RADIO ASTRONOMY LABORATORY
U. S. GOVERNMENT PROPERTY

UNIVERSAL THEODOLITE

WILD T2

MODEL 1956

INSTRUCTIONS FOR USE

Radio Astronomy Lab
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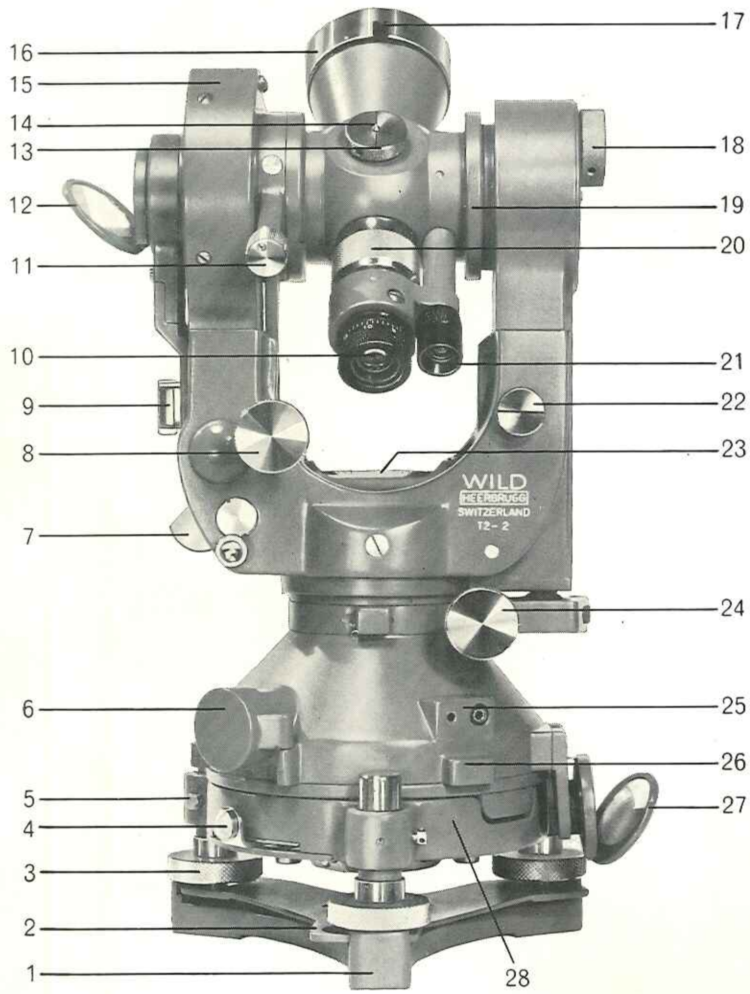

Fig. 1

1 Base plate
2 Spring plate
3 Levelling screw
4 Spring lever of tribrach clamp
5 Tightening screw of levelling screw
6 Circle setting knob (under protecting cap)
7 Reflector for collimation level
8 Tangent screw for altitude
9 Level prism
10 Eyepiece for telescope
11 Clamping screw for vertical circle
12 Illuminating mirror for vertical circle
13 Illuminating mirror for diaphragm
14 Centre point and bead
15 Vertical circle casing
16 Objective lens
17 Front sight
18 Optical micrometer knob
19 Bearing ring for striding level
20 Ring for focussing telescope
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22 Inverter knob
23 Plate level
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SCOPE

It is assumed that the user has a general, basic knowledge of the use of surveying instruments. The purpose of these instructions is to assist the user of the T2 in getting to know the instrument's particular features, to ensure the most advantageous application for the various duties to be performed.

1. THE T2 EQUIPMENT

1.1 Main Items of the T2 Equipment

Every T2 equipment includes:

1. Theodolite with tribrach	weighing 12³/₈ lbs
2. Tripod, either with rigid legs (IIIa)	,, 12³/₈ lbs
or with telescopic legs (IIIb)	,, 14¹/₈ lbs
3. Packing case for the theodolite, consisting of base plate and metal hood	,, 4⁵/₈ lbs

1.2 Additional Equipment for the T2

The following items of supplementary equipment can be supplied with T2:

1.2.1 Additional Equipment for Geodetic Measurements

1. Electric illumination:
   Battery case (with hand lamp and flex)
2. Traversing equipment:
   2 tripods, IIIa or IIIb
   2 theodolite tribrachs (with circular level and optical plummet)
   2 targets (with plate level and light fitting)
   2 battery cases (with hand lamp and flex)
3. Invar subtense bar:
   Tripod, type IIIa or IIIb
   Theodolite tribrach (with circular level and optical plummet)
   2 meter-invar subtense bar (collapsible, in case)
   Battery case (with hand lamp and flex)
   Distance table (360° or 400^g)

4. Precision telemeter DM 1
   DM 1 with balance weight
   2 stands, each with 2 struts
   2 staves
5. Optical plummet
6. Pentagon prism
7. Base plate for mounting on pillars

1.2.2 **Supplementary Equipment for Astronomic Observations:**

Electric illumination as per 1.2.1, in addition to:

1. Eyepiece prisms
2. Sun glasses
3. Diagonal eyepieces
4. Striding level
5. Horrebow level
6. Astrolabe attachment
7. Polar attachment

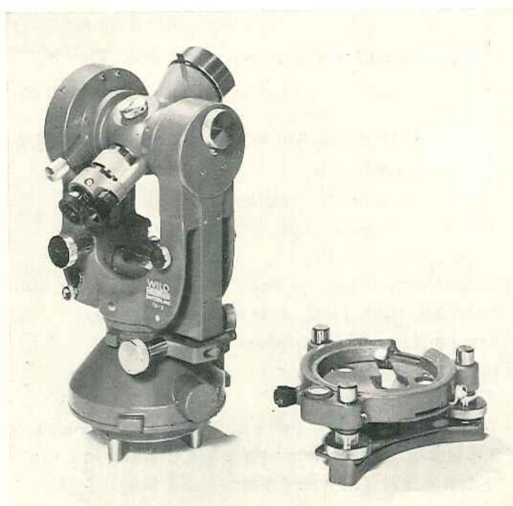

Fig. 2
Universal theodolite Wild T2 with detachable tribrach

2. MAIN ITEMS OF THE T2 EQUIPMENT

2.1 **Theodolite** (Fig. 1 and 2)

2.1.1 **Tribrach** (Fig. 3a and b)

The lowest part of the theodolite, the detachable tribrach (28), is connected to the actual body of the theodolite by means of a coupling device. This consists of three slanting slotted feet on the theodolite and three grip holders on the tribrach. These engage in the slots when the theodolite is mounted; the spring lever (4) at the tribrach's periphery is shifted to the left until it is locked in position by means of a notch. When mounting the theodolite on the tribrach the shoulder on the lower edge of the theodolite base must engage in the recess on the edge of the tribrach. If one first presses the spring lever downwards and then to the right, the theodolite can be removed and replaced by a target or subtense bar etc. The vertical axis of the different equipments will then be automatically centered.

(All accessories supplied as part of the T16 equipment can also be mounted on this tribrach).

The tribrach itself is located on a star-shaped base plate, where the three levelling screws are secured by a rotable spring plate. This spring plate is normally held in position from below, by means of a screw. If one loosens this screw, as shown in the illustration (fig. 3a), the spring plate can be shifted by a small amount. The base plate is thus released and can be dismantled from the tribrach. This base plate is the same as that fitted on the former T2 with the fixed tribrach, enabling its accessories, such as targets, stadias etc. to be used on the 1956 model.

a)

Fig. 3

b)

Apart from this exceptional application, the spring plate on the base plate should always be secured against shifting, so that the instrument cannot fall out.
The tribrach is secured to the tripod plate by means of the central fixing screw. The three levelling screws are enclosed, protected from dust; each has a tightening screw to take up wear. The circular level for quick pre-leveling of the instrument is mounted on the edge of the tribrach. The optical plummet is also fitted in the tribrach.

2.1.2 **Limb**

By limb one means the horizontal circle connected with the vertical axis system.
The T2's axis system consists of the axial sleeve, by means of which the theodolite base is secured in position, and the cylindrical axle, the flange of which is screwed to the alidade. The circular holder with the horizontal circle is located outside on the axis sleeve; it can be turned by the setting knob (6), fitted on the tapered theodolite base and protected by a cap. The 3½ in. diameter glass circle has 20 to 20 minute graduations, 360° or 400ᵍ divisions, every degree being numbered.
The illumination mirror for the horizontal circle (27) is mounted on the base of the theodolite. On the tapered part of the base are the plug sockets (25) for connecting theodolite and battery case. Leads inside the instrument connect these sockets with the two rings, in which the illumination mirrors or tiny electric bulbs are inserted.

2.1.3 **Alidade**

The rotable upper part of the instrument, referred to as the alidade, consists of the uprights, trunnion axis, telescope and vertical circle. The alidade is secured to the lower part of the unit by means of the azimuth clamp; accurate adjustment is obtained with the azimuth tangent screw (24).
The alidade's two uprights take the bearing brackets for the telescope's trunnion axis. Adjustment of the telescope vis-à-vis the alidade upright is by means of the clamping screw for vertical circle (11); final adjustment is obtained through the tangent screw for altitude (8). The vertical circle is positively connected with the telescope through the trunnion

axes; it is protected by a totally enclosed casing (15) and is illuminated by an adjustable mirror (12).
The graduations with 20 minutes intervals are marked on a 2¾ in. diameter circle; they are numbered right through, from 0 to 359° or 399ᵍ respectively. The collimation level (vertical circle level) is illuminated from below, by means of a small reflector (7). The images of both ends of the bubble are brought to coincidence in the rotary prism (9) by turning the level's fine adjustment screw. The plate level (23) is located exactly in the middle of the two uprights, so that the bubble does not run out to one side when turning the alidade.
The optical reading device of both circles is completely incorporated in the alidade.

2.1.4 **Telescope**

The T2 telescope, which is 5¾ in. long, can be transited at both the objective and the eyepiece end. The free objective aperture measures 1⅝ in., magnification is 28 times. The reticule has a single horizontal hair; it has a single vertical hair on the one half and two on the other, which are symmetrically parallel. Additionally, it has two horizontal and two vertical stadia lines with multiplication constant 100. Sharp focussing of the reticule is done by turning the eyepiece (10), the image of the object by turning the focussing ring (20) on the telescope. There is a small mirror inside the telescope, which can be turned from outside by a knob (13), which enables the field of view to be brightened as required, by means of the electric illumination, to render visible the cross-hairs.

2.1.5 **Path of Rays of Circle Reading**

2.1.5.1 **Horizontal Circle Reading** (Fig. 4)

The light for reading the horizontal circle is reflected via the illuminating mirror at the base of the theodolite, the illumination prism and the reading prism, to the two diametral sections of the azimuth circle to be read. The reflected light rays are returned through the reading prism, the horizontal circle objective in the hollow vertical axis and the long rhomboid prism in the right-hand upright of the alidade. After traversing the plane-parallel

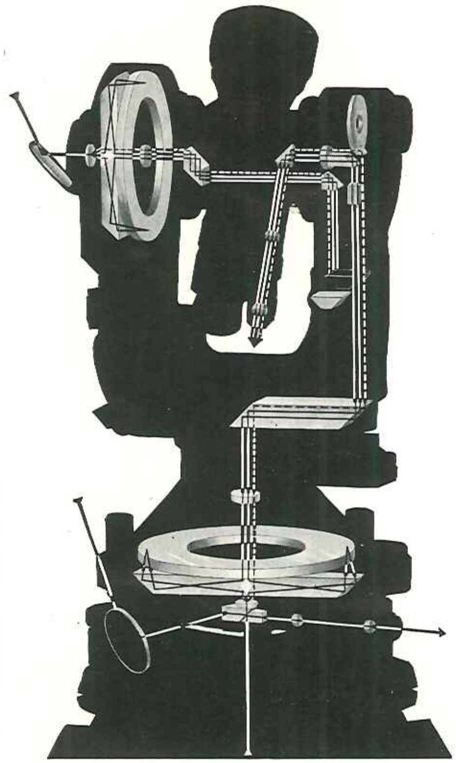

Fig. 4 Path of rays through the optical system of the Wild T2 Universal Theodolite

plates of the optical micrometer and the separating prisms, the rays meet up on the deviating prism's bottom surface, to form the image of both sections of the azimuth circle. These images, in addition to the division of the optical micrometer, are projected through the axis prism and the objective into the reading microscope's eyepiece.

2.1.5.2 Reading the Vertical Circle

The light for reading the vertical circle enters the instrument by the upper illuminating mirror and is thrown on to both the diametral sections of the vertical circle by the reading prism. The reading prism is rotably mounted in the trunnion axis and is positively joined to the collimation level, so that orientation always remains constant while the bubble of the collimation level is centering.

The reflected light rays are returned through the reading prism and from there to the verticle circle objective. Here they are deflected slightly downwards through a rhomboid prism and find their way through the hollow trunnion axis to a prism in the alidade's right hand upright, which reflects them downwards, in a vertical direction. A prism is fitted in the upright, which can be adjusted by turning the inverter knob (22). In the first position (black mark on the inverter knob horizontal), the horizontal circle reading rays are given a free passage upwards, and the path of rays of the vertical circle reading is interrupted. In the second position (black mark on inverter knob vertical) the path of rays of the horizontal circle reading is interrupted and, after dual reflection the vertical circle reading rays are directed into the optical micrometer and into the reading eyepiece.

2.2 Tripod (Fig. 5 and 6)

Generally the T2 is mounted on the rigid 5 ft. 3 in. long tripod IIIa. But one can also use the tripod IIIb, which can be telescope from 5 ft. 3 in. to 3 ft. A leather case is supplied with both tripods, which will accom-

Fig. 5

III a

Fig. 6

III b

modate the plumb line with adapter plug and the tripod spanner. Additionally, every tripod is fitted with a stirrup to take the battery case.
The central fixing screw is secured to a swivable yoke underneath the tripod's base plate, and thus cannot get lost. The base plate has a 2½ in. diameter bore, which is the amount of displacement of the screw when centering the instrument.

2.3 **Packing Case** (Fig. 7)

The T2 is packed in a metal container, consisting of base plate and metal hood.
The theodolite is mounted on the base plate by placing each of the three retaining stops on a support. Each of the stops is held in position by a slide, which is locked by a screw and secured by the domed cover. Two locking hooks connect the cover securely with the base plate, and the case is hermetically sealed by the fitted rubber ring. The following accessories are accommodated on the base plate:

2 plug-in lamps
1 screwdriver
1 dusting brush
2 adjustment pins

Fig. 7

3. APPLICATIONS OF THE T2

3.1 Triangulation

The T2's main field of application is triangulation. The accuracy of angle measurement and the quality of the telescope permit triangles to be measured with lateral lengths up to 10 miles, that is triangulation up to the second order. Thanks to the simplicity of its operation the instrument will also be found suitable for measuring smaller nets.

3.2 Traversing

Thanks to its automatic centering device, the T2 is ideally suited for traverse measurement. Traversing is generally employed for completing nets of triangulation. A further important field of application is the laying out of long tunnels or ducts.

3.3 Distance Measuring

Indirect distance measuring is closely associated with traverse measurement. Thanks to its great accuracy of angle measurement the T2 permits high-precision measurement of distance with the aid of the subtense bar, in a short time. The well-known methods of optical distance measurement can also be employed with the T2.

3.4 Astronomic Observations

The T2 can be supplied with various accessories, enabling the usual methods of astronomic observation to be employed.

4. INSTRUCTIONS FOR USE

4.1 Setting up the Tripod

When doing any kind of surveying the instrument must be set up at a well-determined point of the terrain or construction site (station point). The tripod is so set up that the centre of the tripod head is to within ½ in. above the station point (pre-centering). The plumb line is used for this purpose which, with its adapter plug, is introduced into the tripod's hollow central fixing screw from below and is secured by a quarter turn to the right (bayonet joint). The central fixing screw must be shifted to the centre of the tripod plate.
The tripod plate must be as horizontal as possible in order that the instrument is stable in position. When necessary the point of that tripod leg is displaced laterally, the upper axis of which, fixed to the tripod head, shows the largest inclination. By this way this axis is brought to a horizontal position without disturbing the centering of the tripod.
All three tripod legs are then pushed firmly into the ground, after which the pre-centering and the levelling of the tripod head should be re-checked.

4.2 Unpacking and Setting up the Instrument

Before the instrument is unpacked the case should be placed on a firm surface. The locking hooks of the carrying case are released by pulling both ends of the strap outwards. The cover having been carefully removed, the three securing screws are loosened and the slides pulled back. With the vertical circle clamping screw open the telescope is then shifted from the vertical to the horizontal position. Take hold of the instrument by the **right** upright (on the optical micrometer side, **never** on the side of the vertical circle level) and place it on the tripod. The tribrach should then be so adjusted on the tripod plate that the lower illumination mirror gets as much light as possible, after which the central fixing screw should be tightened. One should finally make sure that the tribrach clamp is tight and fastened and the base plate's spring plate is secured.

4.3 Getting the Instrument Ready for Use

4.3.1 Centering the Instrument with the Plumb line

The plumb line has been suspended from the central fixing screw since the pre-centering of the tripod. This screw having been slightly loosened the instrument is shifted on the tripod plate, until the point of the plummet is within one millimetre of the centre of the station point. The screw is then re-tightened and the plumb line removed.

4.3.2 Centering the Instrument with the Optical Plummet

If one wishes to use the optical plummet to centre the instrument the plumb line must first be removed from the central screw. The optical plummet's eyepiece is then turned until the small cross is sharp and the station point's image appears free from parallax to it. The bubble of the circular level on the tribrach is then centred by adjusting the three foot screws. After slightly loosening the central screw the instrument is moved parallel to itself on the tripod head until the cross mark on the optical plummet lines up with the centre of the station point. The image of the station point in the eyepiece appears as if it were seen from above, so that, instinctively, one carries out the motion in the correct direction. When the bubble of the circular level has been centred the central fixing screw can be re-tightened.

4.3.3 Levelling the Instrument

After the centering has been done by one of the two methods described, the instrument is then levelled. It is turned until the plate level (also referred to as alidade level) is parallel to the connecting line between two levelling screws. By turning these two levelling screws in the opposite direction the bubble is brought into its point of play. After turning the instrument by a right angle the bubble is also centred in this direction by adjusting the third levelling screw. The correction of the plate level and the determination of the eccentricity of its bubble are described in section 6.4.

4.3.4 Precaution for measurements

In order to obtain good results it is essential that the instrument and the **entire** tripod should be protected from the rays of the sun by a parasol. Additionally, the alidade and telescope's trunnion axis should be rotated several times to ensure that the oil in the bearings is positively distributed.

4.4 Pointing

Before starting the measuring operations the telescope should be directed towards the sky and the eyepiece turned until the cross hairs appear black and sharp when viewing with an eye accommodated to infinity. The reading of the dioptric collar on the numbered scale remains constant for the same observer.

With the azimuth and vertical clamp released the telescope is coarse directed at the aiming point, in that the point is sighted with front and rear sight. After both clamping screws have been fairly well tightened the image of the object is focussed by turning the focussing ring until parallax has been eliminated between image and cross hairs.

In the case of directional measurements the horizontal mark is set a little above or below the object by means of the tangent screw for altitude, depending on whether the single or double vertical mark is more suitable for focussing. Then the vertical mark is focussed exactly on the object by turning the side fine adjustment screw clockwise.

In the case of measuring vertical angles the vertical mark is focussed to within a short distance of the object by means of the azimuth tangent screw, after which the horizontal mark is focussed precisely on the aiming point with the aid of the vertical tangent screw. The final turn of the tangent screw must always be in a clockwise direction.

4.5 Reading the Circles

4.5.1 Horizontal Circle

4.5.1.1 Preliminaries

First set the black line on the inverter knob horizontally, so that the two images of the horizontal circle are visible in the reading microscope. Then the illumination mirror at the base of the theodolite is hinged up and so directed towards the light source (sky) that both images of the circle division are as brightly and evenly lighted as possible. Finally, the reading microscope's eyepiece is turned until the graduations of the horizontal circle appear sharply defined.

4.5.1.2 Reading

Two bright images will be seen in the reading microscope. Above is the double image, divided by a fine horizontal line, of the diametrically opposite parts of the horizontal circle, for reading the degrees and tenths of minutes. Below is the small image of the scale of the seconds drum, for reading the individual minutes and seconds.

After training the telescope exactly on to the object, look at the image in the reading microscope before making the coincidence. A fixed vertical line will be seen in the middle of the field of vision on the lower half of the circle image; this does not serve for taking the reading but only to mark the middle of the field of vision and to form a pointer in the immediate vicinity of which the coincidence adjustment of the graduation lines of the two circle images should be done. This is effected by turning the knob of the coincidence adjustment until the graduation lines of the upper half image line up with those of the lower half image in the middle of the field of vision.

Only **after** the coincidence adjustment has been completed the circle can be read.

4.5.1.3 **Specimen Reading for 360° Graduation**

Fig. 8 shows the image in the reading microscope's eyepiece **after** coincidence adjustment. In the upper window the first upright figure left of the dividing mark shows a reading of 285°. Now one counts the intervals from 285° to the diametrically opposite 105° mark. There are five intervals, that is five tenths of minutes, or 50'. A reading of 285°50' is thus obtained from the upper image. In the lower image of the seconds drum scale we read one minute on the lower series of figures, 50" on the upper series and 4."6 on the graduations. 1'54".6 is thus shown on the drum, the complete reading being 285°51'54".6.

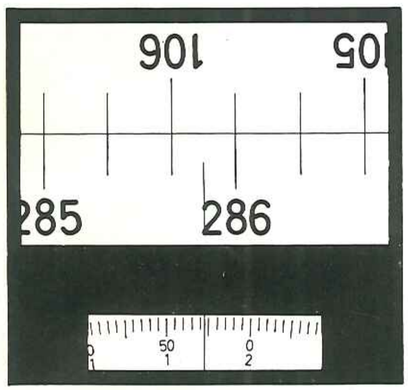

Fig. 8

285° 51' 54".6

4.5.1.4 **Specimen Reading for 400ᵍ Graduation**

Fig. 9 shows the circle images with 400^g graduation **after** coincidence adjustment has been made. In the upper window the number immediately left of the dividing line shows 14^g. 9 intervals, respresenting 9 tenths of a grade, will be counted from this mark up to the diametrically opposite 214^g mark. The circular scale thus reads 14^g,9. The value 425 is read off on the micrometer circle shown in the lower window, and this is added to the upper reading; the complete reading thus becomes 14^g,9425. In the case of the 400^g graduation the micrometer circle is only read off in half intervals, which correspond to a ten-thousandth part of a grade or 1^{cc}.

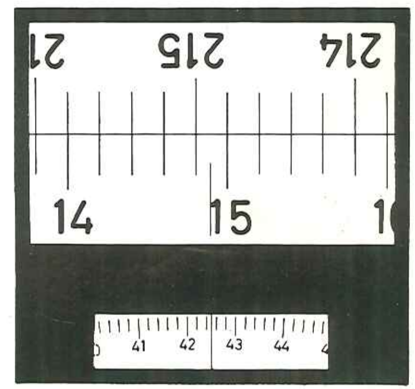

Fig. 9

14,9425 g

4.5.2 Vertical Circle

4.5.2.1 Preliminaries

In order to read the vertical circle one must first set the black line on the inverter knob vertical. The upper illumination mirror is then hinged up and it is so adjusted that both parts of the circle are as bright as possible and uniformly illuminated. Finally, the reading microscope's eyepiece is turned until the vertical circle graduations are sharply focussed.

4.5.2.2 Reading

The horizontal line of the reticule being set exactly on the aiming point and the bubble of the collimation level brought into coincidence by turning the notched tangent screw, the graduation lines of the vertical circle are somehow opposed to their diametral lines. The reading can only be done after the lines of both graduations have been brought into coincidence by turning the knob of the optical micrometer.

4.5.2.3 Specimen Readings for 360° Graduation

The two following reading examples belong to a vertical angle measurement in both telescope positions. The illustrations show the positions of the vertical circle **after** the coincidence adjustment has been done.

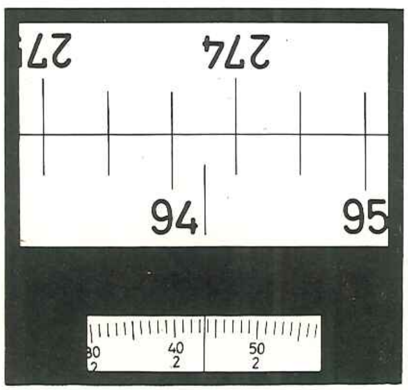

Fig. 10

94° 12' 43''.6

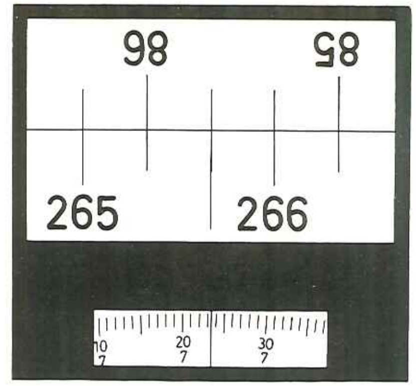

Fig. 11

265° 47' 23''.4

4.5.2.4 Specimen Readings for 400g Graduation

The following images appear in the reading microscope when measuring in both telescope positions, **after** the coincidence adjustment.

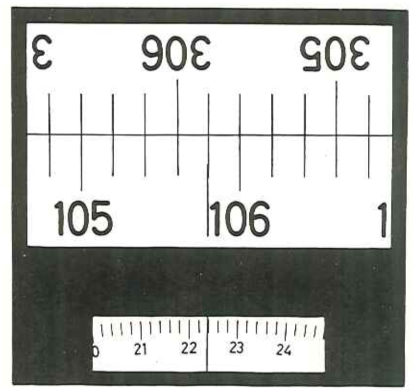

Fig. 12

105.8224g

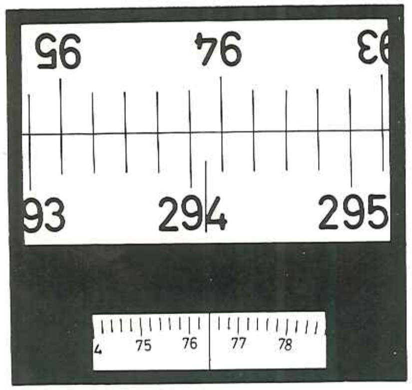

Fig. 13

294.1764 g

4.6 **Measuring with the T2**

4.6.1 **Horizontal Angle Measurement**

4.6.1.1 **Single Angle Measurement**

As a general rule it is recommended to measure individual angles with the T2. An angle is determined as the difference of the directions between an object on the right and one on the left. In order to eliminate instrumental errors (collimation error, inclination of trunnion axis), these differences of direction should always be measured in both positions of the telescope.

The following procedure should be adopted for single angle measurement:

1. The telescope is directed clockwise in the first position to the left-hand object, and the vertical reticule line is set accordingly. With the instrument thus oriented, the micrometer circle is set to a reading of approximately one minute, the horizontal circle is then turned until its zero line coincides with the diametrically opposed line. The circle setting knob is used for this purpose which afterwards should be immediately covered again with its protective cap. After the telescope setting has been checked the circle graduations must be brought to coincidence and the circle read.

2. The instrument is directed clockwise towards the right-hand object, the vertical line is adjusted to it and the circle is read off.
3. Then one transits the telescope, turns the instrument by two right angles in a clockwise direction, sets the vertical line once again to the right-hand object and reads the circle.
4. One turns the instrument in the second telescope position in a clockwise direction towards the left-hand object, sets the vertical line and reads the circle.

By setting the circle reading to zero and approximately one minute when doing the first sighting, one ensures that the circle reading in the second telescope position, despite the influence of instrumental errors, is not less than 180° or 200g respectively.

In order to obtain maximum accuracy of angle care should be taken that all movements of the alidade are carried out in a clockwise direction.

Actually, circular scale errors are small, but when repeating an angle measurement there are two possibilities of further reducing their influence:

1. Reiteration: Each time a further angle measurement is taken, the horizontal circle is oriented to get for the left-hand point the same reading which in the previons measurement was made for the right-hand point. By measuring an angle so observed, all graduation errors of the intermediate readings are eliminated, so that only the errors of the first and last reading are included in the result.
2. Adjusting the circle by $\frac{2R}{n}$: When repeating the angle measurement n times, the circle is moved by the amount $\frac{180^0}{n}$ or $\frac{200_g}{n}$, as the case may be, before making a start on a new measurement. This ensures a convenient elimination of periodic graduation errors.

The so-called sector method can be employed to advantage with station points including several directions. This method consists of first measuring the angles between three or four well spaced main directions (sectors) and then the angles within the sectors.

4.6.1.2 Measuring Sets of Angles

Several directions can be inter-connected by means of a so-called direction set. But measuring sets of angles calls for very rigid setting up of the instrument, since it lasts longer than an individual angle measurement. Setting up on a pillar will ensure very good stability; but it should be strictly noted that, with solid foundation soil, the tripod IIIa will also provide adequate stability.

When measuring sets of angles one direction is selected as the initial direction and is retained as such when repeating measurements. Observations proceed according to the following sequence:

1. One directs the telescope, in the first telescope position, in a clockwise direction towards the sighting point of the initial direction and sets accurately the vertical line. With the instrument so oriented, the micrometer circle is set to a reading of approximately one minute and the horizontal circle is rotated with the circle setting knob until the zero line coincides with that diametrically opposite to it. After the telescope setting has been checked the circle graduations are accurately brought to coincidence and the circle is read.

2. One turns the alidade clockwise as far as the next sighting point, right of the initial direction, adjusts the vertical line to it, after which the circle is read. This is repeated for each subsequent direction, the sequence of directions being clockwise.

3. After observing the last direction of the set the telescope is transited and is directed towards the last sighting point in a counter-clockwise direction. The vertical line is set precisely to this and the circle reading obtained.

4. One directs the telescope, still in the second telescope position, counter-clockwise towards the penultimate sighting point of the set, accurately adjusts the vertical line, after which the circle is read. All the other directions, up to and including the initial direction, are observed in a similar manner.

Circle readings are obtained for each direction in both telescope positions. The mean value of the initial direction is subtracted from the mean values of all directions; the initial direction is thus rated at zero.

If a set is to be measured several times, one does not start every measurement at the same position of the horizontal circle. In the event of n repetitions it is recommended that the horizontal circle be advanced by $180^\circ : n$ or $200^g : n$ respectively before each repetition.

4.6.1.3 Traverse Angle Measurement

The angle between the direction to the point to the rear and that ahead is measured at every point of a polygonal traverse. Single angle measurement is thus carried out according to the following pattern:

Telescope position I: Sighting reverse, circle reading
Sighting forward, circle reading
Telescope position II: Sighting forward, circle reading
Sighting reverse, circle reading

The alidade is always rotated clockwise. When starting the measurement at each point of the polygon it is advisable to adjust the horizontal circle to zero degrees and a few minutes.

4.6.1.4 Angle Measurement with the Subtense Bar

The angle between the two targets of a horizontal subtense bar is measured from one end of a distance to be determined, the subtense bar being set up at the other end at a right angle to the straight line between the two points.

Both targets appear at the same vertical angle; collimation error and error of trunnion axis thus affect both directions equally but no the angle. In this case the angle measurement is carried out in only one position of the telescope. The measurements are repeated several times, depending on the required accuracy and the distance in question. In order to obtain measurements which are completely independent of each other, the horizontal circle is advanced several degrees before each repeat.

4.6.2 Measuring Vertical Angles

The following operations are required for a complete vertical angle measurement:

Telescope position I: Adjusting the horizontal line to the height mark of the object, coinciding the collimation level, reading the vertical circle: A_I.

Telescope position II: Adjusting the horizontal line to the height mark of the object, coinciding the collimation level, reading the vertical circle: A_{II}.

The observations in both telescope positions should follow immediately after each other. The zenith distance z or the vertical angle ß (elevation of the line of sight towards the height mark) can be computed from the two readings A_I and A_{II}. The vertical circle is so incorporated in the instrument that the reading A_I when sighting in telescope position I (vertical circle left), corresponds to the zenith distance at the first approach, reading A_{II}, when sighting in telescope position II, to the complement of the zenith distance to 360° or 400^g respectively, at the first approach. Both results are inaccurate by the index error i of the vertical circle. By computing the zenith distance or the vertical angle according to the following formulae, this error will be completely eliminated.

$$z_I = A_I + i$$

$$z_{II} = 360° - (A_{II} + i) \quad \text{or } 400^g - (A_{II} + i)$$

$$z = \tfrac{1}{2}[A_I + (360° - A_{II})] \quad \text{or } \tfrac{1}{2}[A_I + (400^g - A_{II})]$$

Vertical angle:

$$\beta_I = 90° - (A_I + i) \quad \text{or } 100^g - (A_I + i)$$

$$\beta_{II} = (A_{II} + i) - 270° \quad \text{or } (A_{II} + i) - 300^g$$

$$\beta = \tfrac{1}{2}[(90° - A_I) + (A_{II} - 270°)] \quad \text{or } \tfrac{1}{2}[(100^g - A_I) + (A_{II} - 300^g)]$$

The computation of the zenith distance is much simpler and, above all, unambiguous, since z is in all cases positive. For this reason increasing preference is being shown for the zenith distance compared with the vertical angle.

Examples:

Both the following examples are based on the vertical circle readings as per 4.5.2.3 and 4.5.2.4 and illustrate the computation of the zenith distance and vertical angle with 360° and 400^g graduation.

360° graduation:

A_I = 94°12'43",6	z_I = 94°12'43",6	β_I = -4°12'43",6
A_{II} = 265°47'23",4	z_{II} = 94°12'36",6	β_{II} = -4°12'36",6
	z = 94°12'40",1	ß = -4°12'40",1

400^g graduation

A_I = $105{,}8224^g$	z_I = $105{,}8224^g$	β_I = $-5{,}8224^g$
A_{II} = $294{,}1764^g$	z_{II} = $105{,}8236^g$	β_{II} = $-5{,}8236^g$
	z = $105{,}8230^g$	ß = $-5{,}8230^g$

4.6.3 Measuring Distances with Stadia Lines

Where distance measurements call for no great degree of accuracy one uses the stadia lines, which will be found on the reticule.

4.6.3.1 Distance Measurement with Vertical Staff

The two horizontal stadia lines cut out a certain sector on a vertical staff; its length can be measured with the instrument by means of the graduation on the staff. The procedure is as follows: the upper stadia line (in the field of view) is set to the 1 metre mark on the staff, and the position of the lower line is determined to 1 mm. In the case of horizontal sighting the distance between the instrument and the staff is equal to 100x the distance between the two stadia lines. When inclined aiming is done the sector of the staff should be multiplied by the factor $100 \cdot \sin^2 z$ in order to obtain the horizontal distance between the two points. When measuring in the first telescope position the zenith distance z is read directly on the vertical circle; here accuracy to minutes will be adequate. The vertical staff must be set up exactly in the vertical with the aid of a circular level since, particularly in the case of steep lines of sight, any obliquity will impair the accuracy.

4.6.3.2 Distance Measurement with Horizontal Staff

The sector on a horizontal staff between the two vertical stadia lines can also be measured by the same method. This sector should be multiplied by 100· sin z in order to obtain the horizontal distance between instrument and staff. The staff must be set absolutely horizontal and at right angles on the direction to the instrument.

4.7 Packing the Instrument in its Case

The base plate of the carrying case is placed on a solid foundation and the three slides are then pulled back as far as they will go. The theodolite clamps are then opened, the control springs of the tangent screws are released and the illuminating mirrors are hinged to. Now one takes hold of the theodolite by the right-hand upright (on the optical micrometer side), releases the central fixing screw with the other hand and the instrument is placed on the base plate; the lower part is turned with the free hand so that the three retaining stops rest on the three supports. All three slides are now pushed inwards and are secured by firmly tightening the three black screws. The telescope is moved into a vertical position and the clamping screws slightly tightened, after which the cover can be placed on. It is secured to the base plate by simultaneous pressure on the two locking hooks on both sides, and is locked by lifting the instrument in its case by the carrying strap. Should the instrument have become wet during use, it should be dried as thoroughly as possible before placing it in the case. The case should then be opened when a suitable opportunity presents itself, to permit the instrument to dry off properly.

4.8 To Establish Angles with T-2 Universal Theodolite

1. Set up instrument in the usual manner, centered over the station.

2. Point the telescope to the first station from which the angle is to be established.

3. Using the microscope knob, set the reading of the seconds-drum to 0 minutes plus 5 to 10 seconds. Move the horizontal circle until the 0° and 180° are approximately coincident, zero at the bottom. Complete the coincidence setting of the circle at 0°/180° with the micrometer knob. It is not recommended that an attempt be made to set the circle exactly coincident at 0°/180° by turning the **circle knob,** as excessive and unnecessary time would be consumed thereby.

4. The actual reading of the seconds-drum is a "plus" reading which is added to the actual angle to be set off.
   For example:

Reading of seconds-drum upon completion of steps described above:	0° 0′ 08″
Angle to be established:	45° 32′ 20″
Reading to be placed in T-2:	45° 32′ 28″

Move micrometer until the reading of the seconds-drum is 2′28″, after which the instrument is turned in azimuth until the 45° graduation appears at the bottom. Clamp the instrument, and with the tangent screw, move the alidade until the index line for reading the horizontal circle reading lies half-way between the 20′ and 40′ space. Please note that in making this move with the tangent screw, the graduation lines of the circle must be brought to coincidence. The circle reading is now 45°30′, plus 2′28″ in the seconds-drum and the desired angle (45°32′20″) has been established.

It will be noted that the circle on the T-2 is numbered in azimuth only. If it should be necessary, or desirable, to establish an angle to the left, the procedure would be the same, except that the explement of the angle is used (i.e. the desired angle subtracted from 360°).

5. SUPPLEMENTARY EQUIPMENT FOR THE T2

5.1 Supplementary Equipment for Geodetic Measurements

5.1.1 Electric illumination

An electric lighting set, consisting of battery case with accessories, is used for night observations, in tunnels and mine galleries. Two illumination plugs are supplied with every T2 and are accommodated on the carrying case's base plate.

Fig. 15

Fig. 14

The battery case, which should be hung on the tripod, contains six cells, the three inside ones of which are connected in series and are connected with the switch and plug sockets. The three outer cells serve as spares. Also contained in the case are a hand lamp, a connecting cable and four reserve bulbs. The switch is located alongside the handle; it is combined with a variable resistor for regulating the brightness of the bulbs. It is switched off when the black mark on the knob lines up with the black mark on the case.

The plug sockets are located on the opposite side to the handle. They are protected by a slide against the ingress of dirt and insects and are exposed by shifting the slide knob against the sockets. The outer sockets are connected with the switch and are used for the instrument lighting. The inner sockets, connected directly with the batteries are used for the hand lamp, which has an individual switch.

The two illumination mirrors are removed from their holders and are replaced by two lamp fittings. The lamp holders are removed from the adapters for checking and tightening the bulbs, in case they should have become loose in transportation. When not in use, both illumination mirrors should be stored on the base plate, the plugs normally used to hold the lamps.

5.1.2 **Traversing Equipment**

The T2 traversing equipment will be found ideal for accurate traversing work. This equipment is designed for automatic centering and thus enables to avoid centering errors, which have a very unfavourable effect in long traverses with short legs.

In addition to the theodolite with tribrach, tripod and battery case, the traverse equipment includes two extra tripods, two theodolite tribrachs with circular level and optical plummet, two targets with plate level and lighting elements and two extra battery cases.

Fig. 16

For continuous measuring 3 tripods are set up at three consecutive points 1, 2 and 3. The theodolite on its tribrach is set up centrally above the station point, on the centre tripod 2, and 2 targets in a theodolite tribrach each on the two outside ones, Nos. 1 and 3.

Fig. 17

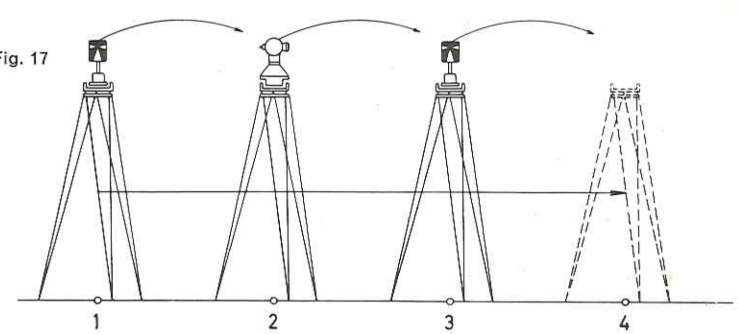

Fig. 18

After measuring the angle 1—2—3 the three tribrach clamps are released, the theodolite and targets are removed from their tribrachs and shifted forward to the next tripod (as shown in the schematic sketch, Fig. 17). They are carefully mounted on the tribrachs which have become free and are secured by tightening the tribrach clamps. The front target can only be inserted after the rearmost tripod with tribrach has been shifted to the front and has been set up at the next point, No. 4 (as described in 4.1). After theodolite and targets have been levelled and the targets have been set up with their front sides facing the theodolite, the

next angle 2—3—4 can be measured. The procedure followed when changing from one point to the other, while retaining the centering, will depend on the number of assistants available. Usually each target will be operated by an assistant.

When using the traverse equipment in tunnels and mine galleries, each tripod must be fitted with a battery case. The targets' reflectors are fixed to the targets and connected to the battery case with the flex provided. When changing theodolite and targets, the flex is disconnected from the battery case, which is left on the tripod.

5.1.3 **Invar Subtense Bar**

The 2-meter subtense bar is used for computing a distance from horizontal angle measurements.

After being hinged up the subtense bar is secured on the tripod centrically over the end point of the distance to be measured. The circular level on the tribrach must have its bubble precisely in the centre, so that

Fig. 19

the base is horizontal. With the hinged up sighting telescope, one sights against the theodolite which is above the other end point of the distance to be measured. As a result, the bar is set at right angles to this direction and is secured in this position by tightening the clamping screw. Then the sign for measuring is given, which is done according to 4.6.1.4. The horizontal distance between instrument and subtense bar is thus obtained in a simple manner by using the table of distances. One enters the table with the mean value of the angle measurements and the respective horizontal distance is interpolated.

Fig. 20

Both targets at the ends of the stadia can be illuminated for distance measurements in tunnels and mine galleries. The battery case is hung on the tripod and is connected with the plug sockets in the middle of the bar by a flex. Both lamps located behind the targets are connected with these sockets by built-in wires.

Further details on the invar subtense bar are contained in the pamphlet BL 82e.

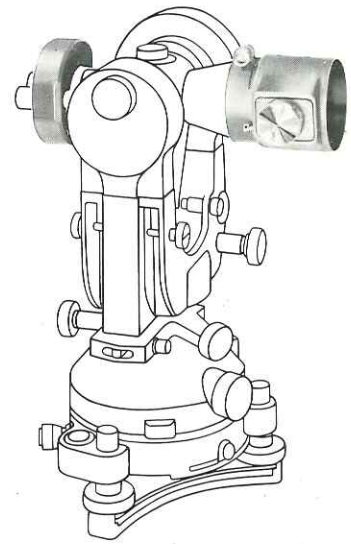

Fig. 21

5.1.4 **Precision Telemeter DM 1**

The DM 1 is used for traverse distance measurements and for accurate cadastral surveys, since it permits accuracy of .1 to .2‰ to be obtained at about 100 metres (330 ft.).

The DM 1 is mounted on the T2 telescope's objective, which is balanced by the counter-weight. Detailed description and instructions for use will be found in the pamphlet Th 98e.

5.1.5 **Optical Plummet**

Apexes can be plumbed by fitting a plumbing device in the T2's tribrach. This device is equipped with a telescope having 5 x magnification and

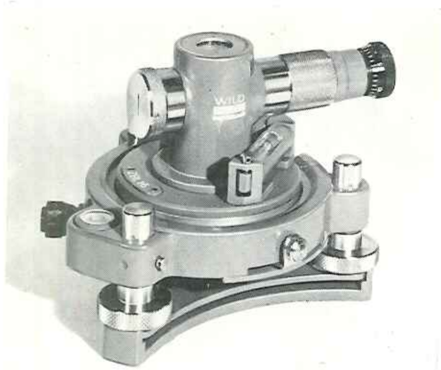

Fig. 22

focusing distances from about 1 ft. to infinity. Additionally, it has two plate levels located at right angles to each other.

5.1.6 **Pentagon Prism**

This equipment is used in mines for transferring directions through narrow shafts; it thus replaces the theodolite with eccentric telescope, formerly employed for this purpose. The pentagon prism is mounted on the T2's telescope objective and is held in position with a clamping screw. A balance weight is secured at the eyepiece end.

To transfer the direction the theodolite is so set up on the tripod centrically above the centre, which is above the shaft's centre line, that the tripod legs and necessary framework interfere as little as possible with the sighting in a downward direction. Two fine- graduation rods are set up parallel in the shaft at the greatest possible distance apart. They should be so placed on a firm base that they are horizontal and at right angles to the required direction.

One now shifts the telescope on the theodolite to the horizontal position and sights the point defining the direction to be transferred through the objective prism. Then the prism is turned downwards, without adjusting anything on the theodolite and telescope, and the readings to be made on both rods are noted. After this the theodolite is turned by 180°, with the telescope remaining in position, and the operation is repeated in this position. A line connecting both the centre points of both stadia reading positions will thus produce the desired direction.

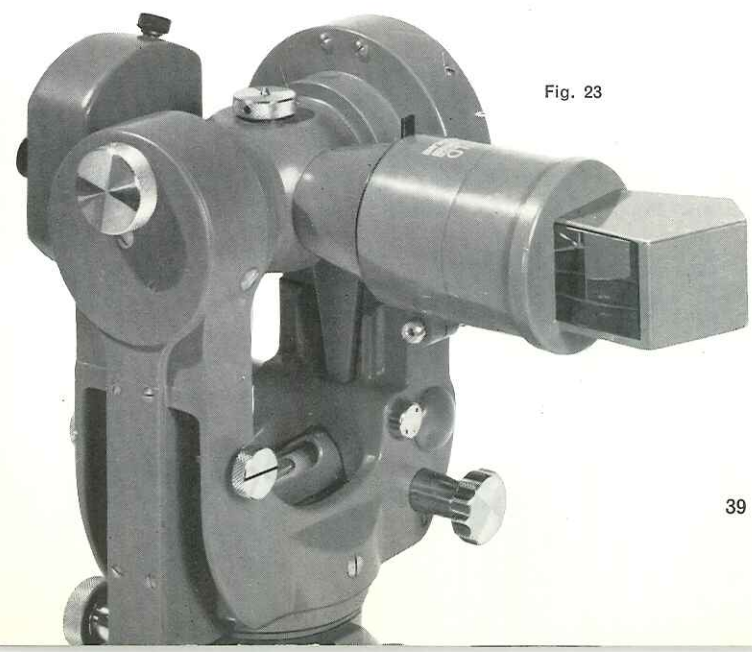

Fig. 23

Fig. 24

5.1.7 **Base Plate for Mounting on Pillars**

A heavy, cast-iron base plate is available for observations on pillars. It is set up centrically to the corresponding mark by means of a centre point with circular level and its three points secure a stable position on the surface of the pillar. The theodolite is fixed to the plate by means of the central fixing screw.

5.2 Supplementary Equipment for Astronomic Measurements

Electric illumination is used for all astronomic measurements as described in 5.1.1.

5.2.1 **Eyepiece Prisms**

Eyepiece prisms are used for steep-angle sightings, with the telescope directed at angles from approximately 30° to 60° above the horizon. The telescope prism is screwed into the thread of the telescope eyepiece. After removing the small eyepiece cap the reading prism is screwed on to the reading microscope's eyepiece.

Fig. 25

5.2.2 **Sun Glasses**

Sun glasses are placed on the telescope prism when sighting against the sun or other bright objects.

5.2.3 **Diagonal Eyepieces**

Diagonal eyepieces are available for sighting up to the zenith. After the eyepieces have been removed from the telescope and reading microscope they are inserted in the eyepiece tubes and are secured by slightly tightening the small lever. When changing over from one telescope position to another, both tubes can be swung by 180°.

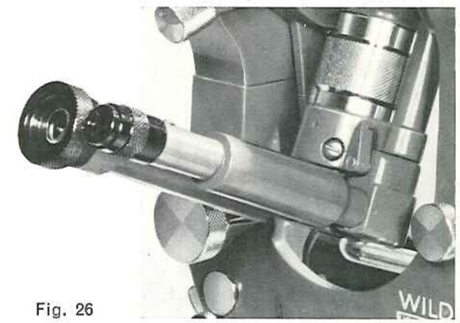

Fig. 26

When replacing the telescope eyepiece, the zero mark of the diopter scale must be set at the index when starting to screw it in, so that the scale is correctly orientated when focussing the reticule. Sometimes a little patience will be required to introduce the eyepiece into the thread.

5.2.4 **Striding Level**

A striding level can be supplied with the T2 for the direct measurement of the inclination of the trunnion axis. It is put on two rings, which are

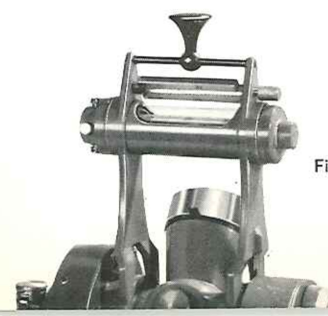

Fig. 27

ground concentric to the trunnion axis. For using the striding level the protecting lacquer of the rings has to be removed. It is advisable to order the striding level with the instrument, or to send the instrument to the factory for fitting.
Before the striding level is mounted on the thoroughly cleaned rings, a small retaining ring must be screwed on to the vertical circle casing. When not in use the two bright rings are coated with a thin film of grease to protect them from rust.

5.2.5 **Horrebow Level**

This level serves for measuring slight changes in the angle of the telescope's inclination, but it cannot be applied for the Horrebow-Talcott method proper since this requires the use of an eyepiece micrometer.

Fig. 28

After removing the three cover screws the level is secured to the elevation clamp with the three screws provided.

Fig. 29

5.2.6 **Astrolabe Attachment**

This attachment, used for determining latitude and local sidereal time from the movement of stars through the almucantar of 30° zenith distance, is mounted on the T2's horizontal telescope.
The prismatic astrolabe attachment is described in detail in pamphlet Th 85e.

5.2.7 **Polar Attachment**

The polar attachment will be found an invaluable aid for the approximate determination of latitude, local sidereal time and north direction. This equipment is mounted on the telescope objective and is balanced by a counter-weight on the eyepiece.
Further details of the polar attachment are contained in the pamphlet MS 132e.

Fig. 30

6. CHECKING AND ADJUSTING THE T2

6.1 Tripod

A stable tripod is a basic requirement for accurate measurement with the T2. For this reason the tripod must have no loose joints.
The tripod legs must be rigidly connected with the metal components; this is achieved by tightening the hexagon nuts (but not excessively so) with the spanner included in the accessories case. In very dry climates the wood can shrink to such an extent that it is no longer possible to make any adjustment. In this case the tripod should be placed in water overnight or covered with wet cloths.
The tripod leg joints are adjustable. But the hexagon screws under the joints must only be so tightened that the legs just remain apart when the tripod is slowly lifted from the ground by its head.

6.2 Levelling Screws

The best way of checking the levelling screws is with the removed tribrach. The levelling screws threads should fit snugly and should not turn too easily. An adjusting screw at the side of each levelling screw serves to affect this adjustment. The adjusting screw can be easily turned by means of an adjustment pin, the levelling screw being turned at the same time until the desired resistance has been obtained.

6.3 Tangent Screws

The threads of the tangent screws are regulated by an adjusting ring, which is located behind the knob. This adjustment will be very rarely required.

6.4 Plate Level

The correction of the plate level is closely associated with the levelling of the instrument.

The instrument is first pre-levelled by using the circular level. To do the fine levelling the plate level is first set parallel to the connecting line between two levelling screws. The bubble is brought into the centre by turning these two levelling screws in opposite direction to each other. Then the alidade is swivelled through 180° and the level is checked again. If the bubble should have moved out of centre, half the amount must be compensated by turning the two levelling screws. The adjusting screw, which is located on the alidade's left-hand upright, under the collimation level's reflector, is turned by the adjustment pin until the bubble takes up its central position again.
The alidade is then swivelled through 90° and the level's bubble is centred once again by turning the third levelling screw.
If the bubble is only a small amount out of centre (1–2 divisions), adjustment should not be done. In this case one notes the eccentricity of the bubble and when levelling one always sets to this eccentricity.

6.5 Circular Level

After the instrument has been levelled with the plate level, the bubble of the tribrach's circular level should be in the center. If it is not, it should be centred by turning the adjusting screws located under the holder.

6.6 Optical Plummet

The instrument is first centred above a clearly marked station point (a cross or ring) by means of a plumb line suspended from the central fixing screw. After the plumb line has been removed and the instrument levelled, the cross of the optical plummet must show on the centre of the station point. Any deviations must be rectified by means of the three adjusting screws, which are located beside and underneath the optical plummet's eyepiece.

6.7 Lateral Collimation

One sights with the vertical line in both telescope positions a sharply defined point on the horizon and reads the horizontal circle. The difference between both circle readings, reduced by 180° or 200^g respectively, is equal to twice the collimation error. The micrometer circle is now set at the mean value of both micrometer readings and coincidence of the graduation lines is produced by turning the azimuth tangent screw. Then the reticle is shifted to the side until the vertical mark is focussed again on the object.

Three adjusting screws have been fitted between eyepiece and focussing ring for this purpose, one is horizontal and the other two are oblique. If, for example, the reticle has to be moved to the left in position I, the two oblique screws on the right are loosened with a screwdriver by the same amount and then one gradually tightens the left, horizontal screw. After the correction has been made the collimation error should be checked once again.

The telescope should then be tilled to check whether the vertical mark is vertical to the axis of tilt. If required, the reticle can be righted by turning the two oblique correcting screws in the opposite direction.

6.8 **Vertical Collimation** (Index Error)

After the lateral collimation has been corrected the object is pointed with the horizontal line in both telescope positions, the collimation level is brought to coincidence and the vertical circle is read. The deviation of the sum of both circle readings of 360° or 400^g respectively, is equivalent to double the index error of the vertical circle. In order to cancel out this error one computes the zenith distance according to 4.6.2. The correct reading is now set on the micrometer circle, and while the horizontal line is still aimed at the object, the graduations of the vertical circle are brought to coincidence by turning the level's tangent screw. The bubble of the collimation level is centred again by loosening one of the adjusting screws with an adjustment pin and slightly tightening the other one. The correction having been made the index error should be re-checked.

6.9 **Supplementary Equipment**

After the instrument its supplementary equipment should also be checked and, if necessary, adjusted. Individual parts of the traverse equipment should be dealt with in the same manner as the main components of

the T2 equipment. The distance readings of the various telemeter devices should be checked over given distances.

Finally, it should be noted that by measuring in both positions of the telescope, the instrumental errors are eliminated. Thus, in order not to affect the instrument's good adjustability, small errors should not always be corrected.

Large deviations, which interfere with a quick computing of arithmetic means, should be corrected with the aid of the adjusting screws. Thanks to its robust design, large deviations are very unlikely to occur on the T2, so that only in very rare cases will adjustments be called for. Nevertheless, the instrument should be checked from time to time, particularly after it has been transported over long distances.

7. CARE AND MAINTENANCE OF THE T2

7.1 Removing Dust and Dirt

All dust should be removed with a brush before wiping dirty components with a cloth. This applies in particular to the optical parts. Chamois leather will be found suitable for this purpose, better still, a clean handkerchief rather than a soiled chamois leather.

No liquid should be used for cleaning, neither water, petrol nor oil. If necessary the lenses may be breathed on before polishing.

7.2 Protection against Damp

If the instrument has become wet it should be dried as well as possible before packing it in its case; it should then be removed when one gets home and dried thoroughly. If one leaves it in the closed case, the air inside the hood will take up humidity by increasing temperature and will in time diffuse inside the instrument. When cooling off the water will condense and from a coating or tarnish, which may well make any sighting with the telescope and reading of the circles impossible.

Every T2 is provided with a small bag of silica-gel when it leaves the factory. This consists of intensely hygroscopical grains of amorphous quartz. They are blue when dry and pink when wet. Since they absorb

damp when exposed to air they should always remain enclosed with the exception of the few seconds when unpacking or replacing the instrument in its case. Grains which have become pink can be regenerated. One pours them from their bag on to a plate which is then heated up to the boiling point of water (test with water drops). If the temperature is too high the grains will split. Once blue again and after having cooled off the grains can be returned to their bag.
Very special attention should be paid to the bright instrument rings used for bearing a striding level when astronomic observations are to be done. After use they must in all cases be coated with a thin film of grease to prevent the formation of rust.

7.3 Tropical Protection

Instruments for use in tropical climates are provided by Wild with a medium which prevents the development of fungus. These theodolites are marked with a red spot. When very damp climates are experienced the instrument should be removed from its case and submitted to a steady light flow of air (Electric lamp, fan).

7.4 Greasing for Cold Climates

Instruments intended for use at very low temperatures must be specially lubricated before leaving the factory. They are then marked with a blue spot.

Illustrations and descriptions contained herein are not binding for sales contracts.

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