Survey of India

DEPARTMENTAL PAPER No. 14

INSTRUCTIONS

FOR THE USE OF

THE WILD UNIVERSAL THEODOLITE

BY

CAPTAIN D. R. CRONE, R.E.

AND

THE WILD PHOTO-THEODOLITE

IN TRIANGULATION AND IN STEREOGRAPHIC SURVEYS
FROM PHOTOGRAPHS TAKEN FROM THE GROUND

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PART I

THE WILD UNIVERSAL THEODOLITE

SECTION I

Description of the Instrument

1. General Description.—The Wild Universal theodolite differs to such an extent from the normal type of vernier or micrometer theodolite that it is necessary to describe it in some detail.

The telescope of the instrument is a compact one of short length with a relatively high light collecting power and having internal focussing. It is fitted with a sight and electric illumination for night work and it is permanently fixed in its horizontal trunnion axis bearings.

The frame carrying the telescope bearings is of solid construction and also carries the optical and mechanical system for reading the instrument. It only permits the telescope to be elevated to an angle of 68° and to transit object-glass downwards. It is supported in a conical bearing by the base which also contains the optical system for illuminating the horizontal arc.

The base is carried by its three foot screws which are permanently held in position in a spring tribrach. The whole forms the single unit of the theodolite. It is fitted in position on its tripod by placing the tribrach on the tripod head and screwing the screw fixed in the head into the centre of the tribrach.

The arcs, micrometer and all the mechanical and optical components are completely enclosed and in fixed adjustment with the exception of the collimation level which is viewed by a prism, the circular base level and the horizontal level, all three of which can be adjusted.

The arcs are both etched on optical glass and silvered after etching.

The horizontal arc is 95 mm. in diameter and is divided from 0° to 360° by 20′ divisions each degree being numbered. The vertical arc is 50 mm. in diameter and is divided with the same number of divisions as the horizontal arc, though the even number degrees only are numbered with values one half of their real values. Each half of the circle is numbered from 45° to 135° in the same sense. Both the arcs are rigidly connected to the telescope and rotate with it.

2. Reading System.—The system to enable the horizontal arc to be read is as follows (*vide* fig. 1).

A beam of light from the sky is divided in half and thrown by a lens and prisms (1, 2, 3 & 4) in the base to two opposite points of the arc (I, I). The prisms are connected to the base through the horizontal arc setting screw the rotation of which has the effect of rotating the prisms (4, 5) about the vertical axis (A A) and thus altering the zero of the round. From the points on the arc, the beams are reflected back by the silver backing of the arc and by a lens and prisms (5, 6, 7) are brought into proximity in one beam so that the two outer edges of the arc coincide as a single line and the divisions appear on each side of it (*vide* fig. 2). Each half of the beam is passed through a parallel plate (8, 9) and brought to the focal plane of the micrometer microscope. The two parallel plates can be rotated in opposite directions by the micrometer screw to which is connected by gearing a glass circle (r) which is divided with 600 divisions 0′ 0″ to 10′ 0″ by seconds. The effect of rotating the parallel plates is to displace halves of the beam parallel to themselves by a small amount in opposite directions and thus to enable the images of one division on each edge of the arc to be brought together in the micrometer microscope. The amount of displacement is measured by the rotation of the glass micrometer circle, an image of which is formed in the field of the micrometer microscope.

By interposing a prism (20) below the parallel plates a beam of light from the vertical arc (II, II) similar to that from the horizontal arc can be substituted for the latter in the micrometer system.

In the case of the vertical arc the prisms (4′, 5′) throwing the beam on to the arc are rigidly connected to the collimation level.

SECTION II

Use of the Instrument

3. Instrument positions.—In place of the usual 'face right' and 'face left' the observation positions of the Wild Universal Theodolite will be known as "Micrometer Right" and "Micrometer Left" according to whether the micrometer microscope is to the right or to the left of the telescope looking from the eyepiece end.

4. Procedure in observing.—The following is the procedure to be followed in setting up and observing with the instrument:—

(*a*) Set up the stand with the head roughly level and over the mark. This should be tested by dropping a stone or any other handy object.

(*b*) Open the theodolite case, withdraw the locking clips and raise the hinged clamps, place the telescope horizontal and place the second and third fingers of the right hand below the base and the thumb over the horizontal level between the pillars. Lift the instrument out of its case with the right hand using the left to steady the telescope. Place the instrument on the stand and screw up the retaining screw in the stand head loosely, so that the theodolite can still easily be moved about on the head of the stand.

(*c*)* Attach the plumb-line, and centre the instrument over the mark, clamp the tribrach with the retaining screw which should be just tight.

(*d*)* Level the instrument by means of the foot-screws using the horizontal level in the usual way. The circular level is a useful indication in the first operation of the foot-screws.

(*e*) Place the telescope in the "Micrometer Right" position, adjust for distinct vision of cross-wires, focus the telescope, and eliminate parallax in the usual way.

(*f*) Focus the micrometer microscope for distinct vision of the arcs.

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* *N.B.*—In instruments fitted with the optical centring device levelling must be carried out before centring the instrument.

Fig. 1.—WILD THEODOLITE: DIAGRAM OF THE OPTICAL TRAIN FOR CIRCLES AND MICROMETER

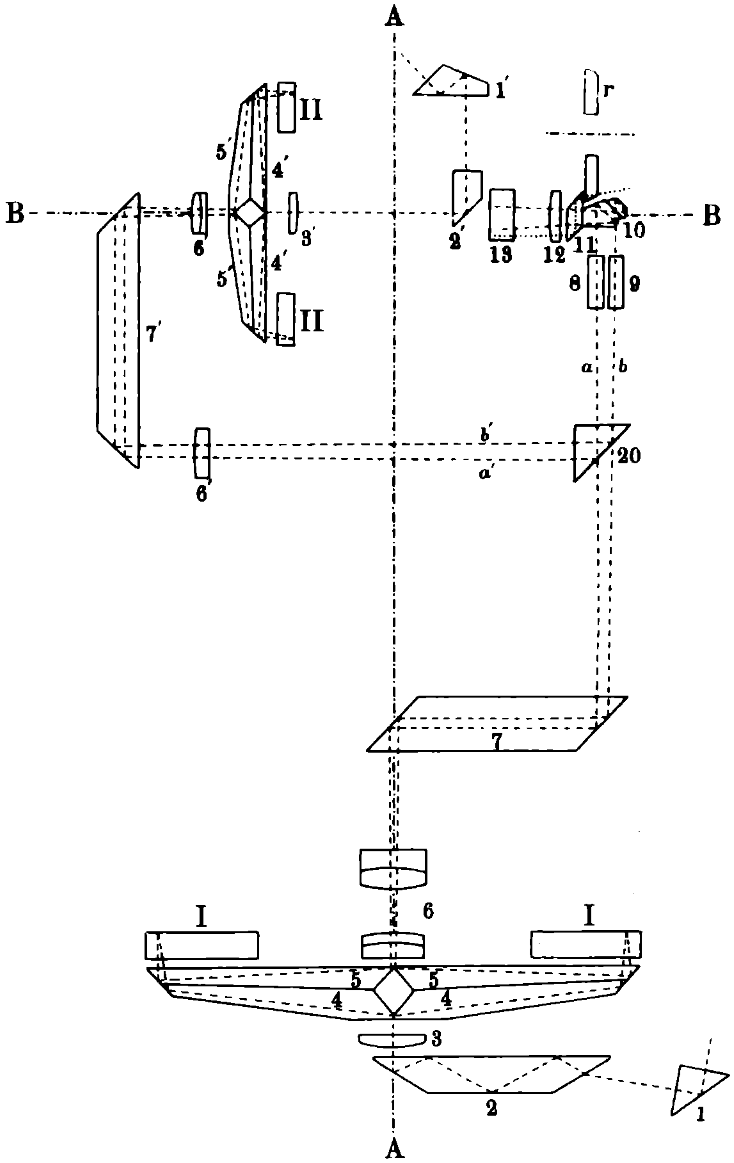
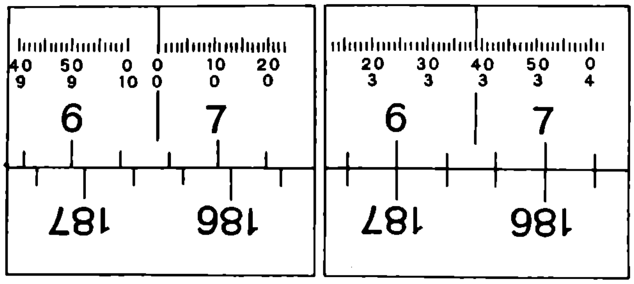


Fig. 2.—MICROMETER EYEPIECE. WILD THEODOLITE



Micrometer at zero, to obtain a rough estimate of minutes.

Micrometer turned to bring divisions into alignment. Reading 6° 33′ 39″·0.

These diagrams are taken from Major Hutchinson's Paper published in the Journal of the Royal Geographical Society for March 1926; by permission of the Council.

(*g*) Adjust the illuminating prisms for even illumination over the whole field of the micrometer microscope.

(*h*) Bring the collimation level bubble to the centre of its run.

(*i*) It may be convenient in certain circumstances to have the first round of angles approximating to bearings from either true north, grid north or magnetic north. If the back bearing of a station is known, the telescope should be pointed at this station and the arc set to the known bearing. Otherwise a bearing may be taken to a station from the plane-table or with a compass and the telescope pointed and the arc similarly set.

(*j*) With the horizontal circle unclamped pull out the micrometer switch. Point the telescope at the zero station and clamp the horizontal circle gently. The vertical circle may require to be lightly clamped but this should only be done where necessary and as lightly as possible. Make the intersection with the horizontal tangent-screw, always finishing the motion of the screw in a clockwise direction.

(*k*) Read the micrometer (*vide* para 5) and record the reading.

(*l*) Look through the telescope to see that the intersection is still correct.

(*m*) Unclamp the horizontal circle and swing the telescope gently by the pillars on to the next station. Clamp and intersect as before. In the event of overswinging, clamp and attempt to bring the telescope back with the tangent-screw, if this is not sufficiently long, unclamp and swing on right round the circle to the station again.

(*n*) Continue the round in this manner and close on the zero station in the usual way.

(*o*) A round of vertical angles is taken similarly with the micrometer switch pressed home. The horizontal circle requires to be lightly clamped during a reading. The vertical arc is clamped lightly and intersection made with the vertical tangent screw. The ends of the collimation level bubble as viewed in the prism are brought into coincidence by the collimation level tangent-screw and the micrometer is read and the reading recorded. The horizontal arc clamp is released and the next station intersected.

(*p*) The rules for measures, swings and positions given in paras 58, 59, 60 & 62 Chap. III, Handbook of Topography will be observed but "Micrometer Right" position will invariably be taken first and entered on the upper line with M. L. readings immediately below. The vertical angles with their correct sign (+ for elevation, – for depression) are then equal to the values in M. R. line minus the values in the M. L. line. The angles will be checked by adding the values on M. R. and M. L., the sum being $180^\circ \pm$ the collimation error.

(*q*) For intersected points and on active service and on rapid work, for stations and intersected points, vertical and horizontal angles will be read from a single setting with both circles lightly clamped. The horizontal angles will be read first and the micrometer switch will be pressed gently home between the thumb and forefinger, the latter being on the opposite side of the pillar. The switch will only be pulled while the horizontal arc is unclamped.

(*r*) To replace instrument in case:—

(*i*) Open case and pull out the locking clips and raise the hinged clamping pieces.

(*ii*) Unscrew clamping screw of tribrach, lift the instrument in the same way as before and place the instrument in the base of the case with the dot on the instrument base opposite the dot on the hinged clamping piece of the base.

(*iii*) Close down clamping pieces and push locking clips home.

(*iv*) Tilt the telescope to its greatest elevation and clamp both circles.

(*v*) Put the cushions in place round the telescope, replace cover with the dot on the cover opposite that on the base.

5. Reading the Micrometer.—There are three methods of reading the micrometer:—

A. By counting graduation *intervals.*

B. By the position of *corresponding* graduations.

C. By the index mark.

In any of these methods the first operation is to rotate the micrometer-screw until the graduations of the upper and lower images of the limbs coincide. Owing to the complex nature of the optical train it is not possible to obtain exact coincidence of *all* the graduations appearing in the microscope field. The centre of the field is marked by an index. In some settings a pair of graduations are in line with the index and in others two pairs are spaced equally on either side of the index. In making the coincidence, only the centre pair should be observed in the first case, and only the two centre pairs in the second. This will ensure uniformity in coincidence setting.

A. *By counting graduation intervals.*

(*i*) *Horizontal Arc.*

(*a*) Make coincidence as above.

(*b*) Read the degree value next to the left on the upper scale.

(*c*) Count the graduation intervals between this degree mark and the inverted degree mark which differs by 180°. These are the tens of minutes of the reading.

(*d*) Read the unit minutes and seconds and if necessary interpolate decimals of seconds for the position of the upper index mark on the micrometer scale at the top of the field of the micrometer microscope. The minutes are the figures in the lower line, the tens of seconds are in the upper line.

(*e*) The reading is the sum of (*b*), (*c*) and (*d*).

(*ii*) *Vertical Arc.*

(*a*) and (*b*) operations are as for the horizontal arc.

(*c*) Count the graduation intervals between the degree mark read and the mark with the same number on the lower scale. These are fives of minutes; multiply the number by five.

(*d*) Read the micrometer scale as for the horizontal arc.

B. *By the position of corresponding graduations.*

(*i*) *Horizontal Arc.*

Make coincidence. Note the graduation of the upper arc "corresponding" to that of the lower (inverted) arc. This coincidence always occurs at the centre of the field below the index mark. In this case the intermediate imaginary divisions, 10′, 30′ and 50′ must be taken into consideration. In fig. 2, the corresponding graduations are 6° 30′ and 186° 30′ (no other graduations correspond, e.g. 6° 20′ coincides with 186° 40′; 6° 40′ coincides with 186° 20′ and so on).

This graduation gives the tens of minutes of the reading. Proceed as in A (*i*), (*d*) and (*e*).

(*ii*) *Vertical Arc.*

In reading the vertical arc, two positions of coincidence are always possible. In method A, either can be used, but in method B that one must be selected which fulfils the conditions noted in the preceding para B (*i*). Again, the coincidence occurs at the centre of the field below the index mark, but in this case there are no imaginary graduations.

The graduation gives the tens of minutes of the reading. Proceed as in A (*i*), (*d*) and (*e*).

C. *By the index mark.*

Make coincidence. Read the position of the index mark on the upper arc. Make (*i*) on the horizontal circle in degrees and tens of minutes, (*ii*) on the vertical circle in degrees and fives of minutes.

Proceed as in A (*i*), (*d*) & (*e*).

In this method the index mark should be in proper adjustment, so that at coincidence it is either in line with a graduation or midway between two graduations, in which case it is the simplest and quickest of the three methods. If it is not so adjusted, there is liable to be confusion and mistakes in reading, and one of the other methods should be adopted.

6. Reading by estimation.—Apart from the precise method of reading to single seconds it is possible to read the circle by estimation without employing the micrometer drum, but the saving in time is very small. The drum is set to zero and is not subsequently moved. In fig. 2 (left-hand diagram) the combined reading of the two limbs is midway between 6° & 186°. In other words it is half the total number of divisions plus the fraction, between these two graduations, viz., $3{\cdot}3 \times 20 \div 2$ or $3{\cdot}3 \times 10 = 33'$. In vertical circle readings the number of divisions and fraction must be multiplied by 5. The index mark also indicates the point midway between the two corresponding degree graduations but as it is seldom in correct adjustment it should not be used to estimate readings.

7. Astronomical Observations.—The angle of elevation of the instrument is limited to about 65°; this precludes the employment of the Talcott method of determining latitudes from high altitude pairs, but for all other normal forms of astronomical observation the instrument is suitable.

The electrical fittings are convenient but it is essential that all the slip rings and exposed contacts be kept scrupulously clean and that the bulbs are kept tightly screwed into their sockets. Those lights which are not required for the observation being made should have their bulbs removed* to save the batteries. It will generally be found more convenient to use an electric hand torch and a strip of paper fixed over the object glass for the illumination of the cross-wires than to rely on the trunnion axis illumination†. A hand torch is required in any case for setting the collimation level bubble. When preparing a star programme it will be helpful to work out the vertical micrometer setting for "Micrometer Right" beforehand to facilitate finding the star. The setting is one half the zenith distance, plus 45°.

8. Use in Traversing.—The procedure to be carried out when using the instrument for traversing is detailed in Chap. IV, Handbook of Topography, paras 34 A, 36 & 43.

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* *N. B.*—This is not possible in some models where the lamps are in series.

† On the earlier models the object glass prism attachment for illuminating the cross-wires is quite satisfactory.

SECTION III

Calibration

9. Adjustments to be determined.—As the whole instrument is supplied in makers' adjustment and errors cannot be eliminated conveniently in the field, it is essential that the value of the errors in all the adjustment settings be determined before and after the field season to determine whether the instrument is of sufficient accuracy for the work or whether the application of any corrections is necessary.

The following constants and adjustments must be determined:—

(*i*) Horizontal collimation error.

(*ii*) Dislevelment of the trunnion axis.

(*iii*) Vertical collimation error.

(*iv*) The value of the micrometer runs on various portions of the micrometer arc.

(*v*) The rigidity of connection between the vertical arc prisms and the collimation level must also be tested.

10. Method of determination of adjustments.—9 (*i*) and (*ii*). Since the telescope trunnions are not accessible for the employment of a striding level, the dislevelment of the trunnion axis must be determined in conjunction with the horizontal collimation error.

The method is as follows:—

Set up the instrument at a distance from an accessible elevated or depressed point so that the vertical angle to the point is about 50° or 60°. Stick a pin in the point selected (if distant a nail or other suitable mark may be used), and take a horizontal arc reading to the pin on each face without disturbing the horizontal arc. Take the reading of the vertical arc to the point of the mark observed. Repeat the observations to a mark approximately in the same horizontal plane as the instrument. Then if R_α, L_α, R_β, and L_β, are the right and left face readings at angles of elevation of α & β respectively,

$$\text{let } \epsilon_\alpha = R_\alpha - L_\alpha - 180^\circ$$

$$\epsilon_\beta = R_\beta - L_\beta - 180^\circ$$

and δ be the dislevelment of the trunnion axis and h the horizontal collimation error

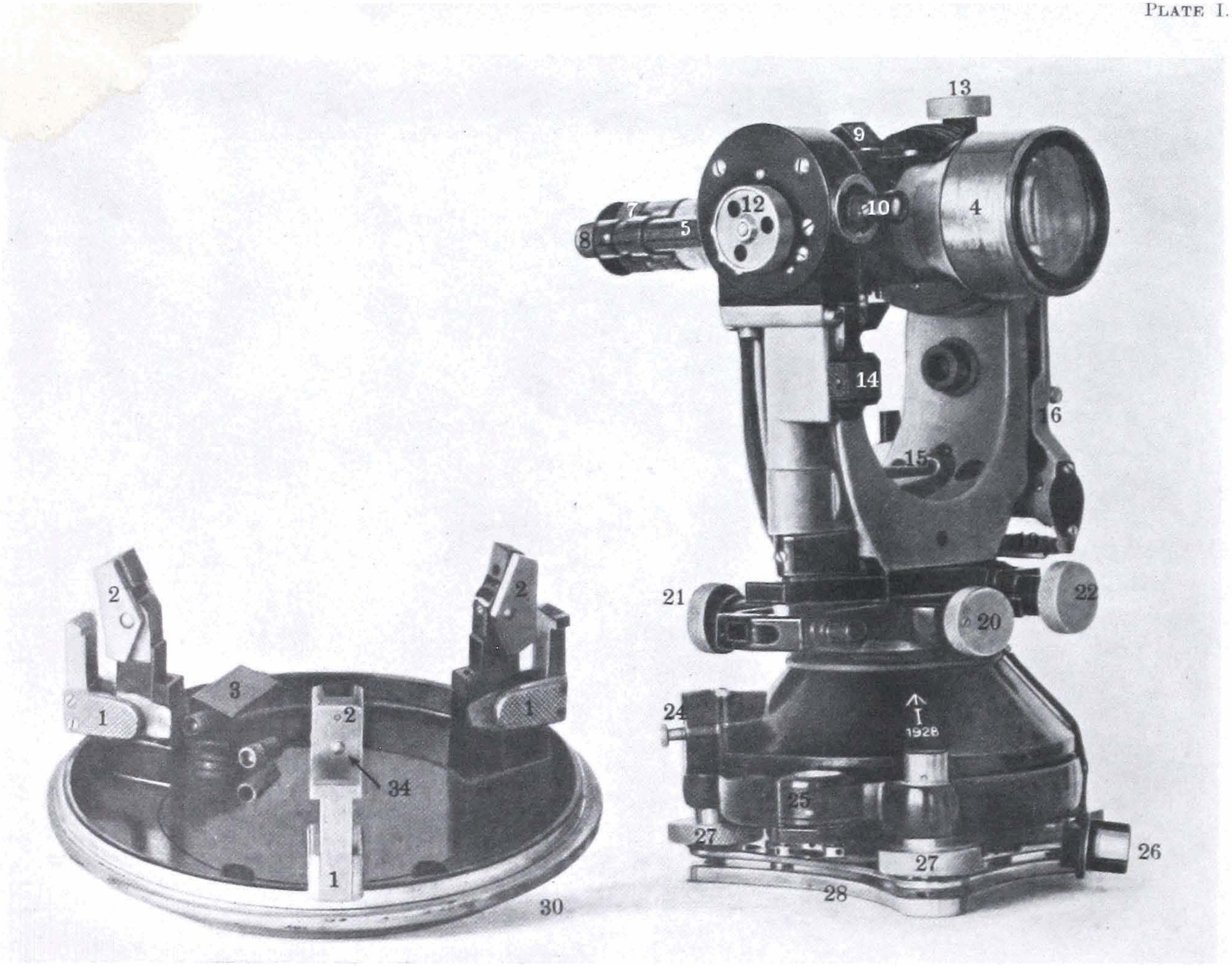
then $$\delta \sin\alpha + h = \epsilon_\alpha \frac{\cos\alpha}{2}; \quad \delta \sin\beta + h = \epsilon_\beta \frac{\cos\beta}{2}$$

and $$h = \frac{\epsilon_\alpha \cos\alpha \sin\beta - \epsilon_\beta \sin\alpha \cos\beta}{2 (\sin\beta - \sin\alpha)}$$

and $$\delta = \frac{\epsilon_\alpha \cos\alpha - \epsilon_\beta \cos\beta}{2 (\sin\alpha - \sin\beta)}$$

which may be evaluated by slide rule, ϵ, h and δ being in the same units viz. seconds of arc.

(*iii*) The vertical collimation error is measured by observing a vertical angle on each face to a distant fixed point, carefully levelling the vertical arc bubble for each reading. The vertical collimation error is the sum of the two readings less 180°. This may be eliminated by setting the collimation level bubble in the centre of its run,



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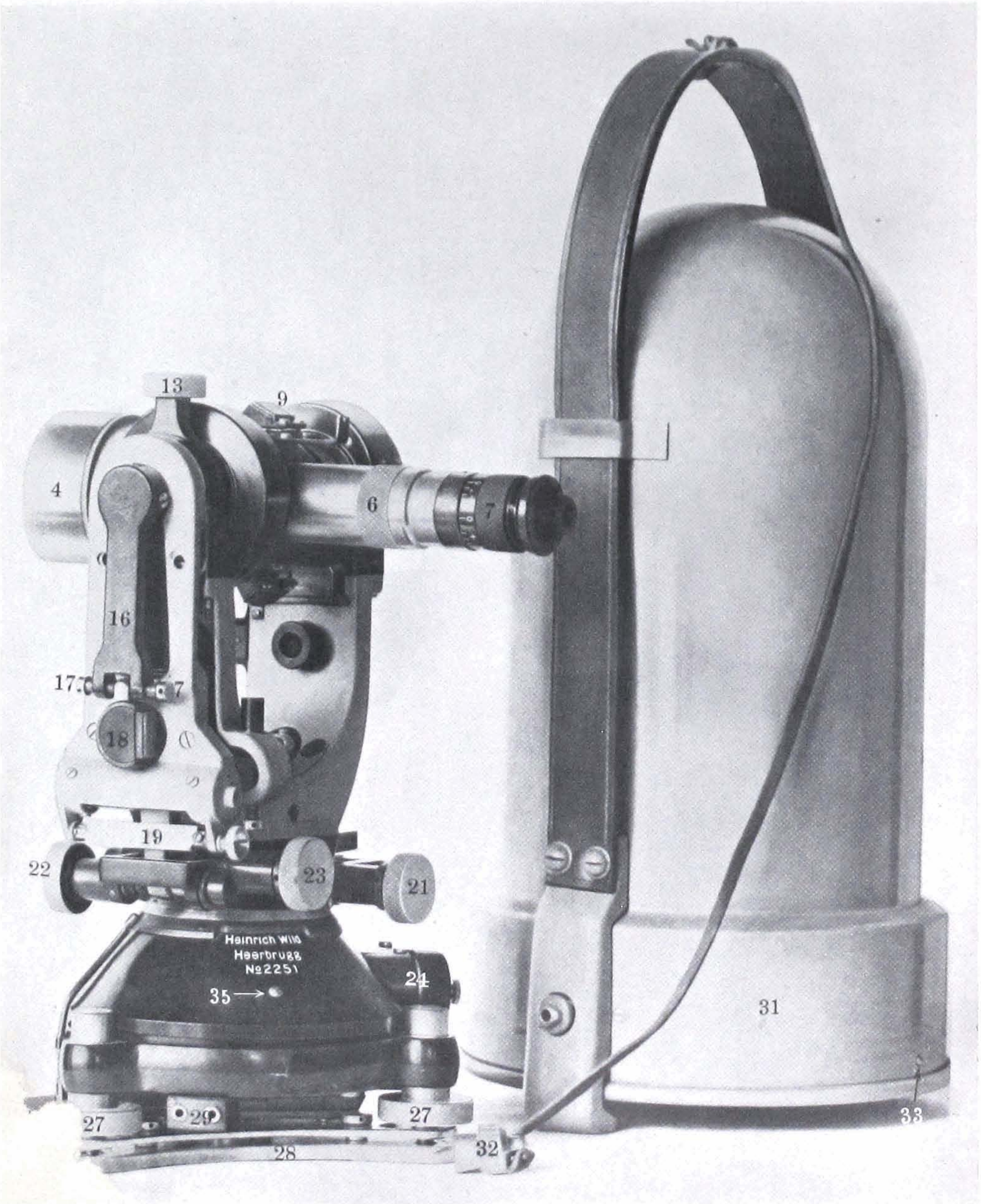
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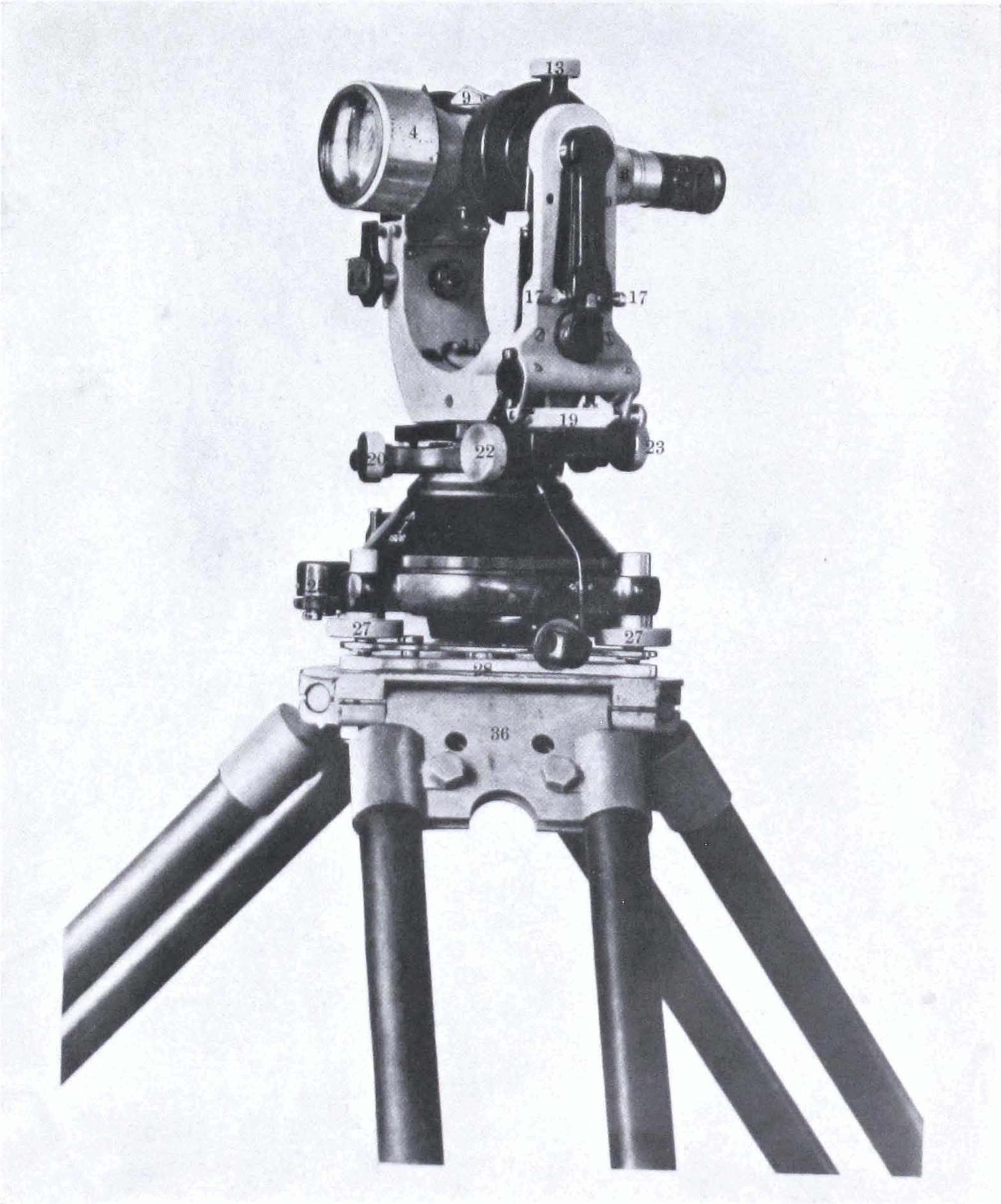
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setting the telescope on the object and making the micrometer read the angle of the face corrected by one half the collimation error, by means of the collimation level adjusting screws.

(*iv*) The length of a division of the vertical arc should be measured with the micrometer, over various portions of the micrometer arc, i.e., from 0′ to 5′, 1′ to 6′ etc., and the measures repeated on several divisions on other portions of the arc. Any variations from the length of 5′ indicate a derangement of the optical system. The total length of the micrometer division, from 0′ to 10′, should be checked against several divisions on the horizontal arc.

(*v*) The connection between the collimation level and the vertical arc prisms should be examined by clamping the arc, setting the bubble with a right-hand motion, setting the micrometer and then, watching the micrometer, slowly rotate the bubble setting screw in a left-hand direction. If the arc setting does not move with the rotation, while the bubble has been found to move, the connection is not rigid. A more rigorous method may be carried out by sticking a gelatine scale to the bubble glass, and with the telescope clamped, reading with the micrometer the angular value of these bubble divisions when the bubble is moved, first with a right-hand screwing motion, then with a left-hand screwing motion. Any irregularity in the intervals measured shows that the connection is not rigid.

A certain degree of lack of rigidity can be eliminated by always observing the rule to finish the collimation level tangent-screw motion in a clockwise direction but it is not generally advisable to take the field with an instrument exhibiting this error.

Parts of the Wild Universal Theodolite, *vide* Plates I, II and III.

1. Locking clips
2. Hinged clamps
3. Diagonal eyepiece
4. Telescope
5. Micrometer microscope
6. Telescope focussing ring
7. Eyepiece „ „
8. Micrometer microscope focussing ring
9. Vertical arc illuminating prisms
10. Micrometer illuminator
11. Sights
12. Micrometer head
13. Vertical arc clamp
14. Micrometer switch
15. Horizontal level
16. Arm connecting collimation level and vertical circle illuminating train
17. Collimation level adjusting screws
18. „ „ viewing prism
19. Collimation level illuminating mirror
20. Horizontal arc clamp
21. „ tangent-screw
22. Collimation level tangent-screw
23. Vertical tangent-screw
24. Horizontal arc setting-screw cover
25. Circular level
26. Horizontal arc illuminating prism
27. Foot-screws
28. Tribrach
29. Socket for electrical illumination plug
30. Base of case
31. Cover
32. Key of cover
33. Dot on cover
34. „ „ base of case
35. „ „ base of theodolite
36. Stand

PART II

THE WILD PHOTO-THEODOLITE

SECTION I

DESCRIPTION OF THE INSTRUMENT

1. Description of the Theodolite.—The Wild Photo-Theodolite consists of a Wild theodolite mounted over a camera holder.

The theodolite is identical with the Wild Universal theodolite* in operation and in construction with the exceptions that:—

(*i*) In place of the conical vertical bearing of the "Universal" theodolite, the theodolite of the photo-theodolite is supported by two plates between which are a large number of steel balls. The lower plate is rigidly attached to the camera holder, while the theodolite is attached to the upper plate. Centring is maintained by a hardened steel pin working in a steel collar.

(*ii*) There is no horizontal arc setting screw. The train of prisms for illuminating the horizontal arc is fixed rigidly in the top of the camera holder so that when the line of collimation of the telescope is in the same vertical plane as the optical axis of the camera the horizontal arc reading is zero, or should be, if the instrument were in perfect adjustment.

(*iii*) The collimation level and the vertical and horizontal tangent-screws are slightly differently arranged. Also there is no horizontal level attached to the theodolite but there are two mounted on the camera holder (*vide* Plates VI & VII).

2. Description of the Camera Holder.—The camera holder is a rigid steel frame carrying, in the top, the train of prisms which illuminate the horizontal arc, and the two horizontal levels. It is provided with two V trunnion bearings in which the camera trunnions are held by means of sliding latches. In front there is a hinged clamp to take the elevating rack of the camera.

The camera holder is mounted on its base plate by a bearing similar to the bearing of the theodolite above it. The base plate fits into a tribrach, in which it is locked in place by two quick motion screws.

3. Description of the Camera.—There are two cameras provided with the photo-theodolite, one the short camera, of focal length 165 mm. and aperture *f.* 12, the other, the long camera of 230 mm. focal length and aperture *f.* 11. The two cameras are identical with the exception of their focal length, aperture and the number of notches in the elevating rack. The size of plate is 15 cm. × 10 cm. and the field of view 48° and 32° for the short and the long cameras respectively. Each camera is provided with two light filters, one orange × 6, one deep red × 50 (both figures for ordinary process plates), and also two lens caps.

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* Described in Part I.

The camera has a light steel body with the lens permanently fixed with its focal plane in the plane of the camera collimating marks and with a fixed aperture. It is supported in its place by two trunnions on brackets, and by the hinged stirrup at the forward end which forms the elevating rack and fits into the hinged clamp on the camera holder.

The elevating rack of the short camera has five notches giving a horizontal position and two positions of elevation and depression. The long camera rack has four notches and only one position of elevation. The angular movement between successive notches is 6 grades or 5° 24′. In the latest models the short camera is fitted with a ladder-like rack having six rungs (2 for elevation and 3 for depression) which gives a maximum depression of over 20°. The short camera can be still further depressed by disengaging the rack and lowering the camera on to a stud fixed in the frame.

The focal plane is marked by a rigid steel frame at the back of the camera and carries the four collimation marks, a tab bearing the camera number, and also three glass numbering drums. These numbering drums are operated with the milled numbering heads outside the camera. The back of the camera which is hinged and opens with a spring latch operated by a milled head, carries inside in the centre a circular disc pressed forward by a strong spring against which it can be withdrawn by screwing up the milled head on the outside. The plate carrier is a rigid metal frame with spring clips to hold the plate in position and a metal slide. When in position in the camera with the spring released the sensitised surface of the plate is held firmly against the collimation frame.

4. Other Equipment.—The remainder of the equipment for the Wild photo-theodolite comprises two additional stands, with tribrachs, three targets with discs and spindles for fitting them to the normal tribrach, and one folding subtense bar with disc and spindle for fitting it to the normal tripod. These require no description.

5. Setting up the Instrument.—The following is the procedure for setting up the instrument:—

(*i*) Set up a tripod over the mark.

(*ii*) Take out a tribrach, place it on the tripod and screw up lightly.

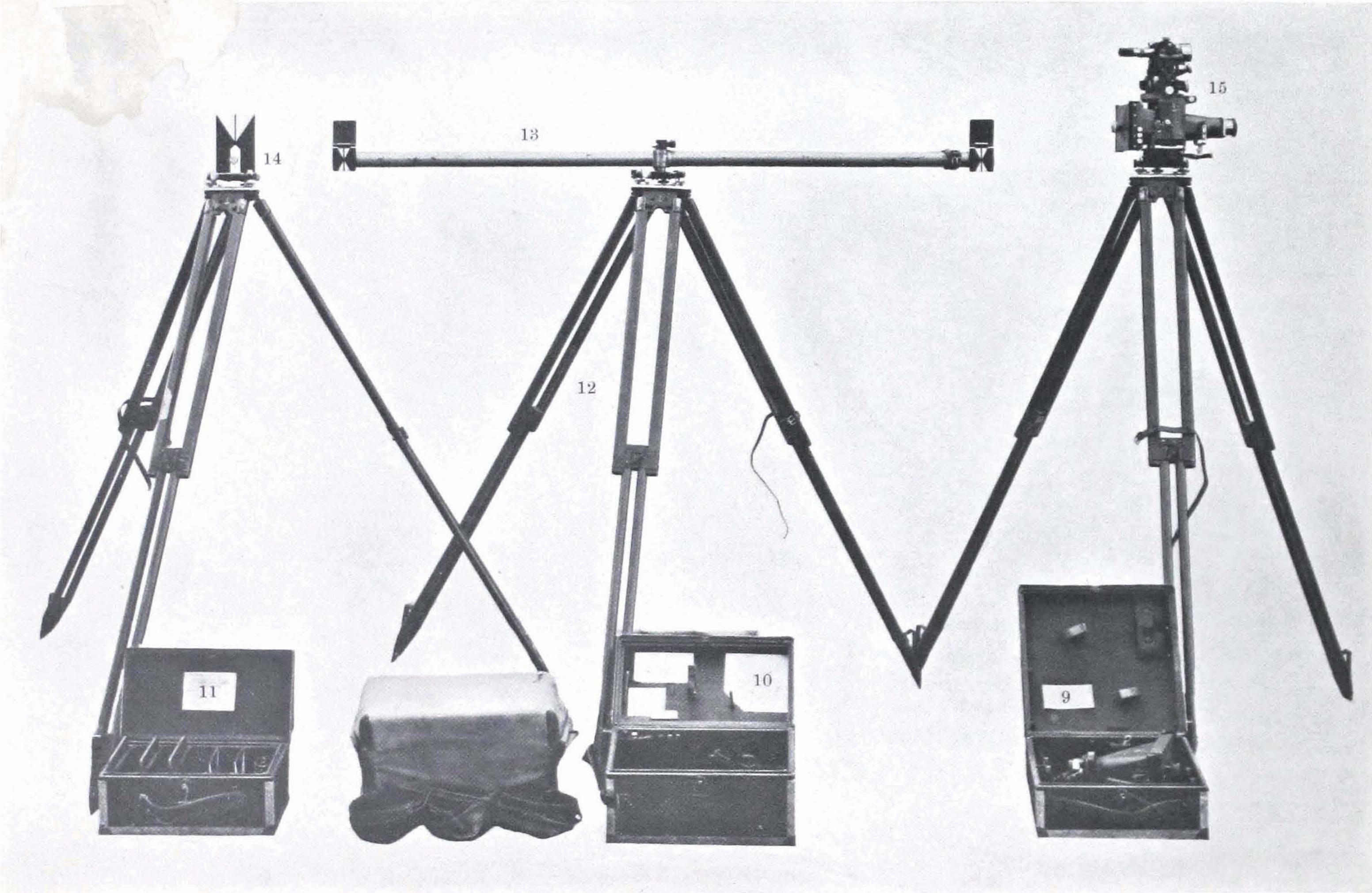
(*iii*) Unscrew the base locking screws.

(*iv*) Open the theodolite box, unscrew the holding down bar across the camera holder, place the fingers of the left hand between the theodolite pillars and with the thumb against the top of camera holder grasp the upper bearing firmly. Take hold of the elevating rack clamp with the right hand and with both hands lift the instrument out of the box, and place it on the tribrach and immediately screw up the base locking screws.

(*v*) Unscrew and slide back the camera trunnion latches, take out the required camera from its box, place it in position in its holder with the lens number above and slide to and clamp the trunnion latches.

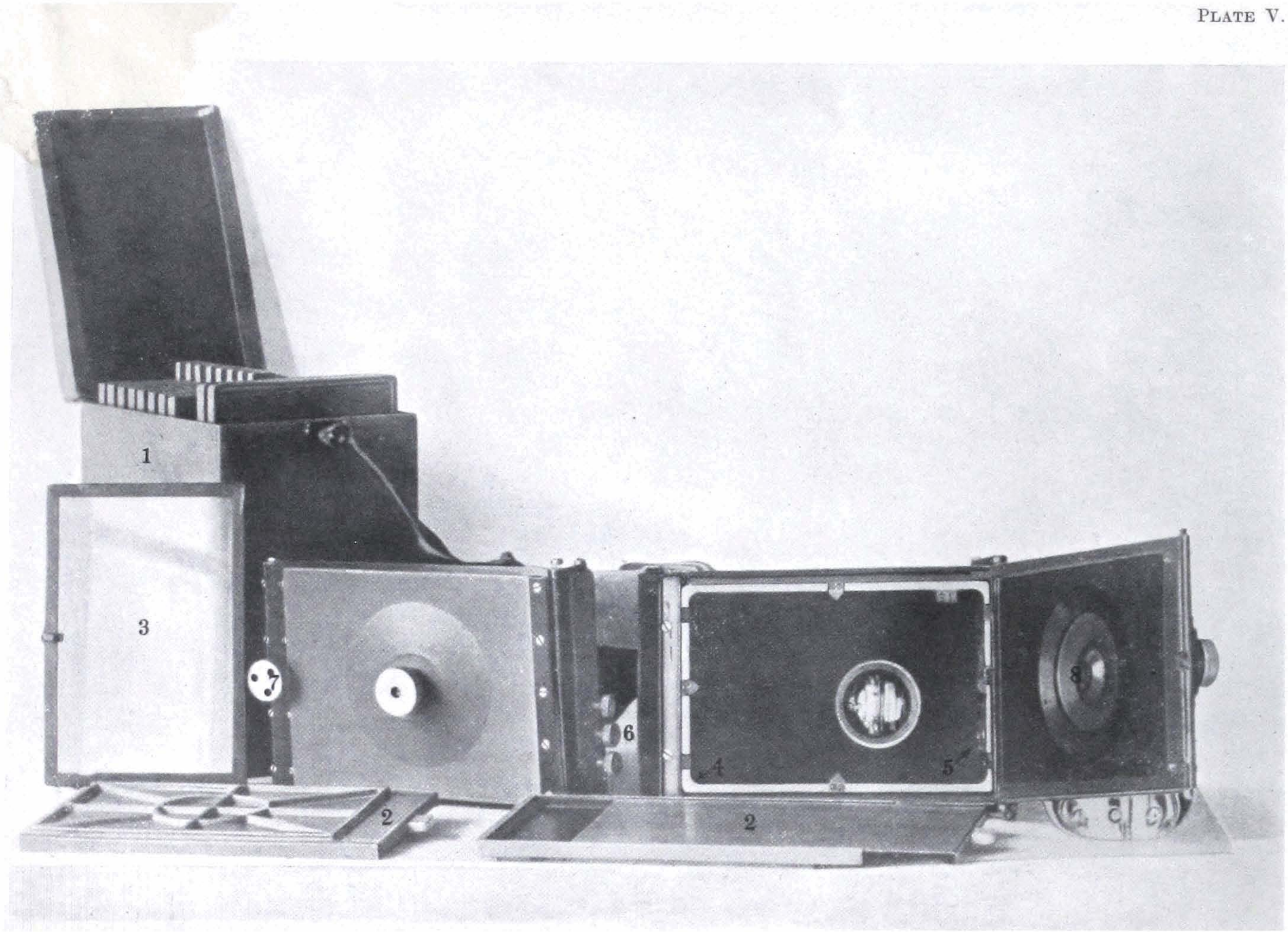
(*vi*) Raise the lens of the camera and put the elevating rack into its clamp. When clamping see that the clamp is roughly horizontal and not sloping downwards.

NOTE:—A compass should not be used anywhere near the instrument as the amount of steel on it would considerably affect a compass needle.



9. CAMERA BOX 10. PHOTO-THEODOLITE BOX 11. ACCESSORIES BOX 12. STAND 13. SUBTENSE BAR

14. TARGET 15. PHOTO-THEODOLITE.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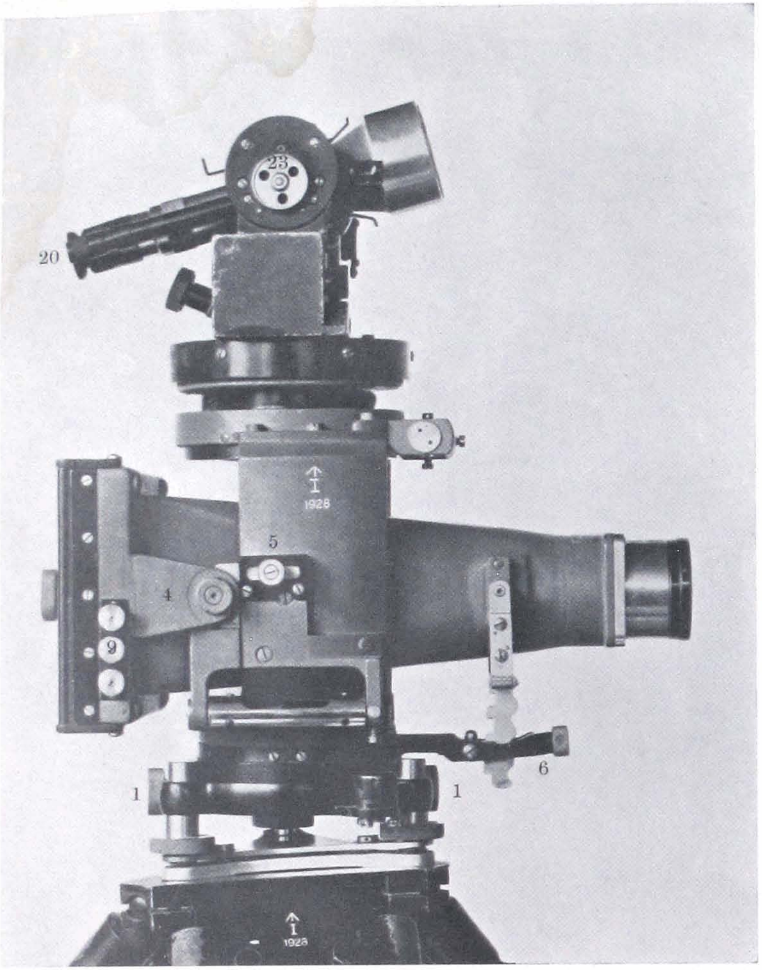
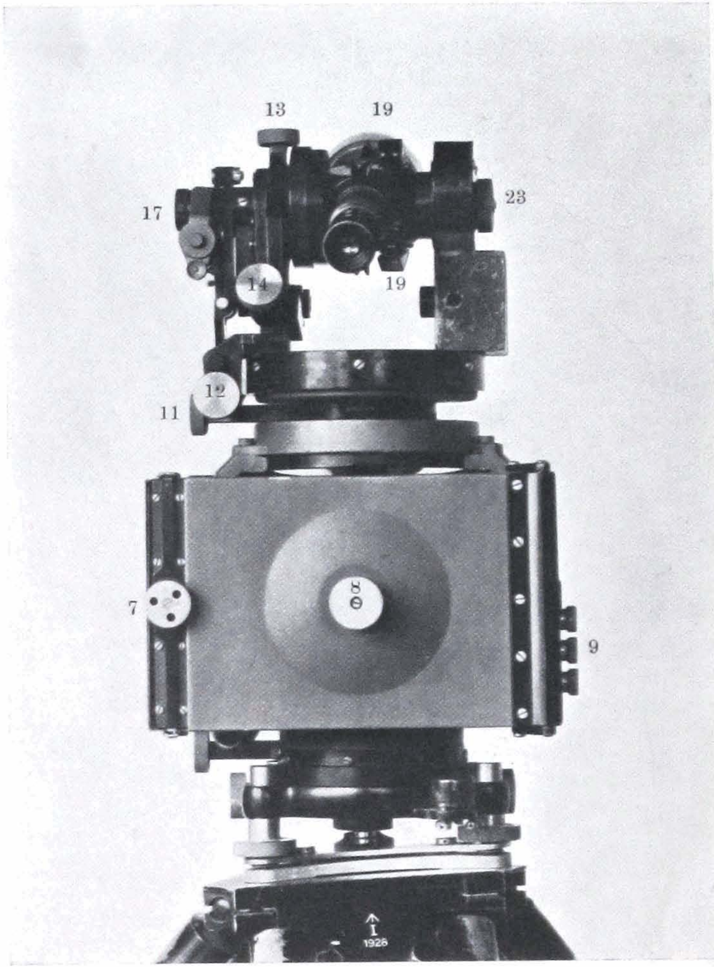
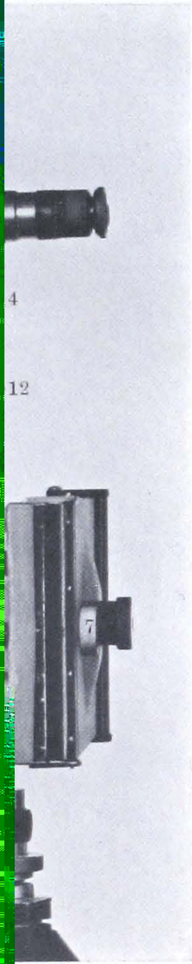
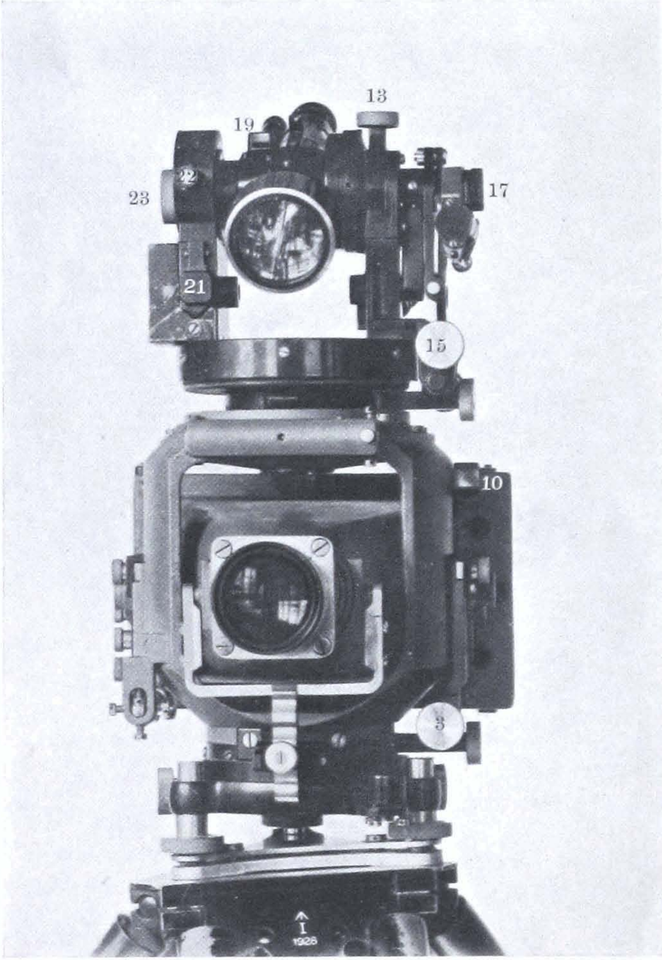




THE WILD PHOTO-THEODOLITE.

1. CLAMPING SCREWS ON TRIBRACH. 4. CAMERA TRUNNION AND 5. LATCH. 6. ELEVATING RACK AND CLAMP. 7. LATCH TO BACK. 8. PRESSURE SCREW. 9. HEADS OF NUMBERING DIALS. 11. CLAMP AND 12. THEODOLITE HORIZONTAL TANGENT SCREW. 13. CLAMP AND 14. VERTICAL TANGENT SCREW. 17. READING PRISM FOR BUBBLE. 19. ILLUMINATING PRISMS, VERTICAL CIRCLE. 20. MICROMETER EYEPIECE. 23. MICROMETER HEAD.





HE WILD PHOTO-THEODOLITE.

CREW. 4. CAMERA TRUNNION AND 5. LATCH. 6. ELEVATING RACK AND CLAMP. 7. LATCH TO
11. CLAMP AND 12. THEODOLITE HORIZONTAL TANGENT SCREW. 13. CLAMP AND 14. VERTICAL
ION LEVEL BUBBLE. 16. REFLECTOR AND 17. READING PRISM FOR BUBBLE. 18. TELESCOPE
L CIRCLE. 21. MICROMETER SWITCH. 22. MICROMETER ILLUMINATOR. 23. MICROMETER HEAD.

6. Packing up the Instrument.—To pack up the instrument,

(*i*) Remove the camera and replace it in its box, reversing the procedure for setting up.

(*ii*) Place the telescope of the theodolite in the "micrometer right" position at about 30° elevation with the eyepiece above the elevating rack clamp, leaving the circles unclamped.

(*iii*) Open the box and see that the holding down bar is unscrewed, unscrew the base locking screws, and holding the instrument as when setting up replace it in its box and clamp the circles gently. Screw down the holding down bar and close and pack up the box.

Parts of the Wild Photo-Theodolite *vide* Plates IV & V

1. Plate box
2. Plate carrier
3. Ground glass screen
4. Collimation frame
5. Numbering drums
6. Milled heads
7. Spring latch
8. Circular pressure disc
9. Camera box
10. Photo-theodolite box
11. Accessories box
12. Stand
13. Subtense bar
14. Target
15. Photo-theodolite

SECTION II

The Principles of Photogrammetric Surveys with the Wild Photo-Theodolite and Autograph.*

7. Stereographic surveys with photographs taken from the ground can only be carried out in hilly or mountainous country where extensive views are obtainable from commanding stations. The development of the method has been due to the demand for accurate maps in the Alpine lands of Central and Southern Europe.

The Wild Autograph (designed and produced by Mr. H. Wild of Heerbrugg, Switzerland) is one of several plotting machines which have been produced in recent years for the plotting of maps from photographs, whether taken on the ground or from the air. The field instruments which are used in conjunction with the Autograph are the Wild Photo-theodolite and the Wild air camera. It is with the use of the former that this paper is concerned.

8. Principles.—Before work can be carried out satisfactorily with the Wild Photo-theodolite, the principles on which the map is plotted must be understood.

Two photographs are taken from the two ends of a base. These two photographs are then viewed stereoscopically in the plotting machine by which a map is drawn of the country visible in both photographs. In the hands of an experienced operator the accuracy of plotting is such that within the area of most effective plotting (*vide* para 14), relative errors of a very small amount in the positions and heights of trigonometrically fixed control points, can readily be detected. At normal ranges, the positions of points can in fact be fixed at least as

* For more detailed instructions and theory of field work, and for instructions in the use of the Autograph, reference may be made to "Stereo-photogrammetry" by Dr. Max Zeller, published by the H. Wild Surveying Instruments Supply Coy., Heerbrugg, Switzerland.

accurately *inter se* as by ordinary topo. triangulation. Absolute position is of course dependent upon the accuracy of the trigonometrical control. Contouring is a speciality of the method. In bare or lightly wooded hills the plotting of contours is practically errorless; even spirit-levelling cannot compete with it, except in densely wooded country, owing to the impracticability of levelling to every point on a contour, and to the errors in surveying a contour by ground methods even if accurately fixed on the ground.

The design of the autograph admits of two or more pairs of photographs being taken from the ends of the base, successive photographs being inclined to the left or right of one another so as to form, in effect, a panorama, thus covering more ground laterally than a single pair.

9. Cameras.—With the theodolite, two cameras are provided:—one with a long focus lens (230 mm. or 10 inch), and one with a short focus lens (165 mm. or 6 inch). These are known as the long and short cameras respectively.

The field of the long camera subtends about 30° and that of the short camera about 50°. A greater width of country can therefore be plotted from one pair of photographs taken with the short camera than from a pair taken with the long camera. The short camera should therefore be used wherever possible.

The long camera is only employed when distant country is to be plotted. Owing to the grain of the emulsion sufficient definition is not obtainable with the short camera for accurate plotting at distances greater than about 10 miles.

It causes delay in plotting if some photographs of a survey are taken with the long camera and some with the short, as various changes have to be made in the plotting machine. In plotting an area it is simpler to plot all the photographs from all stations taken with one camera, and then all those taken with the other. The whole series of photographs should therefore be taken as far as possible with the short camera, except those required for distant areas, and these should be labelled as a separate series, and plotted subsequently.

It simplifies the setting of the plotting machine if each pair of photographs is taken with the axis of the camera at the two base stations parallel.

The camera is supported on trunnions for rotation in a vertical plane and can be tilted upward or downward as required in order to cover the area under survey.

10. Obliquity of successive pairs.—Diagram No. 1 shows two pairs of photographs taken with the long camera from a base X Y.

In the first pair of photographs A X E and B Y F the axes of the cameras are normal to the base and in the second pair of photographs C X G and D Y H the axes of the camera are 20° left of the normal to the base.

The area plotted from the first pair of photographs is B R E while the area plotted from the second pair of photographs is D S G.

It should be noted that although country as close to the base as R and S can be plotted, there is a gap R T S, extending as far as T, between the two areas which are plotted from the two pairs.

The greater the angle between successive pairs of photographs the greater this gap R T S becomes. In the present case T is just under 5 times the base length from the base.

Actually the area R T S could be plotted from the two photographs C X G and B Y F. This however would entail an extra setting of the plotting machine which takes time and is expensive. It is better and cheaper to take more photographs and to arrange that all the plotting required can be done, from pairs of parallel photographs.

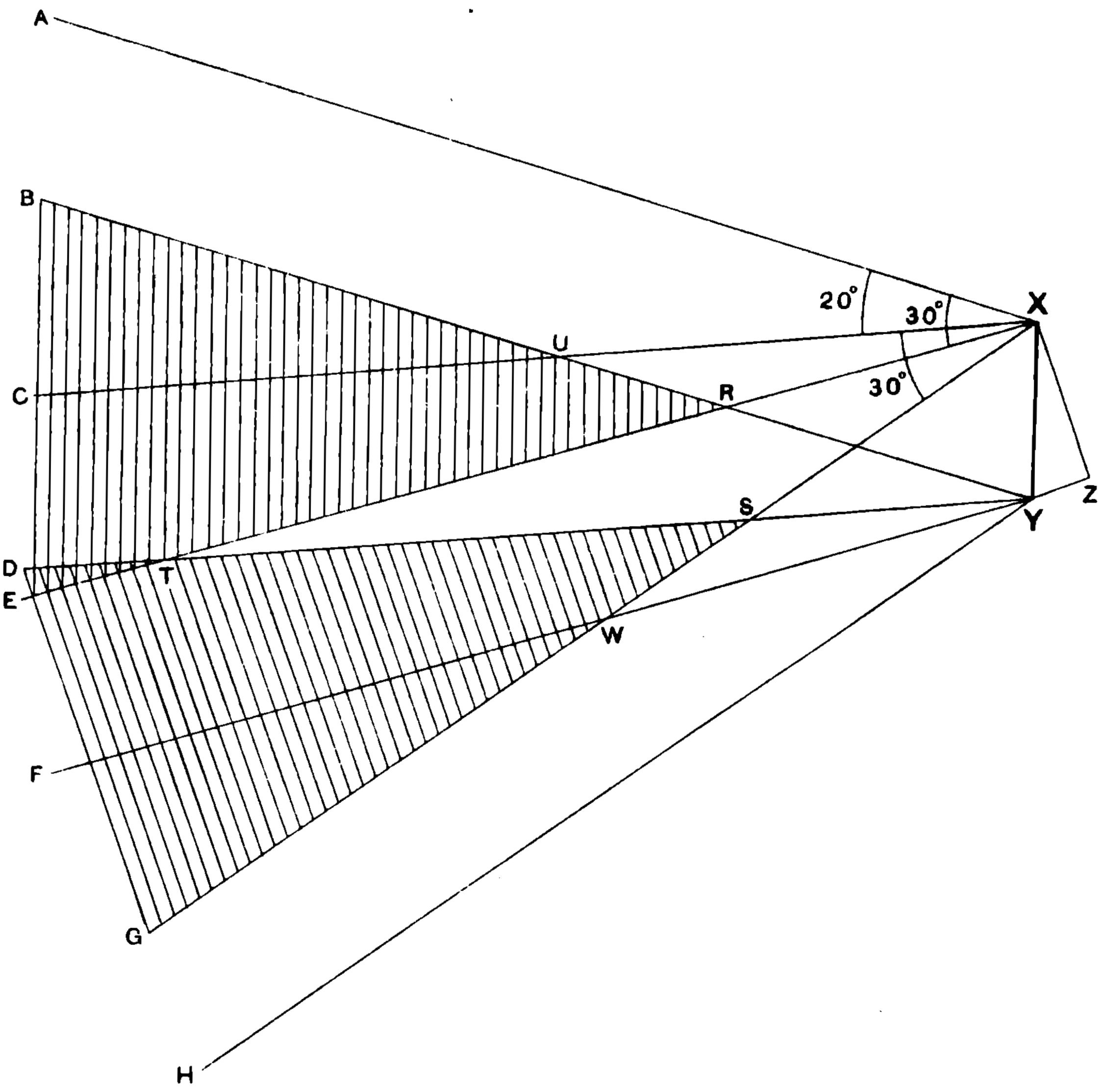


Diagram No. 1

For this reason the axes of adjoining photographs should normally be inclined at 20° for the long camera and 30° for the short camera. For plotting ground nearer to the base than five times the base length, this angle will have to be reduced. If on the other hand, it is imperative for some reason to economise in plates, and only distant areas are to be plotted, the angle between successive pairs may be increased; it should be computed graphically by a diagram similar to No. 1, given the minimum distance at which plotting is to commence. In all cases this angle should be a multiple of 5° to facilitate plotting calculations.

11. Reduction of effective base.—The greater the obliquity of the camera to the normal, the less is the effective length of the base. In diagram No. 1, X Y is the base. When photographs are taken 20° to the left of the normal, X Z is the effective length of the base: this is X Y cos 20°.

The following table gives the effective length of the base for various angles of obliquity of photographs to the normal.

Obliquity to normal.	Effective base-length.
20°	0·94 × Base
30°	0·87 × ,,
40°	0·77 × ,,
50°	0·64 × ,,
60°	0·50 × ,,

NOTE:—*The makers use the terms "obliquity" to denote horizontal deviation from the normal, and "inclination" to denote angles of depression or elevation.*

Photographs are not usually taken inclined at more than 45° to the normal to the base. The reduction of the effective length of the base clearly results in diminished range of plotting and must be allowed for.

It must be remembered that with the short camera inclined at 45° to the normal, say left, the extreme left-hand limit of the photograph will be inclined 70° to the normal (45° + 25°), and that the effective base for plotting detail on the left of the pair will be very small indeed.

In regular surveys, the amount of obliquity should be standardized as far as possible. The following angles have been laid down by the makers as convenient, tables of corrections being available:—

Short camera 45°L, 30°L, O, 30°R, 45°R

Long camera 40°L, 20°L, O, 20°R, 40°R.

12. Near limit of plotting.—In natural sight the limits of accommodation and convergency render it difficult to see an object clearly nearer to the eyes than about five times the interocular distance. In the Wild autograph as in other plotting machines the focus is constant and there is no convergency between the optical axes of the eyes in viewing the photographs. These considerations do not therefore affect the nearness to the base at which plotting can be carried out, and the chief factor governing this is the change in the shape of objects when viewed from widely separated points. The nature of the ground thus governs the near limit of plotting. The most favourable case is that of a slope immediately facing the photo base, where there will be a minimum change in the two aspects of the various features, and objects will fuse stereoscopically at a distance as near as 1 to 1½ times the base length. It will however be unusual to find foreground favourable for plotting at such close ranges. The worst case is that of narrow ridges running at right angles to the base. Here the two aspects might be so different that the right and left slopes of the ridges would appear only in the right and left photographs respectively, so that there might be no possibility of stereo fusion up to distances of 3 or 4 times the base length or even more. In a systematic photographic survey such a situation would indicate faulty siting of the photo stations.

13. Far limit of plotting.– The far limit, in terms of absolute distance, to which plotting can be carried out is governed by the following factors:—

Quality of photographs,
Grain of plate,
Length of base,
Scale of the plot.

It is evident that accurate plotting cannot be carried out, especially at long range, unless detail can be clearly seen on the negatives. Fine grained plates are essential for dealing with the very small scales of distant features. The stereoscopic relief upon which plotting depends is in direct proportion to the ratio of base to distance. In suitable conditions plotting of tolerable accuracy for topographical purposes can be carried out up to about 30 times the base length if the absolute distance is not too great, and the fixing of peaks and crest lines has been done at distances up to 100 times the base length, but contouring in such conditions is not possible.

As the range increases so must the base to distance ratio be increased, in order to counteract the loss of definition caused by the grain of the emulsion, by atmospheric conditions, and by the reduced size of features on the negative.

Plotting of crest lines has been carried out at distances of 40 miles in the Kara-korum and in Irāq with base lengths of 1 : 100 and 1 : 50.

Finally the limitations imposed by the construction of the plotting machine govern the scale of the plot. The size of the plotting board limits the size of the plot, although various systems of gearing enable plotting to be extended beyond what would normally be the edge of the board. With the present design of the Autograph plotting can be carried out from 30 mm. to 1 metre from the base on the scale of the plot. That is to say, no ground further than 1 km. can be plotted on the scale of 1 : 1,000 or further than 20 km. on the scale of 1 : 20,000, and so on.

If however, the photographs have been properly taken and the control is good, plotting is so accurate that it can, if the nature of the terrain is suitable, be enlarged two or three times and still be more accurate than plane-table survey on the scale of the enlargement.

14. Limits of accurate plotting.—The area of most effective plotting is at distances between 4 and 10 times the base length. Or, conversely, for plotting a given area most accurately, the length of the base should be between 1/4 and 1/10 respectively of the distance to the nearest and furthest points to be plotted. These are the ratios which must be worked to in carrying out systematic rigorous surveys.

15. Classes of ground stereographic surveys.—Different classes of work to which the Wild autograph can be applied in India in connection with ground photographs may be enumerated as follows:—

(*i*) Large scale "special purpose" surveys (e. g. cadastral, railway, hydro-electric, etc.).

(*ii*) Topographical surveys.

(*iii*) Provision of "control" for air surveys in areas inaccessible to the ground surveyor.

(*iv*) Correcting and supplementing reconnaissance surveys beyond the frontier or providing a framework for their better execution, by the accurate fixing of crest lines of distant ranges.

(*v*) The measurement of excavation work, e.g. in connection with contracts for the excavation of foundations of dams for hydro-electric projects etc.

16. Regular surveys.—Classes (*i*) and (*ii*) are regular or deliberate surveys carried out almost entirely by the photographic method, only such areas as cannot be covered by the camera being completed subsequently by plane-tabling. They require considerable experience in order to determine the most effective and economical lay-out of the stations from the point of view both of the photography and of the inter-connecting triangulation.

17. Cadastral surveys.—Cadastral work is more limited owing to the large scale that is required. The limitations of the autograph mentioned in the first sub-para of para 7 render it necessary to locate the photo stations 1,000 yards away from the furthest point to be plotted, when the scale of the plot is 1/1,000 (the scale for cadastral work being of this order). Conditions in India do not usually admit of stations being placed so close, as it is necessary to take the photographs from points well above the level of terraced cultivation and facing the general slope of the ground under survey. On the other hand the high precision of the method may often enable this difficulty to be overcome, by plotting on a smaller scale and then enlarging.

The psychology of the people is another factor in determining the suitability of the photo method for cadastral work. Existing ground methods enable disputes to be settled on the ground during the course of survey, when each owner points out the limits of his land in the presence of his neighbour. By the photo method these opportunities do not occur or have to be specially arranged for after compilation. In addition there is further auxiliary work on the ground which adds to the expense. The photo survey will therefore have to show a considerable saving in time and expense if it is to be adopted.

18. Topographical.—For topographical surveys pure and simple, there will be very little application for the method. In Europe the activities of climbers and tourists have created a demand for highly detailed maps of the Alpine areas, otherwise unproductive and sparsely inhabited; but in India the vast Himālayan tracts are quite undeveloped and there is no justification for maps on a larger scale than 1 inch to 4 miles, for which the stereographic method would be most uneconomical and out of proportion to the accuracy which is suitable. It is true that the outer ranges are well populated and would offer an admirable terrain for photo surveys, but here again the plane-table meets all requirements of accuracy and is considerably the cheaper method for the 1 inch scale.

19. Control for air surveys.—In class (*iii*) the Autograph provides very valuable assistance for the compilation of air surveys, in areas which are inaccessible on the ground, but which can be surveyed from the air. It is impossible to fix adequate control for air survey by means of triangulation from stations outside such areas, but from these same stations "patches" of ground on successive ridges can be plotted with great accuracy from Wild photographs and these provide invaluable control for filling in the intervening gaps by air photography, though they do not of course solve the problem of providing height control in valleys.

Class (*iv*) is virtually the same as class (*iii*) and needs no further amplification.

20. Measurement of excavations.—Class (*v*) has had a considerable application in Europe. The area under excavation is photographed from a short base at close range both before and after excavation or at intermediate intervals as required. Contours are plotted at close intervals, say 1 ft. or 6 inches, and the horizontal area between successive corresponding contours is measured from the plot. The volume is thus obtained with a very high degree of accuracy. This procedure is of course only applicable in hilly ground.

SECTION III

Field Work

21. Field work may be divided into :—

Work preparatory to taking the field.

Reconnaissance.

Trigonometrical observations to fix base and control points.

Photography.

Preparatory Work

22. Work preparatory to taking the field comprises :—

(*i*) the collection of data.

(*ii*) the preparation of a rough scheme from existing maps.

(*iii*) the calibration of the instrument.

(*i*) and (*ii*) are the same operations as for normal topographical triangulation, the latter being adapted to the special requirements of the siting of camera stations as detailed hereinafter.

23. Calibration of the instrument.—The theodolite portion of the instrument is calibrated as for the Wild Universal theodolite. The additional adjustments to be determined are :—

(*i*) the focal length of the lens and the position of the principal point relative to the collimation marks.

(*ii*) the angle between the zero of the horizontal arc and the vertical plane through the plate perpendicular of the camera.

(*iii*) the angle of elevation or depression of the plate perpendicular of the camera for each notch of the elevating rack.

(*iv*) the dislevelment of the camera trunnion axis.

It is not necessary that these adjustments should be determined when the subsequent plotting is to be done on the Wild Autograph but (*ii*) should be determined before field work commences as it affords a check on the rigidity of the fixing of the train of prisms illuminating the horizontal arc. In this case it will be sufficient to obtain the angle between the scale zero and the vertical collimation marks.

If photographs taken in the camera are to be utilized for mapping by other methods than the Wild Autograph (e.g. the Canadian Method) these adjustments will require to be determined.

24. Method of determining calibration constants.—The instrument is set up at a point where there is a suitable field of view including points not less than a mile away* on a level with the camera, distributed over an arc of 50° and of a nature to photograph well and give good points to observe to and measure to on the photograph.

(*i*) With the elevating rack in its horizontal notch the camera is set so that six suitable points appear one towards each edge of the ground glass, three near the centre, and one other in the field. The camera is clamped in this position and a reading of the horizontal arc taken to one of the six points (called the check point).

(*ii*) The camera is loaded, the setting of the camera checked by reading the angle to the check point, and the photograph taken. Before replacing the plate slide rounds of horizontal and vertical angles on both M.R. and M.L. are taken to the six points selected.

(*iii*) The camera is reloaded and two exposures are made on the plate, one with the camera at its greatest elevation and the second at greatest depression, the setting of the camera being checked before exposure by reading on to the check point. This is repeated for the remaining notches of the elevating rack on another plate.

(*iv*) To determine the position of the principal point completely, i.e. both its X and Y co-ordinates relative to the collimation marks, similar photographs and angles to those in (*ii*) must be taken for six points lying on or close to the vertical collimation line. In hilly country a site may often be selected where, with the camera as fixed in the instrument, this will be possible. If this is not possible as in flat country, the camera must be dismounted and set up on its side on a plane-table, and as close below the theodolite as possible. It can be levelled by bringing points, for example two, selected by observation, which are at the same level as the instrument on to the vertical collimation line of the camera, which is now horizontal. A photograph is taken in this position and the rounds of angles read to the six selected points. †

When the plates are developed, the distances of the marginal points from the centre are roughly measured and their height above the horizon line calculated. The horizon line is drawn and the plate is set in a co-ordinate measuring machine with this line parallel to one axis, and the co-ordinates of the points and the two collimation marks are read. The distance of the principal point from the collimation marks and the focal length of the lens are then computed on a form similar to the specimen facing page 24. The angle subtended at the back node of the lens by one of the points and the principal point is computed and its difference from the observed reading gives the horizontal angle between the plate perpendicular of the camera and the horizontal arc zero. This computation is then carried out for those six points on the plate which were selected to lie on or near the vertical collimation line and this gives a further value for the focal length and the distance of the principal point from the vertical collimation marks.

The double exposed plates are set in the co-ordinate measuring machine and the co-ordinates with reference to the horizon line, of the same ground point in the elevated and depressed exposure positions of the camera are measured. The angle between the line joining the same ground point in the two exposures and the horizon line is computed and its difference from 90° represents the dislevelment of the trunnion axis of the camera. The ordinate distances between the same ground point in the two exposures and the principal point are measured and from this the angles subtended at the back node of the lens are calculated. The difference between these angles and the observed angle gives the actual elevation or depression of the camera for each notch of the elevating rack.

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* This distance is necessary to eliminate the error due to the fact that the front node is not on the vertical axis of the telescope.

† The whole procedure is similar to that described for air cameras in Professional Paper No. 5 of the Air Survey Committee. War Office, London, 1929.

Reconnaissance

25. Regular Surveys, classes (*i*) and (*ii*).—Stations must be selected so that suitable photographs can be taken from which to plot the required area. At the same time it must be decided how the base is to be located. As the most favourable aspects for plotting are those of slopes facing the camera, main valleys will always be surveyed from bases on either side looking across the valley. Stations will usually be sited on the crest lines, to facilitate triangulation; and in deep valleys it will usually be necessary to have a second line of stations half way down the slopes. These can be fixed from the stations on the opposite crest. It will frequently happen that certain areas cannot conveniently be dealt with by photography, owing perhaps to the difficulty of siting a base or of connecting it with the triangulation, or because forest growth conceals such detail as roads and buildings. It will be necessary then to balance the pros and cons and to decide whether to establish one or more difficult photo stations or to leave the area for subsequent plane-table survey. The orientation of each base should be such that the normal to it passes approximately through the centre of the area to be mapped from that particular station. The length of the bases will be fixed in accordance with the considerations laid down in para 14. If the length of the base is to be measured by the auxiliary base method (*vide* para 30) it must be possible to lay out the sub-base at one station approximately at right angles to the base. As far as possible stations should be so sited that the photographs include a minimum of close foreground which cannot be plotted. The inclination of the base to the horizontal should not usually exceed 12°. The maximum difference in height between the two camera stations which can be allowed for in the Autograph is 30 mm. with a base length represented by 0 to 140 mm. This corresponds to a maximum inclination of 12° when the base has its maximum representation of 140 mm. in the autograph. When the base is represented by a less distance than 140 mm., a greater inclination is permissible, but unless the individual carrying out the field work is familiar with the autograph, it is advisable to be on the safe side by limiting the inclination to 12°.

26. Surveys of classes (*iii*) and (*iv*).—Previous reconnaissance for this class of work will usually be unnecessary, the highest available point in the neighbourhood will be selected, provided that it is possible to lay out a base of suitable length, orientation and inclination. The actual situation of the station is of minor importance, as it is not often necessary to plot any near ground. If plotting over a long range is required, as for example between 3 miles and 40 miles, two bases having one common station may be laid out, of about 1,000 yds. and 4,000 yds. respectively, plotting from the shorter base being carried out up to a distance of 10 miles. The ends of the bases should be on the same ridge if possible so as to facilitate intercommunication, especially if the observation and photography are to be carried out on the same day. In high mountains it is often very difficult if not impossible to find a suitable base at a sufficiently high altitude to obtain distant views, as the higher peaks are generally isolated from one another. For this reason distant work in high ranges is often impracticable.

Trigonometrical observations

27. Data required.—The following trigonometrical data are required before plotting can be carried out. (See also specimen of Register of Photographs page 26).

(*i*) The co-ordinates of the mid-point of the base.

(*ii*) The heights of both ends of the base.

(*iii*) The grid bearing of one end of the base from the other.

(*iv*) The length of the base.

(*v*) The co-ordinates of a certain number of control points in each pair of photographs.

28. Triangulations, for regular surveys.—In the execution of regular surveys, it will generally be necessary to carry out special triangulation for the provision of the above mentioned data. Existing triangulation may be of little assistance, as the stations are unlikely to coincide with any photo station's and the intersected points will not be capable of exact identification on the photographs.

One end of each photo base will as a rule coincide with a station of the triangulation network. The determination of the length of the bases will usually be done by the subtense method and the bearing of the base measured by readings to the other end, included in the round of station angles. This bearing must be correct to 10″.

At least one near and two distant control points should be fixed within the area of plotting of each photo pair. These will be fixed by ordinary methods of triangulation.

The accuracy of the triangulation must be such that there is no plottable error on the scale of the plot, e.g. at a scale of 1 : 5,000, all data must be correct *inter se* to about 1 foot. This will necessitate very careful centring and the provision of special marks for stations and intersected points, which will be visible on the photographs.

29. Triangulation for surveys of classes (*iii*) and (*iv*)—In work of class (*iii*) or (*iv*), any existing triangulation should be sufficient for the control points, but photo stations should always be connected up by observation to and from neighbouring stations. A well fixed intersected point may be accepted as one end of a base; but as the azimuth must be correct to 10″, it will be necessary to observe to back stations in order to determine it. Observations to other intersected points are liable to introduce considerable errors in azimuth.

The use of control points fixed by different series of triangulation, in which there are mutual discrepancies is likely to cause delay and difficulty in plotting. The two series of data should therefore either be adjusted, or else one should be rejected.

In the absence of any other control, intersected points may be fixed from the two ends of the photo base; these are however only of value in correcting the *orientation* of the photographs in the autograph, their *distance* being liable to at least as big an error as that which can be determined from the photographs themselves.

30. Base measurement.—The length of the base can be found by (*i*) direct measurement, (*ii*) single or double subtense, (*iii*) auxiliary base, (*iv*) ordinary triangulation. In normal conditions the subtense method is generally used.

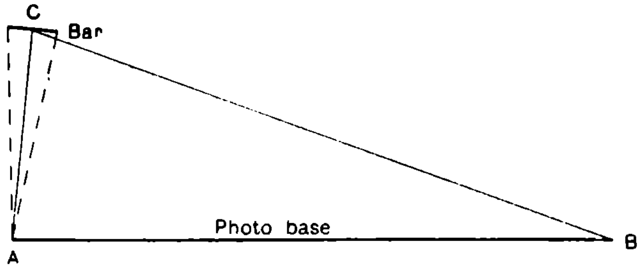
(*i*) *By direct measurement.*—Short bases up to 20 yds. should be measured directly with a steel or invar tape, for the reason explained in sub-para (*ii*).

(*ii*) *By subtense.*—The length of the Wild subtense bar is $\pi/2$ metres ($=1{\cdot}5708$m.). The length of a base is $5400/\theta$ metres, where θ is the subtended angle in *minutes* and decimals. (In centesimal angular measure for which the bar was designed, the length of the base is the reciprocal of the subtense angle in grades).

Since the formula is only applicable so long as the chord $\pi/2$ does not differ sensibly from the arc, distances of less than 20 yds. should be measured directly.

Single subtense may be used for distances from 20 to 200 yds. For distances of 200 to 400 yds. double subtense may be used. The bar is set up at an intermediate point and read from both ends of the base. If the intermediate point cannot be placed in line with the two ends of the base, the direct distance must be computed by measuring the two base angles of the triangle thus formed.

(*iii*) *Auxiliary base.*—When the distance to be measured is between 400 & 1,000 yds. the procedure is as follows :—



The distance A C is found by single subtense, and the triangle A B C is computed, the angle at B being very carefully observed. The angle at C may be deduced, but it is better to observe it so as to prevent mistakes; in that case the triangular error will be distributed at A and C only.

The position of C should be chosen so that the small apex angles at A and B are not too dissimilar, as this will give the least probable error in the length of the base, e.g. if A B is 1,000 yds., A C should be about 50 yds.

(*iv*) *By triangulation.*— Where the foregoing methods are unsuitable or when the length of the base exceeds 1,000 yds. it must be measured by triangulation. If there is a reasonably near station of the triangulation network, in a direction approximately at right angles to the base, the length of the latter may be determined from this single triangle, all angles being observed; the small angle at the further station being measured with extra precision. Failing such a station the base may be measured by observations at both ends to two or more intersected points on either flank of the base, the mean being taken of the several values obtained.

31. Accuracy of base measurement.—The degree of precision which is necessary in base measurement depends upon the maximum error tolerable in the plot and on the furthest distance to be plotted from the base in question. Thus, if errors of 10 yds. are permissible and the area to be plotted extends to 10 miles the base must be correct to 1 in 1,760 or say 1 in 2,000. The necessary number of measures of subtense angles can be calculated in the field from Table 15A Math. Ten measures will usually be ample.

Base lengths determined by direct or subtense measurement must be reduced to sea-level.

32. Elimination of centring errors.—Three similar stands and tribrachs are provided with the photo-theodolite. The theodolite, subtense bar and targets are all designed to fit the stands. Two stands are placed in position at the ends of the base at the outset of operations and the third is used at the point C in case of auxiliary base or double subtense. The stands with tribrachs remain in position until both the angular measurements and the photography have been completed. This eliminates all errors due to centring of the theodolite, camera, subtense bar and targets; and photography should always be completed immediately after the observation of angles. In determining the azimuth or length of the base, and in orienting the camera during photography the sighting targets will always be used for aligning the telescope on the other end of the base or on the auxiliary station.

If for any reason, photographs have to be re-taken on a later date it is advisable to reobserve sufficient angles to determine the azimuth of the base which may be slightly different owing to faulty centring. If the stations have been properly marked it will be unnecessary to measure the base again.

33. Use of single stand.—On difficult climbs it is often impracticable to carry more than one stand. In such circumstances the following procedure has been found to work well. The observer should take with him two of the sighting targets with their base plates. On reaching one end of the proposed base, he selects the position of the other end (it is usually unnecessary to visit the other end at this stage). He sends a *khalāsi* there with one of the targets and with instructions to build a small cairn about 1 foot high surmounted by a flat stone on which the target is placed. After completion of observations and photography at his end, the observer constructs a similar cairn under his stand and centres the other target on it by means of the plumb-bob. He then removes the stand and erects it over the cairn at the other end centring on the target in the usual way. The target at the first end remains in position in charge of a *khalāsi* until completion of work. If it is desired to leave markstones, these can be placed in position, at the first end, before erection of the cairn; and at the other end, at the close of work before removing the stand.

Photography

34. Quality of photographs.—It is most important to get good, correctly exposed photographs. It should be borne in mind that bad photographs are very laborious to plot, an experienced operator has to be put on to the work, and even then only meagre results will be obtained. Good photographs produce large areas of survey at low cost. Bad photographs result in small areas at a high cost. The correct exposure should always be found by exposing trial plates or by means of an exposure meter. Both cameras have fixed *apertures*, *f. 12* and *f. 11* for the short and long cameras respectively.

35. Weather and lighting conditions.—So far as possible, photography should be done on a bright fine day when the visibility is good. Strong shadows are however to be avoided, as they obscure detail. It is therefore better to have the sun behind the camera; long shadows should be avoided by taking photographs within one or two hours of noon. The best photographs may often be taken when the sky is lightly overcast, for the same reason. Photographs if possible should always be taken on the same day and under similar lighting conditions, as this improves stereo fusion and coincides with the requirements noted in para 32. The movement of tree shadows during the interval between exposures causes a false stereoscopic effect so that shadows appear to rise into the air or sink into the ground. This may result in incorrect contouring in the vicinity of trees, though it would scarcely be noticeable on topographical scales.

The exposure is made by removing the cap over the lens for the necessary time of exposure and then replacing it. In short exposures of one second or less, it is better to *raise* the cap above the lens rather than to lower it, as the movements of raising and lowering result in a slightly longer exposure over the foreground portion of the plate and less over the sky and distant landscape areas.

36. Manipulation of plate carrier.—After the carrier has been placed in the camera and the back closed and before exposure is made the slide of the carrier has to be removed and the plate has to be brought in contact with the collimation frame. This latter operation is performed by the pressure disc which is released by unscrewing the milled head in the centre of the back of the camera. If the spring is released before the slide of the carrier is withdrawn, the slide will jam, whereas if the slide of the carrier is totally withdrawn before the spring is released the plate is liable to be partially fogged. The spring has therefore to be released as the slide is withdrawn, and the latter must not be completely withdrawn till the spring is completely released.

After exposure has been made the slide must be replaced at the same time as the pressure spring is screwed up. An umbrella should always be used to protect the instrument from direct sunlight.

37. Wind vibration.—In high winds the instrument vibrates considerably and it is often necessary to wait several minutes for a lull. On windy days the cover must be completely removed as then less surface is exposed to the wind and the camera is not so shaken. Vibration may be avoided almost entirely by suspending a heavy stone (20 or 30 lb.) from the head of the stand.

38. Numbering of negatives.—Every negative must have its own number which is recorded up on it automatically during exposure by means of the numbering drums. There are three of these drums, each numbered 0 to 9, so that the first negative will be number 001, the tenth 010 etc. Photographs should be numbered serially throughout the survey, rather than by a separate series for each base If a duplicate negative has to be exposed, it should be given another number.

39. Orientation of camera.—In order to get the axis of the camera pointing in a particular direction, the telescope of the theodolite is first set at the required reading on the horizontal circle, e.g. if at the R station it is required to take a photograph 20° to the left of the normal, the telescope has to be set at 270° + 20° i.e. 290°. This is set with the slow-motion screw; care being taken that the micrometer records 0′ 0″. At the outset it is easy to make mistakes in the setting of the horizontal circles. If there is any doubt it is advisable to point the camera roughly in the desired direction and then to align the telescope approximately on the other end of the base; a glance at the circle reading will then show what reading is to be set.

To ensure parallelism of the plates, it is essential that only one instrument position e.g. M.L., be used at all stations when setting the camera to take a photograph. If the *telescope* is correctly oriented within 10 secs., it then follows that the orientation of the *camera* will be correct to 10 secs. plus or minus the collimation error between the camera axis and the sighting line of the telescope on M. L. This collimation error is a constant for any particular camera and theodolite and is soon ascertained and corrected during plotting. If however M. R. is used at one end of the base and M. L. at the other, the result will be a want of parallelism between the camera axis at each end, by twice the collimation error of the *telescope*. Such convergency of the plate axes involves a tiresome trial and error correction in the Autograph, as it is difficult to separate from other corrections due to errors in the base length, in orientation, and in the position of control points.

Having set the telescope at the required reading, the camera base-plate is unclamped and the telescope is aligned on the target at the other end of the base by turning the whole theodolite and camera; completing the intersection with the slow motion screw under the camera. Before making an exposure it is essential to make sure that the instrument is level.

40. Taking a photograph.—The operations of taking a photograph are:—

(*a*) Level instrument.

(*b*) Determine the number of photographs required to cover the ground and their obliquities and inclinations (by means of the ground glass) and enter them in the register.

(*c*) Calculate exposure.*

(*d*) Set camera to recorded obliquity and inclination for the left hand photo or that one which is the most favourably illuminated at the moment.

(*e*) Set the serial plate number.

(*f*) See that cap is on lens and insert plate carrier. Withdraw slide and release pressure spring.

(*g*) Check level, bringing both bubbles to centre of run.

(*h*) Align telescope on other end of base and verify circle reading.

(*i*) Expose plate, waiting for lull if wind is strong.

(*j*) Verify levels, orientation and inclination of camera, and serial number.

(*k*) Screw up pressure spring, replace slide and remove plate carrier.

Proceed as from (*d*) onwards for next photograph.

Exposed plate carriers should be placed in their box the opposite way up to the unexposed plate carriers.

41. Filters.—Two filters are provided with the camera, one x 6 and one x 50. The most suitable can only be found by trial. The correct filter also depends on the class of plate used.

42. Inclination of the camera axis.—Photographs may be taken with the camera axis horizontal or at different angles of elevation or depression as described in para 3. This movement is termed "inclination". It is important to ensure that the camera is the right way up (lettering uppermost), and is correctly placed in its trunnions, and that the rack clamp is properly screwed home. The notch is selected to give the best field of view and the camera should be depressed as far as possible. Normally the camera should be similarly set for elevation at both ends of one base, though this is not essential. The camera should not be inclined upwards unless it is absolutely necessary, as this implies the viewing of high ground from low camera stations with the consequent probability of an undue proportion of dead ground where there are convex slopes.

In the survey of deep valleys it may be necessary, in order to cover the area, to take photographs at two different inclinations from the same camera station.

43. Field records.—Full details of the photographs taken at each base must be recorded in a special register, a specimen page of which is given on p. 25. A panorama should be drawn from one end of each base, on which the control points are marked. (See page 25).

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* NOTE:—Exposures should be worked out by means of an exposure reckoner or calculator, for which a special light factor table for the latitude of the survey must be prepared. Most leading firms publish a calculator. The following example is for normal atmospheric conditions:—

Latitude:— 35° Date 15th March Local time 11 a.m.

Weather:— Sun, no clouds. Plate speed H and D 35 Filter x 6

Subject:— (*a*) Near landscape, (say 1/4 to 1 mile). Exposure 1½ secs.

(*b*) Distant landscape (say 5 to 10 miles). Exposure 3/4 sec.

Later, these points will be marked on prints from the corresponding photographs. Angular observations of the accompanying triangulation and for the measurement of the bases will be recorded in an ordinary angle book.

44. Development of negatives.—The negatives should be developed reasonably soon after exposure. On transfrontier expeditions they will generally be developed on return to camp, but in regular surveys it is preferable to send them to headquarters. Negatives should be handled as little as possible and the film should never be touched. Before plotting has been carried out only the minimum number of prints should be taken which are necessary for marking control points and for record purposes.

45. Preparation of data for plotting.—The data required for plotting will be computed in office and drawn up in the form shown in the specimen on p. 26 separately for each base. The following items are required by the plotting office:—

(*i*) Negatives arranged by photo bases.

(*ii*) Set of prints from one or other end of each base marked with control points.

(*iii*) Chart of triangulation showing photo bases and directions of photographs (*vide* specimen opposite).

(*iv*) Data for each base (*vide* specimen p. 26).

(*v*) List of rectangular co-ordinates and heights of control points.

The above noted data should be carefully prepared so as to be readily intelligible to an ordinary operator in the plotting office. If this is not done the plotting will require a higher proportion of expert supervision and the cost will be increased.

46. A specification for plates for use with the photo-theodolite is as follows:—

SPECIFICATION FOR PLATES FOR USE WITH THE WILD PHOTO-THEODOLITE

Size:—10 × 15 centimetres.

Thickness:—Not to exceed 2·5 millimetres.

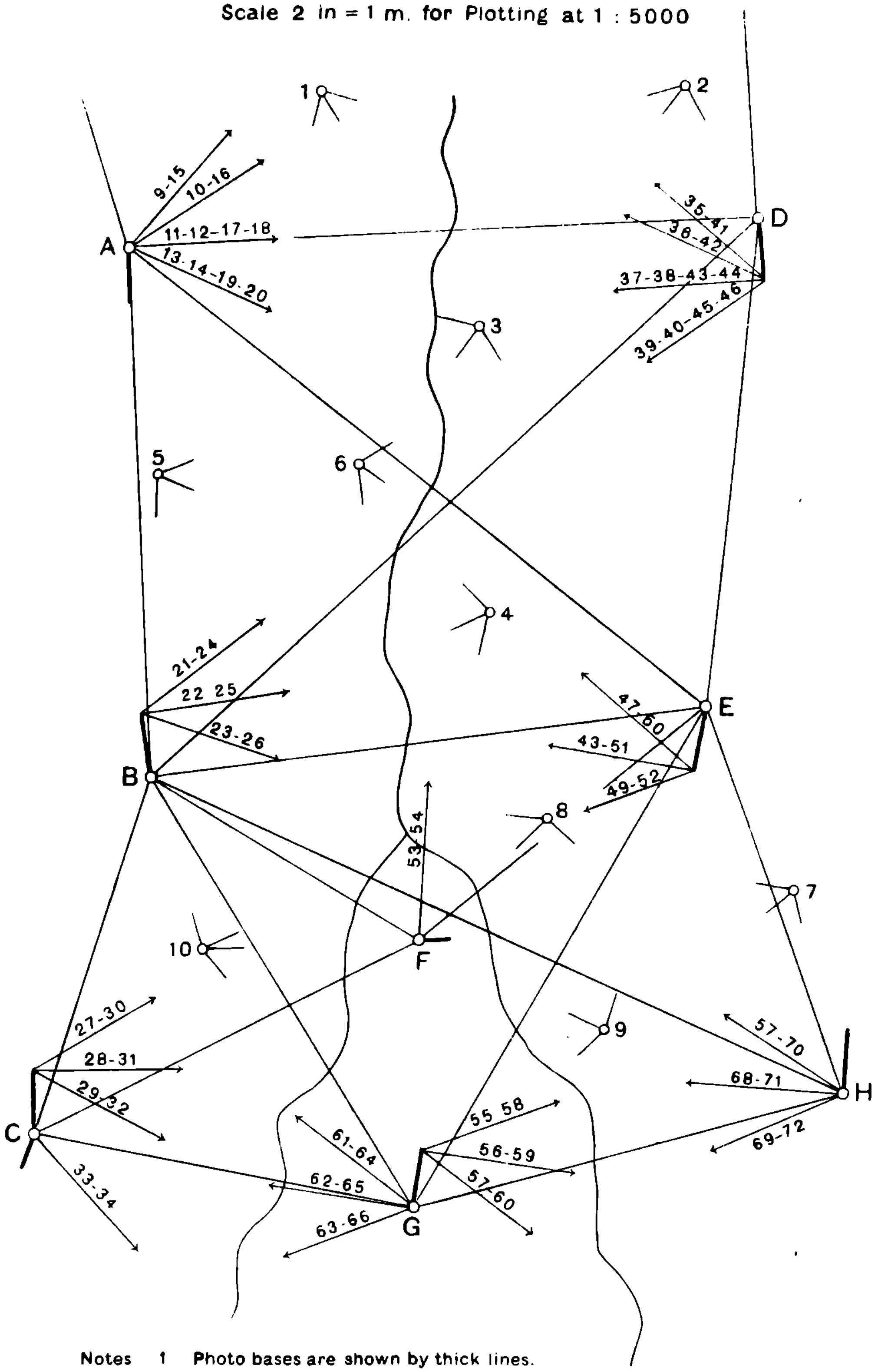
(If thicker than this, the plates will not fit the slides, and they are liable to jam in the developing tank).

Description:—Plate glass.
Process plates.
Speed, H & D 25 to 35.
"Backed", preferably with "self-cleaning" backing.

Fig. 3

SPECIMEN OF CHART

Scale 2 in = 1 m. for Plotting at 1 : 5000



Notes
1 Photo bases are shown by thick lines.
2 Directions of photos are shown by arrows.
3 Arrows at right ends of bases have been omitted.
4 The figures along arrows are the serial numbers of the left and right photos of each pair respectively.
5 The base at station G has been used for both aspects.

Survey of India

18 PARTY (F. C.) SEASON 1931.

Computation of Camera Calibration from five points

Camera No. 37. Wild   Stop f. 11   Ref. Form 13 Air.   Page.........

Focal Length ......230 mm.   Place....Murree

Instrument Panel   Date.....18 · 9 · 31

Point	a (Form 13 Col. 4)	a^2	α (Form 13 Col. 2)	Cot α	$b = a$ Cot α	b^2	ab
C. L	58·09	3374·4	13° 37′ 26″	4·12598	239·68	57445·6	13922·9
C	66·52	4424·9	15 39 15	3·56857	237·38	56349·9	15790·6
C. R	79·71	6353·7	18 58 30	2·90833	231·82	53741·9	18478·6
R	132·01	17426·6	31 08 28	1·65503	218·48	47733·7	28841·6
Sum	(1) 336·33	(2) 31580·			(3) 927·36	(4) 215271·	(5) 77034·

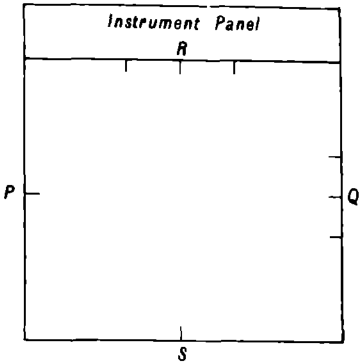
(6)	(3)×(2)−(1)×(5)	29·2858 − 25·9087 = 3·3770×10⁶	(9)	(1)×(4)−(3)×(5)	72·4022 − 71·4382 = 0·9640×10⁶
(7)	(2)×(4)−(5)²	6798·20 − 5934·20 = 864·00×10⁶	(7)		
(8)	V=(6)÷(7)	3908·7×10⁻⁶	(11)	U=(9)÷(7)	1115·6×10⁻⁶
(12)	V² + U²	15·28 + 1·24 = 16·52×10⁻⁶	(12)		
(13)	f=(8)÷(12)	236·60	(14)	d=(11)÷(12)	67·53

(21)		α	24° 05′ 30″	(15)	a for collimating mark P	−0·99
(22)	Check Point	tan α	0·44714	(16)	a ” ” ” Q	132·61
(23)	Check Point	(11) × (22)	498·85×10⁻⁶	(17)	(14)−(15) Dist. of P. Pt. from P	68·52
(24)	Check Point	(23) + (8)	4407·51×10⁻⁶	(18)	(14)−(16) ” ” ” ” Q	−65·08
(25)	Check Point	(22) ÷ (24)	101·45	(19)	Dist. of P. Pt. from } (Page......)	
(26)		Measured distance	101·49	(20)	” ” ” ”	

Computed by Kanshi Ram Saluja 29.9.31   Checked by......K. Kumar K 29·9·31

Final Focal Length =

The diagram illustrates a positive print viewed with the emulsion side uppermost, or a negative viewed from the glass side



Length of P. Q. on glass plate =

” ” R. S. ” ” ” =

SPECIMEN PAGE OF REGISTER OF PHOTOGRAPHS

(*See also chart, facing page 24*).

Photo base at triangulation station **A** Date 12/2/28

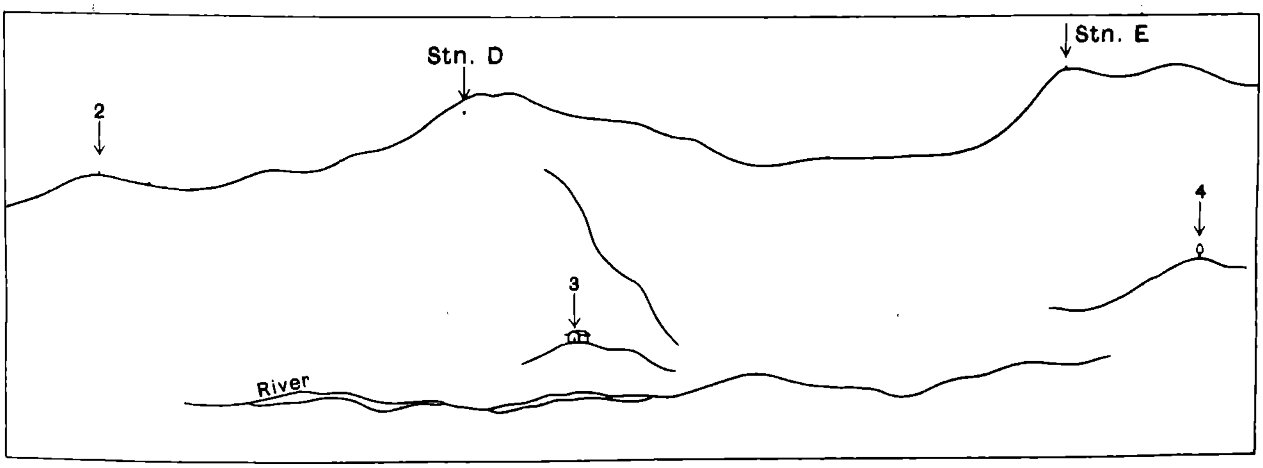
Station **A** is the **L** end of the base.

Theodolite No. 15 Camera Short Filter 6

	Left End Base				Right End Base			
Slide No. ...	1	2	3 5	4 6	7	8	9 11	10 12
Serial No. ...	009	010	011 012	013 014	015	016	017 018	019 020
Circle Reading, MR/~~ML~~ ...	135°	120°	90°	60°	315°	300°	270°	240°
Obliquity ...	45 L	30 L	0	30 R	45L	30L	0	30R
Inclination* ...	−1	−1	0 −3	0 −3	−1	−1	0 −3	0 −3
Time (L.M.T.) ...	←———	—10·30	to 11·	05——→	←——12·	25 to	13·	10 ——→
Exposure (Secs) ...	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	1	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$
Light ...		Sun	No	clouds	Sun	No	clouds	

* Inclination:— +1 = 1 notch elevation
0 = Horizontal.
−1 = 1 notch depression.
−2 = 2 notches depression.
−3 = Bottom stop.

PANORAMA FROM L END BASE



SPECIMEN SHOWING FORM OF DATA FOR EACH BASE REQUIRED BY THE PLOTTING OFFICE

Base at Station A.

Length :—527·37 metres.

Grid bearing from north, of R end from L end. 177° 34′ 23″

Height of L. end (Stn. A). 1410·6 m. R. end. 1423·4 m.

Co-ordinates in metres.

	Northing	Easting
Mid point of base	1048013·3	3119402·7

Directions of photographs.

	Left End				Right End			
Serial No.	009	010	011 013	012 014	015	016	017 019	018 020
Angle Left or Right of normal to base. (Obliquity)	45L	30L	0	30R	45L	30L	0	30R
Notches of elevation or depression. (Inclination)	−1	−1	0 −3	0 −3	−1	−1	0 −3	0 −3