THE TAVISTOCK THEODOLITES.

A meeting of British instrument-makers and surveyors was held at Tavistock in 1926, and at this meeting were drawn up specifications concerning the actual design of new instruments. A specification for a British theodolite was drawn up, which should combine the latest ideas in design with the well-known qualities of strength and reliability possessed by the existing types of British make. The chief difficulty the makers had to contend with was in producing an instrument that would not transgress existing patents. Messrs. COOKE, TROUGHTON & SIMMS, Ltd., have succeeded in doing this, the optical arrangements of their model and the method of reading it being different in every respect from existing patterns. Messrs. E. R. WATTS & Son, Ltd. on the other hand, came to an agreement with the firm of ZEISS and have incorporated in their model several of the ZEISS patents ; thus it can hardly be said that theirs is an all-British instrument. So far nothing has materialized from the third firm of instrument-makers, Messrs. C. F. CASELLA & Co, Ltd.

The new patterns are intended to meet the following requirements :- (1) Smallest possible dimensions and weight in order among other advantages to increase stability in high winds; (2) convenient manipulation and increased speed in manipulations; (3) greater insensibility in respect of transport, rain and dust; (4) combination of images, from two opposite parts of the circle, on one dividing line, for observation in one eyepiece; (5) images of opposite points of the circle to be reproduced through the hollow axis, so that the circles might be completely enclosed; (6) use of a highly sensitive micrometer for adjustment of coincidence to allow of direct reading of the arithmetical mean; (7) use of glass circles to ensure a symmetrical type of graduation; (8) reduced surface dimensions for temperature change disturbances.

A description of the new British make of apparatus is given in the *Geographical Journal* of June, 1929, pp. 513-528, which reproduces a paper read at the Afternoon Meeting of the Royal Geographical Society on 11 February 1929, by Captain E. R. L. PEAKE, R. E.

We here reproduce a few details of the two instruments as given in the above-quoted paper :-

THE WATTS-ZEISS INSTRUMENT.

The horizontal circle is 3 inches in diameter and is divided on glass to 20'. The vertical circle is 2 inches in diameter and is similarly divided. The images of opposite sides of each circle are brought together and automatically meaned by an optical micrometer and viewed in the one eyepiece as in the ZEISS and WILD Theodolites. Direct readings to single seconds can be made.

The telescope, which has a prism in its optical system in order to make the instrument more compact, transits eye-end only. The object-glass aperture is 1 5/16 inches and the magnification 25.

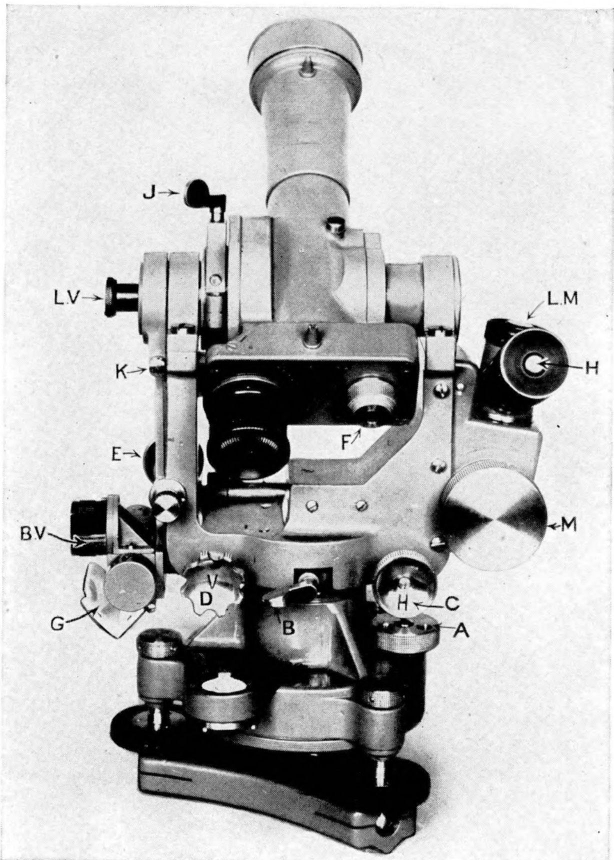
Both the plate and altitude bubbles are of the "constant" type, the former giving a sensitivity of 30" per 0·1-inch division and the latter 17" per 2 m/m division.

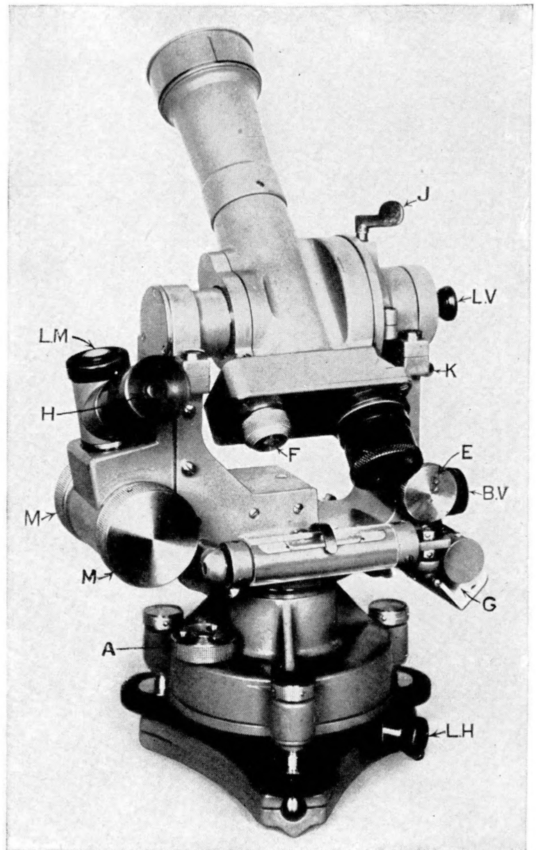
The altitude bubble can be read from the observing position by means of a reversible prism of the ZEISS pattern; the reflector fitted to the underside of this bubble is hinged, and when folded up gives it protection.

The Tribrach is fitted with three foot screws with dust covers.

For night use both circles, the altitude bubble, and the micrometer are illuminated by small electric lamps fitted in sockets that can be swivelled or slid in and out so as to get the best illumination. A wandering lamp is used in conjunction with the reflecting cap on the O. G. end of the telescope for illuminating the diaphragm. A battery box fitted with a switch and rheostat is strapped to a leg of the tripod. The lamp is connected direct to the terminals of the battery box, while the other lamps are connected by way of a plug-and-socket contact.

Tripod. — The legs are of the open-frame pattern with a centering head giving a total movement of 1 1/2 inches. The clamp for this head is operated by means of a long handle pro-





THE WATTS-ZEISS THEODOLITE.

A. Milled Head for changing position of Horizontal Circle.

B. Clamp for main axis.

B.V. Bubble for Vertical Circle.

C. Slow Motion for main axis.

D. " " " Telescopic axis.

E. " " " Bubble of Vertical Circle.

F. Focussing Milled Head for Telescope.

G. Folding Reflector for V. Circle bubble.

H. Micrometer Eye-piece.

J. Clamp for Telescope axis.

K. Bubble Adjustment for B. V.

L.V. Lighting Prism for Vertical Circle.

L.H. Lighting Prism for Horizontal Circle.

L.M. Lighting Window for Micrometer.

M. Micrometer Milled Heads.

THÉODOLITE DE WATTS & ZEISS

A. Tête molletée pour changer la position du cercle horizontal.

B. Frein de l'axe principal.

B.V. Niveau à bulle du cercle vertical.

C. Mouvement lent de l'axe principal.

D. Mouvement lent de la lunette.

E. Mouvement lent du niveau du cercle vertical.

F. Tête molletée de mise au point de la lunette.

G. Réflecteur pliant du niveau du cercle vertical.

H. Oculaire du micromètre.

J. Frein de l'axe de la lunette.

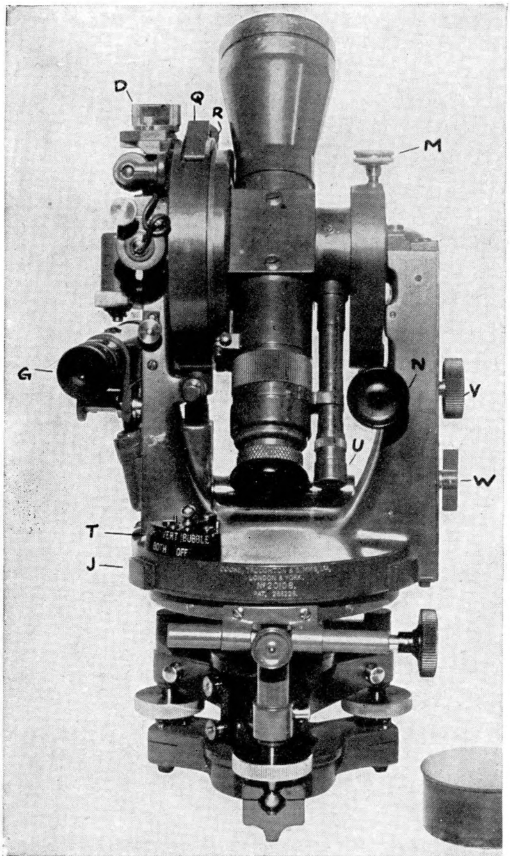
K. Réglage de la bulle du niveau vertical.

L.V. Prisme d'éclairage du cercle vertical.

L.H. Prisme d'éclairage du cercle horizontal.

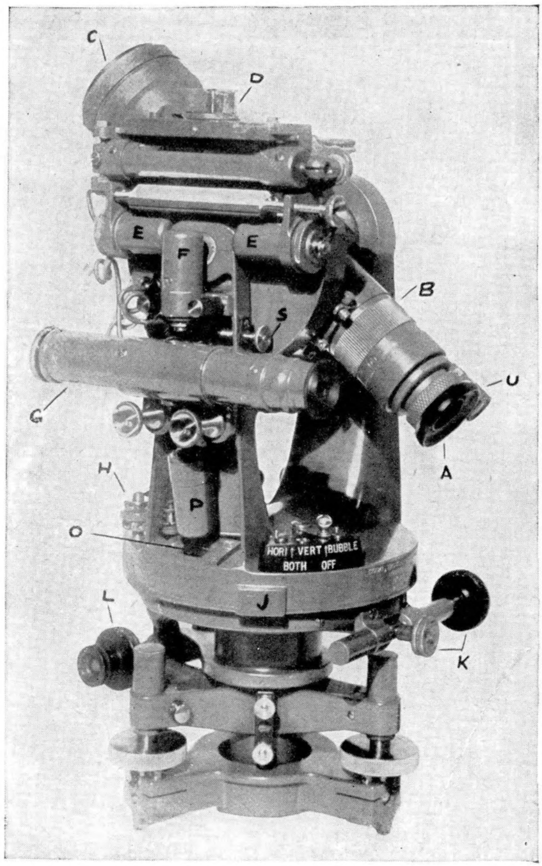
L.M. Fenêtre d'éclairage du micromètre.

M. Têtes molletées du micromètre.



THE COOKE, TROUGHTON AND SIMMS THEODOLITE.

A. Telescope eye-piece.
B. " focussing collar.
C. " object glass.
D. Altitude bubble reader.
E. " " electric lamps.
F. Diaphragm illumination electric lamp
G. Telescopic Compass.
H. Plate Bubble.
J. Lugs for securing instrument in case.
K. Upper clamp and slow motion.
L.. Lower " " "
M. Vertical clamp.
N. " slow motion.
O. Window illuminating horizontal circle.
P. Electric lamp illuminating horizontal circle.
Q. Window illuminating vertical circle.
R. Electric lamp " " "
S. Rheostat.
T. Switch.
U. Eye-piece for reading circles.
V. Milled head operating circle graticule.
W. Lever for switching from horizontal to vertical circle and vice versa.



THÉODOLITE DE COOKE, TROUGHTON & SIMMS.

A. Oculaire de la lunette.
B. Collerette de mise au point de la lunette.
C. Objectif de la lunette.
D. Lecture du niveau d'altitude.
E. Lampes électriques du niveau de hauteur.
F. Lampe électrique d'éclairage du diaphragme.
G. Lunette du compas.
H. Niveau à bulle de l'embase.
J. Tenons pour fixer l'instrument dans sa boîte.
K. Frein supérieur et mouvement lent.
L. Frein inférieur et mouvement lent.
M. Frein vertical.
N. Mouvement lent en hauteur.
O. Fenêtre d'éclairage du cercle horizontal.
P. Lampe électrique d'éclairage du cercle horizontal.
Q. Fenêtre d'éclairage du cercle vertical.
R. Lampe électrique d'éclairage du cercle vertical.
S. Rhéostat.
T. Interrupteur.
U. Microscope pour la lecture des cercles.
V. Tête molletée agissant sur le réticule du cercle.
W. Levier pour permuter du cercle horizontal au cercle vertical et vice versa.

jecting downwards between the legs. Any play in the legs can be taken up by suitable fittings. The upper surface of the tripod head is fitted with a protecting cap which, when the instrument is being used, is screwed to a special stud on one of the legs. A circular bubble is fitted to the tripod head for rough levelling. The legs are finished off with bottom shoes and foot-rests for ramming in the legs in soft ground.

The instrument is carried in a teak box 10 1/2×8 1/4×7 1/4 inches, which is in turn encased in a thick leather covering; this has rucksack fittings so arranged that the instrument is carried in a vertical position

The weight of the instrument alone is 9 3/4 lbs., the box and all accessories 6 lbs., and the leather outer case 5 ½ lbs., making the total weight 21 1/4 lbs.

The telescope is sighted, clamped, and adjusted on the mark. The circles are then viewed through the eyepiece of the micrometer and the illuminating prisms adjusted to give the most suitable field of light. The view of the circles might be as in Fig. 1*a*, showing the Horizontal and Vertical circles in separate fields, designated by the letters *H* and *V*. At the bottom of the field of view will be seen illuminated micrometer scale of seconds.

To read the azimuth, by means of the micrometer drum *M* you bring the two opposite sides of the Horizontal Circle, as seen in field *H*, into coincidence (see Fig. 1b).

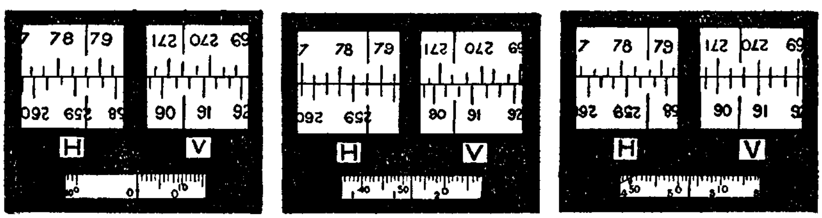


Fig. I. *a* *b* *c*

a) The circles at the end of the observation with micrometer at zero;
b) Reading of Horizontal Circle 78°41'52";
c) Reading of Vertical Circle 90°35'3".

(*N. B.* — It will be noted that coincidence always comes either with a circle division directly in line with the index line, as in this case illustrated, or with the Index midway between two circle divisions shown in Fig. 1*c*.).

Take the reading as given by the Index on that side of the circle of which the figures are upright, say 78°40'; add the reading of the micrometer scale, say 1'52"; the azimuth reading is 78°41'52".

In the same manner, to read altitudes, make coincidence of the Vertical Circle in field *V* (see Fig. 1*c*); read the Index on the upright figures, say 90°30'; add the micrometer reading, say 5'3"; the altitude reading is 90°35'3".

It will be seen that the Index gives the reading direct to the nearest 10', the whole circle being divided to 20'.

THE COOKE, TROUGHTON & SIMMS 3 ½-INCH DOUBLE-READING THEODOLITE.

The horizontal circle is 3 ½ inches in diameter and is flat divided on glass to 20'; the vertical circle is 2 3/4 inches in diameter and similarly divided.

The images of opposite sides of each circle are brought together and are viewed through a single eyepiece situated near the eye-end of the telescope. Readings are taken by means of a patented diagonal scale direct to 10", and by estimation to 5" or even 2 ½". The change over from horizontal to vertical circle or *vice versa* is made by means of a lever on the standard. The horizontal circle is carried on an independent axis with its own clamp and slow motion for repetition.

The telescope is of the "no constant" type and can transit at both ends even with the diagonal eyepiece in position. The focussing, which is internal, is actuated by a milled collar on the telescope. The object-glass aperture is 1·5 inches and the power 22.

The plate bubble has a sensitivity of 20" per 2 m/m division, and the altitude bubble 10" per 2 m/m division. The latter is fitted with a device to enable it to be read from the telescope eye-end in any position.

The Tribrach is fitted with three levelling screws with dust covers.

The illumination of the circles (by *P* and *R*), altitude bubble (by *E*), and diaphragm (by *F*) for night use, is effected by standard 4-volt lamps permanently fixed but easily accessible for replacement. A switch on the cover plate controls each light separately, with an extra stud for illuminating both circles together. This switch is wired to terminals on the tribrach for the battery connection. A rheostat (*S*) is fitted for controlling the diaphragm illumination.

The tripod legs are of the open-frame pattern, and are made of mahogany. There is a centering movement of 1 1/2 inches. The fitting of the hinge pins which connect the legs to the head is capable of being adjusted in the field by a spanner provided. The thread on top of the tripod head is fitted with a protecting cap and a circular bubble is fitted for rough levelling. Bottom shoes which are securely attached to the legs have foot-rests forming an effective grip for the foot.

The instrument is packed complete in a vertical position in a duralumin box, in which are fitted all the necessary accessories. The instrument is clamped at three places on the cover plate to a frame which is supported on shock-absorbing springs, thus minimizing any risk of injury to the instrument during transit and ensuring that the axis, standards and circles are free from all risk of strain. A light canvas outer case is provided with rucksack fittings for carrying the instrument in a vertical position.

The weight of the instrument alone is 11·5 lbs., the box and all accessories 6·9 lbs., and the canvas case 4 lb., making the total weight about 22 1/2 lbs.

By optical means, images of the divisions from two diametrically opposite points on the circle are brought together at a suitable focal plane, and appear adjacent to each other, but separated by a broad black line in the field of view of the circle eyepiece, as shown in Fig. 2. The circles are divided to 20' and on being rotated the images of the divisions at each side of the broad black line move past each other in opposite directions.

Although the circles are divided to 20' the intermediate 10' readings are read by the stationary reading mark (x) as shown on drawing Fig. 2. After reading to the nearest 10' by the

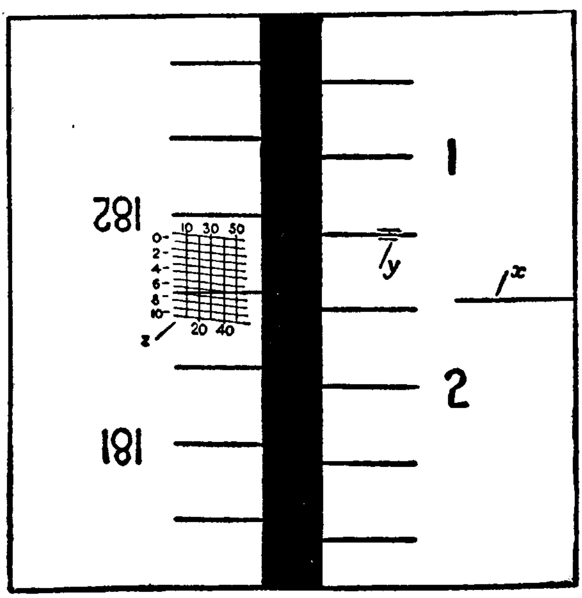


Fig. 2

Micrometer with diagonal scale reading 1° 37' 30

stationary reading mark (x) the final or exact mean reading is obtained by measuring the separation of a pair of adjacent divisions, one on each side of the broad black line by means of a special ruled graticule (z). This graticule is ruled with a number of vertical and sloping lines forming a diagonal scale with appropriate figuring, and the optical arrangement is so devised that the images of the diagonal scale and the circle divisions are superimposed and simultaneously in focus.

The total vertical length of the diagonal scale is made to coincide exactly with a 20' space on the circle, but is figured to read 10' instead of 20', so that the mean circle reading is indicated directly, thus obviating the necessity for adding the two readings and dividing by 2. The graticule can be moved in a direction parallel with the broad black line by rotating the milled head (*V*) on one of the standards, and the accurate reading is made by moving the graticule until the space between the two short lines (*y*) on the right is bisected by a circle division and then observing that point on the diagonal scale where a circle division is symmetrically placed between two adjacent sloping lines as illustrated on the drawing.

The reading obtained is the equivalent of the mean of two independent readings of opposite points of the circle, and is free from any inaccuracies due to excentricity of the circle.

The makers are now at work on a second model, which, though built on the same general lines as the earlier one, incorporates a method of reading invented and patented by Captain T. Y. Baker, B. A., R. N., which is very ingenious.

The new method is as follows: By optical means images of the divisions from two diametrically opposite points on the circle are brought together at a suitable focal plane and appear adjacent to each other, as shown in Fig. 3, one portion of the circle appearing to follow on the

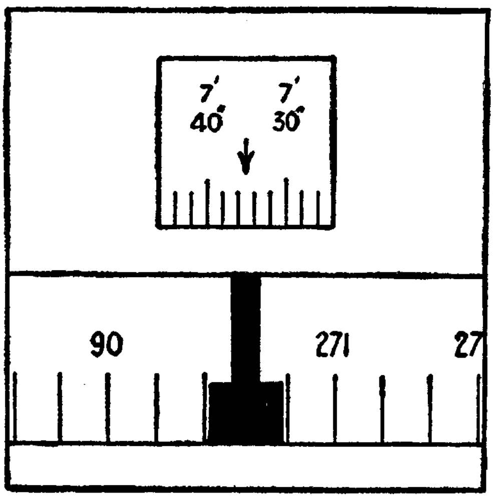


Fig. 3.

Micrometer
(Capt. Baker's patent)
reading 90° 47' 35"

dividing of the opposite portion, but with a space between them. This space is just a fraction larger than a fixed black mark situated in the centre of the field.

A micrometer scale, which carries a pointer fixed symmetrically over the black mark, appears in the field of vi·ion immediately above the circle images. This scale covers the complete range of 20' and is subdivided down to 2", thus giving readings direct to 1". To read, the micrometer drum is rotated till the black mark is symmetrically placed in the space between the circle images. Degrees and twenties of minutes then being read off the circle, the remaining minutes and seconds are taken from the micrometer scale.