given by the intersection of the ray from point A and the ray from the first plane-table

fixing, and draw a line towards the other point B ; it will meet the ray, drawn through B at the first station, at a point C.

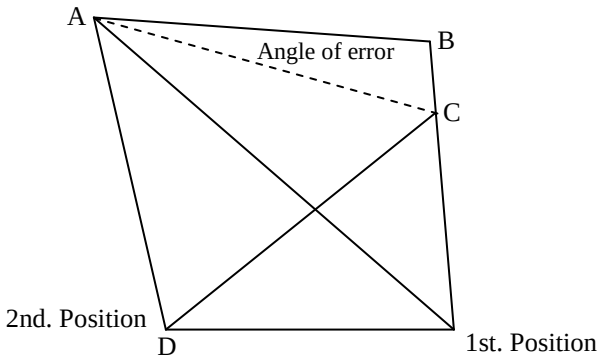
The board is out of orientation by the angle CAB, and may be corrected in the following way; place the sight-rule on the line AC, and pick up a distant object, then put the sight-rule on the line AB, and turn the board until the same distant object is intersected.

The board is then truly oriented and the surveyor may resect his position and draw a ray towards his first station.

Returning there, and setting by the new back ray, the resection from the two points should fell on the ray.

Diagram to illustrate the 'two-point problem'

Fig. III



(b) Interpolation should, wherever possible, be made from at least three fixed points in the following manner :—

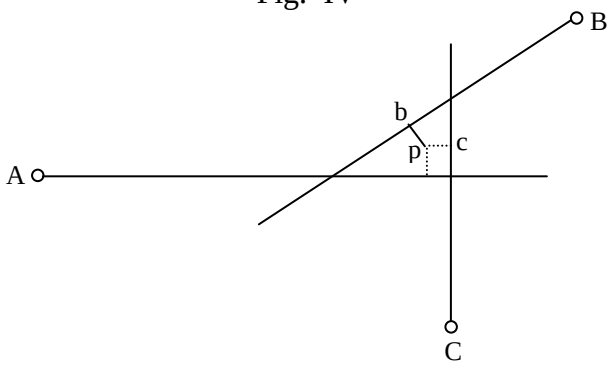
The surveyor should set up his plane-table, and level it, at some convenient spot, from which at least three fixed points are visible. The compass, which, in this case, should be looked upon as merely a convenient aid for obtaining a first approximation, should then be placed on the line previously drawn to indicate the magnetic meridian as previously described; and the plane-table turned round in azimuth until the needle points to 0°, and then clamped. Three fixed points should then be selected, from which to interpolate the position. Two of these should be as near as possible, and one more distant, and they should be chosen, so as, if possible, to ensure the observer being inside the triangle formed by joining the three points. The near points serve to fix the position, and

the distant one ensures accuracy of setting. The sight-rule is then laid on each point in succession, and lines are drawn along its edge. If the plane-table has been set up accurately in azimuth, the three rays will intersect in a point, which is the required position. More frequently, however, the intersections form a small triangle of error, in which case it is necessary to determine the true position. This is done by what is known as the 'three-point problem'. The size of the triangle of error depends on the amount of the angular error in the orientation of the table. The three-point problem can be solved by trigonometry; but the graphical method, described below, is the method of solution adopted in practice. There are three cases which have to be considered.

Case 1. Where the observer's position is inside the triangle formed by joining the fixed points. In this case, the true position will be within the small triangle of error formed by the intersection of the rays. It will also occupy such a position that its perpendicular distance from each ray will be in proportion to the distance of the observer's position from the respective fixed points.

Thus, in Figure IV, p will be the correct position, if the perpendicular distances pa, p b, p c are proportional respectively to p A, p B, p G.

Fig. IV



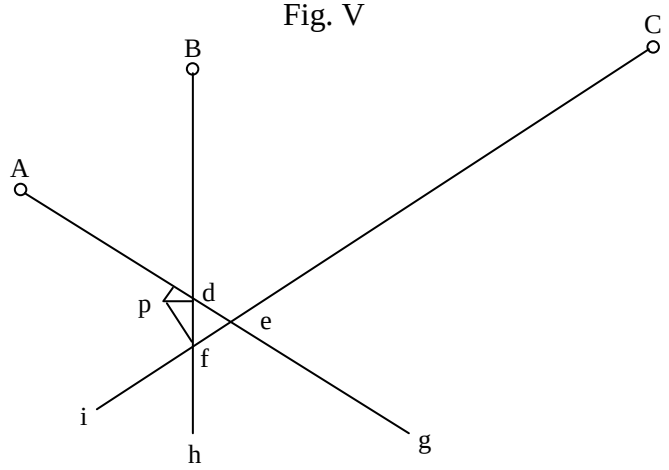
Case 2. Where the observer has been forced to use three fixed points so placed that his position lies outside the triangle formed by joining them. In this case, the point will lie outside the triangle of error.

The same condition holds, i.e., that the distances of the point from the rays will be proportionate to the distances of the respective fixed points ; but there is another condition which must be satisfied:—the point must be so situated that all the rays have to move hi the same direction round their respective fixed stations in order to reach it when

the table is turned in azimuth. The simplest way for the observer to find his position is to orient on the most distant point of the three, then his position will be on the same side of the ray from the most distant point as the point of intersection of the other two rays.

Taking the second condition first, a glance at Fig. V will show that there are only two possible positions of the fixing which fulfill it, i.e., in the space C e g, where all the rays would have to swing to the right, or in the space A d f i, where they would all have to swing to the left.

Fig. V



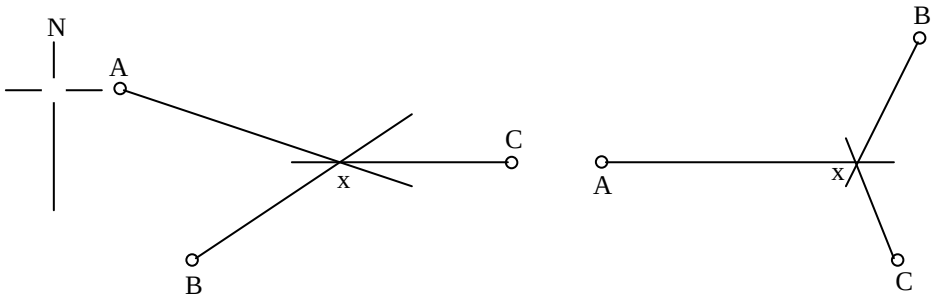
Now the first condition of the relative distances will decide which position is the correct one. It will be seen that there is no point in C e g which fulfils this condition ; but in the space A d f i there is one point p, the perpendicular distances from which on to the rays A g, B h, and C i are proportional to the distances A p, B p and C p. With a little practice, the position of this point can be estimated most accurately. Having determined the approximate position of the point, lay the ruler over it and the *most distant* visible fixed point of the board, and turn the board in azimuth till that point is intersected, and clamp it. The interpolation should then be repeated, when, if the point has been properly chosen, the rays will intersect on it ; if any small error still remains, the process should be repeated. The rule of setting in azimuth by a distant point is one which should always be borne in mind, as the effects of errors in laying the rule over the points, and in the accuracy of the assumed position, are much minimized.

Case 3. If the surveyor's position is such that only 3 fixed points are visible, and these are so situated that the circumference of the circle passing through, or nearly through, them also passes through, or nearly

through, the surveyor's position, no accurate determination of the position is possible. In such cases the surveyor must trust to his compass for setting, and fix his position by the two most suitable fixed points, the nearer they are the better.

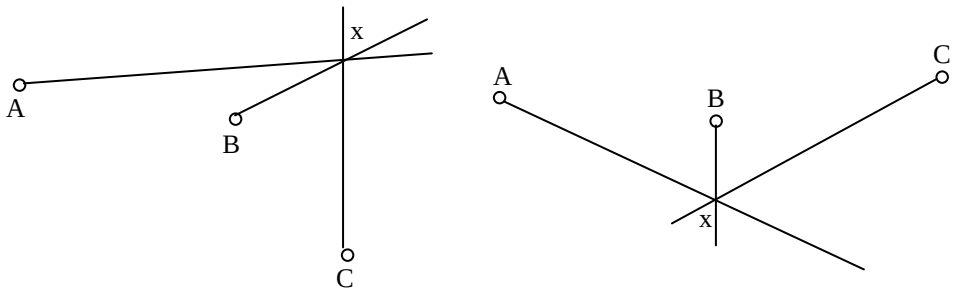
During training, it is a good plan to take surveyors to a point exactly "on the circle" ; they will then find that for *any* orientation of the plane-table (within certain limits) all 3 rays will meet at a point. It is a departmental practice to require the surveyor always to make "inside" fixings (Case 1). The object of this is to avoid any possibility of Case 3 arising without being recognized by him. Certain classes of "inside" interpolations, however, are unreliable, whereas some cases of "outside" fixings are extremely accurate, as the following examples illustrate :—

(1) Examples of inaccurate "inside" interpolations.



The position of x is liable to error in an east and west direction in the first case and in a north and south direction in the second. The latter is an example of a particularly bad interpolation, as a very small error in the position of B or C will result in a large change in the position of x, whereas to the inexperienced plane-tabler, it has the appearance of being a good fixing.

(2) Examples of accurate "outside" interpolations.



SECTION III. — PLANE-TABLING METHODS

In making interpolations in open hilly country, surveyors should be taught to dispense, as much as possible, with the magnetic compass as a means of orienting the plane-table. After a certain amount of detail has been inserted, it is possible to orient the plane-table correctly by making use of two known points, which happen to be in line with the plane-table station, where a fixing is to be made. The usual procedure is to select a distant trigonometrical point and to note some near item of detail in line with it, such as a knoll, stream bend, village, etc., which can be identified on the plane-table. If none such can readily be found, the sight-rule is aligned on the distant point and some points of detail selected in the opposite direction, by looking along the sight-rule in the reverse way. Having selected the two points, the surveyor places his sight-rule on the plane-table along the line joining them and turns the board so as to align the sight-rule on the more distant. The board is now correctly oriented, and he proceeds to make his interpolation by drawing one more ray from a near point on one flank. He may check the fixing by drawing rays to other points. If no two points, exactly in line, can be found, some point close to the ray from the distant point can be used, by estimating its distance from the ray ; or it may be noted that the ray cuts the line joining two near points in a certain proportion. This distance or proportion is then taken into account hi aligning the sight-rule on the plane-table. This method of orientation not only results in a considerable saving of time, but also develops the surveyor's eye for country.

27. Tracing paper solution of the three-point problem.— The position can be also approximately fixed, very rapidly, by means of tracing paper in the following manner :—a piece of tracing paper, large enough to include the positions of all four points, is fastened on to the board by means of drawing pins, and the estimated position marked thereon. The sight-rule is then aligned on the three fixed points, and lines are drawn in then- direction from the point marking the position. The tracing paper is then taken off, and moved about until the lines drawn on it pass through the fixed points as marked on the board. The point marking the position on the tracing paper will then be approximately over its correct position on the plane-table, and may be pricked through.

28. Plane-table reconnaissance.—It is always useful, and often absolutely necessary, for a plane-tabler to make a reconnaissance before commencing his actual detail survey, for the purpose of fixing auxiliary points and forming a general plan for carrying out his work. On reaching his area he should visit one or more trigonometrical stations, for the purpose of identifying his points and getting them flagged. Magging will

be necessary only in flat or undulating wooded country where trees cannot otherwise be identified with certainty. While flagging is in-progress, he should spend his time in fixing auxiliary points and determining their heights.

His camp should be so situated that he can carry out his reconnaissance conveniently from it. In two or three days he should be able to reconnoitre a 5-minute section on the 1 : 50,000 scale, and the time is well-spent. The best plan is to keep to the higher ground, making fixings on prominent tops and at conspicuous trees and buildings, and intersecting other prominent objects, flagging where necessary. Well-marked points, fixed by good intersections from three known points, may be used with every confidence in the same way as points fixed by triangulation or by plane-table resection. The surveyor should not neglect to fix the positions of points outside the limits of his work, as well as inside.

In deciding where to commence work, it should be remembered that perennial water-limits (large rivers or lakes) are best surveyed as late as possible in the season, i.e., in March or April. The same applies to all areas covered with high grass which is generally burnt in March.

When working in plains, he should keep on testing the accuracy of all plotted traverse and other stations and their heights, before using them as he proceeds with the work.

29. Detail survey.— (i) Except during the early training of a plane-tabler, the survey of detail and contours will always be carried out together, although they are dealt with separately in paras 29 and 35. In flat or undulating country, or where there are low outcrops of hills, it is possible to treat the representation of hill features more or less separately from detail; but, in hilly ground proper, contouring assumes at least equal importance ; while at high altitudes there are frequently many square kilometers of country in which there is not a single item of detail, and the whole of the work of the plane-tabler consists in the delineation of mountain forms. It is here that the man with an "eye for country" finds full scope for his powers.

(ii) After carrying out his reconnaissance, the surveyor should be in a position to commence sketching detail; that is to say, he should have fixed sufficient auxiliary points, in addition to those already fixed trigonometrically, to enable him to resect his position almost anywhere. It will frequently happen that he will find this impossible in certain areas of low ground, in which case these will be left until he has fixed further points during the course of sketching surrounding detail.

SECTION III. — PLANE-TABLING METHODS

The surveyor now proceeds to some commanding position, from which he will draw rays to all objects such as peaks, spurs, ravines, villages, etc. marking lightly the approximate shape and position of each item on its ray. He next proceeds to some other commanding station, where he again fixes his position, and intersects the same objects, thus establishing their position on the board. The position obtained by intersections between 60° and 120° may be assumed to be correct, but only approximate when the intersections are more acute ; and they must be again intersected from some other more favourable station. Generally the position of any object should not be considered as finally determined, until tested by three rays intersecting at favourable angles.

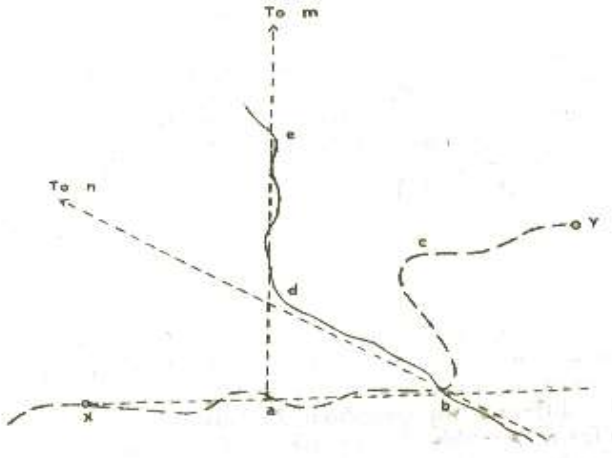
(iii) It is important, in regular work, to guard against the tendency to waste time by drawing rays to distant objects, whose position will be more easily fixed, later on, by shorter rays. The drawing of an excessive number of rays from one fixing leads to confusion on the plane-table, and occupies time which would be more usefully employed in making a second plane-table fixing elsewhere, and again drawing a moderate number of rays from that. This does not apply to reconnaissance survey, or survey carried out during military operations in a country, where the freedom of movement of the surveyor will always be restricted, and it is consequently of the utmost importance to get all detail fixed, even approximately, whenever and wherever the opportunity may offer.

When surveying in the vicinity of the external frontier of India, the surveyor should include as much of the country across the frontier as he can, from fixing within the frontier; the courses of streams and the limits of water forms, which have not been surveyed with sufficient accuracy, should be indicated by broken lines ; and similarly the hills should be shown by broken contour lines, so as to avoid giving the impression that the ground has been visited and rigorously surveyed.

(iv) In hilly country, it is usually best to commence work from the tops of the hills, and work downwards, rather than *vice versa*, as the extent of the country visible enables the surveyor, not only to see sufficient fixed points necessary for a good intersection, but also to draw rays to more items of detail than he can from low ground. The different topographical features should, however, be sketched, as far as possible, from stations of a similar altitude, as they assume a far truer relative value, when viewed from such points, than when seen either from far above or from below. It is always best to fix the position of detail on a slope from two or more fixings on an opposite slope, rather than from those on the slope itself. On the other hand, the shape of the ground, changes of slope, etc. can be better seen in profile than from an opposite

point. Fixings on both sides of a main valley are, therefore, necessary ; and there will of course always be the necessity of making fixings on the low ground, in order to survey detail, which it has been impossible to fix from the higher and more distant plane-table stations ; but their number will be comparatively few, and their attainment, owing to the number of good plane-table points, which will already have been fixed in their neighbourhood, a matter of comparative ease. In the case of minor parallel side valleys, it will usually be sufficient to visit the alternate ridges, surveying the intermediate ridges by intersection from both sides.

(v) The surveyor's mind must be constantly on his work, as he proceeds from one fixing to another. Not only must he watch the changing appearance of the objects to which he has taken rays, so as to recognize them from his next station, but he should also get into the habit of memorizing different items of detail and minor features on the way, so that he can record them on his plane-table, when he next sets it up. A note-book is useful for this purpose, if the surveyor cannot trust his memory. He should also be able to judge short distances accurately, up to say, 200 meters, and he must be able to measure distances correctly, up to half a kilometer, or more, by pacing. The following is a simple example of what may be done, while moving from one fixing to another :—



The surveyor has completed his work at X, and intends to make his next fixing at Y; he cannot see the intervening ground, but has drawn a ray along the path x *ab*. He proceeds along the path, pacing as he goes. At a (175 m), he notices that he is in prolongation with a section of the

stream *de,* and that this direction is in line with a distance point *m* on the horizon, 20 km away ; without stopping he proceeds to *b (* 335 m), and notes that the direction of the stream *bd* is in line with another distant point n. He paces be (160 m) and cY (220 m). These data may either be memorized or noted roughly in a note-book. He then sets up his board at Y, fixes his position, and plots the foregoing details. He first plots the positions of *a* and *b* along the ray drawn from X ; he then aligns his sight-rule on *m through a,* and on *n through b,* and thus draws the directions *de* and *bd.* The fact that these alignments are taken from Y does not sensibly affect their directions, owing to the great distance of the points *m* and *n. (*It is immaterial whether *m* and *n* are fixed on the plane-table section or not). Such expedients as these, many of which will suggest themselves to the surveyor as he gains experience, enable him to dispense with many fixings, which would otherwise be necessary. He will thus increase his out-turn, and, at the same time, train his powers of observation and improve the accuracy of his work. A surveyor should also train one or more men of his squad to pace distances, much time is often saved, if distances to neighbouring detail are measured, in this way, while a surveyor is making his fixing.

(vi) In densely wooded low ground, which is commanded by hills, it is frequently possible to fix points by sending men to light fires at the selected points, preferably with dead leaves, which make a good quantity of smoke. The surveyor then fixes the point of origin of the smoke by suitable intersection, and also gives a height to the tree tops at the point. Such points are invaluable for con trolling traversing in the low ground.

(vii) In wooded hills, where the cost and labour of clearing hill-tops would be prohibitive, a clear view of the country may often be obtained by building a *machan* in a tall tree. The upper branches should be cut off above a suitable fork, upon which the *machan* is constructed. A platform of small branches should be made and surrounded by a rail. If the trunk of the tree is devoid of branches, a pole or rope-ladder may be necessary.

(viii) In surveying winding streams and broad *nalas* or rivers with islands and sand banks, if there is surrounding high ground, from which commanding views from different aspects are obtainable, it is better to draw tangent rays, to all bends and curves, rather than to intersect definite points on the banks. In this way it will be found, after rays have been drawn from half a dozen fixings or more, that the shape of the stream or *nala* banks have been completely delineated by means of the tangents. This method does not, of course, obviate the necessity for intersecting definite points for the purpose of determining heights.

(ix) In the plains, special care must be taken in the survey of such items of artificial topographical detail which follow straight lines and regular curves, such as railway lines, metalled roads, canals, etc. The straight sections must be ruled, and must not have any kinks or small changes of direction, that result from inaccurate drawing or from arbitrary adjustments with adjoining plane-table sections. To ensure this, fixings must be made at each end of a straight section at the precise point where the curve or bend commences, and no intermediate fixings, made for the purpose of surveying other detail,, must be allowed to influence the direction or position of this straight section of railway line, canal, etc. The point where a curve or bend commences on a railway line is indicated by a pillar or plate on the ground. Railway curves should be drawn, either with compasses, the centre of the curve being found by geometrical construction (this applies only on the smaller scales, railway curves not being parts of circle), or with French curves. Care must be taken to ensure that the curve is truly tangential to both the adjoining straight sections of the line. This is not easy to do, when using French curves, and requires careful supervision

30. Details to be shown on the plane-table section. — The depiction of details is dealt with more fully in paras 53-74. The limitations of topographical scales of survey impose the necessity of generalizing detail to a certain extent. It is a mistake to attempt to show too much, as it only tends to confusion. Generalization will usually take the form of entirely omitting certain items, such as minor streams, foot-paths, small patches of cultivation where there is much cultivation, etc. Such detail, as is surveyed, should not, however, be over-generalized. For example, the bends of roads and mule-paths in hills, conspicuous minor bends in streams, which are elsewhere straight, should be surveyed and even exaggerated, as such items form valuable identification points to the map-user. The amount of generalization permissible will also depend on the general value of the survey, and on the nature of the country. In dense forest, unpopulated areas, and high mountains, it may be desirable to increase output at the expense of accuracy. Special orders will always be issued in such cases. Men under instruction should be required to show the maximum amount of detail which the scale will permit, and should not be allowed to generalize until fully trained.

On the 1 : 50,000 scale, any natural feature, such as a ravine or water-course, less than 150 metres in length, cannot well be shown ; and, if the country be intricate and full of detail, watercourses less than 300 metres in length cannot easily be represented without creating confusion; but due discrimination should be exercised in omitting any detail.

Ravines and intricate ground, or hills of irregular formation, are generally of little value, and do not demand such precision and minuteness of detail as more valuable land. In such wild tracts it is sufficient that the prominent features of the ground be distinctly shown; in this case water-courses 300 metres long would hardly attract attention; but all perennial water should be shown.

31. Military surveys. — Special surveys of limited areas on larger scales than 1 : 50,000 are sometimes required by the military authorities for tactical purposes in the maneuvering of troops. The only difference between the surveys and an ordinary topographical survey is that the contours have to be inserted with greater care and exactitude, especially in undulating ground, where also a much larger number of clinometric and relative heights must be scattered about in places of military importance. The positions and heights of all conspicuous objects, such as isolated trees, mounds, rocks, houses, temples, permanent wells, etc., should be carefully fixed for the purpose of range-finding. Bridges, culverts, embankments and cuttings on railways must be shown, and all roads and foot-paths carefully classified. The depth to the surface of the water, as well as the depth of the water, in wells should also be recorded.

If such surveys are to be published in black and brown only, conspicuous and isolated trees should be shown by the appropriate symbol, surmounted by a flag. Care must be taken that all such trees so marked are really isolated and conspicuous. For surveys published in colours, the ordinary rules regarding trees will apply.

The actual shape of an area covered by a clump of trees should be carefully surveyed. See para 40, 3rd sub-para.

Surveys of a similar nature are sometimes required of military defensive positions on the scale of 1 : 25,000 and 1 : 10,000, or even on larger scales. In such surveys, still greater accuracy is required, and the contour lines should usually be at a maximum vertical interval of 2 • 5 metres, whilst every fourth contour on undulating ground should be carefully surveyed with a clinometer and clinopole..

For routes, 1 :50,000 and 1 :25,000 scales are generally adopted.

32. Fixings.—In easy ground, free from jungle, three or four fixings per square kilometer are often sufficient to enable a practised plane-tabler to show all necessary detail on the scale of 1 : 50,000 ; in more intricate country six to eight or more may be necessary.) In high mountains, where extensive views are obtained, and the number of fixings is limited by the difficulty and time taken in getting over the ground, one to two

fixings per square kilometer will often be found sufficient. In the case of larger scales, or with inexperienced workmen, the numbers must be increased in proportion. Plane-table fixings by interpolation are to be marked on the sections by small crimson crosses, and points fixed by intersection but not visited, by small crimson dots. When there is a paucity of trigonometrical points, a surveyor should go over the ground, and supplement them by so-called "plane-table auxiliary points", which have been well-tested by three or more rays. When a surveyor has to resort to plane-table traversing, traverse stations should be indicated by crimson dots, connected by fine pecked lines in blue.

It is important that it should be apparent from a plane-table section where the surveyor has been and how he has worked. He must, therefore, ink up all his fixings and intersections.

33. Traversing with the plane-table.— (i) When surveying in jungle-clad country, where clearings are rare and distant views seldom obtainable, it is evident that the method of plane-tabling previously described is not possible, and recourse must be had to traversing with a chain and setting the plane-table at each station "by the back ray", as explained in para 25, or by the help of the magnetic compass. The method of setting by the back ray should preferably be used in surveys on scales larger than 1 : 25,000 and in fairly open country, or in an area of magnetic disturbances.

(ii) In setting by the back ray, the surveyor should keep the following points in view :—

(1) The actual plotted position of the station on the board (not the centre of the plane-table) must be centred over the mark on the ground, as an error of 30 centimetres in centering, in the case of a short ray of 20 metres, will result in an error of 1° in orientation, and the error will be carried on.

(2) The forward station must be carefully located, and marked by a flag or a mirror, before a forward ray can be taken. The back station must be similarly marked.

(3) The forward ray should be marked on both edges of his board, so that he may obtain an accurate setting at his next station by using the whole length of the sight-rule.

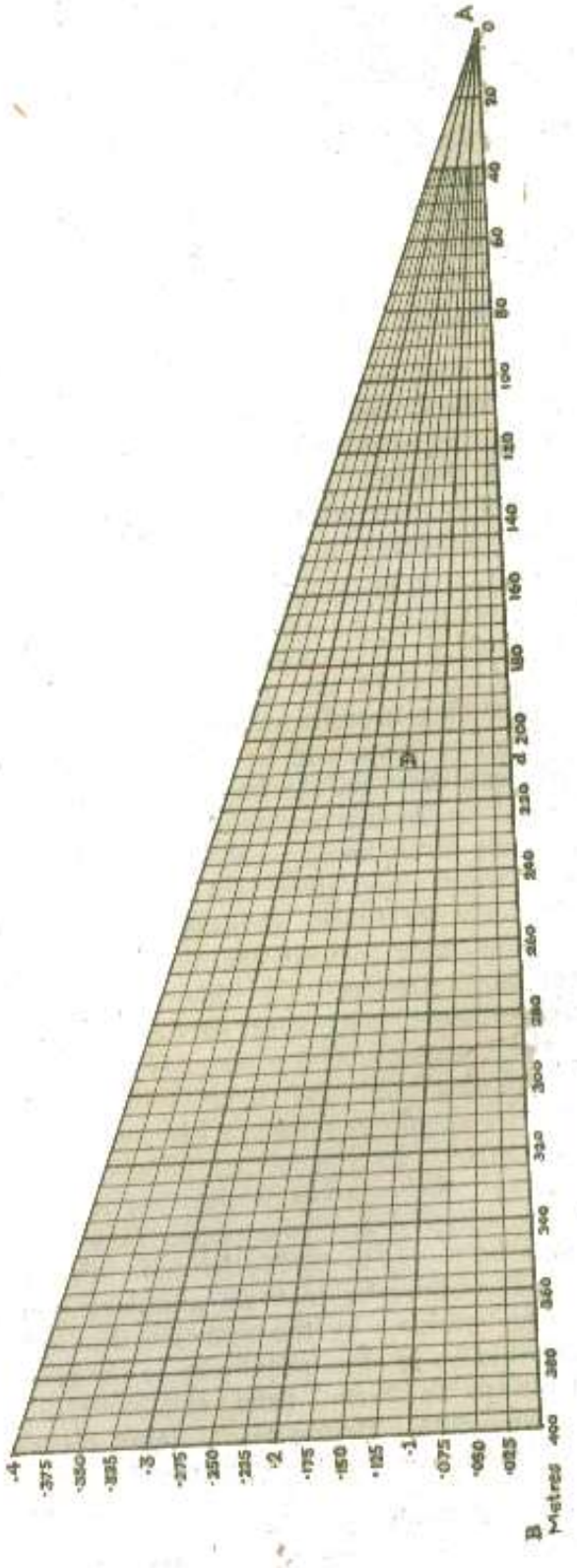
(4) The same side of the sight-rule should always be used.

(iii) From the above, it will be clear that setting by the back ray, though accurate when carefully done, is lengthy and tedious and is not

suitable for normal 1 : 50,000 surveys, except in an area of magnetic disturbances, and when working along railways, near railway station yards or along telegraph or electric power lines, in which cases the magnetic compass should never be used. For ordinary 1 : 50,000 surveys in flat country, the setting of the plane-table by the help of the magnetic compass is more suitable, as being quicker ; errors are not cumulative as in setting-by the back ray, and correct centering is unnecessary. Whichever method is used, it should be remembered that the most accurate setting is obtained by orientation on a distant fixed point; and, whenever such a point is visible, it should be used as a check on the compass or back ray setting. But, before using the compass, its declination must be carefully determined, either by the camp officer, by taking an azimuth from sun or stars, or by the surveyor himself, by setting up the plane-table at two fixed points, which are intervisible, and are not less than 8 cm apart on the plane-table section ; or, if that is not possible, by taking a traverse from one fixed point to another. Suppose A and B to be the two fixed points, and b, the position of B, as fixed by traverse from A, then the angle between the lines A B and A b, is the correction to be applied to the assumed north and south line of the compass. The process should be repeated till the exact position is obtained by traverse. It has been found in practice that magnetic disturbances are rare in a flat country; and compass declination, once carefully tested, is not likely to change in an area of one plane-table section on the 1 : 50,000 scale. Values of magnetic declination in the area of survey may also be taken from the Magnetic Declination Chart.

(iv) In flat country, where no triangulation is possible, and, consequently, theodolite traverse lines are run to provide points for plane-tabling, the surveyor has to decide whether the country is sufficiently open to allow him to fix his own auxiliary points (generally prominent tree tops or buildings) from the theodolite traverse points, and proceed, thereafter, by the resection methods described in paras 26 to 29. If possible, the resection method should be used in preference to the plane-table traverse described below, as the former is more accurate, especially as regards heights. Frequently a judicious blend of both methods is possible where the country is flat, and not open enough to allow resection methods only. Before commencing work, he should run his own plane-table traverse connecting up the theodolite traverse lines, thus breaking up the areas in squares or quadrilaterals of 8 or 10 cm sides. To keep the error at a minimum, his lines should be as straight as possible, and should preferably be along roads, cart-tracks, or main streams, to obviate the necessity of surveying them again. He should use flag or mirrors for forward and back stations, when taking rays to them,

SLOPE CORRECTION DIAGRAM
READING NATURAL TANGENTS
SCALE 1 : 2,5000



and be very careful in chaining the distances and plotting them on the board. He should also record them, as he goes along, in his note-book, so that, if at the end he finds a large closing error, he may check the distances before adjusting the errors by the method given in Appendix III. He should also mark conspicuously for future identification important traverse fixings, which he is likely to visit again, especially at junctions of roads, cart-tracks, or streams. The importance of having traverse stations marked permanently at points such as culverts, distance stones, wells, injunction's, cannot be too strongly insisted upon. If a surveyor gets a closing error of over 1/100th of the length of the traverse, he should re-measure his traverse rather than adjust so large an error. In jungle-clad hills, where accurate chaining is difficult, and the compass decimation is liable to local variation, and where a high degree of accuracy may not be so important, this limit may be raised to 2½/100ths under the orders of the wing in charge. "The surveyor may fix auxiliary points from his traverse stations for working by the resection method, but these auxiliary points should be in close proximity to the traverse line. Traverses should always be started from, and closed on, resected fixings or other fixed points. Before actual detail survey is commenced, the surveyor should reconnoitre at least a 5-minute section.

(v) In difficult country, where traverse lines are necessarily very short, the traverse may be plotted on a large scale, until the traverse is closed and adjusted. The plane-tabler should make every effort to reduce the jungle clearing to a minimum by utilizing such roads, paths, fire lines, beds of streams, game runs, etc. as already exist. Where the undergrowth is heavy, iron chains are apt to catch and break when dragged through it, and in consequence, the work is much impeded. A steel band chain will be more suitable, but the surveyor should see that it is carefully used by the chain-men, as it is very liable to break, if allowed to kink. When not in use, it should be rolled up on its frame. A chain made of "lead line" rope also, well-stretched and tarred, can be easily pulled through jungle. One end should be formed into a loop to aid the man in dragging it, and small strips of leather let in between the strands at 2 metres intervals for the odd measurements. The length of the rope chain should be tested daily, before work, with a standard iron chain or steel tape in camp, but it has been found in practice that a well-seasoned rope does not much alter in length except in wet weather, and wears well. Rope chains should be adjusted by relashing the loop at one end. Canes well dried may sometimes be used with advantage in country where they abound.

(vi) Each surveyor should be given form 16 Trav. completed with the co-ordinates and full descriptions of all points falling in his area, so that, if necessary, he can find the position of points obscured by detail he has already surveyed.

(vii) In filling in topographical detail by traversing in a densely jungle-covered country, it will be found that it is frequently quite impossible to see the forward flag-man even when only 40 or 50 metres away. Clearing is impossible owing to the delay and expense. In such country, mirrors are essential, flashed by the forward and back flag-man in the direction of the surveyor as they can generally be seen through apparently very dense jungle-Where, however, mirrors cannot be seen, it has been found that very fan- work can be done by judging of the direction of the forward station by sound ; any tapping noise or shouting made by the forward man can be located with quite sufficient precision up to a distance of 80 or 100 metres.

(viii) In traversing on steep slopes, as is often necessary in forest surveys, a correction must be applied to chained distances to reduce them to the horizontal. This is most easily done graphically by means of the diagram.

The diagram scale is numbered for use in connection with 1:25,000 surveys, distances being applied on ten times the scale of survey.

For use on all scales, set off the distance chained along the appropriate line corresponding to the tangent reading of the average slope of the traverse leg, e.g. A—D, and use the reading A—d on the horizontal line for plotting the correct distance on the scale of survey.

For distances up to 200 metres it is convenient to use the horizontal line as a scale, but for longer distances a special scale must be prepared, which, for increased accuracy, may be 10 times the scale of survey.

(ix) In surveying tidal creeks, where the banks are fringed with mangroves, it is generally impossible to set up a plane-table. A good plan is to go up the creek with the flood tide, with two boats, and survey down with the ebb, the distances being obtained by means of a long rope with large corks attached at 20-metre intervals to float it, and the angles with a prismatic compass suspended in gimbals. The survey can then be plotted separately on a piece of paper, and transferred to the plane-table. A good method of measuring the distances is to mark a length of 10 metres, or longer if possible, on the side of the boat: then post a *khalasi*

with 10 light bamboos at the front mark, and another *khalasi* at the back mark. Punt or tow the boat along the stream. The forward *khalasi* drives in a bamboo at the front mark, which the back *khalasi* pulls out as it passes the back mark; simultaneously the front *khalasi* drives in a fresh bamboo at the front mark.

(x) The following method may be adopted for fixing points on coast-lines or in tidal creeks, where there is commanding high ground in the near vicinity. Prom a fixing on a high point, the surveyor draws single rays to various points on the visible high-water line. Prom a knowledge of the difference in height between his station and the high-water line, and from the clinometric readings to the points selected, he calculates the horizontal distances, which are then set off along the respective rays. The accuracy of the method decreases with the angle of depression, and it should not be used with small vertical angles. Its application may be considerably extended by using a theodolite for measuring the vertical angles, and for determining the height of the fixing. The height of the high-water line above the M.S.L. datum of trigonometrical points must also be accurately known.

(xi) Traversing with chain and hand compass has been used successfully under certain conditions, and has resulted in a great speeding up of work. In dense forest areas, such as are found in parts of Assam and West Bengal, where the only communications are stream beds, which are very tortuous and, in parts, consist of a series of small hair-pin bends, such surveys give a very faithful representation of the course and bends of the streams, and provided that the work can be closed on reasonably close fixings or main traverses, result in no loss of accuracy as compared to other methods.

Possible disadvantages are that there may be errors in reading or plotting but, by the exercise of care and method, and with supervision, these should not occur.

Advantages are that, as the stream beds usually offer little impediment, chaining is very accurate and traverse can proceed rapidly, even though traverse legs have to be excessively short ; also the surveyor is not tempted to avoid too frequent setting up of the plane-table by taking long rays and measuring crooked chain lines.

The method adopted is that the surveyor precedes the chain-men and measures the back bearing at every change of direction, noting the chainage and bearings in his note-book, and making a rough sketch of the line.

Plotting is then carried out as follows :—

The compass is placed upon the sight-rule, and the latter on the plane-table so as to coincide with the North line. The plane-table is then oriented so that the compass reads north, and clamped. Each traverse leg is then plotted by moving the sight-rule, with the compass still in position, until the compass reads the back bearing of the leg being plotted. This method practically obviates the possibility of gross error in plotting. Where average length of traverse legs is so short that they cannot conveniently be plotted on the scale of survey, they may be plotted on a larger scale and afterwards reduced.

(xii) Methods of adjusting traverses are laid down in Appendix III. It should be noted that no rigid solution is possible, as nothing is known as to the source of error. Traverses should be run as straight as possible, and closed, or nearly closed, circuits should be avoided, especially in case of main circuits, as these tend to close correctly even if burdened with consistent linear or angular error.

34. Representation of hills.—In Survey of India topographical maps, hills are represented by contours. The delineation of ground by this method, by means of which relief is obtained by the relative frequency of the contour lines, gives a faithful representation of its inequalities and slopes ; it ties the surveyor down to a system which produces uniformity of style, and prevents any gross misrepresentation of the ground ; finally it enhances the value of the map as a guide to engineering and military operations.

Rock features are normally represented by horizontal hachuring drawn in such a way as to give the most realistic representation of the type of formation, as well as of the shapes of minor features as surveyed on the ground. Rock masses usually have definite limits which should be accurately surveyed and represented on the plane-table section ; the gradual merging of rock features into contouring should seldom occur.

The various methods of drawing rocks, which are reproduced in the table of conventional signs, are intended to represent some of the more usual types of rock formation. They are not, however, exhaustive and peculiarities in rock features should be drawn in the most suitable manner, bearing in mind that what is intended is a pictorial representation in plan of actual shapes and forms as they exist in nature.

35. Contouring. — (i) The term "contouring", as applied to the system adopted in this country, is used in its widest sense ; the work is carried

out with a Survey of India pattern clinometer, used in conjunction with the plane-table, numerous heights being fixed all over the area surveyed; contours are inserted by eye from plane-table stations with the assistance of the clinometer used as a level. The system cannot be considered a rigorous one, such as deliberate instrumental contouring done by means of the total station or level, or even by means of the water-level, but, if carefully carried out, it gives a very accurate representation of the relief on the 1 : 50,000 scale ; as the scale of the survey increases, the necessity for more rigorous contouring becomes greater, but, on the smaller scales, hill features must, like the detail, be generalized to a certain extent.

There are two ways of considering contours :—

(a) as independent horizontal lines, (6) as a means of representing the angle of slope by the distance apart (in plan) of successive contour lines. Both aspects have their application, but it is the latter with which the map-user is almost always concerned, and it is from this point of view that the plane-tabler must approach the task.

(ii) Contouring is carried out *pari passu* with the survey of other forms of detail. At each fixing, after obtaining his height, the surveyor will locate the contours in his immediate neighbourhood, and, as soon as he has fixed the position of a certain number of features, he will commence to sketch in lightly the shape of the ground. In order to do this, he must train himself from the very outset to identify different degrees of slope with the corresponding horizontal distance between contours. He will thus be able to draw in the approximate number of contours on any given slope with very fair accuracy, before the absolute heights are definitely known. When sufficient heights have been fixed, the lightly sketched contours will be corrected, so as to make them agree with the heights, at the same time preserving the relative spacing by which changes of slope are shown. On long regular slopes, such as occur on river fans, contours can be inserted with accuracy, up to considerable distances from the fixing, by taking clinometer readings along the slope in several directions, more especially up and down ,the slope. The horizontal distance between successive contours along each ray is then found from the height indicator, with reference to the contour interval and the clinometric reading.

(iii) The determination of height of a point fixed by plane-table intersection should be commenced from the outset, before the point is fixed, by recording the clinometric reading, either against the initial ray to the point, or in the height book, with a reference number, so that the

height computation from two or more stations may be carried out as soon as the point is definitely fixed.

(iv) Whenever possible, the clinometer should be used as a level for finding such points of equal altitude on neighbouring ground, as can be located on the plane-table. This is of great assistance in contouring, especially in determining how far up minor side valleys contours should be carried.

(v) In high mountains, topographical detail consists almost entirely of cliffs and contours. Above a certain level there are no streams, for the reason that water seldom flows ; the only movement being that of avalanches, rock-falls and scree slides. Here the surveyor is concerned only with contours and cliffs. The shape of the latter must be surveyed accurately, especially the lower limits of rock masses, where uniform slopes of scree commence, and which usually form such a conspicuous feature of the landscape at high altitudes. In areas of rock formation, which are represented entirely by the cliff symbol, and where there are no contours proper to indicate the direction of the slope, it is essential to make use of *shading* in the line work of cliffs, in order to show up ridges and spurs. It is usual to assume a northerly direction of light as in half-tone hill shading. Instructions for the survey of snow and ice features are contained in Appendix IV.

(vi) In lower regions, where plane-tabling is complicated by the presence of villages, cultivation, forests, etc., the shape of the ground is still of paramount importance, and contours *must* be worked out, and inserted, at the same time as other detail. This is troublesome, as it entails frequent use of the India-rubber before the final result is obtained. Other detail is erased and has to be pencilled in again. The tendency is, therefore, for the surveyor to shirk the drawing of his contours on the spot, and to rely upon his heights for the insertion of contours subsequently in camp, long after he has forgotten the shape of local ground forms. In congested areas, a solution is to ink up all black, red and blue detail, which has been finally surveyed, while still at the fixing, and then to proceed with the contours.

(vii) In surveying hills, it must be borne in mind that the spurs are usually more important than the streams from the point of view of the map-user. Lines of approach to high ground generally follow spurs, and not depressions ; the former should, therefore, be surveyed with as much care as the latter. All spur crests should be pencilled in, just as streams are, as a guide to contouring. It is far better to spend more time in showing shape by contours, *while on the spot,* rather than to take a large

number of heights for the purpose of correcting contours subsequently. A large proportion of such heights are necessarily "single" values, and are often considerably in error owing to slight errors of position of the points observed, especially when vertical angles are big. The surveyor then forces his contours to agree with his heights and may thus get his shapes and slopes quite wrong. He has spent all his time in taking heights, and has devoted insufficient attention to actual forms while on the ground. Another source of error in contouring, when the latter is not completed on the spot, is due to inaccuracies in the survey of streams. If a stream is out of position, the contours on one adjoining slope will be over-congested, and on the other over-spaced. This will be obvious if the contouring is done *in situ* and it will be seen that something is wrong with the position of the stream. A correct and constant appreciation of the correlation between contours and other items of detail thus forms an additional safeguard to the accuracy of the work. The surveyor must, therefore, continually ask himself if the angles of slope, as depicted on his board agree with the facts in nature.

(vii) (a) The contouring of very steep ground should not be abandoned in favour of hachuring, except in case of actual precipices, cliffs, or continuous rock surfaces of sufficient extent to be separately surveyed, and never because there is no room to draw the fine contours. In such cases the thick contours should be surveyed as carefully as in any other ground and the fine contours omitted if necessary. See also para 69.

(viii) The direction of sunlight has a considerable effect on the appearance of hill features. When the sun is behind the plane-tabler, slopes facing him appear flat and featureless, and successive ridges cannot be readily distinguished ; while, if the light is from a flank undue prominence may be given to minor spurs by the contrast of light and shade. The surveyor must bear this in mind in sketching hill features.

(ix) Due attention must be paid to the correct contouring of main valley floors. The fact is not always recognized that most rivers or large streams have a regular bed fall, except in places where there are rapids or falls. The accurate representation of the bed fall of a river is an important matter, and the surveyor should be instructed to determine carefully the point at which each contour crosses, and to draw the contour across the actual river-bed. The latter procedure is necessary, as, in many cases, rivers run for long distances between high banks or in gorges, in which contours are lost in the cliff symbol, and the only indication of height is given by occasional spot heights. Owing to the difficulty of fixing accurate heights at water-level in deep valleys, it

frequently happens that such heights are discordant, and the necessity for locating contour crossings will ensure the investigation and adjustment of heights. The surveyor should reject all heights which contradict the regular spacing of contours along those portions of the river in which the bed fall is obviously constant. It is better to observe heights to intersected points on river banks *upstream,* and not down, as the smaller the angle of depression, the more accurate will be the result.

(x) The correct grading of hill roads should be shown by the contours, which should be drawn so as to cross a double-line road at right angles on the 1 : 50,000 and larger scales. Care should, be taken to ensure that contours cut the road at regular intervals, where the grade is constant, and that they run parallel to the road level sections.

(xi) Contours must be generalized to a certain extent in the same way as other detail, but this does not necessarily apply to minor streams, which are less than 6 mm in length and omitted purposely to avoid congestion in detail appearing in black. The majority of such streams should be indicated in pencil in the course of survey, so that the contours may be made to conform, the streams themselves being omitted in inking up. Ground consisting of minor “hummocks” and depressions cannot be surveyed in detail, but contours should be "waved" slightly and irregularly, to indicate the nature of such ground.

It is occasionally permissible definitely to "stretch" one or more contours by a small amount, in order to indicate minor features or changes of slope, which would not otherwise be apparent. Such indications are often very valuable to the map-user in locating his position.

The true art of the topographer is to convey the best possible impression of ground forms which the scale will permit.

36. Vertical intervals.—The normal vertical intervals between contours for 1 : 25,000, 1 : 50,000 and 1 : 250,000 maps are 10,20 and 100 metres respectively.

The contour interval for high hill areas for 1:25,000 scale will be 40 metres for those sheets in which the contour interval in F.P. System on 1-inch scale was 100 feet. Similarly the contour interval for high hill areas for 1:25,000 scale will be 200 metres for those sheets in which the contour interval in P.P. System on ¼-inch scale was 500 feet. 1:250,000 sheets which contain both mountains and plain areas may have both contour intervals with a special foot-note indicating the elevation beyond which the contour interval has changed.

Exceptional cases, where departure from the above is required, should be referred to the Surveyor General by the GDC Directors through Director, Map Publication for special approval on the merits of each case. Full reasons in support of each case should be given.

In the cases of 10, 20 and 40-metre intervals, every fifth contour, should be distinguished on the plane-table sections by being drawn more heavily. This is solely for the purpose of ready identification. The intermediate thin contours are not intended to be surveyed less rigorously than the thick ones, and all contours have equal value in the representation of ground forms. Thin contours should rarely be omitted on plane-table sections, as this tends to carelessness both in survey and in inking in (see para 69 second sub-para).

Where the contours, at the prescribed vertical interval, do not adequately represent the features of the ground, these features should be indicated, where necessary, by fine broken lines called *form-lines*. A form-line (not to be confused with the approximate contour used in reconnaissance and sketch work), is an intermediate contour, which is continued, as far as may be necessary, to indicate the desired feature. It may be at any intermediate altitude between the two adjacent contours, as best suited to the case ; as its name implies, it indicates *form* rather than *height*. Form-lines are used to indicate minor summits, marked changes of slope, minor features or depressions in flat or undulating ground, etc. Where a summit is already shown by a firm ring contour, it is usually unnecessary to add a form-line, unless the hill-top is a broad one, and has one or more minor tops. The practice has arisen of confining the use of form-lines to ring contours ; they should, however, be freely used for all the features mentioned above.

Contour values should be entered occasionally in brown in the margins and body of plane-table sections, particularly where the contouring is very close, or where one or more contours run in and out along the margin, or where contoured summits emerge from ravines or cliffs, in such a way that it is difficult or impossible to ascertain the contour values by counting from adjacent known contours.

37. Heights for contouring.—The number of clinometric heights required depends to a great extent on the nature of the country. In mountainous tracts and in undulating ground, heights should be taken at nearly every plane-table fixing, and to nearly every important intersection, but, in open level country, this is not necessary.

In addition to heights required for contouring, heights will be taken at important points for showing on the map. Such points are—road

and river junctions, isolated hillocks, ferries, fords, bridges, distance stones, surveyed trees, saddles, passes and near villages. These, except in very exceptional circumstances, when a single height is of great topographical importance, should all be well proved heights, derived from observations from or to at least two points.

In flat country, especially where there are no contours, a large proportion of the heights selected should show the general level of the country, rather than the level of specially marked features on incidental or artificial ground.

The method of recording heights on plane-table sections and traces is described in paras 70 and 52 respectively.

In the case of rivers running through steep wooded hills in a gorge several hundred metres below the hill-tops, it is difficult for a surveyor to obtain good results from a clinometer. In such cases the camp officer should fix a certain number of heights along the river-bed with a theodolite.

38. Height traverses.—For forest surveys in hilly country, however, densely wooded, it is generally possible, without very excessive labour, to obtain sufficient clinometric heights by clearing the tops of the higher hills, wherever a good view can be obtained; but, when the forest lies on flat, or only slightly undulating, ground, clearing is of no use, and clinometric heights are no longer directly obtainable from known fixed points. In a country of this sort, the survey of all detail has to be carried out by plane-table traversing, and the delineation of contours by taking clinometric observations from station to station, for which there is generally ample time whilst the rays to the forward stations are being cleared of jungle. Since the rays are often very short (not more than 40 or 60 metres, and sometimes less), experience has shown that the chance of an error of measurement and reading, when taking off, with the dividers, a very short distance from the scale and applying it to the "Height indicator", is much greater than when performing the same operation with a much longer distance, such as 2,000 metres. To obviate the difficulty, the following method may be adopted :—

The measured distance may be multiplied by 10 or 100, and the difference in height divided by 10 or 100, according as 10 or 100 is used as the multiplier.

Example :— Distance measurement 46-2 metres.

Reading on clinometer -02.

Take 46.2 metres as 4,620 metres. Place on 0.2 line of height indicator : the difference of height will be 92 metres; re-placing the decimal point two places to the left, the true difference will be 0.9 metre.

When surveys based on revenue traverse data are carried out in country containing sufficient relief to necessitate the use of contours, it may be advisable to fix the height of a suitable number of points during the previous season. For this purpose compass height traverses may be run, at 10 to 15-cm intervals across the area, with a telescopic clinometer. Position will be checked occasionally at injunctions, whose height will be fixed, and, during the course of traversing,, heights (both top and ground) will be thrown to prominent objects, which will be fixed by offset or intersection. The position of these objects will thus be fixed with sufficient accuracy to enable them to be identified subsequently by the plane-tabler, who will be provided with a trace of his area giving descriptions of the points and their heights. Such height traverses should not be used for the purpose of fixing the *positions* of points ; this will be done by the plane-tabler.

39. Relative heights.—Relative heights should be taken at [suitable points :—on the banks of streams and rivers at about |5-cm intervals, on the plane-table sections or wherever great changes occur ; at cuttings and embankments on roads and railways, on selected tank bunds, on bridges and in broken ground at suitable places ; also on sand-hills, isolated rocks and rocky scarps. These should be carefully measured. Relative heights less than 2 metres are not usually recorded.

Relative heights are difficult to measure and are usually over-estimated. Two methods of ascertaining them are as follows ;—

(i) *By clinometer.*— Set up the plane-table at some point distant not less than five times the amount of the estimated relative height and not much above or below the feature to be measured ; measure the horizontal distance preferably by chaining, or from the plane-table if this is impossible ; take clino. readings to the top and base of the feature : if of the *same* sign *subtract* the less from the greater, if of the *opposite* sign *add* the two readings ; the result multiplied by the horizontal distance gives the difference in height. In the case of mounds or sandhills in level plains, readings should be taken to the top only, when the reading multiplied by the distance, plus the height of plane-table, gives the relative height. This method can be usefully employed to obtain the ground height of objects of which the top height is known.

(ii) *By comparision with a known heigltt.*— Send a man to stand on the top or at the base of the feature to be measured. From a distance of not less than 5 times the estimated height, hold out a pencil, point

downwards and vertical, at arm's length, hi the direction of the man, closing one eye. Make a mark on the pencil such that the distance from the mark to the tip of the pencil corresponds to the apparent height of the man. Make another mark corresponding to the height of the feature. With a pair of dividers, measure the number of times the former length goes into the latter and multiply the result by the measured height of the man, e.g. Height of man: 1.7 metres; number of times he goes into the height of the object: 6 ½ times. Height of object 1.7 x 6.3 = 10.7 or say 11 metres.

40. Trees and Vegetation.—The introduction of green trees has given surveyors increased scope for the artistic and faithful representation of vegetation.

Vegetation should always be entered on the ground, either on the plane-table section or trace, and every effort should be made to bring out variations in type and density of vegetation. It will be shown on the trace only, in hill areas, where, if shown on the plane-table section, it would interfere with contouring or other detail. In jungle areas, where the vegetation will appear as a green tint on the published map, the area will be shown by a green wash on the colour trace, and the type of vegetation and the density written in appropriate places.

The relative distribution of trees in cultivated areas is often of very great importance. In places where there are concentrated masses of trees such as mangoes or palms, the limits of which will not be shown on the fan- sheet, the limits should be surveyed in pencil. These limits may, if desired, be shown by the broken green line indicating an abrupt change in vegetation. This green line will usually be unnecessary if trees are drawn up to and close together round the perimeter, so that the whole of each symbol falls within the area. The shapes of the concentrated masses will thus stand out and scattered trees can be drawn freely in the open areas without losing the effect.

Very small topes, which generally stand out conspicuously, may have to be exaggerated at the expense of neighbouring scattered trees.

When trees, such as palms, grow along a tank bund, they should be drawn, wherever possible, with their bases on the bund. Otherwise, in the case of a tall symbol of this kind, the trees do not look as though they are growing on the bund.

In some areas, there are scattered large trees which stand out conspicuously from smaller trees such as, say, *babul* trees, which are little bigger than scrub. If this distinction is not emphasized, a totally wrong effect is produced.

Trees in orchards should be drawn small and in regular rows.

SECTION IV.– OUTLINE OF SURVEY METHODS FOR NEW AND REVISION SURVEYS

41. Different classes of survey.—The different technical classes of survey are defined in Chapter I, para 21 (7th Edition, 1966).

42. Original Survey.—Original Surveys are normally carried out by any of the following three methods :—

(a) On blank paper with plotted Control.

(b) Taking blue-prints of the detail, etc., surveyed from air photographs to the field. The details are verified, and contouring carried out on the ground.

(c) Using blue prints of old (pre-1905) survey, if considered of requisite accuracy, e.g., experience has shown that old 4 inches to 1 mile Forest Surveys on reduction generally prove suitable.

In making the decision whether or not to use the old survey the following points should be taken into consideration :—

(i) The use of older work, if reasonably accurate, tends to speed up out-turn. On the other hand the tendency to accept such work without adequate check may perpetuate errors and necessitate rigorous and searching supervision.

(ii) If the previous survey is much below standard in accuracy or if there are wholesale changes by reasons of development, then the use of a print of that survey may be dangerous and a hindrance rather than a help.

43. Revision Survey.—When the existing modern surveys are out-of-date owing to large areas having been developed, the existing maps should be brought up to date by Revision Survey methods.

This should either be done on blank paper using plotted control, or by using prints of the previous survey, which may have been carried out at or the same or a larger scale. In making a decision on the method to be used, sub-paras (c) (i) and (c) (ii) of para 42 should be considered as these are equally applicable to Revision Survey. The three methods of carrying out Revision Survey are :—

(i) On blank paper without making use of the existing modern survey. Such cases are likely to be rare, but this method may have to be used if good reasons exist for not using the previous work.

(ii) Blue-print Survey.—This is used where the accuracy of the basic detail of the previous work is considered reliable, and the areas for revision if extensive result from development and physical changes. Normally the survey blue-print will be a combination of 'outline' and ‘contours’. The whole of the work is inked up~ afresh in colours. In cases where there are registration or other errors involving a shift in the work, it may be necessary to utilize separate black prints transferring the old work by hand after adjustment on fixings. Black and brown prints on tracing paper should always be provided in case they may be required for this purpose.

(ii) Colour-print Survey.—This is used when the previous work is known to be accurate and where there is a major proportion of unchanged detail and hill features. In such circumstances it is necessary to preserve the accuracy of the unchanged work by eliminating the process of inking it up afresh in the field; otherwise there is a danger of progressive deterioration in each revised edition of the sheet. For this purpose the survey will be done on a combined print with the 'outline' in *dark* grey and the contours in brown, i.e., in colours which will photograph without being inked over. Corrections will be effected by *erasing* the old work and inking in the new in *black* and *brown.*

Colour-print Survey will be the normal method when revising post-1958 work of standard accuracy, when there are no extensive areas of major change.

In both methods (ii) and (iii) above the whole ground has to be systematically covered.

44. Verification Survey is carried out when only the checking of specified items of detail reported to have undergone changes, is involved. For this purpose the survey will normally be carried out on a combined print with the 'outline' in *dark* grey and the contours in brown, i.e., in colours which will photograph without being inked over. Corrections will be effected by *erasing* the old work and inking in the new in black and brown.

Where the verification work is not heavy, a print of the published map may be used, new detail being inked in red, while old, non-existent detail is deleted in green.

Cases may arise where there is some doubt as to whether a survey is to be classified as *Revision* or *Verification.* The decision regarding this classification rests with the Director concerned.

44A.Rapid Verification Survey.—Due to adoption of digitization in the department, map processing has reached a fast pace. Hence the speed of ground survey is also to be in accordance with the renewed technology. To supply the updated data for OSM(Open Series Map) and DSM(Defence Series Map) sheets, it has become necessary to adopt rapid verification method, without departure from departmental survey methods.

The verification has to be carried out on print of the published map or blue print which is used as base material. The new details are inked in proper colour and transferred to a clear film with good stability. The non-existent details which are to be deleted are inked with green colour. Contours are need not to be revised. All the existing contours will be accepted, since large scale physiographical changes occur very rarely. As far as possible, existing details and control points will be used excessively for fixing and new details are surveyed. In this way, new detailed will be incorporated with reasonable accuracy, by spending lees man days in the field.

45. Combination of methods.—While the normal procedure will be to survey a complete sheet area by one of the three methods outlined in paras 43 and 44 above, it will often happen that certain areas in a sheet have to be surveyed by a method different to that of the remainder, owing to local development or to varying degrees of accuracy in the previous work. After due investigation the limits of the areas to be surveyed by different methods will be decided; these may follow natural features or arbitrary straight lines. The class of survey employed will be recorded on the plane-table section, and, with a suitable index, in the history file of the sheet.

46. (a) Utilization of cadastral survey.—In the case of areas previously surveyed cadastrally, and for which maps on the 1 inch or 2 inches to 1 mile scales have been prepared by the State Governments or the Survey of India, one or other of the following methods may be adopted :—

(i) A large saving in office time can be effected by the direct use of blue-prints on paper ready-mounted on cloth, or on zinc, for the field work. These blueprints should be obtained direct from the original fair drawings, or their standing plates, on the proposed scale of survey, though, when errors in dimensions of good prints can be photographically corrected, these may be

used. If the *distortion* of the graticule exceeds 2.5 mm, the print should be rejected for direct work, and one of the methods explained below be restored to.

(ii) Prints on tracing paper, on the scale laid down for the survey, should be obtained from the reproduction office. These prints are given to the surveyor who carefully adjusts them with the trigonometrical stations or points and the graticule projected on his board, and transfers them by means of blue transfer paper. It will usually be convenient to tackle each 5-minute section separately, as required ; after being transferred, the lines may be drawn over in pale cobalt.

(iii) First plot on a sheet of drawing paper all triangulation or traverse points falling in the area; then cut up a tracing paper print of the old map and adjust each portion of it on to the plotted points. This forms an original, from which a blue-print is obtained for the plane-tabler to work on.

(b) Utilization of Project and other Surveys done by the Survey of India.—The preparation of blue-prints from cadastral surveys has already been dealt with in sub-para (a). The same principles apply to other cases. When blue-prints have to be prepared from surveys on a larger scale, it may be necessary to prepare preliminary blue-prints, probably on an intermediate scale, and to ink up on these such details as are required. These inked up blue-prints will then be reduced to the scale of survey. The decision has often to be made whether old contouring should be inked up as it stands, with the necessary modification of contour interval, or whether hill features should be partially shown by depicting tops, laddies, etc. or omitted altogether. In certain cases, where more than one sheet is involved, it may be necessary to obtain black-prints on the proposed scale of survey from the above inked up pints, mosaic them on a projected sheet of drawing paper with all triangulation or traverse data plotted thereon, and obtain blue-prints from them by direct reproduction.

———————

SECTION V. – INKING UP AND PREPARATION OF TRACES

47. Inking up.—A copy of the booklet, "Instructions to Plane-tablers", showing conventional signs, should be issued to each surveyor for guidance as to how field sections are to be inked up.

All the work on the plane-table section is, in the first place drawn in pencil in the field ; and as the work advances, the pencil work, with the exception of rays, rough notes, and preliminary sketching, of each small completed area should be drawn over with a pen in the colours laid down for the different items. It is important that this work should not be left in pencil longer than is necessary, and inking up should be carried out at least once a week, an oftener, when the surveyor is untrained or a bad draftsman. No washes or ribands of colour, with the exception of a very light was of cobalt for water areas, and of yellow and green lines for limits of cultivation and forest boundaries respectively, should be used on the sections in the field. Perennial streams represented by a single line should be drawn in strong colour to ensure their appearing on the photographic print or the blue may be mixed with a little alizararin crimson. The pencil work need not be rubbed out until the plan table section has been finally passed and is ready for despatch to the reproduction office. The great drawback to the use of colours (plane-table sections is that the colours used are not waterproof permanent; and every precaution should be taken to prevent the section being unnecessarily exposed to damp or direct sunlight Writing ink should not be used on any plane-table section.

48. Colours generally used.—A drawing pen should used as far as possible for inking in the detail, but, for ornamentation, dots and lettering, a crow quill or mapping pen will be found most suitable.

The colours generally used on plane-table sections are follows :—

Black	..	Indian ink.
Red	..	*Plane-tabling symbols in alizarin crimson, all other in vermilion.
Brown	..	Burn umber or burnt sienna
Green	..	Viridian
Yellow	..	Aureolin and yellow ochre.
Blue	..	Cobalt (where this has to reproduced by photography, some alizarin crimson may be mixed with it).
Do(for washes)	..	Cobalt

* NOTE : Plane-tabling symbols are on page 34 of Instructions to Plane-tablers.

49. Colouring of details.—(a) All symbols representing vegetation, that are to be printed in green, should be drawn in black on the palne-table section, excepting vegetation in the hills which will be drawn on colour trace.

(b) Symbols in the beds of rivers or streams, or in the coastline, such as anchorages, light-ships, arrows indicating the flow of streams or tidal currents ; also buoys, beacons, steamer signals, navigation marks, etc. if unlighted, should be drawn in black.

(c) Symbols representing grass and reeds should be drawn in black, except when they occur in marshes or swamps, when they should be drawn in blue. High grass or reeds in perennial water should be shown by the high grass symbol in blue. Grass on hills shall be drawn on colour trace.

(d) Symbols representing buildings, churches, mosques, temples, pagodas, lighthouses, watch-towers, forts, deserted village sites, also buoys, beacons, steamer signals, navigation marks, etc. if lighted, should be drawn in vermilion.

(e) Miscellaneous symbols, such as those representing battlefields, rifle ranges, air-bombing ranges, air-firing ranges, mooring masts, wireless stations, graves, oil wells, and mine shafts, should be drawn in black. An oil pipe-line should be shown by the pipe-line symbol in black, with the words "Oil pipe-line" printed along-side.

(f) Symbols representing wells and springs should be drawn in blue.

(g) Symbols representing waterfalls, rapids, locks and weirs, should be drawn in blue and black, according to whether the rivers, streams, or canals, are perennial or non-perennial.

(h) Broken ground and precipitous banks of ravines and streams in flat or open country will be drawn in black. But, when broken ground, cliffs, etc., are intimately connected with contours, as is generally the case in mountainous country, they will be drawn in brown.

(i) A fine green line should be drawn over the external forest boundary symbol and a fine yellow line over the cultivation limit symbol at the time of inking up, taking care that these lines follow the centre of the symbol.

(j) A broken green line should be drawn to indicate the outside limits of hill or jungle areas in which vegetation symbols gave not been drawn on the plane-table section. Where this is a surveyed line, and not coincident with other surveyed detail, it should be inked up in the field, but otherwise may be added in recess from the colour trace. It may be

omitted, in obvious cases, at the discretion of the wing in charge of the field wing, where it follows surveyed detail. It may also be used to mark the limits of abrupt changes in vegetation.

(k) Colours used in depicting hill features are dealt with in para 69, and in Appendix IV.

50. Colour and height traces.—For the purpose of photography, it is desirable that plane-table sections should be free from colour washes (except light blue washes of cobalt) and from anything which would tend to confuse the detail; consequently two traces (a colour trace and a height trace) should be prepared on tracing cloth, covering the area of each plane-table section. These traces should be kept up daily by the surveyors in the field.

51. Colour trace.—The following should be entered on field colour traces :—

(a) Administrative boundaries in their appropriate symbols in black. The exterior boundaries of reserved and other forests should be shown by continuous green lines over the symbol.

(b) Locality, tribal and range names, and their limits, in black, crimson and brown respectively.

(c) All cultivated areas in a dark and complete yellow wash. The limits of this wash should be shown by cultivation dots, or the actual item of detail, e.g., path, boundary, stream, etc., which forms the limit on the plane-table section. Where, within the area of permanent cultivation, numerous bits of fallow land, and field bunds below 2 metres in height exist, and have not been surveyed, the following note should be entered across the area in addition to the yellow wash : "Periodical cultivation dependent on rainfall; numerous field bunds of less than 2 metres in height" Field bunds of 2 metres and over in height will be shown on the plane-table sections in the usual manner. See also para 65.

(d) All blue detail in strong colour.

(e) Trees, undergrowth, grass and scrub in the appropriate symbols in black, the closeness of the symbols indicating the density of growth. Undergrowth and scrub should be represented by dots of varying sizes; the sparing use of irregular half-circles, as shown in the symbol tables is permitted where scattered dots do not give sufficient prominence. Vegetation in hilly areas, which is not drawn on the plane-table section, should be drawn on the trace, on the ground by the plane-tabler. In jungle areas where the vegetation will appear as a green tint on the published map, the area will be drawn by a green wash on the trace and the type of vegetation and density written in appropriate places.

(f) Surveyed conspicuous trees, which are to be shown on the outline original in black within a red circle.

(g) In addition to the appropriate symbols, which should conform to these entered on the plane-table section, where not omitted from the latter, uncultivated areas should be indicated by descriptive remarks entered across the areas, or in the margin of the trace with an arrow from the remarks to the area concerned, for example : —

> "Open jungle with scrub" "Dense jungle mainly teak" "Impenetrable scrub with scattered trees" "Scrub, grass and boulders" "Stony waste" "Sheet rock and boulders" "Rock outcrops", etc[·].

(h) A short cross-line in green across railway lines marking the beginning and end of each curve on the line, as surveyed on the ground, vide para 29 (ix). On all railways these points are marked by a plate or by a pillar at the side of the line showing the dimensions of the curve. At the discretion of the Wing in charge these indications may be omitted where, as in mountain railways, there are few straight sections of line.

These remarks are very useful for co-ordinating different surveyor's work in recess.

(i) A broken green line to indicate the outside limits of hill or jungle areas within which vegetation symbols have not been drawn on the plane-table section, or interior limits where vegetation changes abruptly. This green line will invariably be drawn on the colour trace even if not shown on the plane-table section. [See para 49 (j)].

(j) Descriptive remarks with regard to roads, bridges, fords, ferries, etc., where these cannot be entered on the plane-table section, e.g. : —

> *Roads.* — "Motorable", "Motorable in dry season", "Bridged, November to June", "Gravelled", "Jeep-able", etc.
>
> *Water crossings.* — "Steel girder bridge, 6 masonry pillars, spans 15 metres", "Bridge of boats, March to June", "Ford, October to May", "Ferry", "Passenger ferry", "Motor car ferry, June to September", etc.

[·] NOTE : Metalled roads are assumed to be motorable unless otherwise stated.
Unmettaled roads are assumed not to be motorable or jeepable unless the fact that they are so is definitely stated.
An unmetalled road is a track which has a made formation (ditched and drained).A cart-track has no made formation, but may be motrable.

"Causeway" will be entered against important raised or paved crossings, "Low level" against bridges that are submerged at exceptional flood (official classification usually submersible).

(k) In case of scattered sites covering large areas, each area should be encircled by a red line, with the reference number in the centre.

(l) Anything that is likely to be overlooked or is liable to misinterpretation, e.g., special symbols, such as temples, mosques, graves, springs, etc. anything which is not clear owing to bad drawing or congestion of detail; also anything which should be emphasized on the fair map.

(m) In quarries, the names of minerals or rocks excavated from them should be entered, e.g., " Stone ".

(n) In the case of old sites, monuments and caves, indicate whether they are antiquity or non-antiquity.

(o) In the case of high grass, height and variety of grass should be stated.

(p) Abbreviations such as PO, PTO, DB, EH, PS, etc. and other important information such as "Court", "Jail", "Power house", "Hospital" or "Dispensary", etc. pertaining to towns and villages, should also be entered. These abbreviations should be entered in such a way that they should show exact location because PO, PTO, RH etc. are shown by special symbols in OSM and DSM sheets.

(q) Destinations along the outer edges of the surveyed area.

(r) Remarks with regard to distance stones on railways, roads and canals whether they are in kilometres or miles.

(s) Gauges of railways, to two decimals of a metre.

52. Height trace.—The following, with their appropriate symbols should be entered on the height traces :—

(a) The height of all trigonometrical stations, intersected points, bench-marks, and the heights of waterfalls in black.

(b) All relative heights in red.

(c) All clinometric ground heights, of auxiliary points, at fixings or to definite objects or intersections, with their serial numbers, in blue; also useful top heights, such as those of auxiliary points, in blue. Selected heights [see paras 37 and 70 (c)] should be selected in the field and inked up in red under the orders of the camp officer. Heights of

indefinite objects, obtained purely for contouring purpose, should be omitted. Such items of detail and contouring should be entered on the height trace as are necessary to indicate the correct position of the height, e.g., plane-tabling fixing, auxiliary point or intersection, road junction, temple, stream junction, saddle, end of spur, top, etc.

When ground heights cannot be observed, or measured, but have to be obtained by deducting the estimated height of tree, bamboo or other jungle, from observed top heights, the estimated value should be rounded off to the nearest 2 metres. In case of recorded top and ground heights the letter (E) should be entered against such ground heights.

Where selected heights are rounded off under the order contained in para 70 e (t), the actual mean obtained should be entered hi blue and the rounded off selected height in brackets in red.

(d) All fixings, auxiliary points and intersections which have heights, by the appropriate symbol in red.

(e) All theodolite or total station and plane-table traverses, with or without heights. Plane-table traverse heights in blue.

Height traverses will be shown as follows :—

Traverses should be numbered serially commencing with ' a' thus—

1st traverse 1a 1b 1c……etc.

2nd traverse 2a 2b 2c……etc.

If there are more than 26 stations in a traverse line, capital letters should be used from the 27th station, thus—

….4x 4y 4z 4A 4B 40……etc.

Should there be more than 52 stations, the small alphabet may be used again and so on.

Height traverses only will be numbered and lettered and numbers and letters must correspond with those in lines 1 and 2 of the height book. In very crowded traces, some numbers and letters may occasionally be omitted as long as traverse dots are clearly shown and the order of numbering is not altered.

(f) Depths to water surface and bottom of *all* wells in desert areas and of 3 or 4 wells in other areas in a 5-minute square, in red.

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SECTION VI. – SURVEY AND DEPICTION OF DETAILS

53. Symbols.—All symbols should be shown strictly in accordance with the pamphlet " Instructions to Plane-tablers ". Whenever a special symbol is used on a plane-table section, an explanatory note should be entered on the section.

Symbols should not be exaggerated, and, in surveys on the 1:25,000 scale, the symbols for the 1 : 50,000 scale should be used.

In the case of symbols shown in profile, such as temples, surveyed trees, etc., it is important that they should be drawn so that the actual surveyed position falls in the centre of the base of the symbol (at the foot of the trunk in the case of a surveyed tree). In the case of symbols shown in plan, such as huts, wells, etc. the surveyed position should be the centre of the symbol. Where there is a group of symbols consisting of a surveyed conspicuous tree, a hut and a well (such as frequently occurs in the plains), and there is not room on the scale to show all these in their correct positions, the conspicuous tree, if to be shown as surveyed tree, should be correctly placed, and the other symbols shown as nearly as possible in their true positions ; if there is no conspicuous tree, the hut should be truly placed and the well shifted.

54. Trigonometrical points, plane-table fixings, etc. -Trigonometrical stations should be shown by a small triangle, and intersected points by a small circle, in black ; but stations, which are, or will be treated as intersected points in the triangulation pamphlets, should be shown by a small circle in black.

Theodolite or total station traverses should be shown by continuous blue lines. Permanent stations and intersected points (i.e., those which are so close to permanent details, such as bridges, distance-stones, conspicuous trees, etc. as not to give any plottable error on the scale of survey) will be shown with black circles, others in blue. In the case, however, of topographical theodolite or total station traverse or cadastral traverse which has been accepted as a basis for topographical survey, trijunctions should be shown at the time of plotting by open black squares ; in the case of cadastral traverse these will be unconnected by blue lines.

Plane-table auxiliary points, fixings and intersections are shown by crimson circles, crosses and dots respectively. See also para 32.

All plane-table traverse lines should be shown, whether with or without heights, by crimson dots for stations, joined by blue pecked lines. An exception would be in the case of such surveys as those in rectangulation areas, where traverse almost always follow *murabba* lines

which are occupied by detail (irrigation channels, cultivation boundaries or roads), In such cases, it is sufficient to show traverses on height traces only. It may also, in exceptional cases, be necessary to omit traverse lines from plane-table sections in very congested areas in, the plains. Where traverse lines follow detail, it is permissible to shift the blue pecked line slightly, but the red dots should invariably be drawn in the correct adjusted positions of the traverse stations.

55. Survey of boundaries.—The survey of boundaries requires special care on the part of the surveyor and his supervising officers, and no plane-table section should be passed until the boundaries have been carefully checked in the field by an officer, and compared by him with the existing maps and descriptions. It is very important that the boundary should be correct with regard to local detail as well as strictly in position with regard to the graticule.

All boundary pillars should be entered either as surveyed or with the symbol indicating a pillar not found on the ground. If pillars which are shown on previous maps, or described in the written description of the boundary, cannot be found on the ground, then the camp officer must record the fact for the information of the wing in charge of the wing. Whenever the cairns are pulled down to identify pillars, they must be rebuilt at once ; no *pakka* pillar is ever to be injured for such a purpose. All pillars found must be described by their proper numbers if numbered, and their descriptions recorded in the village lists.

In the case of boundary which has already been accurately traversed or surveyed, the alignment may be taken from reductions of cadastral maps, or other accurate maps or data and accepted after surveyor has satisfied himself, by testing it at occasional points, that its geographical position is correct.

Where a boundary has not previously been accurately surveyed, all possible information should be given to the surveyor who should be told whereabouts to look for the boundary pillars and be given a general description and approximate line, based on the best information available. The boundary will then be accurately surveyed, throughout its length, where it is demarcated or where it has been ascertained, either from maps or description, or by reference to local authorities, to follow natural features ; where it follows arbitrary alignments, the local authorities must be asked to point them out to the surveyor, and if in jungle, to clear them. In the case of a difference of opinion, the alternative boundaries, as pointed out by different authorities, should be surveyed and the matter referred to the proper authority.

SECTION VI. – SURVEY AND DEPICTION OF DETAIL

It is very difficult to check a boundary unless some details beyond it are shown; therefore, whenever a watershed forms a boundary, the reverse slope should be surveyed, and the boundary line should never form the actual limit of any survey, unless it is inaccessible and nothing beyond it is visible. In the case of a river forming a boundary, both banks should invariably be surveyed.

The names of peaks, ridges, streams, etc. near the boundary, should be carefully verified, and, if found not to agree with those in the description, the matter should be reported to the GDC Director, who will, in the case of the external boundary of India, forward the report to the Boundary verification wing of International Boundary Directorate, Dehradun.

After the conclusion of the survey, it is usual to submit the alignments of boundaries to the local officials for verification. On the trace or print showing the boundary alignment, sufficient area on both sides of the boundary should be inked up in colours to facilitate reading of the detail. To help the local officials to come to a decision, relevant points only from the following notes should be incorporated in the forwarding letter : —

(i) The boundary alignment has been carefully transferred/ photographed from the plane-table surveys recently carried out in the area..

(ii) The boundary was/was not found clear and demarcated on the ground.

(iii) The boundary and pillars were surveyed as pointed to the surveyor by the local officials on the spot.

(iv) The plane-table survey was based on precise theodolite triangulation or traverse, thereby ensuring the accurate representation of the boundary in position and direction. Its position relative to the topographical detail shown on the trace/print is correct.

(v) Where official verification is effected by the comparison of the newly surveyed alignment against local records, the survey of which was not controlled by theodolite triangulation or traverse, the verifying officer should be asked to compare the detailed shape of the boundary, piece by piece, and not to consider the alignment as a whole. In cases where the boundary is described as following certain tope-graphical features, it should suffice to verify that the line surveyed does follow these features on the trace/print.

In the cases of the external boundary of India, if a discrepancy is disclosed, a trace will be prepared by the wing in charge of the field wing showing in different colours :—

(a) The line as laid down by treaty, adapted to the topographical features shown on the map.

(b) The line as shown on the older maps, if this differs from (a).

(c) The boundary as surveyed in the field.

(d) The line which the wing in charge of the field wing considers should be adopted. His opinion must be based on the description of the boundary given in the records.

This trace, with sufficient topographical details along the boundary to enable it to be checked from the records, will then be submitted through the GDC Director to the Boundary Verification wing of International Boundary Directorate, Dehradun for orders.

In the case of boundaries between states, reports will be referred to both the parties concerned.

Differences in boundaries of districts and other minor sub divisions will be referred by the GDC Director to the Local Government concerned.

All decisions which involve the alteration of the alignment of any administrative boundary on an existing map should be at once reported by the GDC Director to the Boundary Verification wing of International Boundary Directorate, Dehradun.

56. Boundary pillars.—The symbol for a boundary pillar is a solid black square ; the position of any boundary pillar not found at the time of survey should be shown in the position originally assigned to it, by an open black square, and a note be made on the plane-table section to that effect.

When a boundary pillar occupies the same position as a trigono-metrical or traverse station, or intersected point, the symbol for both should be shown.

International and State boundaries.—All boundary pillars marking the external boundary of India and boundaries of states, should be shown, and the numbers marked on them should be entered on the plane-table section. When the number happens to be in Roman figures, it is admissible, when such numbers extend to great length (e.g., LXXXVIII), to print them in Arabic figures so as to avoid interfering with detail, but the numbers in anyone plane-table section should, as far as possible, be in the same style.

Pillars on district, tahsil and minor boundaries will not be entered on 1:50,000 plane-table section, unless they are conspicuous *pakka* marks or have been used for control of survey.

Forest boundary pillars should always be shown on 1:25,000 surveys, but on smaller scales only when they are *pakka* and conspicuous.

Pillars on village Injunctions.—Pillars on village trijunctions which are conspicuous *pakka* marks or have been fixed by topographical theodolite traverse, or by cadastral traverse if this has been accepted as control, will be shown on 1:50,000 and larger scale plane-table sections. The hollow, black square already plotted (see para 54) will be filled in if the pillar is found on the ground. Village trijunction pillars, where village boundaries are not shown, will be shown by the crow's foot symbol.

57. Boundaries, how shown.—The following boundaries *are shown* in black by their appropriate symbols :— (For symbols see Instruction to Plane-tablers).

(a) The external boundary of India by Boundary International symbol.

(b) Boundaries of States and Centrally Administered Territories.

(c) Boundaries of civil districts, and *taluks, tahsils,* etc. or corresponding sub-divisions of districts.

Minor partitions of districts may be substituted for the above if asked for by Local Governments. See Chapter VI, para 148 (d).

(d) Boundaries of estates, if of sufficient importance, with the permission of Local Government, will be shown by the symbol for a *tahsil* boundary. A descriptive remark may be typed along the symbol.

(e) Boundaries of reserved and protected forests, if cleared and demarcated.

(f) Boundaries of the five frontier divisions of the North-East Frontier Agency.

(g) Boundaries of areas delimited and declared as such for Scheduled Tribes in the autonomous districts of Assam, if specially asked for by the Local Government.

The following boundaries *should not* be surveyed in the field or shown on plane-table sections, except as stated below ; when surveyed, they will be shown in black by their appropriate symbols :-

(h) Boundaries of municipalities or cantonments.

(i) Boundaries of private estates and plantations, except as laid down in (d) above.

(j) Village, *kwin*, and other similar boundaries, except when required for special editions, or when, as in parts of the country such as Kerala, where villages consist of huts or houses scattered over the area, they may be required to be shown on ordinary editions. In these cases, boundaries may be taken from cadastral maps and if necessary, checked on the ground. If Local Government should desire village boundaries on 1:50,000 maps, they must pay the whole post of preparing a special edition, oft which village boundaries will be surprinted. For 1:25,000 maps village boundaries should be shown as per SG's orders. Similarly when only a few copies are required, village boundaries may be entered by hand, and those concerned shall pay the whole cost.

(k) The inner line or any special note concerning that.

(l) Sub-divisions of the frontier divisions of the North-East Frontier Agency.

(m) The symbol for a boundary will be entered :—

(i) In its proper position, when the boundary runs along the bed of a river or stream shown by double lines, wide enough apart to admit the symbol conveniently.

(ii) Alternately on either side of a road which follows a boundary, or of a road, river, stream, etc., the centre of which forms the recognized boundary, when it cannot be conveniently shown as in (i). In this case, when the boundary symbol consists of crosses or dots in combination with bars, one cross or dot with one bar should be placed alternately on either side of the road, river, stream, etc.

(iii) Close outside and parallel to the symbol of a road, river, stream, etc. the edge of which forms the recognized boundary. The symbol will be entered on the correct side, i.e., if the boundary is along the north edge or bank, then the boundary symbol will be entered on the north side of the symbol for the road, river, stream, etc.

(n) The ordinary or undemarcated boundary symbol will be used as laid down in Chapter VI, paras 148-154.

58. Railways, tramways, etc.—All railways, tramways and mineral lines should be shown on plane-table sections by single, thick, continuous, black lines. Short lengths of double line, along a single

line of railway, should be shown by a second line drawn close to, and parallel with, the main line, but the ordinary short lengths of double line at railway stations should not be shown. Places where a double line is contracted to a single line should be drawn attention to, by a reference number and a note in the margin. Sidings and short branches should be indicated by single continuous lines in then: positions, as surveyed.

The limits of railway station enclosures will be shown, as surveyed, by a fine continuous black line, and the station buildings will be shown in vermilion. If no enclosure exists, the site of the railway station should be shown by the symbol, as given in the pamphlet "Instructions to Plane-tablers".

It is most important that straight lengths of railway should be drawn truly straight. Such lengths should not be inked up until their whole alignment is surveyed and should then be ruled throughout their length. See para 29 (ix).

When a road crosses a railway, etc. at an acute angle, the exact position of the crossing should be distinctly shown. Any case which is not provided for by these instructions should be met by a marginal note added in recess. Curves and bends along lines of railway should be carefully checked by camp officers. This is especially necessary where the curves or bends are in any way irregular, or exceptionally sharp.

Bridges, distance stones, and their numbers in connection with railways, etc. should be shown in black. Milestones and kilometre stones, should be shown in their correct positions, as surveyed, and not entered arbitrarily on one side of the line.

Care should be taken that railways in hills, and contouring, conform, so that correct gradients are maintained and the railways are correct relative to features.

59 Telegraph and electric power lines. — Electric power lines and ropeways are shown by the same symbol. When used for a ropeway, this symbol will be drawn distinctly heavier. Substations along power lines will be shown by small red -blocks and terminal " points of a ropeway will be shown by small red blocks inside black enclosures, as for railway stations. A destination should be entered for a ropeway which cuts the edge of the sheet.

Power lines will either be surveyed conventionally, or in the case of lines carried on pylons, actual spans will be surveyed if the scale permits.

60. Buildings.—Towns, villages, deserted village sites, forts, houses, and other buildings, such as churches, mosques, temples and pagodas,

will be shown by their proper symbols in vermilion.

Towns and villages should not be arbitrarily blocked in; the surveyor should endeavour to represent them as nearly as possible as they are. In the case of compact villages without gardens there is no difficulty in doing this ; but, in villages consisting of scattered huts in the midst of gardens or orchards the plane-tabler should survey the outer limits of the village sites and should draw in the huts by eye ; the sites can then either be blocked in or not, as the wing in charge may direct. In some cases the blocking is done more 01 less automatically by the house symbols becoming crowded together In all cases, care should be taken that roads and tracks which are continuous on the ground are shown as continuous on the map. When the garden land belonging to a village is of sufficient importance, its limits should be surveyed.

Towns and village sites should be filled in with a red hatching on plane-table sections in the field, with the exception of ruined villages and temporarily occupied huts, which should be left in outline, and of scattered huts, which should be blocked in with red.

Departmental and public road-side inspection bungalows and rest houses should be shown by the names by which they are known locally. The following abbreviations are authorized, and others should not be used, unless explained on the plane-table section or by a special note : CH, DB, TB, IB, RH.

Hospitals, dispensaries, markets, post offices, telephone offices police stations, etc., be shown in villages; in towns and cities. Schools should be omitted. Sites of important buildings, when shown, should be blocked in when situated inside a hatched site.

Toll-gate huts will be in red, the actual site of the gate being shown by a black line across the road, extending beyond the limits of the road on both sides, with the word “Toll” added.

The words, "in ruins", should be entered against the names of ruined towns, etc. both in the name list on the plane-table and in form 22 Topo.

61. Details to be shown in aerodromes. — (i) All details in an aerodrome will be shown as surveyed. The amount of detail to be depicted will, of course, depend on the scale of the map. On 1/:25,000 & 1/:50,000 scales, if space permits, details such as Run-ways, Taxiways, Hangars, Terminal buildings, Control Tower, Signal Base, etc. will be shown with appropriate descriptive remarks.

(ii) Details will generally be shown by the appropriate topo. symbols with the following modifications :—

(a) The perimeter will be shown by a fine continuous line or by a dotted line according as the limit is permanently fenced or not; the description about fencing should be given in colour trace.

(b) Runways with turning points as surveyed will be drawn by fine continuous lines in red. The length and width will be shown to scale subject to a minimum conventional width of 1 mm.

(c) Descriptive remarks "Aerodrome", 'Hangars' 'Control Tower', 'Signal Base', 'Quarters', ' Runway', etc., as appropriate will be entered.

(d) Terminal buildings will be designated as Air Station (Stn.).

(e) Taxiways will be shown as for roads, metalled or un-metalled according to their nature.

(f) Radio facilities and other aviation aids will *not* be shown.

62. Names and reference numbers.—All the villages, named streams, etc. on a plane-table section should be serially numbered and their names, with the corresponding numbers, entered at once in the table in the margin. The names in this table should be compared with those in the village lists, with which they should agree. All information of any importance given in the village register should be entered on the list of names on the plane-table section against items to which they refer.

Reference numbers on a plane-table section should be neatly entered in black within a blue circle, 5 mm in diameter, in such positions as not to obliterate important detail. Detail and contours should not be broken for reference numbers unless it is absolutely necessary for the sake of clearness. Reference circles and numbers should not be inked up until it *is* certain that the position will not interfere with detail.

63. Water features.—The following rules should be observed in showing water features :—

(a) Rivers & streams.—Except as laid down in (*p)* below, the banks of all rivers and streams, the courses of which are wide enough to be shown by two lines should be shown by continuous black lines, or by the appropriate symbols, see (*b)* below. If such a stream contains perennial water, then where the channel is wide enough, the perennial water should be shown by a blue wash; but, where the channel is not wide enough, the perennial water should be shown by a single continuous blue line. Except as laid down in (*p)* below, the course of all streams which are not wide enough to be shown by two lines should be

drawn by single continuous black or blue lines, according to whether the stream does not or does contain perennial water. The appropriate symbol for sand, grass, cultivation, etc., should be shown in beds of dry double-line rivers.

(b) The different types of banks of double-line streams, and junctions with tributary streams, are illustrated in the pamphlet "Instructions to Plane-tablers", and these should be carefully followed. The method of showing river banks is based on the following principles which are to be applied to streams and rivers passing through flat or undulating ground, and not to those banks which are essentially part of a hill-side and which should always be shown by fine lines :—

(i) A shelving bank of a double-line stream should be shown by a fine line.

(ii) A steep bank of double-line stream, which is less than 3 metres in height, should be shown by a fine line, but if the bank is so steep that it is impossible for country carts to go up and down at intervals of every kilometre at least, then it should be shown by a thick line, provided that this thick line can be employed for a continuous length of at least 25 mm on the published sheet.

(iii) A steep bank of a double-line stream, which is from 3 metres to 6 metres in height, should be shown by a thick line.

(iv) A steep bank of a double-line stream which is 6 metres or more in height will be shown by hachuring. For heights between 6 and 15 metres a single line representing the top of the bank will be drawn. For heights of 15 metres and over another line representing the base of the bank will be entered, with breaks as surveyed. The base line will be drawn fine, and the upper line both for heights between 6 and 15 metres and above 15 metres will be considerably finer than the lines from 3 to 6 metres in the proceeding sub-para. Hachures will be *fine*, close together, without any thickening at the upper ends, and not too regular, being thus similar to shading in a pen-and-ink sketch.

The object of the methods of showing banks outlined in sub-paras (iii) and (iv) above is to give an effect of a line of homogeneous texture and of gradually increasing width to represent increasing height. The more nearly vertical the bank the closer should be the hachures. The hachuring should not in the least resemble that for embankment and cuttings.

In cases where only one bank of an old river is discernible on the ground and is not sufficiently high or steep to be shown by hachures, the direction of slope will be in doubt. The best way to indicate this is by the use of spot heights at suitable places on the high and low ground. These need not be too close together. The depiction of such features by a form-line or one-sided ravine symbol in brown will frequently be the most suitable treatment, especially in cases where the degeneration of the original bank is considerable.

(c) It is difficult to lay down hard-and-fast rules as to how streams should be shown, but, as a general rule, all rivers, streams, channels and *nalas* should be shown, if 1 mm or over in width, by two lines, and if narrower by a single line graduated according to the length. All water-courses visible on the ground will be surveyed if the scale permits. (See para 30, sub-para 2).

A stream emerging from hills may spread out into numerous small channels, some of which are clearly visible and others not, and of which the main one varies with each spate. In such cases, bars of varying lengths (to distinguish them from unsurveyed streams) should be drawn to represent the more prominent channels, as actually surveyed. This symbol may also be used where it is important to show lines of drainage which are not sufficiently defined to be shown as streams and which are not indicated by the contours.

(d) The Survey of India is not required to make elaborate or special researches to ascertain whether there is perennial water in any particular portion of a river or stream. It will be sufficient if this is indicated as correctly as possible, in the course of survey operations, from local information. The plane-table sections should (by the dumb-bell symbol drawn in red across the river or stream) distinguish the part of the stream that contains perennial water from that which does not contain perennial water.

(e) Waterfalls and their heights, rapids, rocks, islands and weirs should be shown.

(f) Sand in rivers, streams, and on the fore-shore or sea-shore, should be drawn by black dots. Generally speaking, non-perennial portions of all river beds, if devoid of vegetation, should be shown by fine black dots (with the addition of symbols for "rock in riverbed" or "sheet rock" if appropriate). Dots should not be shown in very narrow streams or ravines. Submerged sand should be shown in blue.

Sand shown in black should be lightly shaded when it touches the low-water line of the fore-shore, the edge of the water in double-line perennial channels and where it forms the banks of depressions or non-perennial channels (except when a double-line non-perennial channel joins a creek). (See symbols in the Instructions to Plane-tablers).

(g) In the case of a dry, double-line stream joining a river, tidal or non-tidal creek, lake, tank or other tinted sheet of water, in which the blue tint either does not reach the bank, or is shown up to the bank, no line will be drawn across the mouth of the dry double-lined stream, unless a definite bank or drop is known to exist.

(h) **Lakes & tanks.**—The following may usually be taken as a useful guide in depicting the limits of lakes, tanks and ponds :—

(i) The limit, where there is no embankment nor excavation, should be shown by a fine continuous black line.

(ii) The limit, where there is an embankment or an excavation, should be shown by a thick continuous black line. The thickened lines indicating bunds should be drawn so decidedly thicker that there is no doubt what is intended.

(iii) The limit where there is an embankment which is 3 metres or more in height, should be shown by hachuring in black on the outside of the thick line, and where the outside of the embankment is very steep and its outside top edge is sharp, with a fine, continuous black line along the top of the hachuring. If the addition of this fine line would give to the symbol more space than is desirable and would cause the displacement of symbols, as would occasionally happen where a double-line road traverses an embankment, then the fine line should be omitted.

(i) The extent of perennial water in all lakes and tanks should be shown by a light blue wash within a fine continuous black line, but, where the limits of the perennial water fluctuate, or can only be entered approximately, the doubtful margin should be shown by a fine broken black line. Lakes and tanks which are undoubtedly non-perennial, should not be coloured blue, but the appropriate symbol for marsh, grass cultivation, etc., or, if devoid of cultivation, a black dotted tint, should be entered in them. Low-lying land, usually flooded for a considerable period every year, will have the words—"Usually flooded from _____to_____" entered, but will not be shown as a lake.

(j) When the water of a perennial lake or tank is found to be salt or brackish, a note to this effect should be entered against the name of such lake or tank in the name list on the plane-table section.

(k) **Marshes.**—All marshes should be shown by their proper symbol in blue. Mud should be shown by broken blue horizontal lines. Reeds in perennial water will be shown by the high grass symbol in blue.

(l) **Canal systems.**—All canals, field channels and drains which form part of a recognised canal system should be shown by their proper symbols in blue or black according to whether they are perennial or non-perennial. As a general guide, which may be freely departed from to suit local conditions, field channels and drains which are less than 2 metres in depth from the top of the bund to natural ground level, or which are less than 1500 metres in length should usually be omitted.

The term "perennial canal" is understood to mean a canal to which water can be supplied at any time during the year from the parent river. All branches of it, from the main branch to field distributaries, should be shown in blue.

Tank-fed canal systems should also be shown in blue if the supply is available during the greater part of the year.

Non-perennial or inundation canals are those which can only receive water when the river from which they take off rises above a certain flood level. The whole of such systems should be shown in black.

(i) Locks, weirs, distance stones and their distances, occurring in canal systems, should be drawn in the same colour as the canal symbols, but the names will be printed in black.

(ii) Curves and bends along canals should be carefully checked by camp officers.

(iii) Canals, of which the width of clear waterway is 20 metres or over, should be shown by fine double lines. The interval between the lines should not be less than 0 • 6 mm, but may be greater if the actual width when drawn to scale exceeds this interval.

(iv) Canals and drains, of which the width of clear waterway is less than 20 metres, are to be shown by single lines of width varying in accordance with their relative importance, the entire canal system being considered as a whole.

(v) Roads along canal embankments will not be shown, unless they are suitable for wheeled traffic. For general guidance, the following principles should be adhered to :—

Roads suitable to wheeled traffic, and avenues along canals, should be shown, but on crowded sheets the limitations of scale will necessitate the use of footnotes. The footnote should be in the following form :—

"Roads fit for wheeled traffic, and avenues of trees, exist along all main and branch canals and distributaries on this plane-table section, except (here detail any exceptions). Permission to use these roads is required from the Irrigation authorities".

Embankments along canals should, as a rule, be indicated (without the symbol) by a liberal use of relative heights, combined with a note on the plane-table section in the following form :

"Relative heights marked along canals indicate the height of the top of the canal embankment above the adjacent country".

In exceptional cases, on plane-table sections where other detail is light, the embankment symbol, as well as relative heights with footnote, may be shown.

On crowded plane-table sections, the order of omission of canal detail should be—

(a) embankments, (6) avenues, (c) roads on one side or other and (d) roads on both sides of the canal.

On most plane-tables, owing to the limitations of scales, these omissions will be necessary, either in part as a whole.

(m) **Karezes.**—*Karezes* in use should be shown by the proper symbol in blue, with the depths of shafts in metres, at intervals, in the same colour. Disused *kdrezes* and the depths of their shafts should be in black.

(n) **Pipe-lines.**—Main pipe-lines should be shown by the symbol for a *karez* in blue, with the words "Pipe-line" printed in black alongside.

(o) **Wells.**—Important wells should be shown by their appropriate symbol in blue. In arid country, every well is important and should be shown. If the water in any well shown on the section is found to be saltish or brackish, it should be noted alongside the symbol. Depths to water surface and bottom of 5 or 6 wells in a 5-minute square should be measured and entered on height trace.

(p) **Glaciers.**—Glaciers and perpetual snow are shown by green contours and their limits by green dotted lines. Crevasses and other ice forms are also shown in green, in accordance with the symbols laid down. (See Appendix IV).

(q) **Coast line & fore-shore.**—Along the coast, the line of high-water of ordinary spring tides should be surveyed as accurately as can be done with convenience, and should be shown by a continuous blue line. The approximate position of the line of low-water of ordinary spring tides should be shown by a dotted blue line. When the high-water and low-water lines are so close together that the two line cannot both be shown, only the symbol for the high-water line should be entered. As far as the tide reaches, the banks of double-line streams will be shown by continuous blue lines. If such a stream is wide enough, the perennial water should be shown by a blue wash, and the limits of the wash should be shown by fine dotted blue lines, but, where the channel is not wide enough, the perennial water should be shown by a single fine dotted line in blue.

Single-line streams passing through the fore-shore will be shown by a continuous blue line, whether perennial or not.

Important permanent features on the fore-shore will be surveyed and shown in black. For example, high banks of both classes of streams, not necessarily forming limits of water channels, and not covered by ordinary spring tides, but which form permanent features of the fore-shore, should be shown in black.

Mud on the fore-shore should be shown by broken blue horizontal lines drawn more closely together towards the low-water line.

(r) **Steamer routes.**—Routes for steamer service will be surveyed, as accurately as can be done with convenience, and will be shown by the prescribed symbol in blue, with the words "Steamer service" entered in black at suitable intervals along the symbol No symbol will be shown along single line streams, but the word. "Steamer service" will be entered along the stream, or in the border if necessary. Routes for ocean-going steamers in sea areas will not be surveyed or shown on the plane-table sections.

64. Ravines, cuttings, embankments, tunnels, etc.—The edges of ravines and broken ground should be clearly denned in black; the symbol should not, however, be drawn heavily, except in the case of ravines with steep banks 6 metres or more in height. When considered necessary, a dotted line, showing the limits of cultivation, may be drawn along the edges of ravines or broken ground.

The rule laid down for fan: mapping is that broken ground adjacent to streams and *nalas*, and their precipitous banks, will ordinarily be drawn for reproduction in black, but that, when these are intimately connected with the contouring, they will be drawn for

reproduction in brown; this should guide the surveyor in delineating features of this nature on the plane-table section.

Cuttings, embankments and tunnels should be shown in black, whether they occur on roads, paths, railways or canals, the figures denoting relative heights and depths, should be in crimson.

A line should only be shown at the top of an embankment or cutting when the top edge is sharp, and the embankment or cutting is very steep. If the addition of a line at the top gives to the symbol more space than is desirable, and this leads to the displacement of village sites or other symbols, as occasionally happens when a double-line road traverses an embankment or cutting, the line at the top should be omitted.

The following may usually be taken as useful guides in depicting embankments and cuttings in connection with roads, railways, etc. :—

(i) An embankment or cutting, which is less than 2 metres in height or depth, should not be shown.

(ii) An embankment or cutting, which is 2 metres to 3 metres in height or depth, should be shown by hachuring in black.

(iii) An embankment or cutting, which is 3 metres or more in height or depth, is very steep, and the top edge of which is sharp, should be shown with a fine continuous black line along the top of the hachuring. If the addition of this fine line would give to the symbol more space than is desirable, and would cause the displacement of village sites or other symbols, as would occasionally happen when a double-line road traverses an embankment or cutting, then the fine line should be omitted.

65. Limits of cultivation, wooded areas, etc.—The limits of cultivation (which would include all areas liable to be cultivated, but lying fallow for the time being), of defined wooded areas and of orchards and gardens, should be shown in black, by a dotted line, if open, and by a fine continuous one, if enclosed by a wall. or permanent fence ; village enclosures will be similarly shown. Where detail such as road, path, boundary, field-bund, stream or canal forms the limit of cultivation, the black dotted line should be omitted, except when considered necessary at the edge of ravines, as described above in para 64.

Where, within areas of permanent cultivation, there are numerous bits, of fallow land, and field-bunds below 2 metres in height, the following note should be entered in the reference list with a number :—

"Periodical cultivation dependent on rainfall; numerous field-bunds of less than 2 metres in height". Field-bunds of 2 metres and over in height will be shown in the usual manner. See also para 51 (c).

No attempt should be made to indicate the exact limits of areas that are cleared for temporary cultivation and revert to jungle after a few years. Such cultivation is known as *Jhum* in Assam and as *Bahi Tasa* in the Ganjam Hills. It is sufficient to show such clearings as covered with the form of jungle likely to succeed the cultivation, with the appropriate symbol.

As fine dotted lines do not always reproduce clearly on blue prints, continuous yellow lines should be entered over the limits of cultivation, where these limits are shown by dotted black lines. See para 49 (i).

Surveyors should be careful to find out from local residents whether any areas in lakes or tanks are cultivated, in order to show them as cultivated areas on plane-table sections.

The limits of military camping grounds, when demarcated, will be shown by black dotted lines.

66. Roads and paths.—The following rules should be observed when showing roads, tracks and footpaths:—

(a) All roads, tracks and paths, and their bridges, ferries and fords, will be shown by their appropriate symbols in vermilion, except recognized routes over glaciers and permanent snow which Will be in blue-green, see sub-para (i).

(b) Great care should be taken to classify .roads, tracks and paths correctly and uniformly ; when there is any doubt as to the nature of any road, a reference should be made to the R & B Department/NHAI. All information regarding classification of roads and their fitness for motor traffic, and regular transportation services such as steamer or ferry services, if any, in the area, should also be verified by a reference to the same authorities. See note para.51(j). In enclosed country, and where there are a large number obstacles, the pack-track symbol may be more freely used.

The symbols for the different classes of road shown on published maps, which are only differentiated by width of symbol and thickness of line, will not be distinguished on plane-tables. It will, therefore, be the particular duty of the camp officer to enter all information regarding classification in the chart described in para 80.

(c) All milestones or kilometre stones, should be shown in red on 1:50,000 and 1:25,000 sheets unless this seriously interferes with the

entry of more important information. Distance stones should be shown in then- correct positions, as surveyed, and not entered arbitrarily on one side of the road. All distance stones should be numbered on 1:25,000 sheets. The numbering should, however, give way to more important detail. When distance is recorded to and from two places, the numbers should be shown as a fraction, thus:— 2/14; when distance is recorded to three or more places, the numbers referring to the least important destinations may be omitted under orders of the camp officer.

Any anomalies in the numbering or distance apart of distance stones should be reported at once to the camp officer, who should make investigations with a view to such action as is necessary being taken before the surveyor leaves the ground.

(d) The pass symbol should be drawn in black at the highest point of a pass, and the height in red should be entered whenever possible.

(e) Where avenues of trees exist, they should be shown by their appropriate symbols, in black, on the side, or sides, of the roads where they occur. The distance between the tree symbols should vary with the prominence of the avenue.

(f) When a track or path is coincident with detail along which it cannot conveniently be drawn, such as a single-line, or narrow double-line, stream, or a boundary, only the symbol for the stream, etc. should be entered and that for the track or path should be omitted. When the .fact that the track or path is coincident with the detail is not sufficiently obvious, one or more arrows (for a stream pointing downstream) should be entered, in vermilion, along it, on alternate sides, and, in cases where the coincidence is lengthy, the words "Track, or path (as the case may be), follows bed, boundary, etc." may also be printed along the coincidence.

(g) When a road crosses a river by a bridge of boats, ferry or ford, the description should be entered, either in the body of the plane-table section, or in the reference table, with a reference number. If the means of crossing is only periodical, the description, should be qualified in the reference table by adding the limit of the period thus :—Bridge of boats (March to June), Ferry (March to June), etc. This information also appears on the colour trace— see para 51 (j). Causeway will be shown by its appropriate symbol. Low level bridges submerged at exceptional flood level will be shown on plane-table sections by the ordinary bridge symbol.

(h) Care should be taken that roads in hills, and contouring conform, so that gradients are maintained and the roads are correct relative to features. See para 35 (x).

(i) Recognized routes (or parts of routes which are well established) over glaciers and permanent snow will be shown by the foot-path symbol in blue-green. The symbol should be confined to areas of open ice or snow and should peter out at ice-falls, crevassed areas and over moraines, owing to the fact that in the latter, conditions vary from day to day and a selection of route has to be made on each occasion.

67. Motor transport turning points.—Turning points for motor transport specially constructed by or for the Army will be shown by the prescribed symbol and explained in a special foot-note on the plane-table section by the camp officer. The symbol will not be used for turning points or termini on motor bus routes.

68. Fire-lines—All important forest fire-lines will be surveyed and shown on topographical maps if the scale permits. The symbol will be the same as for unmetalled roads but with very short bars, in black, except where the fire-line is in regular use as a line of communication, in which case only the appropriate road or track symbol will be used.

69. Hill features.—The contours and form-lines, described in paras 34-36 should be drawn in brown.

Even in steep ground, all contours, whenever possible, should be shown as described in para 36, but, when the space between two consecutive thick contour lines is less than 2.5 mm, and where the ground slopes uniformly between them, the intermediate contours may be omitted on plane-table sections. Vertical hachuring in brown should only take the place of contours in the case of precipitous ground. Broken ground on a hill side which is not actually precipitous, should be shown by short vertical brown strokes between contours. The showing of contours in conjunction with roads and railways is referred to in paras 35 (x), 58 and 66 (h).

Bocks, rock outcrops and boulders should be shown in brown except when within river banks, or on the sea shore, when they should be in black.

Glaciers, moraines and all ice, snow, and rock features above the snow-line will be correctly surveyed, as far as the scale permits. Contours across clear ice or living moraines and in permanent snow areas will be shown in blue green (viridian) ; those across dead moraine, scree, etc., in burnt seinna. No colour wash will be used.

Brown contours should seldom be shown above the snow-line, as bare ground above this line will usually be cliff, which will be shown appropriately in brown. It must be understood that the snow-line to be

surveyed is *not* the actual limit of snow at any particular place, nor the average for that region, but the actual limit of permanent snow at the height of summer.

The method of showing rock cliffs should never be applied to ice features, i.e., the "cliff symbol" should not appear in blue. Ice cliffs or walls of ice only occur at the snouts and sites of longitudinal and hanging glaciers, and where the ice stream flows over precipitous rocks, causing a break in the continuity of the glacier. They should be shown as in the specimen in "Instructions to Plane-tablers".

The colours to be used on plane-table sections for the various high mountain features, and a glossary of terms used, are given in Appendix IV.

70. Heights.—Heights are of great importance from a military as well as from an engineering point of view.

Heights within the area of work are entered on the palne-table section as follows, and except in the case of triangulation stations and bench-marks, must always be ground heights :—

(a) Those fixed by triangulation, to one decimal of a metre, with reference numbers, in blue, before the section is handed over to the surveyor. These should be inked up in black at the same time as the contours and detail in the vicinity. Triangulated heights will be entered in black in the list of points. Where these are top heights, and ground heights are obtained by the surveyor, the latter will be entered, those accurately measured in black to one decimal of a metre, others in red to the nearest metre. The height of triangulation stations will be that of the mark-stone, and of the upper mark when there are two. In the case, however, of G.T. towers and stations on buildings only the natural ground level height will be entered, in red, whether accurately measured or not.

(b) Those fixed by theodolite traverse, to one decimal of a metre, in blue, before the section is handed over to the surveyor. Heights of permanent traverse stations and intersected points (i.e., those which are so close to permanent details, such as bridges, distance stones, conspicuous trees, etc. as not to give any plottable difference on the scale of survey) will be treated similarly to triangulated heights and will be finally inked up in black.

(c) Olinometric heights :—

(i) Selected clinometric heights, to the nearest metre, as shown on the height trace [para 52 (c)], should be recorded in crimson at

important points—see para 37. These heights should always be well-proved heights, derived from observations to or from at least two points. In high mountains, clinometric heights are liable to greater errors than in low country owing to large vertical angles, and, in the case of small scales, to longer rays. When it is found that the discrepancies between the values of heights, as determined from different points, are exceeding 5 metres on an average, all heights entered in red on the plane-table section (i.e., for inclusion on the fair sheet), should be rounded to the nearest 2 metres. These rounded values should not, however, be used for computing the heights of other points and the actual computed height should be recorded on height traces. See para 52 (c).

Other considerations being equal, accurate heights to the nearest metre, will be selected where possible in preference to rounded off heights referred to above, or those referred to in para 52 *(c)*, but a rounded off height at an important point may be more valuable than a more accurate one at an unimportant feature.

(ii) In areas, such as high mountains or intricate hills, heights may be entered in blue in suitable places to assist the checking of contouring ; in such areas the heights entered on traces are apt to be congested and difficult to read and locate on the plane-table section.

(d) Relative heights are entered by the surveyor in crimson, to the nearest metre. The method of measuring these, and points at which they are required are described in para 39. Relative heights of less than 2 metres are not usually recorded.

(e) Heights of Geodetic, secondary and tertiary benchmarks which are of permanent nature, when verified on the ground, to one decimal of a metre, in black ; those of canal, to the nearest metre, in blue; and those of other bench-marks, to the nearest metre, in crimson.

Values of Public Works and other bench-marks will only be accepted (as approximate heights) when heights would otherwise be wanting and if they do not materially disagree with Survey of India heights.

(f) Heights of waterfalls, as "Falls 38 metres" in black.

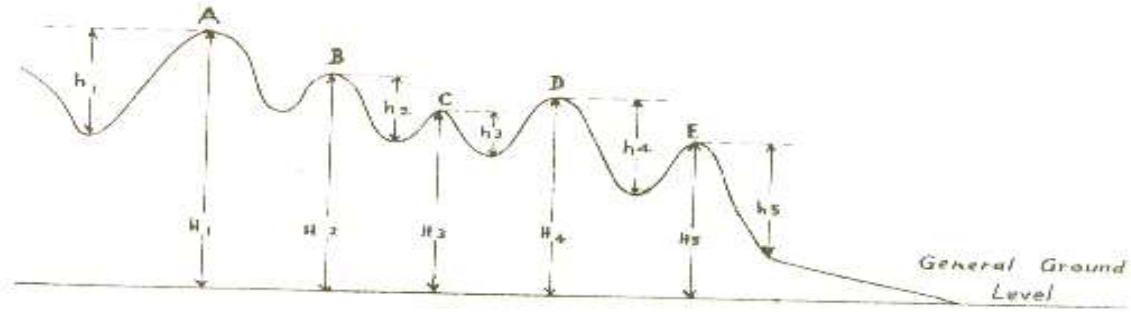
Heights outside the area of work will all be in blue, and may be top or ground heights, or both. They will be shown as indicated in the specimen plane-table section in "Instructions to Plane-tablers".

71. Surveyed trees.—Conspicuous trees should be surveyed, and drawn larger than those which are to appear on the map in green, with the red circle or dot indicating an auxiliary or intersected point. Only trees which are really conspicuous and capable of easy identification on the ground should be shown.

72. Sand-hills; shifting dunes, etc.—Sand-hills and dunes, and shifting sand-dunes will be correctly surveyed in accordance with the following principles :—

(a) (i) The ridges of the sand-hills will be depicted by brown dots. The size of the ridge dots to be inked up on the plane-table section will depend on the relative heights of the sand-dunes with respect to the general ground level. The size of the ridge dots *vis-a-vis* relative heights to the general ground level will conform to the standard ridge dot card prepared under R.S. No. 6757 HD'59(HLO). (See diagram and explanation below). Limits of sand-hills will be shown by fine brown dots 1 mm apart both on plane-table section and colour trace.

(ii) The relative heights of the sand ridges will be entered after deducing them with respect to the base of the individual sand-ridges concerned (deepest part near the ridge). (See the diagram and explanation below). Relative heights for dunes on the flanks of a series of sand-dunes or for the extremity (or end) of a dune will be measured from the nearest patch of flat-sand or area clear of sand.



The relative heights to be entered on the plane-table and height trace for the points A, B, C, etc. will be hi, h2, h3, etc. and not HI, H2, H3, etc. but the ridge dots will be inked up on the plane-table section in size of dots meant for relative heights, HI, H2 and H3, etc.

It is not necessary to give relative heights to all tops of ridges; and for the number of relative heights see sub-para g(iii).

(b) Size of dots for ridges intervening between those for which heights have been obtained will be drawn correctly in the field after estimating their heights.

(e) The biggest size dot will be for the highest place of the sand-dunes. This will be followed by dots of smaller sizes. The smallest size dots are to be used for the portion of the ridge which merges with the general level of the ground.

(d) The steep face of the sand-hill will be shown by a series of fine dots entered against the ridge dots, the smaller dots being towards the steep face, and relative height will be entered for the steep face.

(e)(i) Limits of shifting sand-dunes will be shown by fine brown dots 1 mm apart on plane-table section and colour trace with a descriptive remark on the colour trace. If, however, the areas of shifting sand-dunes are small, they may be shown as per the conventional symbol on plane-table section.

(ii) Conical tops of dunes and elevated flat-sand areas will be delineated as per the conventional symbols. Sandy bumps in areas of flat-sand will be shown by a central thickish dot surrounded by a circle of six closely drawn fine dots.

(iii) Limits of flat-sand areas as also limits of areas clear of sand will be shown by fine brown dots 1 mm apart with a descriptive remark on the colour trace. If, however, the areas of flat-sand are small, they may be shown as per the conventional symbol with the limits.

(f) Contours will not be drawn over sand-hills or dunes but will be drawn over flat-sand and where they follow the foot of a sand-hill.

(g) Other points to be kept in mind while surveying in desert or semi-desert sheets are :—

(i) Limits of sand-hills and flat-sands will be omitted both from plane-table section and colour trace where they coincide with-details, except along cultivation limits where the sand-limits will be shown on colour trace only.

(ii) Where cultivation limits follow sand ridges neither the yellow ribands nor the black dots will be drawn on the plane-table section; these limits will be depicted on colour trace only by the brown ridge dots.

(iii) In a 5'-square 25 relative heights to sand-dunes should normally be given. Of these about 50% should have spot

heights also. The remaining relative heights need not be spot-heighted. In addition, there should be 10 more separate spot heights. In case part of a 5'-square is clear of sand-dunes the number of relative and spot heights will be proportionately decreased. A relative height will be given invariably only to the highest sand-hill in a particular vicinity.

(iv) Where boundaries follow ridges, the symbol will be shown on either side in the same way as boundaries which follow detail, (the brown ridge dots being considered as detail for this purpose). Similarly cart-tracks and pack-tracks along sand-ridges should be shown by red arrows on either side of the ridge dots. The boundaries, cart-tracks and pack-tracks will, however, be correctly shown on the colour trace.

(v) Broken ground in areas of sand-dunes or shaded sand areas will be shown in brown even along stream banks.

(vi) Areas which offer any difficulty to walking are to be considered as flat-stand.

(vii) Scrub and flat-sand dots will be shown in cultivated areas where appropriate. This is a feature of desert sheets.

(viii) Flat sand dots on the P.T. section will be drawn at 2 • 6 mm apart.

(ix) Form-lines should be used in flat-sand areas to depict gradually rising raised ground. (x) Where scrub appears in areas of flat-sand, only the brown sand will be drawn on the P.T. section and a descriptive remark regarding the scrub will be entered on the colour trace, together with the necessary scrub symbols as and where appropriate.

73. Degrees of reliability of plane-tabling.—During the course of regular surveys it frequently happens that owing to inaccessibility or partial accessibility the rigorous survey of certain areas cannot be carried out such as those across the external boundary of India. In such cases the surveyor, with the assistance of previous work, if any, will sketch in as much of the inaccessible country as he can see.

The symbols to be used in order to indicate different degrees of reliability, below that of rigorous survey, are as follows :—

(a) *Drainage.* To be shown by broken lines. *Bars* to be not more than 6 mm long for main double and single-line streams and to be reduced in length at the heads of minor streams. As reliability falls off, the *breaks* to be increased in width up to a maximum of about 1.5 mm.

(b) *Communications.* Sites and other details the accuracy or existence of which is uncertain should have query marks placed against them.

(c) *Contours.*

(i) Broken thick and broken thin contours.

(ii) Fine broken form-lines.

(iii) Indication in skeleton by form-lines of tops, ridges and main spurs only.

Any of the ways showing relief given in (c) above may be used with broken line drainage or even with rigorously surveyed drainage according to circumstances. Thus (*i*) would be used when heights (based on adequate height control) can be taken freely but inaccessibility prevents local detail and hill forms being accurately surveyed. On the other hand it may be possible to survey planimetry correctly but to have no time to take heights for contouring, in which case (*ii*) would be used with continuous line streams wherever the latter have been rigorously surveyed (iii) will generally be confined to the more distant areas when only broad facts are distinguishable.

If it has not been possible to do so on the ground, the O.C. unit will in recess assess the value of surveys carried out in the circumstances described in the para, by a study of the fixings and heights, and may order correction of symbols in the plane-table section, in order to prevent undue reliability being attached to the work by reason of the optimism of the plane-tabler.

74. Mud valcanoes, etc.—Large flows of mud similar to glaciers, mud hills, and large mud craters will be correctly surveyed, as far as the scale permits. Flows should be shown by the glacier symbols in brown, hills of normal or broken contouring, and craters by the devil's cauldron symbols. The descriptive remarks 'Mud flow' and 'Mud vent' will be entered for mud flows and mud craters respectively.

Where the features of the mud hills are too small to be shown individually on the scale of survey, the pinnacles and craters may be shown conventionally by the ice pinnacle symbol in brown and by the devil's cauldron symbol also in brown respectively. These symbols will be superimposed on the broken contour symbol, and the descriptive remark 'Numerous mud vents' will be entered in the colour trace.

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SECTION VII.–ACCESSORY WORK IN THE FIELD

75. List of stations and points.—Trigonometrical stations and intersected points which are found to be wrong, should be crossed out in red in the marginal table, and completely erased from the body of the plane-table section. The computation should, however, be checked before a station or point is finally rejected. When stations or points, which have the letter "P" entered against them in the marginal table, *vide* para 21 (b), are found not to be of a fairly permanent character, the letter "P" should be crossed out in red ; and, conversely when stations and points, which have not the letter "P" entered against them in the marginal table, are found to be of a fairly permanent character, the letter "P" should be entered in red. Peaks, bench-marks, village trijunction pillars, temples and *pakka* buildings are usually, but trees are only occasionally, of a fairly permanent character. In order that all alterations may be noted in the computation volumes concerned, and that the material for the triangulation pamphlets concerned may be correctly prepared, each surveyor on his list of trigonometrical stations and intersected points on form 9 Topo., should cross out in red all the wrong stations and points, should enter or cross out in red the letter "P" where necessary, and should also enter in black or red all the additional ground level heights which he has obtained, vide para 70 (a). Surveyors should submit their forms to their camp officers, who will deal with them in accordance with para 87 (e).

76. Records.—The following records must always be kept up-to-date by the plane-tabler in the field :—

1. Village field book.
2. Colour trace.
3. Height trace.
4. Form 17 Topo (Height book).
5. Tabular forms on the plane-table section.

77. Village field books and name list.—A register of village names and other details must be kept. Form 22 Topo. is that which is usually employed, but executive officers may find it necessary to modify the form, to meet the requirements of the particular survey on which they are engaged. The register should be filled up *daily* in ink; otherwise wrong names may be inserted, and confusion may arise.

The surveyor whether conversant with English or not, should be careful to enter the place names daily in ink in the first column, in the written character with which he is most familiar, in order to get the true values of the various sounds. He should also, if possible, get the names written by the village headmen, or patwaris, in their own vernacular. The correct transliteration will be carried out, according to the rules laid

down*, either in the field, or in recess, under the orders of the wing in charge of the wing.

Place names should also be entered daily, in the table provided for the purpose on the plane-table section, either in English or the vernacular. (See para 62).

It is important that each plane-table section should be as complete in itself as possible, and not dependent on any book, tracing, etc. for any topographical information, except such as is expressed by washes and ribands of colour, or vegetation in certain areas. The village field book will be disposed of in recess in accordance with para 87 (6).

78. Other tabular forms.—It is necessary to append extra tabular forms to plane-table sections, which are usually printed on the section.

Such forms are —
Administrative index.
Index to adjoining plane-table sections.
Index showing test fixings and partals.

79. Chart to be kept up by camp officers.—Camp officers should keep up a chart of their camp areas. The object of this chart is to check and supplement information given by the surveyor. It should show :—

(a) All double-line roads mentioned in para 66 (6), all railways, with names and gauges, and whether single or double, all regular rivers and stream ferry services, and all main canal systems and whether perennial or not.

(b) All boundaries, names and areas of sub-divisions, forest reserves, and wooded areas.

(c) Administrative headquarters, important towns, and any unusual information regarding them.

(d) Inspection and other bungalows, archaeological ruins, etc.

(e) Limits of tidal flow, name and courses of steamer service routes.

(f) Large river with names, specially noting where the same river is known by different names along its course.

(g) Names of mountain ranges, of important localities, including those which are too extensive to be shown on 1:50,000 maps and the limits to which they extend, and any other information which the surveyor is not likely to have incorporated in his survey.

For disposal of charts see para 87 (p).

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* Vide instructions for spelling and transliteration of names in Section IV and Appendix B of Chapter VI.

SECTION VIII. – DUTIES OF SUPERVISING OFFICERS

80. Supplementary framework.—In difficult ground, where, in all probability, the areas allotted to surveyors are small, and where fixings and intersections may be very difficult to obtain, it may be of the utmost assistance if the camp officer, or even the wing in charge of wing, plots boards for his own use, embracing areas being surveyed by several surveyors. He can then, while on the march, fix or take rays to prominent objects and, by so doing, be able to help surveyors whom he visits. He can also plot on his board reliable points fixed by surveyors and pass them on to other and, in these ways, help to supplement the framework. This also affords a valuable means of obtaining and coordinating heights where these are difficult to obtain.

81. Partalling and checking of field work.—*A. Responsibility of wing in charge and his assistants.* The wing in charge of a field wing is responsible for the accuracy of the maps produced by his party.

He should detail a responsible officer for charge of each section or camp, who will primarily be responsible for the thorough examination of the survey of his whole area ; and this camp officer will be held personally responsible for any inaccurate work that may be discovered later on. The number of surveyors and the size of area allotted to each camp should not be greater than one officer can properly supervise. It is often advisable to give a camp or section officer one or more assistants to assist him in the supervision and instruction of the younger men.

B. Inspections by an wing in charge of field wing. The wing in charge of the field wing has too large a charge to inspect his whole area in person, but he should make every endeavour to test the work of every officer and surveyor at least once during each field season. His inspections and tests should be thorough and sufficient for purposes of:—

(a) seeing that the survey is up to the required standard of accuracy,

(b) judging the ability of the surveyor,

(c) judging the capacity of the camp officer, both as to his efficiency in checking the work, the methods he is teaching his surveyors, and the standard of accuracy he is setting.

A hurried inspection of few hours is of little value for any of the purposes here mentioned. A surveyor's work is generally most accurate where the ground is easy of access and open to good view. An inspecting officer cannot rightly judge the quality of the work till he has tested it in a difficult area.

SECTION VIII. – DUTIES OF SUPERVISING OFFICERS

To test the ability of a camp officer, the wing in charge should occasionally leave the camp officer to test or instruct a weak surveyor, and observe his methods.

To test the ability of a surveyor, and to see the methods taught by the camp officer, the wing in charge should occasionally watch a surveyor at work for a whole day, taking the opportunity to teach as occasion arises.

C. Testing a plane-table. The most rigorous methods of testing a plane-table section are :—

(a) the running of a partal line by using total station,

(b) the complete examination of a definite area from several

The most thorough examination, for a single view-point, is of little value in testing the work of a trained surveyor, for the reason that the surveyor has probably set up his plane-table at this same point during his own survey, and is just as likely to be accurate in his rays as the inspecting officer.

The most satisfactory test is one made by methods that the surveyor has not used himself, or from several view-points that the surveyor has not occupied. Similarly, when testing hill work, heights should be taken to features, for which the surveyor himself has not fixed heights.

It is particularly important to test a surveyor's work along its edge, at its junction with the work of another surveyor, and, in this case, it is useful for the inspecting officer to have a trace of the neighbouring surveyors' margins with him.

By whatever method the inspecting officer makes his tests, the first essential is to see that the triangulation or traverse framework is reliable, and that the surveyor has made good connection to it. It is, therefore, important to commence inspection, either from a trigonometrical or traverse station, or from a point where several triangulated points are visible. Throughout his inspection, the inspecting officer should avoid making test fixings from the surveyor's own auxiliary points, and should subject these auxiliary points to severe independent check.

The surveyor should explain how he intends to locate his position and orient his board, and should then do so to the satisfaction of the inspecting officer. The inspecting officer should then examine the work, so far as is possible, from that spot, and decide on his plan of inspection, after studying the ground ; and settle what parts of the plane-table survey he would like to examine closer.

He may elect to run a direct line using total station through a certain area to certain definite points, or else to make a series of plane-tabling fixings with some definite objective.

The standard of accuracy to be set is, that the inspecting officer should be unable to correct the position or shape of any object that is clearly visible on the ground, and is of sufficient importance to be shown on the scale of survey.

D. Details of an officer's inspection. The following list of points should be of value to an officer inspecting a plane-table ; the answer to all questions should be satisfied by personal examination:—

(a) *Preliminary inspection of plane-table.*

(i) Is the plane-table section neat and clean, and inked up-to-date?

(ii) Is the outturn satisfactory for the nature of ground and skill of surveyor ?

(iii) Has the surveyor any special difficulties ?

(iv) Are the symbols correctly used, and is all accessory work on the section correctly shown ?

(v) Are colour and height traces and village lists up-to-date and correctly kept ?

(vi) Have sufficient heights been taken for the control of contouring and have heights been taken at suitable points for inclusion on the map ? (See para 37).

Are the height observations properly recorded in the height book, accurately worked out, and in mutual accordance ?

(vii) Have names been attested by local authorities or camp officer ?

(viii) Are all instruments in good order and is the clinometer in adjustment ?

(ix) What previous inspections have been made, at what points was the plane-table set up by the examining officer, and are his recorded remarks satisfactory ?

(x) From what fixed point did the surveyor commence work; and has he found all other fixed points in agreement ?

(xi) Has the surveyor made any supplementary fixed points of his own ? And in what direction did he work ?

(b) *Testing of work.* Commence at a fixed station, or a point where several triangulated stations and points are visible:

(i) Does the surveyor set up his board speedily, and by correct methods ?

It is a good test to make him set up without his compass.

(ii) Is the board correctly oriented ? Do all triangulated or other fixed points cut correctly ?

(iii) Watch the surveyor observe with clinometer and work out the height of the fixing. Are his methods sound, and results accurate ?

(iv) Does the height observed agree with surveyor's previous value and with his contours ?

(v) Test the surveyor's work visible from the fixing :—

(a) by sight-rule ray, or

(b) by total station measure, and

(c) by clinometer.

Distinguish between discrepancies that are clear, and can be corrected at once, and those that are uncertain, and must be checked from another position.

(vi) Besides testing detail for exact position and height, see that the surveyor shows the character and form of the ground, and uses his symbols correctly. See that the character of vegetation is correctly shown, both on the plane-table and the trace, as regards nature and density.

(vii) Before now moving to another fixing, decide whether to measure the line. If the ground is suitable, this is by far the best test of accuracy. A prominent point, at suitable distance, should be pointed out, and a ray to it marked on the plane-table. The total station can be used to measure the line, and keep a record of all objects crossed by the line. Set up the plane-table at any point along the line ; orient the board by compass or back ray; plot position by distance measured by total station; check position by sight-rule rays to any points that may be visible; and check position of detail either by distances given by total station or by sight-rule rays.

It is undesirable to carry on a test line for a long distance

without an intermediate setting of the plane-table; otherwise, when the closing point is reached:, it may be too far to go back and investigate a discrepancy disclosed by the test.

The test by total station may be continued until a reliable point is reached on which the line is closed.

(viii) If the ground is suitable for "total station line of sight", move to another point, where a reliable interpolation can be made, and where a closer view can be got of any detail that appeared doubtful from the first fixing.

When moving from one point to another, stop and compare the plane-table with the ground at frequent intervals. The ease with which position can be identified without instruments, is a very good criterion of the accuracy of the survey.

E. Record of inspection and correction of bad work. Before leaving the surveyor, the inspecting officer should mark up his inspection fixings or partal lines on the plane-table, and write the brief report on the result of his inspection.

This report should be written neatly in ink by the inspecting officer himself, and signed and dated by him ; it is very important that it should be preserved as a permanent record. It should on no account be written in pencil to be inked up by the surveyor.

If a surveyor's work is found inaccurate, the inspecting officer must record the orders that he gives for its proper revision.

The inaccuracies may be of a petty nature and the corrections made by the inspecting officer, sufficient.

The surveyor may be ordered to go over his work again, either over the whole of it, or over certain definite areas ; hi this case, it is very important that the work shall be examined a second time.

It may be necessary to get in another surveyor to revise the faulty areas, or it may be necessary to reject the work altogether, and have it resurveyed on another board.

In cases where revision of the work is necessary, the examining officer should take a trace of the faulty work, before he leaves the surveyor. This trace will be compared with the work as finally revised, and will be an evidence of the surveyor's inaccuracy.

82. Responsibility of survey.—The surveyor will turn out good and thoroughly reliable work both in quality and quantity.

SECTION VIII. – DUTIES OF SUPERVISING OFFICERS

83. Erasing inaccurate work.—With the present system of drawing in colours, and photographing the plane-table sections, it is essential that these should be clearly and correctly drawn. It is thus necessary to allow examining officers to make erasures; the officer who examines the work should, therefore, when he finds errors in any part of it, erase the errors, and correct each item hi its proper colour on the plane-table section.

After the survey of the plane-table section has been completed and it has been brought to recess quarters, no additions or corrections may be made in the body of the plane-table section, *vide* para 27 "Corrections during publication" in Section I of Chap. VI.

84. Plane-table edges.—When edges of newly surveyed plane-table sections are found not to agree with adjoining work, previously surveyed and mapped, they should be carefully examined by the wing in charge of the field wing or camp, who should erase any erroneous work, and make the necessary corrections on the plane-table sections. If the new work is correct, the examining officer should make a note to that effect against the edge examined, and no adjustment should be made on the plane-table section to suit the previous work.

Such discrepancies are due to the following causes :—

(a) Errors in survey of the existing published sheet.

(b) Changes in natural detail; usually they are confined to the shifting of the main river beds.

(c) New artificial detail, including changes in the alignment of roads, railways and boundaries.

They should be corrected respectively in accordance with the following principles :—

(a) The errors in the existing published sheet should be corrected on the ground, entirely, if they are of small extent, otherwise up to a reasonable distance, so as to avoid arbitrary adjustments as much as possible, especially the introduction of curves in straight railways or roads.

(b) If the changes in natural detail extend only a short distance into the old sheet, they should be surveyed on the ground. If, however, the whole of the changed detail cannot conveniently be surveyed, it should not be surveyed at all, and the edge should remain unadjusted.

(c) Normally new artificial detail will only be surveyed into the old sheet, if it terminates within a short distance of the edge.

When a surveyor finds errors and changes of the above types on his margin extending into an old sheet, he should at once ask for instruction from his camp officer as to how far he is to carry the revision of the detail into old sheet.

If there is a likelihood of the revision of the old sheet being taken up in the near future, it would be unnecessary to do any adjustment survey in the old sheet at all, and the camp officer will inform the surveyor accordingly. If, however, the old sheet is not likely to be revised at an early date, the camp officer will issue instructions to the surveyor in accordance with the principles given above, as the case may demand, so that any necessary corrections may be carried out by the surveyor, before he leaves his ground.

At the same time, the camp officer should send the wing in charge of the field wing a report, accompanied by a trace, showing to what extent he proposes making corrections, and asking whether any further corrections are necessary. On receipt of this report, the wing in charge of the field wing may issue final orders, or, hi case of doubt, refer the question, with the trace, to the GDC Director for decision.

All edges and overlaps of plane-table sections and colour traces which have been surveyed from two sides, but have not been mapped, must be compared during the field season, all discrepancies being examined and corrections made before leaving the field by the camp officer, who should enter, sign and date, along each edge the following remarks "edge adjusted and corrected in the field" ; arbitrary adjustments in connection with these edges, when the fair maps are being drawn, will thus be avoided. Correct work should, however, never be altered to conform to incorrect work.

It is advisable for camp officers to make tracings of all rejected work and of its correction.

85. Inspection of G.T. Stations, etc.—Executive officers or responsible assistants, should inspect all G.T. and other protected stations and primary protected bench-marks falling within the area of their work and enter remarks thereon in their note-books. A return giving this information, should, at the commencement of the recess season, be submitted by the wing in charge of the field wing, to the Director, Geodetic and Research Branch.

Attention is also called to Chapter III, para 37 (5th Edition).

SECTION IX. – FINAL ACCESSORY WORK

86. Before sending for photography.—Before plane-table sections are sent for photography, they will be finally scrutinized by camp officers who will see that all the line work is clear and suitable for photography and that the sections are complete and correct in every respect.

87. In recess.—Before the original plane-table sections and colour and height traces are sent to the Director, for record, they must be signed and dated in the right hand bottom corner, by the wing In-charge of the field wing responsible for the mapping of the fair sheet, as indicating that they are complete in every respect and that the following details and all other orders have been attended to. The Wing In-charge of the field wing responsible for the field surveys must sign and date form 0.144 and see that all other signatures on that form, indicating responsibility for different items, have been correctly signed and dated, and in his absence, his full name, designation and date when handing over charge should be clearly typed at the bottom of the form.

(a) No names or descriptive remarks will be entered on the face of a plane-table section, but reference numbers will be entered in black within a blue circle 5 mm in diameter, and abbreviations, such as PO, PS, etc. which refer to particular buildings will also be entered in the body of the plane-table, when space permits.

(b) Names must be hand-printed or typed in the marginal reference table in accordance with the finally accepted spelling. The name list on the plane-table section must then be signed and dated by the section officer under the following entry:— "Spelling of names compared, and found to agree with the corrected spelling in the village field book". The names given in the Gazetteer of the Indian Union (the old Imperial Gazetteer) should be underlined in red in the name list on the plane-table section and the village list and a note to this effect given at the bottom of the lists.

The village field books will be sent for record to the Director, together with the fair sheets and other records.

(c) Trigonometrical and other heights, as entered on the plane-table section should be checked and corrected, if necessary.

(d) The heights of bench-marks of the net-work of spirit-levelling are in slightly different terms to triangulation. Triangulation pamphlets show the area in which no adjustment of the G.T. heights to the spirit-levelled heights has been made. On all plane-table sections, containing such areas as well as bench-marks, the following foot-note should be made :—

"The triangulated heights (and contours) on this plane-table have not been adjusted to the heights of the spirit-levelled bench-marks and may not be strictly in accordance with them".

(e) Camp officers should compile from form 9 Topo. as submitted by plane-tablers, *vide* para 75, all necessary information on their own list of trigonometrical points on that form and submit the letter to the wing in charge who will arrange for all the alterations being at once noted in the computation volumes concerned, and for the forms being carefully filed, for reference when the material for the triangulation pamphlets concerned is being prepared.

(f) The note regarding edge where the section joins on to inaccurate work should be entered in accordance with para 84.

(g) Blue washes will be applied to perennial water areas by an experienced colourist, from the information of the colour trace.

(h) The broken green line, entered on the colour trace to indicate the area within which vegetation symbols have been omitted from the plane-table section, will be completed, see para 49 (j), and a remark made on the section as to ffie area within which vegetation will be taken from its colour trace.

(i) The symbols employed on the survey should conform, both in drawing and colouring, to those laid down, but in every survey there may be need for the use of other symbols, to represent information not otherwise provided for; a reference to any symbol, not specially provided for, must be made in the margin of the plane-table section in which it is used.

(j) Attention is drawn to "Photographic enlargements or reductions" in Section II and "Storage of plane-table sections" in Section XIV of Chapter VI (9th Edition, 1962).

(k) Remarks on boundaries, etc. which will help the writing up of the history sheet, should be entered by the camp officer as foot-notes, in black, on the plane-table section. The places from and to which roads and steamer service routes, which out the edge of the section, lead, should be typed or hand-printed within the border.

(l) The paper is never to be detached from the cloth on • which it has been mounted. The size of all the sheets should be nearly equal, allowing for the removal of the dirty edge. As a further protection, the edges must be bound with ribbon, as soon as possible after the sections are cut off the board.

(m) A border must be drawn round the graticule in accordance with the border specimen for topographical maps on metric system; size to be reduced by one-third, the figures for the latitudes and longitudes to be carefully hand-printed, or typed. The border may be broken, to avoid interfering with the marginal reference tables, or be offset, when the survey has, for any reason, been extended beyond the edge of the normal section area. It should include the whole area of the sheet if possible even if only a portion has been surveyed. If for any reason it cannot be so completed, as much of it as possible should be drawn in its correct position according to sheet limits. The headings should conform to the most recent specimens.

(n) Boundary ribands will be entered on colour traces in accordance with para 88. No boundary ribands will be entered on plane-table sections except the fine green and yellow lines for reserved forest and cultivation limits respectively.

(o) The gauge of railways, and whether the line is single or double should be confirmed from the History of Indian Railways and entered, either typed or neatly hand-written.

(p) To ensure that such information is not lost sight of in the preparation of smaller scale maps, charts kept up by the camp officers should be submitted to the GDC Director with the fair sheet, when they contain information that should be recorded on the Office Copies, or sheet files, of the small scale maps affected. See para 79.

(q) Plane-table sections will be numbered by degree sheets according to the system described below. This system, which is of universal application, indicates the geographical position of the *centre of the work* on the section to the nearest minute (tenth of a minute on scales larger than 1:25,000), the season of survey and the scale, and is as follows :—

(i) The India & Adjacent Countries and International numbers of the degree sheet, in which the work falls, will first be shown (bracketed together), the former appearing above the latter thus:—

54 H
H 43 X

(ii) The co-ordinates of the centre of the work on the section will then be shown to the nearest minute of longitude and latitude (tenth of a minute on scales larger than 1 : 25,000). Longitude

will come first and the two values will be separated by a dash, thus 59-01 (or 59-3-01-2).

$$\left.\begin{matrix}53\ H\\ H\ 43\ X\end{matrix}\right\} 59 - 01 / 62 / 1 : 50{,}000.$$

88. Boundary ribands.—The following will be the widths of boundary ribands when these boundaries are coloured :—

(a)	External of India or international, two ribands, each .	.. .. 2.0 mm
(b)	State, two ribands, each	.. .. 1.5 mm
(c)	Districts, including frontier divisions of the North-East Frontier Agency, two ribands, each	.. .. 1.0 mm
(d)	Taluks, or similar boundaries for which tahsil boundary is used, total width	.. .. 1.0 mm
(e)	Exterior boundary of areas of reserved, and protected forests, total width	.. .. 0.5 mm

An exterior boundary of areas of reserved, or protected, forests is the boundary which separates reserved, or protected, forests from other land, and the narrow green riband will therefore be entered round exclusions, but will not be entered along the common boundary between two reserved, or protected, forests ; except when the boundary is between forests of contiguous states.

No riband should be superimposed on another riband, and the following rules should be adhered to :—

(i) A green forest riband should always be entered on the inside of the boundary symbol.

(ii) Any other single riband should be entered on its boundary symbol, i.e., with the boundary symbol in the centre of the riband, but, if it would coincide with one of the ribands mentioned in (i), then the other single riband should be entered on the opposite side of its symbol.

(iii) Each component riband of a double riband should be entered on the inside of its boundary symbol, i.e., with boundary symbol between the two ribands, but, if it would coincide with the riband mentioned in (i), then the component riband should be entered on the inside of the riband mentioned in (i).

SECTION IX. – FINAL ACCESSORY WORK

Light colours should be used for boundary ribands, especially in the wider ribands, to avoid obscuring detail.

When double or single ribands are necessary along a boundary in the bed of a river, it is permissible to enter a riband on each bank in the former case, and on either bank in the latter case, if the character of the river would be obscured by placing the ribands or riband along the boundary symbol.

The broken riband along the undemarcated boundary symbol will have each space the length of one bar and a cross of the symbol, and each bar of colour will be twice that length.

In the case of a town or village site close to the boundary, the riband should not be coloured over the blocks,

In the case of the external boundary of India, the riband on the Indian side will always be orange. The Indian State boundary riband, being of a different colour, will stop at the external boundary of India.

PLANE-TABLING

IN INDIA		***Colour Ribands***
Andaman & Nicobar Islands	…	Pink
Andhra Pradesh	…	Burnt Sienna
Arunachal Pradesh	…	Pink
Assam	…	Indigo
Bihar	…	Burnt Sienna
Chandigarh	…	Pink
Chattisgarh	…	Jaba Red
Dadra & Nagar Haveli	…	Pink
Daman & Diu	…	Pink
Delhi	…	Pink
Goa	…	Pink
Gujarat	…	Burnt Sienna
Haryana	…	Bluish Purple
Himahcal Pradesh	…	Jaba Red
Jammu & Kashmir	…	Indigo
Jharkhand	…	Burnt Sienna
Karnataka	…	BluishPurple
Kerala	…	Indigo
Lakshadweep	…	Pink
Madhya Pradesh	…	Bluish Purple
Maharashtra	…	Reddish Purple
Manipur	…	Golden Yellow
Meghalaya	…	Burnt Sienna
Mizoram	…	Pink
Nagaland	…	Bluish Purple
Orissa	…	Indigo
Pondicherry	…	Pink
Punjab	…	Burnt Sienna
Rajasthan	…	Indigo
Sikkim	…	PrimeroseYellow
Tamilnadu	…	Reddish Purple
Tripura	…	Golden Yellow
Utttarakhand	…	Burnt Sienna
Uttar Pradesh	…	Reddish Purple
West Bengal	…	Reddish Purple

OUTSIDE INDIA

Afghanistan	…	Light blue
Bangladesh	…	Jaba Red
Bhutan	…	Primerose Yellow
Burma	…	Burnt Sienna
China	…	Bluish purple
Nepal	…	Indigo
Pakistan	…	Green Viridian
Srilanka	…	Reddish purple
USSR	…	Reddish purple

APPENDIX I

PLATE I

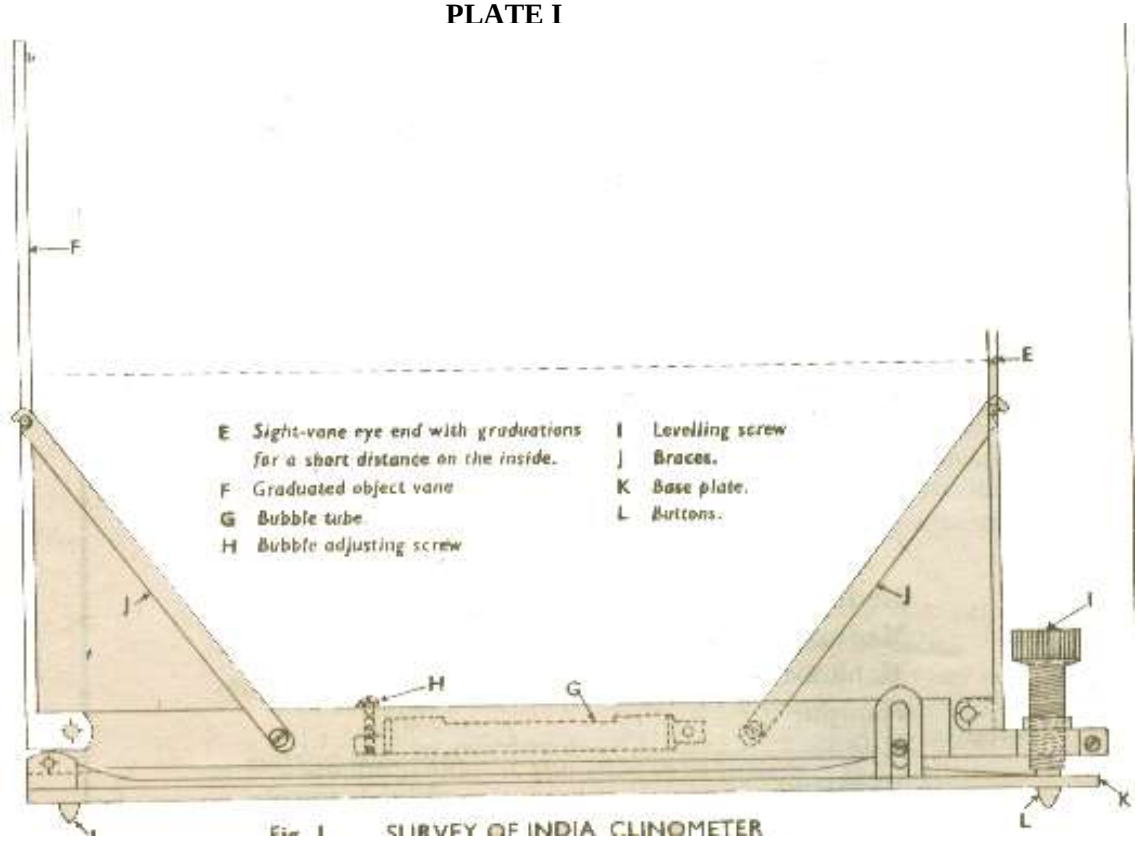


Fig. 1 SURVEY OF INDIA CLINOMETER

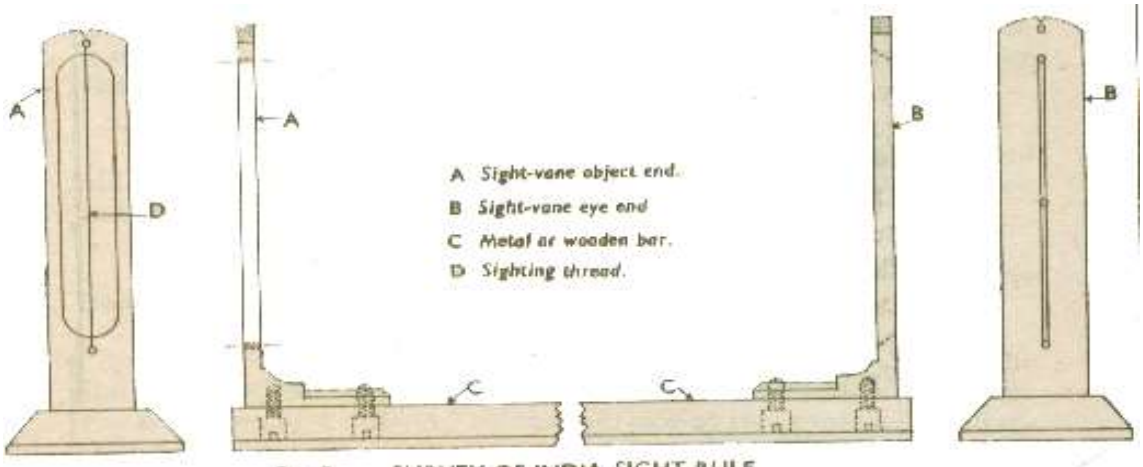


Fig. 2 SURVEY OF INDIA SIGHT-RULE

APPENDIX I

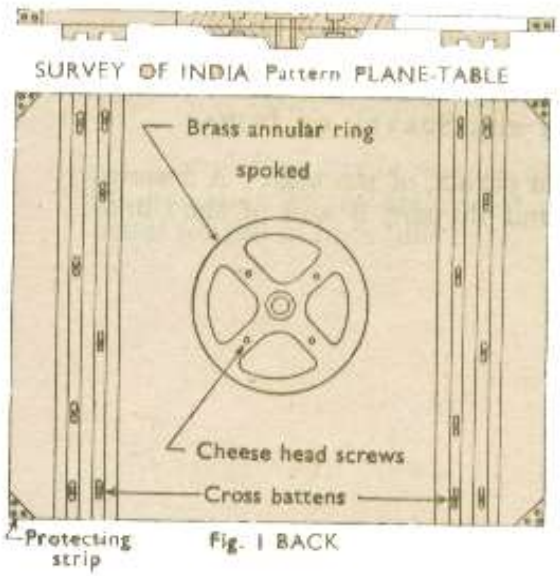


Fig. 1 BACK

PLATE II

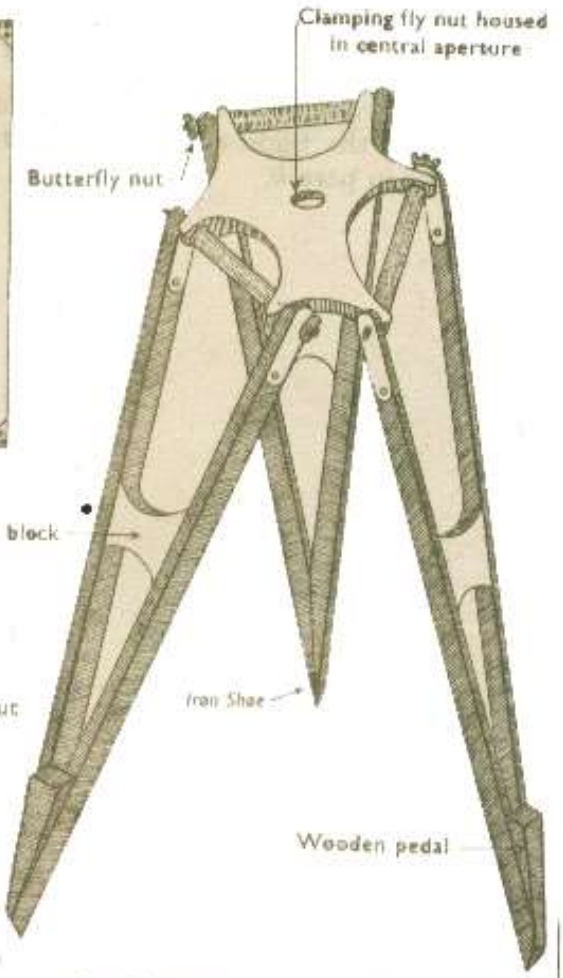


Fig. 3 TYPICAL PLANE-TABLE STAND

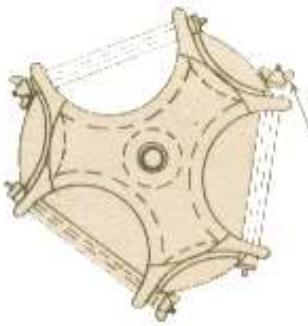


Fig. 4 TYPICAL CLAMPING HEAD

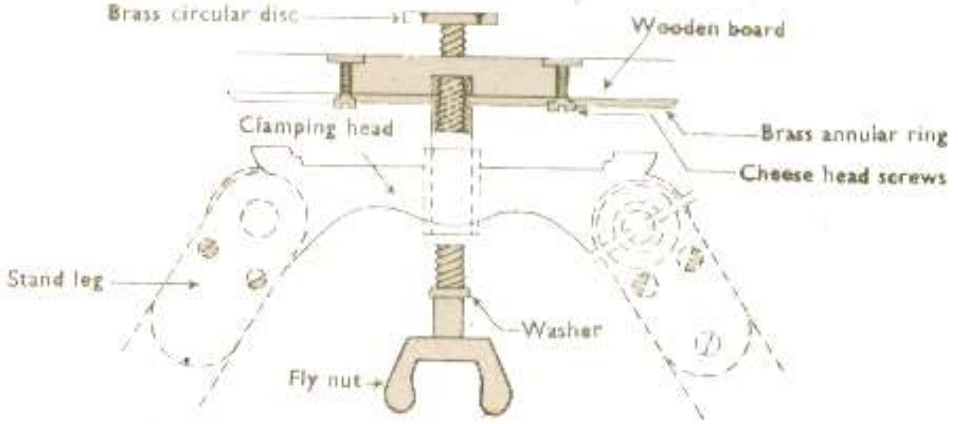


Fig .2 CLAMPING ASSEMBLY

APPENDIX I

ILLUSTRATION OF THE CLINOMTER, SIGHT-BLUE AND PLANE-TABLE IN GENERAL USE IN THE SURVEY OF INDIA

The Plane-table is described in para 2 of the text. A description of the Sight-rule will be found in para 3 and of the Clinometer in para 6.

APPENDIX II

COMPUTATION OF CLINOMETRIC HEIGHTS

Corrections for curvature and refraction for use in determining heights with the clinometer are given in Tables A & B, Table B being for use in high hills only.

APPENDIX II

Table A. – Clinometric Heights – Correction for Curvature and Refraction to Heights observed with the Clinometer

Dis-tances in Meters	Coefficient of Refraction 0.07										
	0	100	200	300	400	500	600	700	800	900	1,000
	Corrections in Metres										
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
1,000	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.3
2,000	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.6
3,000	0.6	0.7	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1
4,000	1.1	1.1	1.2	1.3	1.3	1.4	1.4	1.5	1.6	1.6	1.7
5,000	1.7	1.8	1.8	1.9	2.0	2.0	2.1	2.2	2.3	2.4	2.4
6,000	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.0	3.1	3.2	3.3
7,000	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3
8,000	4.3	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.3	5.4	5.5
9,000	5.5	5.6	5.7	5.9	6.0	6.1	6.3	6.4	6.5	6.6	6.8
10,000	6.8	6.9	7.1	7.2	7.3	7.5	7.6	7.8	7.9	8.1	8.2
11,000	8.2	8.4	8.5	8.7	8.8	9.0	9.1	9.3	9.4	9.6	9.8
12,000	9.8	9.9	10.1	10.3	10.4	10.6	10.8	10.9	11.1	11.3	11.5
13,000	11.5	11.6	11.8	12.0	12.2	12.4	12.5	12.7	12.9	13.1	13.3
14,000	13.3	13.5	13.7	13.9	14.1	14.3	14.5	14.7	14.9	15.1	15.3
15,000	15.3	15.5	15.7	15.9	16.1	16.3	16.5	16.7	16.9	17.1	17.4
16,000	17.4	17.6	17.8	18.0	18.2	18.5	18.7	18.9	19.1	19.4	19.6
17,000	19.6	19.8	22.5	20.3	20.5	20.8	21.0	21.2	21.5	21.7	22.0
18,000	22.0	22.2	22.2	22.7	23.0	23.2	23.5	23.7	24.0	24.2	24.5
19,000	24.5	24.7	24.7	25.3	25.5	25.8	26.0	26.3	26.6	26.9	27.1
20,000	27.1	27.4	27.4	27.9	28.2	28.5	28.8	29.1	29.3	29.6	29.9

Note :- For distances exceeding 21,000 meters, obtain correction for half the distance and multiply by 4, to get the value.

Example :- Correction for 37,500 meters =
(Tabular quantity for 18,750) x 4
= 23.8 x 4 = 95.2 meters.

APPENDIX II

Table B. – Clinometric Heights – Correction for Curvature and Refraction to Heights observed with the Clinometer (For use in high hills only)

Dis-tances in Meters	Coefficient of Refraction 0.06 Average elevation of region 3,000 to 5,000 meters										
	0	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1,000**
	Correction in Metres										
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
1,000	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.3
2,000	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.6
3,000	0.6	0.7	0.7	0.8	0.8	0.8	0.9	1.0	1.0	1.1	1.1
4,000	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.6	1.7	1.7
5,000	1.7	1.8	1.9	2.0	2.0	2.1	2.2	2.3	2.3	2.4	2.5
6,000	2.5	2.6	2.7	2.8	2.8	2.9	3.0	3.1	3.2	3.3	3.4
7,000	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4
8,000	4.4	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.4	5.5	5.6
9,000	5.6	5.7	5.9	6.0	6.1	6.3	6.4	6.5	6.7	6.8	6.9
10,000	6.9	7.1	7.2	7.4	7.5	7.7	7.8	7.9	8.1	8.2	8.4
11,000	8.4	8.5	8.7	8.9	9.0	9.2	9.3	9.5	9.7	9.8	10.0
12,000	10.0	10.2	10.3	10.5	10.7	10.8	11.0	11.2	11.4	11.5	11.7
13,000	11.7	11.9	12.1	12.3	12.5	12.6	12.8	13.0	13.2	13.4	13.6
14,000	13.6	13.8	14.0	14.2	14.4	14.6	14.8	15.0	15.2	15.4	15.6
15,000	15.6	15.8	16.0	16.2	16.6	16.7	16.9	17.0	17.3	17.5	17.8
16,000	17.8	18.0	18.2	18.4	18.7	18.9	19.1	19.4	19.6	19.8	20.0
17,000	20.0	20.3	20.5	20.8	21.0	21.2	21.5	21.7	22.0	22.2	22.5
18,000	22.5	22.7	23.0	23.2	23.5	23.7	24.0	24.3	24.5	24.8	25.0
19,000	25.0	25.3	25.6	25.8	26.1	26.4	26.7	26.2	27.2	27.5	27.8
20,000	27.8	28.0	28.3	28.6	29.2	28.2	29.4	30.7	30.3	30.3	30.6

(Contd…)

Note :- For distances exceeding 21,000 meters, obtain correction for half the distance and multiply by 4, to get the value.
Example :- Correction for 37,500 meters =
(Tabular quantity for 18,750) x 4 = 24.4 x 4 = 97.6 meters.

APPENDIX II

Table B. – Clinometric Heights – Correction for Curvature and Refraction to Heights observed with the Clinometer (For use in high hills only) – (Contd...)

Dis-tances in Meters	Coefficient of Refraction 0.05 Average elevation of region 5,000 to 7,000 meters										
	0	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1,000**
	Correction in Metres										
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
1,000	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3
2,000	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.6	0.6	0.6
3,000	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1
4,000	1.1	1.2	1.2	1.3	1.3	1.4	1.5	1.6	1.6	1.7	1.8
5,000	1.8	1.8	1.9	2.0	2.1	2.2	2.2	2.3	2.4	2.5	2.6
6,000	2.6	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5
7,000	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5
8,000	4.5	4.7	4.8	4.9	5.0	5.1	5.3	5.4	5.5	5.6	5.8
9,000	5.8	5.9	6.0	6.1	6.3	6.4	6.5	6.7	6.8	7.0	7.1
10,000	7.1	7.2	7.4	7.5	7.7	7.8	8.0	8.1	8.3	8.4	8.6
11,000	8.6	8.7	8.9	9.0	9.2	9.4	9.5	9.7	9.9	10.1	10.2
12,000	10.2	10.4	10.6	10.7	10.9	11.1	11.3	11.4	11.6	11.8	12.0
13,000	12.0	12.2	12.4	12.6	12.7	12.9	13.1	13.3	13.5	13.7	13.9
14,000	13.9	14.1	14.3	14.5	14.7	14.9	15.1	15.3	15.5	15.8	16.0
15,000	16.0	16.2	16.4	16.6	16.8	17.0	17.3	17.5	17.7	17.9	18.2
16,000	18.2	18.4	18.6	18.9	19.1	19.3	19.6	19.8	20.0	20.3	20.5
17,000	20.5	20.7	21.0	21.0	21.5	21.7	22.0	22.2	22.5	22.7	23.0
18,000	23.0	23.2	23.5	23.8	24.0	24.3	24.5	24.8	25.1	25.3	25.6
19,000	25.6	25.9	26.2	26.4	26.7	27.0	27.3	27.5	27.8	28.1	28.4
20,000	28.4	28.7	29.0	29.2	29.5	29.8	30.1	30.4	30.7	31.0	31.3

Note :- For distances exceeding 21,000 meters, obtain correction for half the distance and multiply by 4, to get the value.
Example :- Correction for 37,500 meters =
(Tabular quantity for 18,750) x 4 = 25.0 x 4 = 100.0 meters.

APPENDIX II

1. The *clinometer reading* gives us the tangent of the angle of elevation or depression to an outside point, and is given a + sign for elevations, and a — sign for depressions. A reading of + .100 means that the line of sight rises one tenth of a metre for each metre of distance from the instrument.

Therefore, to get the *observed difference of height* in metres, we must multiply the clinometer reading by the distance of the object in metres.

The clinometer height indicator card enables one to do this multiplication automatically, by opening a pair of dividers to the known distance and applying it to the part of the card which corresponds with the known clinometer reading, when the observed difference of height may be read off.

To get the *true difference of height* we have to make two small corrections as follows :—

2. *Correction for curvature and refraction.*

The *curvature* of the earth always *lowers* a distant object; as may be easily seen by drawing a rough section of the curved earth, with the observer at the highest point of the curve.

The *refraction* of the air, on the other hand, always *raises* a distant object, but its mean effect is *always less* than the effect of curvature.

Thus the effect of *curvature and refraction combined* is always *to lower* the distant object. We may therefore call this combined correction the "curvature" correction for the sake of brevity.

The envelope in which the height indicator card is kept has a special scale which shows the amount of this combined correction in metres for any given distance on the plane-table. Its amount varies as the square of the distance; so that if the scale is not long enough, we can take half the distance and multiply the result by four. "

If we have no special scale, the amount of this correction in metres may be got by taking *one-fifteenth (correct factor is 0.0676) of the square of the distance in kilometres.* Thus if the distance in kilometres is 7.2, the square of this is 51.84 and 1/15 of 51.84 = 3.5 metres, which is the required amount of the correction.

Sign.—Having thus found how much the distant object is lowered by curvature, we must *raise* it up by the same amount to get its true height; that is to say our correction must *increase* on observed *elevation,* or *decrease* the amount of an observed *depression,* and, since we call our elevations + and our depression —, it will be seen that our correction must be *always* +.

APPENDIX II

3. *Correction for height of instrument.*—This is equal to the height in metres of the eye-hole of the clinometer above the ground level of our fixing.

In plane-tabling, it may nearly *always be called* 1-2 metres. Commonsense will show the rare cases where 1-2 metres is not sufficiently correct, and some other figure must be used instead.

Now this 1.2 metres raises us amongst our surroundings, and therefore makes *distant objects seem lower* than if we were observing from the ground ; we must therefore apply this correction so as to *raise* the distant object by 1.2 metres; so its *sign,* like the curvature correction, must be *always* +.

4. *Summary.*—We thus see that our two corrections always have the same sign, namely + ; one is the curvature correction, which varies from about 1 metre at 4 kilometres distance to 27 metres at 20 kilometres distance, and £he other is the instrument correction which is practically always 1.2 metres.

It is quite easy to add 1.2 to the curvature correction in one's head and the form 17 Topo. provides for these two items being written down at once, as " + curvature correction + 1.2 ", instead of separately. That is, if the curvature correction is 3-5, we would just write down + 4.7. It must always be remembered, however, that this -f- 1.2 represents the height of the instrument, and that when this is seriously different from 1.2 the true height must be substituted instead of 1.2 and a note made to that effect.

We thus get only one combined correction which has to be applied to the observed difference of height in order to get the true difference of height, and its sign is always plus.

5. The rules for signs in working a height computation are therefore as follows :—

Elevations+, or depressions –, and combined correction always +.

The algebraical sum of the above gives the *true difference of height,* which is applied to the *known height,* with sign unchanged when the height of fixing is known arid we want an outside height, and with sign reversed when the outside height is known and we are computing the height of fixing.

APPENDIX II

Examples

			(a)	(b)
Depression	..	..	–86.3	–0.9
Combined correction	..	..	+2.1	+1.8
True difference of height	..	..	–84.2	+0.9

therefore, in example (*a)*, if the known height is at the fixing, *subtract* 84.2 *to get the outside height;* or, if the known height is outside, change sign and *add* 84.2 *to get height affixing.*

6. This simple calculation is made still more easy in the field by the fact that a surveyor can generally see at a glance which of the two points is the higher, and has therefore no doubt as to whether to add or subtract the true difference of height to get the required height.

The only possible difficulty is where a very small depression gives a minus quantity, which is less than the + correction, in which case the true difference of height will of course be a small +. Surveyors who are not very familiar with signs should be taught this special case. See example (b) above.

7. *A correction for height of signal* is to be applied when one *observes* to the top of a signal and *computes* with the ground height at the foot of the signal.

Its amount is the height of the signal in metres, and its sign, as applied to the observed difference of height in the above method of computation would be *always minus.*

8. *Sources of error.*—When several heights are worked out from different points for the same place, they will usually differ in value more or less from one another. An error in the clinometer reading in the fourth place of decimals will give a considerable difference of height, increasing with the distance. Agreement between several heights is not an absolute criterion of accuracy, as a consistent error in the clinometer readings will give accordant heights if the distances are approximately equal.

When there is no reason to consider one height better than another, the mean value may be adopted, but a truer value may often be got by considering intelligently which results are *likely* to be best and a surveyor, who wishes to get the best results, and to choose the best points for observation, should make himself familiar with the following principles.

APPENDIX II

A man can see for himself that a very distant point is liable to be indefinite, and requires very careful reading of the clinometer. For instance an error of .001 in the reading will give a height error of 1 metre in 1000 metres (because 1000 X .001 = 1), of 10 metres in 10,000 metres, and so on.

Also if there is any inaccuracy due to the faults in the clinometer the effect will increase with the distance, in the same way; and the refraction of the air also becomes more uncertain for distant points.

Other things being equal, the *accuracy varies inversely as the distance;* that is to say, if one point is at half the distance of another, its height should be twice as accurate.

On the other hand, there may be considerable inaccuracy even in near points *if the clinometer reading is large.* The reason for this is, that our result depends on multiplying the distance by the reading, and the plane-table may not give us the distance very accurately.

Thus, on the 1: 50,000 scale, a distance of 20 metres is hardly noticeable, so that we may easily have an error of 20 metres in our distance. Now with a low clinometer reading, less than .020, this error of 20 metres in distance will only give an error of less than 0.4 metre in height (because 20 x .020 = 0.4), but, if the reading is .200, the height error will become 4 metres, and, if it is .400, 8 metres.

When points are badly fixed, or not clearly marked, or when expansion or contraction makes the scale of the plane-table sensibly different from that of card-board scale, we may of course get even worse errors of distance, which will have a bad effect when the clinometer reading is large.

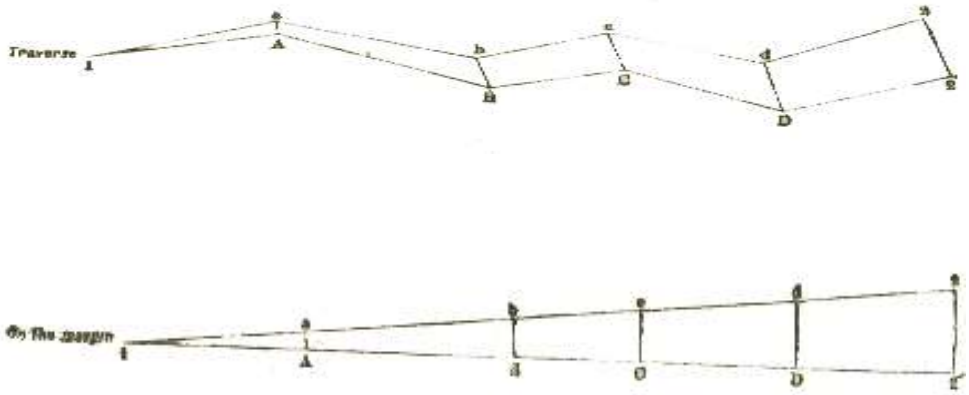
Height of a fixing should be deduced preferably from three fixed points, two of which are on opposite sides of the fixing and one at right angles to the line joining those two points. When height of a fixing is deduced from two fixed points only, they should be on opposite sides of the fixing.

9. We thus see that when the distance is great the clinometer reading must be very accurate, and when the clinometer reading is great we require to take the distance more accurately. Also, near points will give much better results, than distant ones; except when the clinometer reading is great and the distance, owing to the smallness of the scale or other reasons, is not very accurate.

10. These refinements of procedure are of little use unless the whole work is neat and accurate, and the clinometer carefully used and kept in perfect adjustment.

APPENDIX III

A GRAPHIC ADJUSTMENT OF ERRORS IN PLANE-TABLE TRAVERSING



Let 1 be the starting station and 2 the closing one, the positions of which are fixed and known.

Let A, B, C, D denote the succeeding traverse stations from 1, and let 2' denote the position as given by the traverse, which would beidentical with 2, if the traverse had no error.

Now 2'2 is the error to be adjusted.

Lay out a line on the margin and mark on it 1, A, B, C, D and 2' at their respective distances from each other, so that the distances from 1 to A, A to B, etc., may respectively be equal to the distances from 1 to A, A to B, etc., of the traverse.

At 2' on this line erect a perpendicular 2'2 equal to the length 2'2 of the traverse.

Join 1 and 2 and erect perpendiculars at A, B, C, D to meet the line 12 at a, b, o, d respectively.

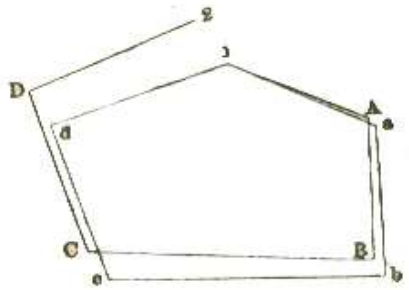
Join 2'2 of the traverse, and at A, B, C, D draw parallels to 2'2 and on these parallels mark *off* a, b, c, d, so that Dd, Co, Bb, and Aa of the traverse may be equal to the perpendiculars Dd, Cc, Bb, Aa on the line in the margin.

Join la, ab, bc, cd, d2.

Then 1abcd2 represents the adjusted traverse. If any offsets or 'Katans' are taken they may be traced and fitted on bit by bit between 1a, ab, bc, etc.

APPENDIX III

Corollary I. When running a closed circuit, i.e., when the traverse is started from 1 and closed on to 1, the procedure is the same except that 2 will coincide with 1 as in the following illustration.



Corollary II. Suppose a traverse were started from a fixed known point A, and continued as far as 0 (without closing); and another traverse started from B, another fixed known point, and continued towards 0, but, when closing on 0, the error was found to be CO', as shown in the figure.

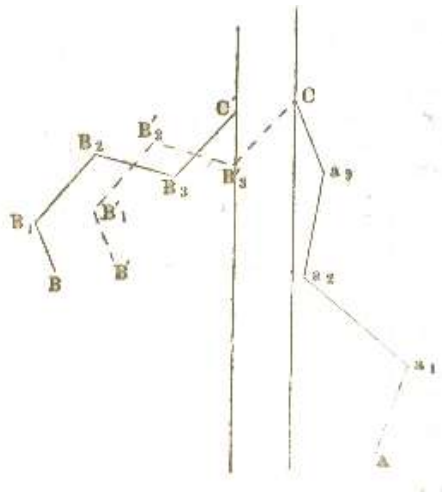
The adjustment is as follows :—

Draw the parallels at C & C' (i.e., parallels to the nearest graticule, latitude or longitude line, according to the 'lie' of the traverse) and trace on tracing paper one of the two traverses, preferably the shorter $BB_1\ B_2\ B_3\ C'$, with the parallel at C' (as in figure below); superpose this on the other traverse from A, so that C' may coincide with C, and the parallel at 0' with that at C.

Then transfer the traverse $BB_1\ B_2\ B_3$ on the plane-table as $B'\ B'_1\ B'_2\ B'_3$ in the figure.

APPENDIX III

Now the whole traverse $Aa_1\ a_2\ a_3\ CB'_3\ B'_2\ B'_1\ B'$ can be treated as one traverse, with the error B'B for adjustment, as per the method first dealt with.



Alternative method of adjusting errors in a plane-table traverse run in approximately the same direction.

Suppose A and B be the two fixed points, and suppose the plane-table traverse from A ends at B_2, instead of at B.

On a piece of tracing paper, make a careful trace of the actual traverse AB_2, with all detail in proper colours ; and examine it carefully. Rub out the pencil work on the plane-table section, join the line AB (in pencil), and also join the line AB_2 on the trace (in pencil). Now place the point A of the trace on the point A of the plane-table, and the line AB on the line AB on the plane-table; this has the effect of correcting errors in azimuth of the traverse as a whole, but the distance AB_2 will seldom be found to be equal to the distance AB. The difference should be distributed as noted below :—

APPENDIX III

Divide the line AB_2 into a suitable number of equal parts (4, 6, 8, etc., according to the difference in the two lines AB_2 and AB), and mark these x, y, z, w, u, v, etc. ; divide AB also into as many equal parts; x_1, y_1, z_1, w_{1t}, u_1, $v_{1;}$ etc. Now place A on A, and the line AB_2 on line AB, and transfer details etc., bit by bit, taking care that details on either side of A, x, y, z, etc., on trace, occupy relative positions on either side of A, x_1, y_1 z_{1s} etc., on the plane-table section. Examine and ink up in colours as on trace.

APPENDIX IV

REPRESENTATION OF GLACIATED REGIONS

I. *Tabling showing colours of different items of high mountain features on plane table sections.*

–	Features	Colours on plane-table section	Remarks
i.	Limits of all areas of permanent snow or glaciation, and all ice features	Blue-green (Viridian)	Limits of all areas of ice and permanent snow, will be shown by a *dotted* line, which is omitted below rocks having a definite edge. The rock cliff symbol will never be drawn in blue to present ice-falls or ice walls. These features have special symbols. The dotted line will not be shown except round the lower parts of glaciers where these extend below the snow-line in areas features have not been accurately surveyed.
ii.	Water features, whether on or off ice	Violet blue	--
iii.	Live or barren dead moraines, lateral, medical, or terminal; scree, rock-falls and fans.	Black	Care should be taken to avoid the appearance of sand. The rocks comprising moraine are of all sizes; so also should be the dots. Screes, on the usually uniform and regular, and should be represented by uniform data, generally in fanwise lines.
iv.	Dead moraines, if under vegetation (grass, scrub, or trees)	Burnt Sienna	--

(Contd…)

APPENDIX IV

Tabling showing colours of different items of high mountain features on plane table sections – (Contd…)

–	Features	Colours on plane-table section	Remarks
v.	Contours across ice and permanent snow including those across live moraine.	Blue-green (Viridian)	--
vi.	Contour values pertaining to the above, across ice, permanent snow, and live moraine	Blue-green (Viridian)	The contour values should break the contours, as in brown contours.
vii.	Contours across hill slope below the snow-line, across dead moraines, scree, fans, etc.	Burnt Sienna	*The contours should seldom be shown above the snow-line*. Bare ground above this line is usually cliff, which should be shown in the appropriate style. Brown contours will always have brown contours values.
viii.	Cliff above or below the snow	Burnt Sienna	--
ix.	Recognized routs over glaciers and permanent snow	Blue green	--
x.	Club huts	Red	--
xi.	Passes and names	Back	--

Glossary

2. *Ablation valley.*—Afsubsidiary valley between a glacier and its valley wall, generally due to wastage of the glacier-ice, caused mainly by radiation from the hill side.

Arete.—The crest of a ridge or buttress leading to a summit.

Avalanche–A mass of snow detached and sliding from a mountain side.

APPENDIX IV

Bergschrund.—The crevasse, often of great depth, formed by a glacier moving from its neve. It always occurs at the change of slope between the neve" on a mountain side and the gentler slope of the nascent glacier in the valley.

Cornice.—Overhanging compacted wind-driven snow formed on the side of a crest or arete opposite to the prevailing wind.

Couloir.—A steep gully on a precipitous mountain side, either with or without ice (*ice-couloir, rock-couloir*).

Crevasse.—A rent or crack in the surface of glacier, caused by the uneven bed, or motion of the glacier.

Fan.—Erosion debris emerging fan-wise into the gentler slopes of the valley bottom. The debris may be mud, sand, gravel, scree, boulders, etc., and may be overgrown by grass or scrub.

Oalcier.—A mass of compacted ice, originating above the snow-line and usually descending below that line.

Glacier table is formed by a moraine slab, supported on an ice-item. Its formation is due to the protection of the underlying ice from the heat of the sun.

Hanging glacier is one formed by an ice-cap, and clinging to a steep mountain side. It frequently terminates in an ice-wall on a precipitous edge.

Longitudinal glacier is one flowing in a main valley-trough, parallel to a main range. *Its fall* is generally small.

Saddle glacier is one descending to, and lying astride, a ridge, sometimes throwing branches into the valleys on each side of the divide.

Transverse glacier is one flowing transversely to the axis of a main range. Its *fall* may be great.

Valley glacier is one flowing in a valley.

Ice-cap.—Compacted snow and ice on summits and ridges above the snow-line.

Ice-fall.—This occurs in a glacier at a change of slope to a steeper gradient, where crevasses are formed. When such crevasses intersect one another at right angles, they often degenerate in seracs and tumbled blocks of ice resembling a rock-fall.

Moraines are formed by debris detached from exposed rocks and deposited on glaciers.

En-glacial Moraine.—Bock debris carried along with the body of a glacier.

APPENDIX IV

Lateral Moraine.—Rock debris carried along at the sides of glaciers (*live*), or deposited on the valley floor from the sides of glaciers (*dead).*

Live Moraine.—Live moraines are carried on the surface or in the body of a glacier. Moraines deposited on the valley slopes or floor are *dead.*

Medial Moraine.—Rock debris carried along on the surface of a glacier below the junction of two or more glaciers.

Sub-glacial Moraine.—Rock debris dragged along beneath a glacier.

Terminal Moraine.—Rock debris deposited from the snout of a glacier, from the medial, lateral, and sub-glacial moraines.

Neve.—Snow above the snow-line, which has not reached the consistency of ice.

Regelation.—The process continually taking place in the lowest strata of a glacier, causing the glacier to move.

Rock-fall.—A mass of tumbled rocks in a gully or on a mountain side.

Scree.—Loose small rock or shale debris standing at or near its limiting angle of slope.

Seracs.—Detached broken columns of ice in the crevassed areas of glaciers, often formed by crevasses intersecting one another. The term is sometimes loosely but incorrectly applied to all ice-pinnacles on a glacier, however they may be formed.

Snout.—The lower end of a glacier, where melting by the increased temperature of lower altitudes balances the supply of ice from above.

Snow-bridge.—Snow, covering crevasses and bergschrunds, and formed by snow fall or avalanche.

Snow-line.—The altitude in any region above which snow lies permanently throughout the summer. This altitude usually differs considerably on north and south aspects.

3. The accompanying plan and cross-sections of a typical glacier explain some of the items mentioned above.

4. Surveyors before taking the field for the survey of glaciated areas should have the Professional Paper No. 25, on 'The Representation of Glaciated Regions on maps of the Survey of India' (by Major K. Mason, M.O., B.E.) explained to them, and practise drawing the symbols. They should try and recognize the various features and become expert in surveying them. Skill will only be attained by experience.

APPENDIX IV

PLAN AND SECTIONS OF A TYPICAL GLACIER

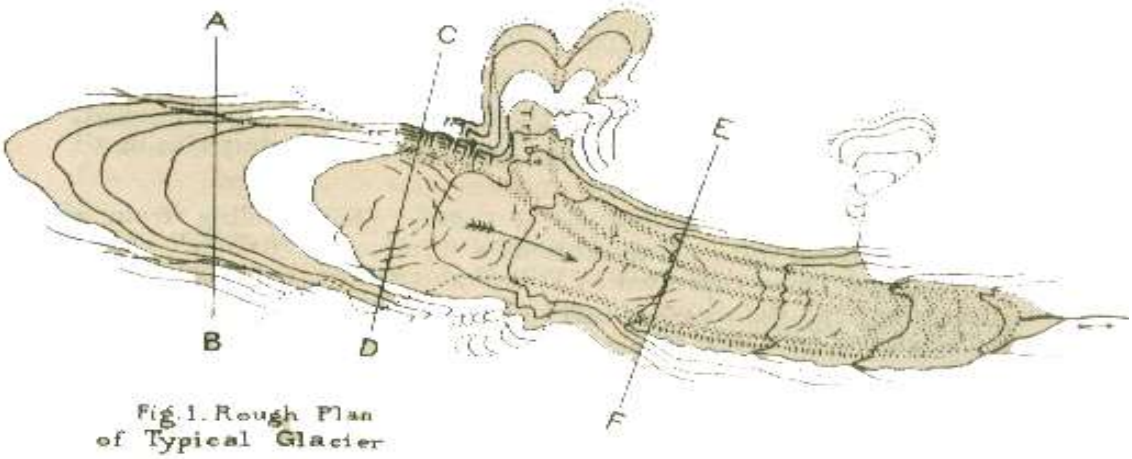


Fig. 1. Rough Plan of Typical Glacier

Fig II. Section on AB

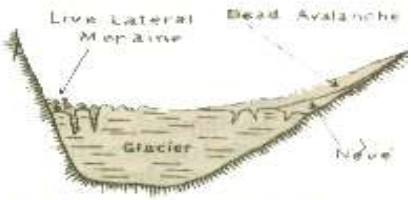


Fig III. Section on CD looking down stream

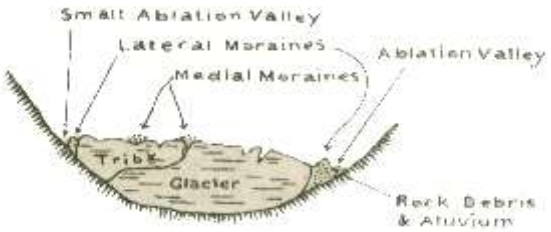


Fig IV. Section on EF looking down stream

APPENDIX V

NOTE ON MODEL PLANE-TABLING

1. The following instructions for what may be described as "model plane-tabling" are issued for the guidance of all concerned. The method will be useful not only in training units, but also in all topo. field parties.

Briefly stated the principle is indoor plane-tabling from a model by setting up a plane-table at a number of "fixings" round it. The model may represent (i) planimetry only : a representation of topographical detail on a sheet of paper, or (ii) relief : clay or sand modelled hills, or (ii) a combination of both.

2. A well-lighted room not less than 6 m by 5 m is desirable. The end of a large room not less than 5 m wide is suitable. This is to accommodate a drawing table 1.6 m x 1.1 m placed in the centre (or near end of large room) so that a plane-table can be set up and worked at anywhere round the table, with its centre at a distance of 0.3 to 1.0 m from the edge of the table.

3. The first procedure is to provide a triangulated frame-work for the "model". This consists of "points" marked on the walls. Five or six points are sufficient. The actual features comprising each "point" should be sketched on the wall : a hill top, a tree, a temple, etc. Their heights above the floor should vary and be not less than 1 m and not more than about 1.5 m. Points require a temporary vertical line drawn through them to facilitate the measuring of horizontal distances between points. A point should also be supplied within the area of the model table by suspending a plumb-bob from the ceiling (with variable length cord as in theodolite plumb-bob). A sufficient number of sides of the triangles joining the points are then accurately measured, correct to 1 mm ; in this measurement it should not be assumed that three or more points on a wall of the room are in the same vertical plane. Walls are seldom exactly true and variations of the order of 10 mm are not unusual, this represents 10 m on the scale of the model. The triangulation is then computed in grid terms on a scale of 1:1,000 (see para 5). It should be imposed on an arbitrary grid of 1,000-metre squares, approximately parallel to the sides of the room.

4. Heights of points are measured in mm correct to 0.2 mm, above or below an arbitrary datum which will be marked on the walls below (or above) each point (at about 1.2 m above the floor) by means of a theodolite or level. Convert heights to "model" metres correct to 0.1 metre at the scale of 1:1,000, add a suitable round number, say 1,000, so as to bring "M.S.L." below the level of the model table, and enter up heights in bold figures on the wall against the points. The representation

of the point on the wall should be to scale, e.g., a tree should be about 10 mm high (10 m).

5. It is suggested that the presumptive scale of the model system should be 1:1,000. With this scale, the largest scale on which the trigs, can be plotted on a 60 cm X 50 cm plane-table is 1 :10,000, if the room is of the size given above. The model (size l.5m X 1.0m) on the drawing table, at 1:1,000, will cover about 1,600 m X 1,000 m. It should not be made to represent more than this, otherwise pupils may get into the bad habit of thinking that they can survey large areas from the outside without making any fixings within them. In surveying the model the nearest they can get is about 0.3 m (say 300 m) from the edge of the work.

For instruction in special hill features or methods the scale of the model can be made double, i.e., 1:500. In this case the triangulated points must be plotted with half the co-ordinate value given in trig. list.

6. *The model.*— (i) Planimetry.—Several types of plain country should be depicted each on a sheet of cloth-mounted paper of size about 1.5 m x 1.0 m, bearing in mind that the scale is intended to be about 1 : 1,000. Streams, roads and railways should be drawn in ink on the paper, using red for roads, blue for perennial water, and yellow for cultivation. Houses can be represented by rough wooden blocks to scale; single trees: cotton wool on pins; topes and forest: a layer of cotton wool 10 mm thick stained green; mounds and bunds : in plasticine ; and so on.

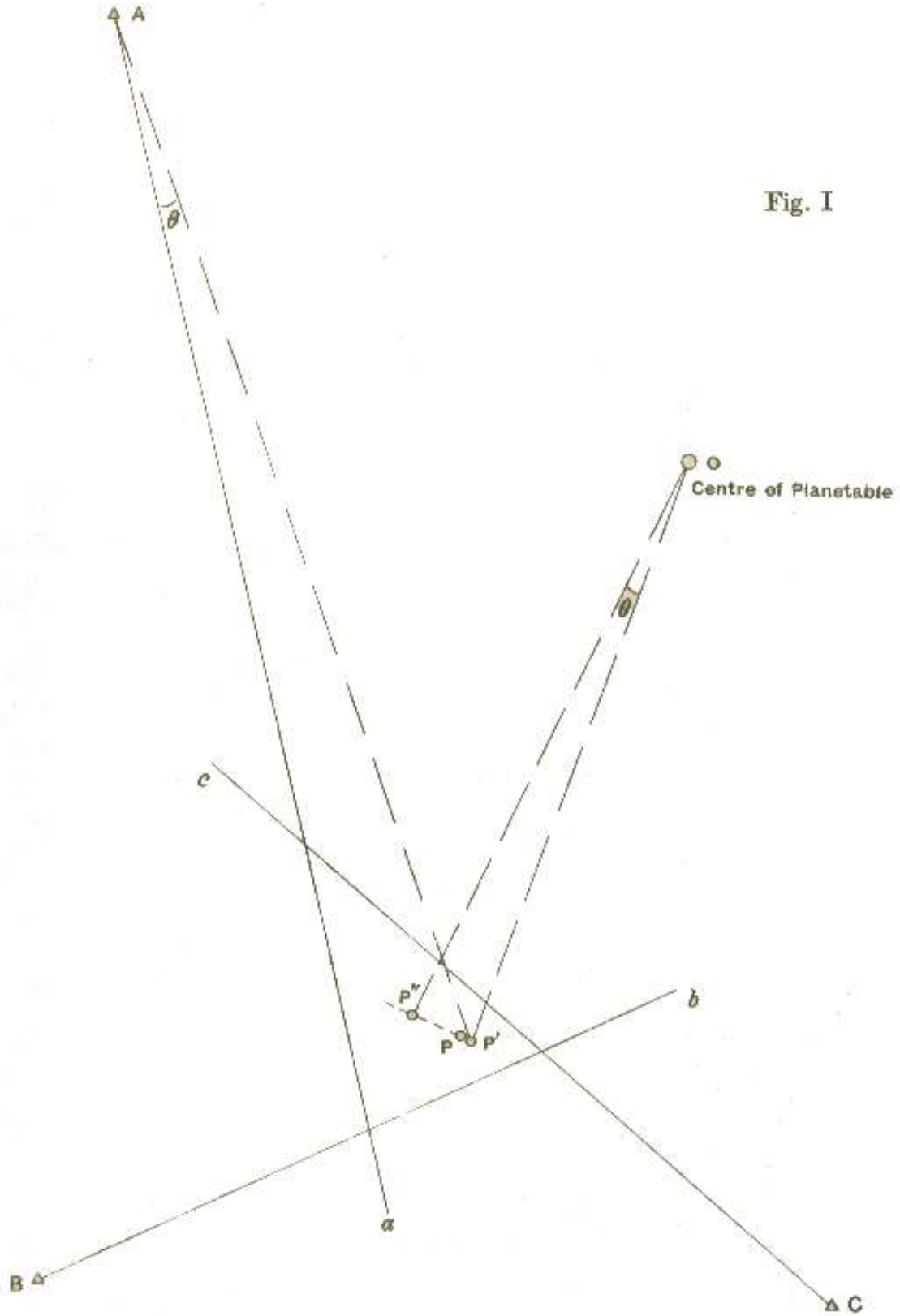
(ii) Relief.—One (and if possible more than one) complete clay model should be prepared on a wooden board, size as above, showing a variety of hill forms, e.g., rounded spurs, sharp spurs, V & U streams, rock features, horizontal scarp, inclined scarp, river fan, etc., etc. The vertical scale must *not* be exaggerated. A graded hill road with some hairpins should be included and also graded, pack-tracks.

A zinc-lined "contouring-bath" should be constructed in which the model is placed, after baking hard. A scale of 10 m contour intervals (10 mm) is marked up the sides of the bath. Cloudy water is poured in up to each mark in turn, taking care that the bath is level. The water line of each successive filling is pencilled in on the model.

When the finished model is placed on the table its height must be adjusted so that the contours are correctly related to the triangulated heights. For more practised pupils the contour lines should be rubbed out or be left so faintly indicated that they cannot easily be seen.

(iii) Combined planimetry and relief.—On the plane models, [Item (i) above], hill features can be inserted either by preparing some isolated

Fig. I



Plan of Sight-rule

clay hill forms and making different combinations with them, or else by making relief with dry sand.

7. A suitable point on each model, viz., a tree, temple, or cairn on hill top is selected as the triangulated point within the model area referred to in para 3 and the table is shifted until this point is correctly centered under its plumb-bob (which may then be pulled up). Alternatively the table need not be shifted, but a moveable tree, temple, etc., is centered below the bob.

8. For convenience a small plane-table should be used, 60 cm X 50 cm will do. (A special light 5-ply board is suggested). All the usual plane-table instruments are required, except that the sight-rule preferably about 60 cm long, has to be modified so that the working (right hand) edge is in exactly the same plane as the slit and wire of the vanes. (See Fig. I). This can be done by having an ordinary wooden sight-rule cut back to its centre line up to about 10 cm from each end and re-bevelled. It is particularly important that the top thread, vane slit and wire, and the working edge should all be in the same vertical plane. For left-handed surveyors the vanes can be interchanged end for end. 12-cm vanes-should be provided.

9. The normal height of the table is 75 cm, that of a plane-table about 100 cm so that if the plane-table is set up 65 cm away from the table, the distance of the centre of plane-table to the centre of the model represents about 1,200 m and the height above it about 250 m. This height "command" is slightly high for instruction in plane-table sketching methods, except in high hill work and should normally be reduced by raising the table about 10 cm.

10. Heights are observed with the clinometer in the usual way and computed or read off a height indicator. The clinometer rear vane aperture must be carefully centred over the fixing on the plane-table. The height obtained from the trigonometrical stations is of course that of the clinometer aperture and there is no need to reduce this to the level of the plane-table (about 125 m below) as heights 'thrown' on the model will also be with reference to the clinometer aperture. For this reason it is essential that the plane-table be accurately levelled so as to ensure a minimum travel of the clinometer levelling screw. 1 mm variation in height of the reading aperture makes a difference of 1 m in the resulting height. This error is eliminated if each height determination is reduced to the level of the plane-table fixing, but this involves measuring the height of the aperture above the plane-table surface for each vertical angle read, which is laborious.

APPENDIX V

The plane-table should be carefully levelled in both directions by reference to window frames or other horizontal lines in the room. This method should be taught as it is also the best one to use out of doors, against the horizon.

11. If a wooden floor is not available coir matting should be stretched tight over the floor and nailed down, to prevent plane-table legs slipping. A shift of 1 mm is equivalent to moving the plane-table 1 m when plane-tabling out of doors. The metal-shod ends of the stand legs should be sharpened.

12. There is another source of error which may be embarrassing in extreme cases :—Having set the plane-table either by compass or by aligning its grid parallel to the walls, the usual triangle of error is obtained. *The solution of this involves resetting the plane-table and consequently moving the position of the fixing appreciably with respect to the model system.* The amount of the error introduced is dependent on the size of the triangle, on the relative distances of the fixing from the setting triangulated point and from the centre of the plane-table and also on the orientation of the plane-table centre with respect to the setting ray. In any case unless the setting was correct in the first instance (i.e., there was no triangle) the position of the final fixing will be different from that found from the first approximation. For this reason the work should be kept as near as possible to the centre of the plane-table and triangles should be kept small by careful initial setting.

An analysis of the operation of making a fixing shows that the error is small and quite unembarrassing in all cases likely to arise. Referring to the diagram (Fig. I), A, B and 0 are trigonometric stations/points 0 is the centre of the plane-table. *Aa,* B6, Cc, are three rays forming a triangle of error. P' is the correct position of the fixing, i.e., its distances from the rays are proportional to its distances from the plotted trigonometric station/point. Then if the plane-table could be rotated about P' (instead of O) correct setting and position would be achieved. As it is, the aligning of P' on A involves the shifting of the point P' to position p" *in the model system.* But the position of P' *on the scale of the plane-table* is

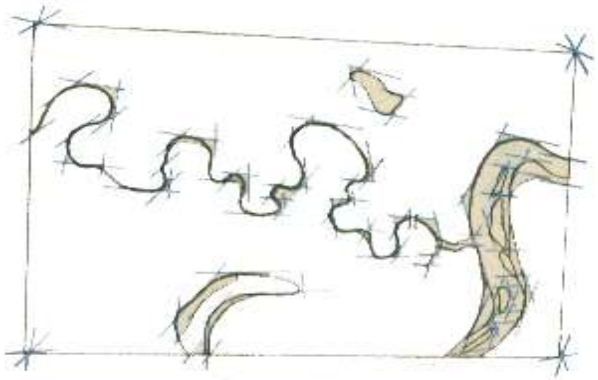
at P, such that $\frac{P'P}{P'P''} = \frac{\text{scale of plane-table}}{\text{scale of model}} = \frac{1}{10}$ when scale of plane-table is 1:10,000 and scale of model is 1:1,000. This distance is very small and even in extreme cases, is never likely to be greater than the error of locating P' in solving the triangle of error. Strictly the aligning

APPENDIX V

Fig. II

+A

+B

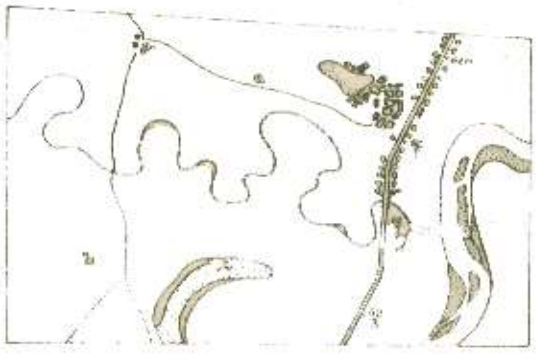


+C

Reproduction of 1:10,000 scale p.t. survey of the model from fixings A,B,C, showing tangent ray method of survey (roads, village and trees omitted).

APPENDIX V

Fig. III



Reduction of elementary plane model from 1/0000 scale to 1:10,000 scale.

of P'A on the trigonometric station/point gives an incorrect setting involving a second approximation (unless the direction of O is at right angles to the setting ray). It is the estimated ray PA that should be aligned. In practice the difference is negligible unless the first triangle is very large (e.g., 5-cm sides). There is, therefore, no reason why the 3-point problem should not be taught from the model, provided that due regard is paid to the point raised in the italicised portion of the sub-paragraph above : owing to this danger of vitiating the fixing by the resetting of the plane-table with each tentative solution of the triangle, it may be inadvisable to teach raw beginners the 3-point problem on the model, as it may cause them to lose confidence in their fixings.

13. There is little to be said about the actual work, which consists of making fixings from the trigs, at different places round the table and surveying detail and contours just as this would be done from nature. The great virtue of working from a model is that wrong methods of work and errors such as those in depiction of shapes both in planimetry and relief can be so easily pointed out "on the ground" and the errors can be demonstrated beyond all doubt in the pupil's mind by comparison of his work with a photographic or pantographed reduction of the plane models, which should be prepared, and printed on tracing paper on the 1:10,000 and 1:25,000 scales. These models should have registration marks at the corners which the pupil will intersect during the course of the survey.

Four people can work at the same time following each other round the table. Instructors should be tested with the model and made to demonstrate the methods they impart to pupils.

14. Contoured relief models may be of use in air survey training, by photographing vertical overlaps from a suitable altitude, viz., 3 to 4 m (3,000 to 4,000 m) above the table. Photos could be taken of the model with and without contours.

15. Figs. II and III show a survey from a plane model from 3 fixings, to demonstrate the method of surveying a winding stream by tangent rays; not a single intersection proper has been made, except to fix the four corners of the model.