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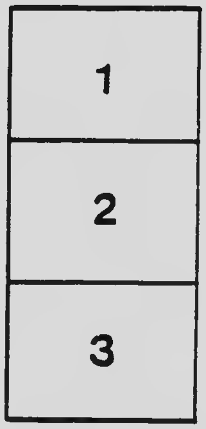
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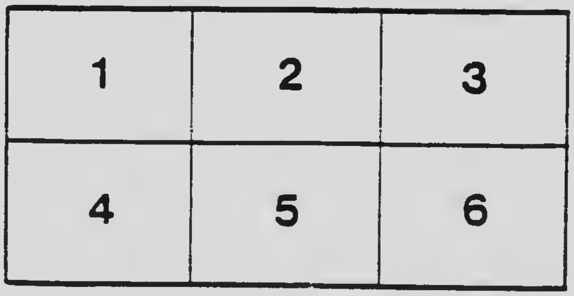
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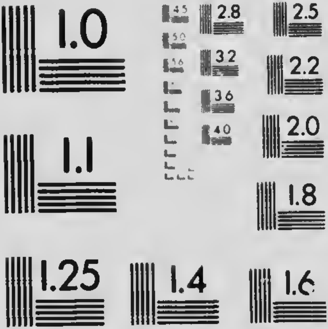
MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



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DESCRIPTION, ADJUSTMENTS AND METHODS OF USE

OF THE

SIX-INCH MICROMETER BLOCK SURVEY REITERATING TRANSIT THEODOLITE 1912 PATTERN

By

W. H. HERBERT, B.Sc.

BULLETIN 34

OTTAWA
GOVERNMENT PRINTING BUREAU
1916

CONTENTS.

ILLUSTRATIONS.

GENERAL REMARKS

The transit theodolite used on the survey of Block Outlines is described briefly in Appendix "D" of the Manual of Surveys.

A Block Surveyor may, in the course of his work, have to perform the following operations:

1. To run a straight line.

2. To turn off or measure small angles, such as: The deflection of base lines at township corners, the measurement of the angle between the Pole Star and the meridian, and the telemetric measurement of distances.

3. To turn off or measure large azimuth angles, such as: The turning off of base lines from meridians, and the measurement of angles in triangulations.

4. To determine the direction of the astronomical meridian.

5. To determine the latitude.

6. To determine the local time or the longitude.

Accuracy in running straight lines is secured by a long transverse axis, a powerful telescope, and an eye-piece micrometer for measuring small deviations. The measurement of small angles, either horizontal or vertical, is made with precision with the eye-piece micrometer. Accuracy in measuring or laying off larger angles is obtained by micrometer microscopes. The powerful telescope, eye-piece micrometer, diaphragm and sensitive levels render the instrument especially convenient and accurate for the determination of the meridian by Pole Star observations in day time, of the local time by meridian transits and of the latitude by Talcott's method.

It is used without the clamp of the transverse axis for running lines, fig. 1; for observing for local time by meridian transits, fig. 2; and for observing azimuth in day time, figs. 3 and 4. The clamp arm is put on for making instrumental adjustments and for latitude observations, in which case the instrument is used as a zenith telescope, figs. 5 and 6.

These instructions and explanations have been prepared for the purpose of supplying to surveyors only certain requisite information not readily obtainable from text-books, and also certain information peculiar to this type of instrument.

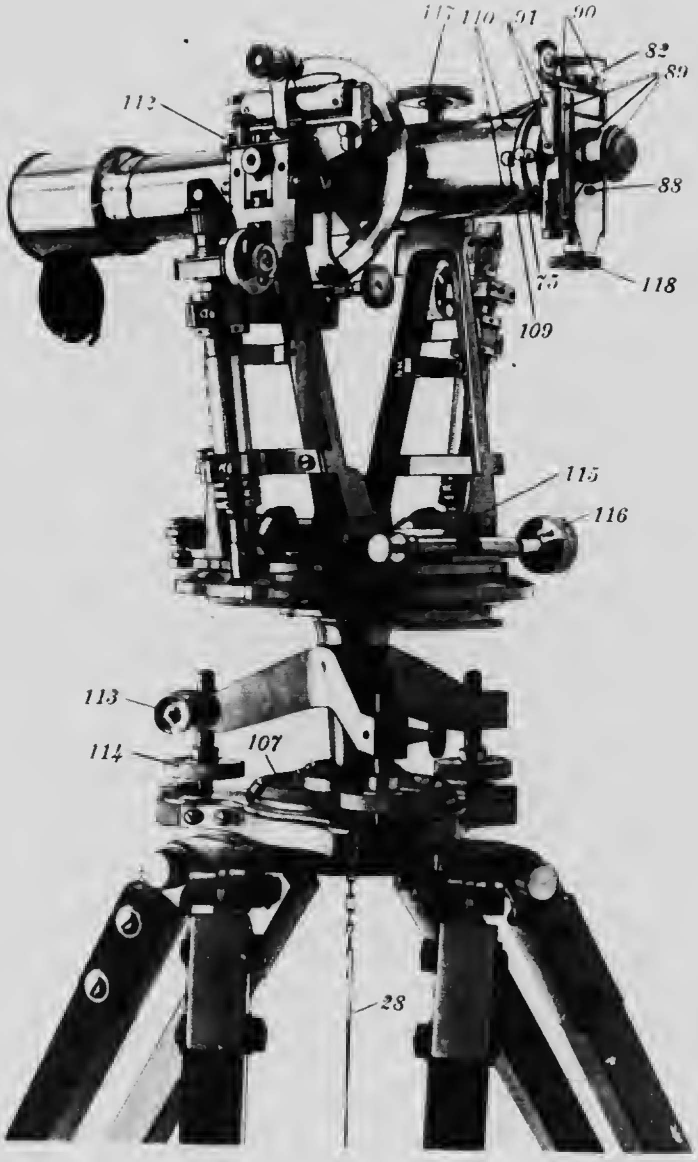


FIGURE 1. Instrument Set Up for Running Lines.

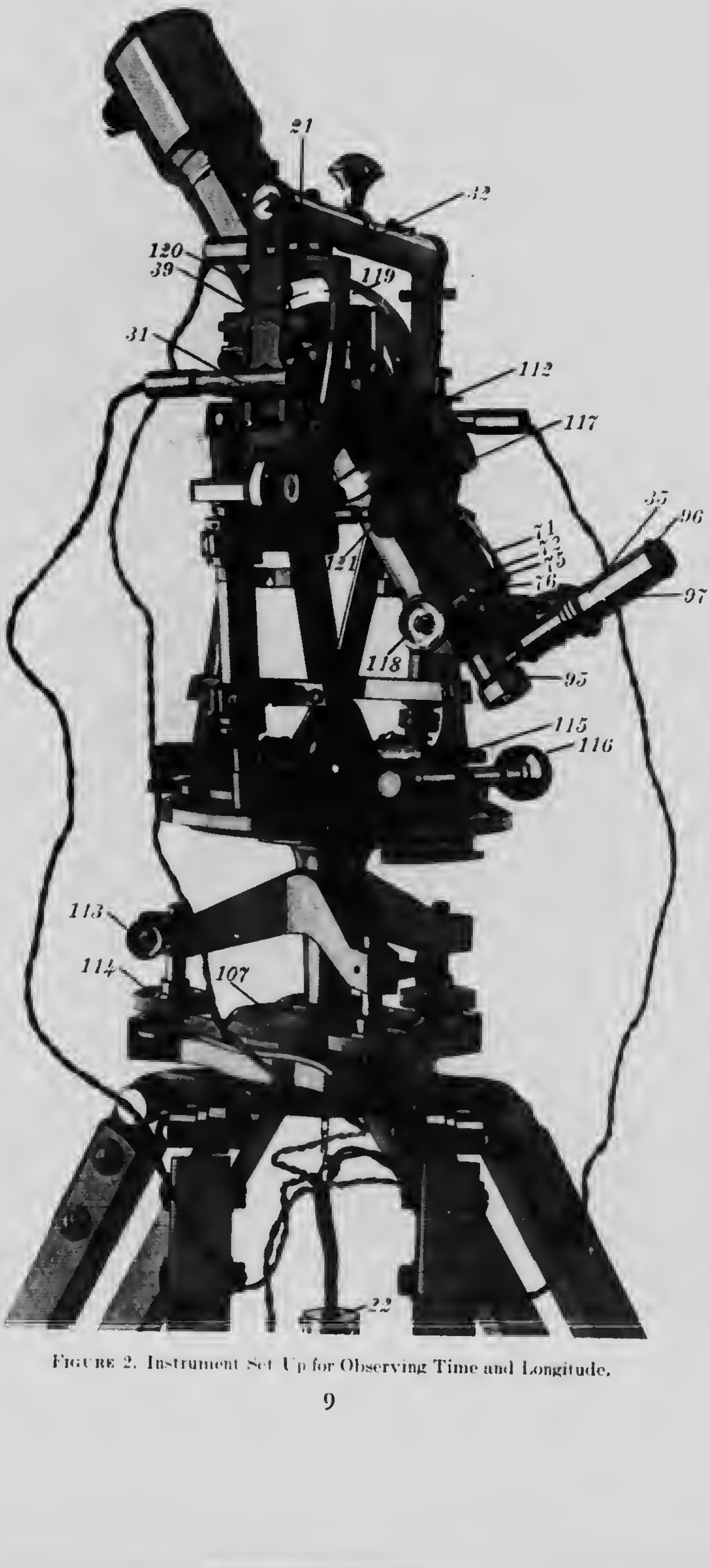


FIGURE 2. Instrument Set Up for Observing Time and Longitude.

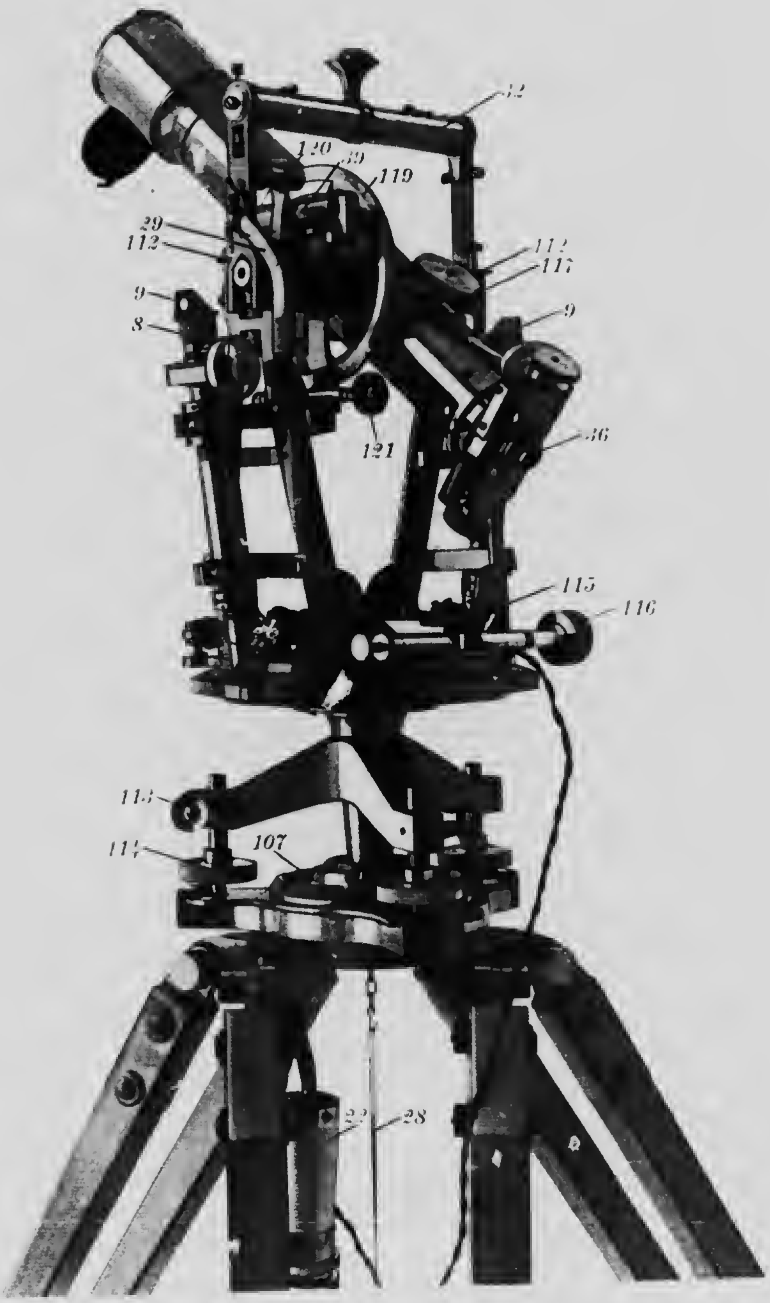


FIGURE 3. Instrument Set Up for Observing Azimuth on the Horizontal Circle.

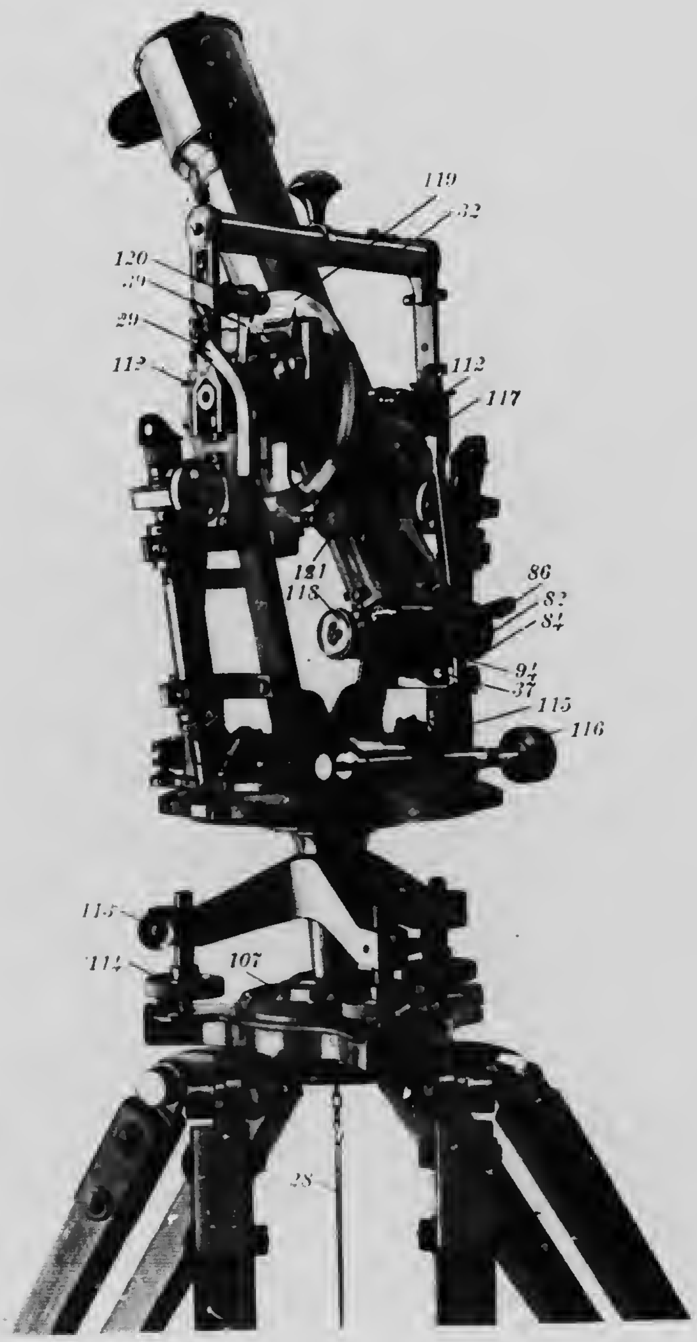


FIGURE 4. Instrument Set Up for Observing Azimuth with the Eyepiece Micrometer.

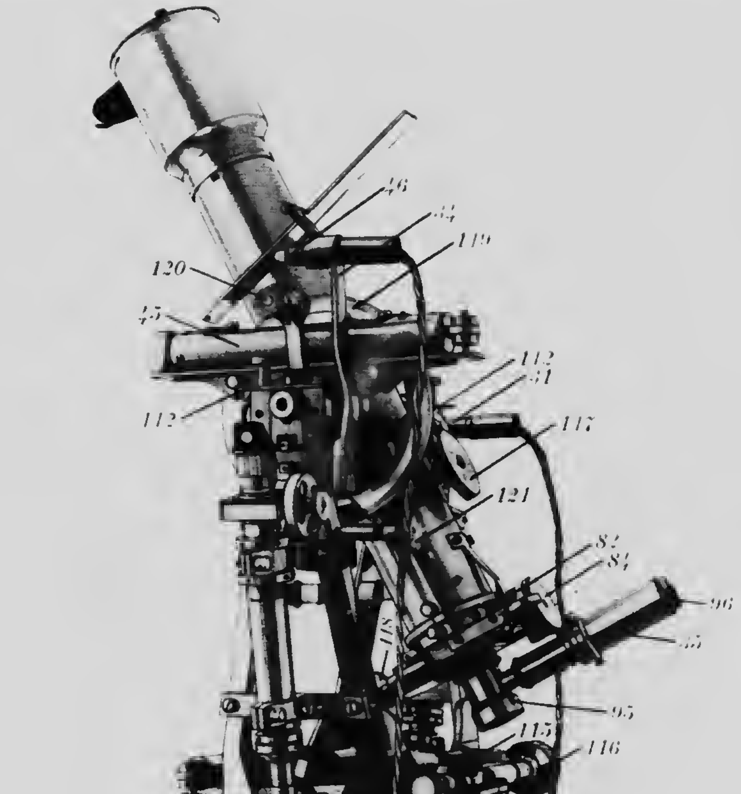


FIGURE 5. Instrument Set Up for Observing Latitude—Looking South—Viewed from East.

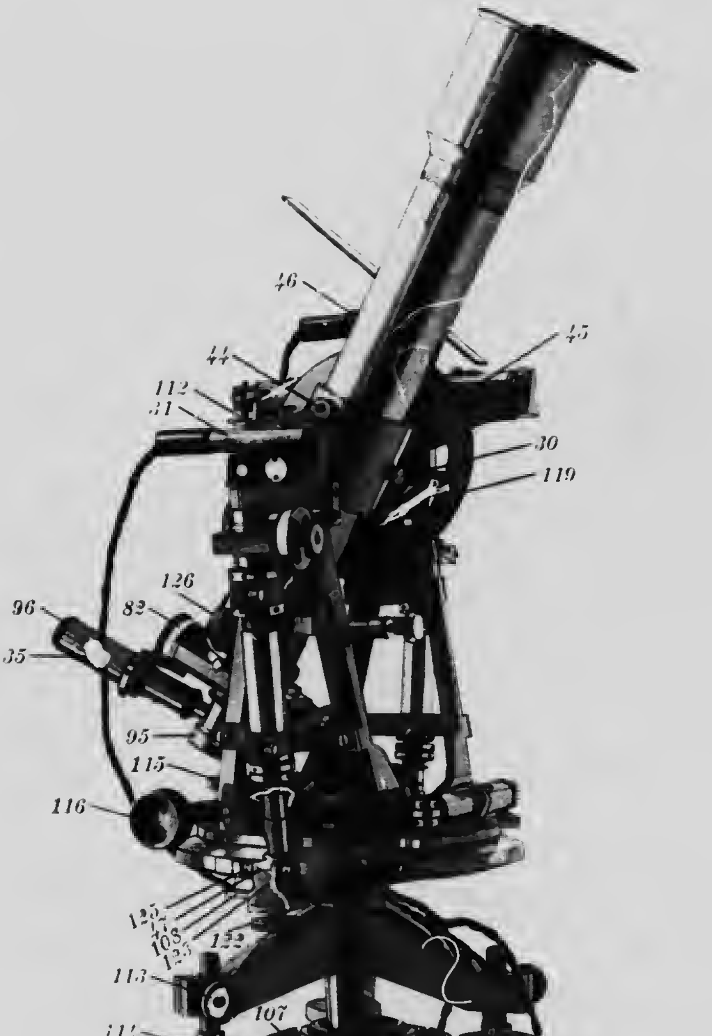


FIGURE 6. Instrument Set Up for Observing Latitude—Looking North—Viewed from East.

FIGURE 7. Instrument Accessories.

21. Lamp Holder and Lamp for Reading Vertical Circle.
22. Rheostat and Lamp Leads.
23. Battery Leads.
24. Large Screw Driver.
25. Small Screw Driver.
26. Wrench for Tripod Nuts.
27. Key for Shifting Tripod Head.
28. Plumb-bob.
29. Stride Safety Holder.
30. Telescope Mirror and Case.
31. Lamp Holders and Lamps for Illuminating Diaphragm.
32. Stride Level.
33. Camel Hair Brush.
34. Lamp Holder and Reflecting Mirror used in Observing Latitude.
35. Long Diagonal Eye-Piece.
36. High Power Inverting Eye-Piece and Covers.
37. Prismatic Eye-Piece and Cover.
38. Low Power Inverting Eye-Piece.
39. Small Vertical Circle Level.
40. Large Adjusting Pin.
41. Small Adjusting Pin.
42. Light Sun Glass.
43. Dark Sun Glass.
44. Transverse Axis Clamp.
45. Latitude Level.
46. Spare Lamps.
47. Latitude Stop Clamp.
48. Bottle Lubricant.
49. Bottle Watch Oil.
50. Spare Latitude or Stride Vial.
51. Spare Vertical Circle Vial.
52. Spare Plate Vial — Large.
53. Spare Plate Vial — Small.
54. Instrument Cover.
55. Telescope Plug.
56. Sun Shade.

DESCRIPTION AND ADJUSTMENTS

MICROMETER MICROSCOPES

DESCRIPTION OF MICROSCOPES.—See fig. 8. The reading microscope as now constructed is a species of compound microscope consisting of three lenses, one of which, 62, is the object lens, the other two, 5 and 6, forming a positive eye-piece. The amplifying lens is omitted as the field is not required to be extensive and the measure is made near its centre.

When firmly fixed and truly adjusted, it is capable of subdividing the minutes into seconds with great accuracy and ease. It admits of the divisions on the limb being well illuminated, and does not injure them by friction as happens with the vernier, over which it possesses all the advantages of convenience combined with high magnifying power and micrometrical nicety of measurement.

Its value, however, is entirely dependent on its being kept in perfect working order and true adjustment; for which reason a knowledge of the principles of its construction is essential to an observer who aspires to great precision.

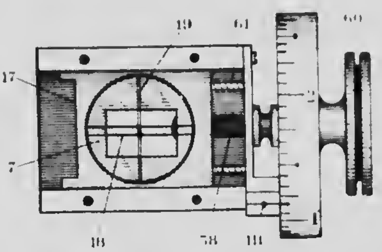
EYE-PIECE.—The eye-piece consists of the draw-tube 4, fig. 8, in which are mounted, each in its own cell, the field lens 5 and the eye lens 6. This eye-piece possesses an equivalent focal length of about three-quarters of an inch, and is focussed on the glass diaphragm 7 by turning the swivelled focussing nut 8.

To obtain distinct vision of th lines, place a slip of white paper under the microscope. The lines will thus be projected upon a blank field, in which state the eye is better able to judge of the.r distinctness. Now turn the focussing ring 8, fig. 8, until the lines appear sharply defined. This is a personal adjustment and varies with the focal length of the eye of the observer.

A reflecting prism 9, deflecting about 75 degrees, inclosed in the cover 10, and held in place by two small screws 11, is fixed over the eye-piece for convenience in reading. The prism cover 10, is painted a matt, or absorbent black, both inside and outside; inside, for the purpose of absorbing any extraneous light rays; outside, for the purpose of supplying a blank field upon which the magnified image of the horizontal circle graduations may be viewed with great distinctness.

REMOVAL OF EYE-PIECE.—Removal of the eye-piece may be effected by any one of three methods. First, by taking out the small screw 12, which slides in the slot 13, and turning the swivelled focussing nut 8 to the left until the eye-piece becomes disengaged. Second, by unscrewing the eye-piece from the top of the micrometer box 14. Third, by removing the four screws 15 and the two outside screws 16, and lifting off the top of the micrometer box. This third method is the one by which access is gained to the micrometer box.

MICROSCOPE CARRIAGE AND DIAPHRAGM.—The diaphragm carriage 17 travels back or forth when the micrometer screw is rotated by means of the milled head. This carriage supports the glass diaphragm 7 upon which two pairs of lines are engraved at right angles to each other; see also fig. 9. The pair of lines 18, fig. 8, which appears at right angles to the horizontal circle



View of Micrometer
with Cover Removed.

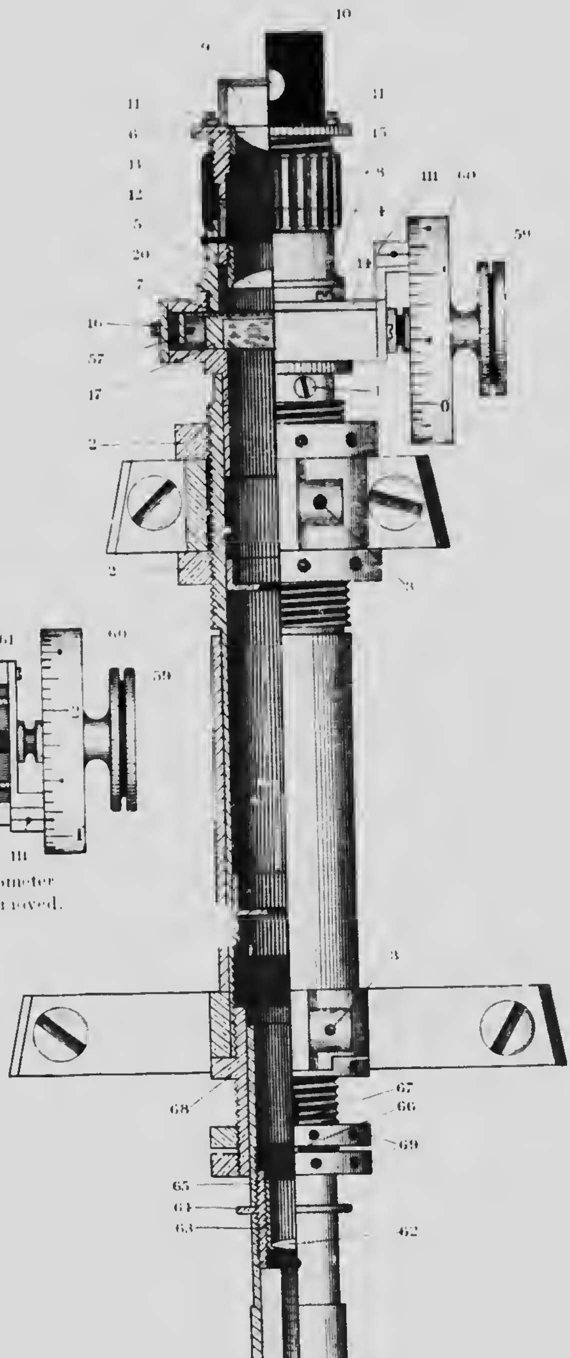


FIGURE 8. Side View and Part Section of Micrometer Microscope.

graduations, subtends an apparent angle of about four minutes on the circle when viewed through the eye-piece, and the part of the graduations included between these two lines is the part upon which all readings are to be made. The pair of lines 19 which appears parallel to the horizontal circle graduations subtends an apparent angle of about one minute on the circle when viewed though the eye-piece, and the inside distance separating these two lines is just a little greater than the width of a graduation. The advantage in using two lines placed close together over using a single line or a point is that the pair of lines averages any small irregularities existing in the graduations, thus giving more consistent readings.

MICROSCOPE COMB. In place of the usual comb possessing many teeth, there is used a blank comb or index plate 20 having but a single notch upon its edge, which lies very close to the glass diaphragm, its apparent distance from the nearer line being about a minute of arc on the circle. The comb is a strip of brass dovetailed into the cover of the micrometer box, and remains stationary while the diaphragm moves. It is attached to the left end of the micrometer box by means of the middle screw 16 which projects through the small steel spring 57, thus supplying a means of moving the notch in the comb to any desired position in the field of view.

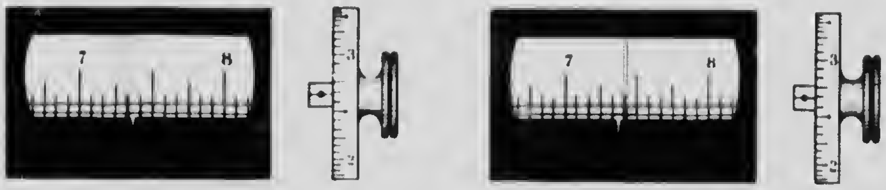
MICROMETER SCREW AND DRUM. The micrometer screw 58 is rigidly attached to the milled head 59, while the micrometer drum 60 rotates on the same axis, but its position relatively to the milled head may be readily changed. This is accomplished by loosening the small screw in the centre of the milled head 59, and holding either the head or the drum while the other is rotated. The micrometer screw has forty-five threads to the inch, one revolution corresponding to five minutes of arc on the horizontal circle. A positive, constant contact between the threads of the micrometer screw and the threads of the diaphragm carriage is maintained by means of the two small springs 61; but all settings of the micrometer must be made by screwing up; i.e., by rotating the micrometer head in a clockwise direction, for the purpose of avoiding any lost motion due to friction.

The micrometer drum 60 is divided into five equal parts, each part representing one minute; and these minute parts are each subdivided into twelve equal parts, each part representing five seconds. The fifteen-, thirty-, and forty-five-second marks are longer than the others. Single seconds may be readily estimated by eye, but it must not be inferred that the precision of the instrument is anything like this.

AVOIDANCE OF LOST MOTION.—It has been mentioned that the setting on a division should always be made by screwing up against the springs. This is done in order that the shoulder of the micrometer head may be made to press steadily on its proper bearing.

When the milled head is released it leaves its bearing, and the screw is not retracted but for the action of the springs, upon the efficiency of which the uniformity of the motion of the micrometer during the releasing process entirely depends.

It has, however, been found in practice, that, owing to irregularities of friction or other causes, the springs do not act upon the screw uniformly and instantaneously. The head may be released before motion takes place. This is called "lost motion" and occurs in all screws when the action is reversed. No reliance can therefore be placed upon the action of the micrometer unless the springs and the screw are acting in opposition, whereby the bearing of the female screw is preserved, and the uniformity and steadiness of action is maintained in immediate obedience to the rotation of the micrometer head.

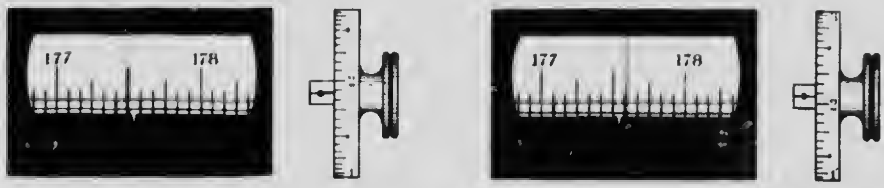


A.

F = 2′ 39″ IMAGE CORRECT SIZE B = 2′ 39″

CIRCLE = 7° 20′

READING = 7° 22′ 39.″0

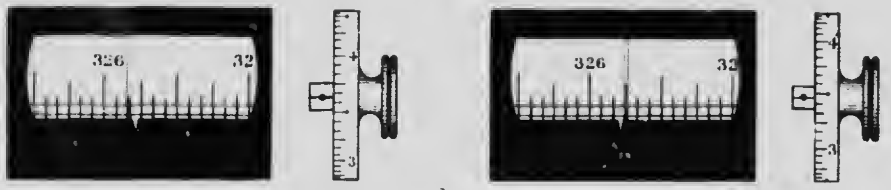


B.

F = 1′ 54″ IMAGE TOO SMALL B = 2′ 03″

CIRCLE = 177° 30′

$$\text{READING} = 177^\circ 30' + 1' 54'' \times \frac{5'}{5' + 1' 54'' - 2' 03''} = 177^\circ 31' 57.''5$$



C.

F = 3′ 38″ IMAGE TOO LARGE B = 3′ 28″

CIRCLE = 326° 10′

$$\text{READING} = 326^\circ 10' + 3' 38'' \times \frac{5'}{5' + 3' 38'' - 3' 28''} = 326^\circ 13' 31.''0$$

FIGURE 9. Method of Reading Micrometer Microscope.

METHOD OF READING MICROSCOPE.—The method of reading angles by the use of the microscopes is illustrated in fig. 9. A reading is made by superimposing the pair of bisection lines upon the graduation lying upon each side of the notch in the index plate so that the graduation just fills the space between the two lines. In all cases it is necessary to read and record the values obtained by setting on both the forward and backward divisions; that is, on the divisions to the apparent left and right of the notch, respectively. When the forward and backward readings are equal, the total reading is obtained directly by adding the drum reading to the circle reading as shown at "A." However, this equality of the readings is the very rare exception.

Owing to errors in the circle graduations, to the fact that the distance between the microscopes and the limb varies with the temperature, and to slight errors in adjustment which are bound to occur when handling the instrument in the field; it is almost invariably the case that the image is either too large or too small. The latter case is represented by "B," fig. 9; while tee former is shown by "C." The method used in deducing the final reading is as follows:

Let F = forward, or apparent left, reading.
Let B = backward, or apparent right, reading.
Then distance between readings is equal to $5' + F - B$.
Error of run = $F - B$.

$$\text{Correction to } F = -F \times \frac{F-B}{5'+F-B};$$

$$\text{or, corrected reading} = F - F \times \frac{F-B}{5'+F-B};$$

$$= F \times \frac{5'}{5'+F-B}.$$

This applies both when the image is too large and when too small.

This form is not very convenient for practical use where a large number of reductions is to be made. By multiplying both numerator and denominator by $5'-(F-B)$ the expression for the corrected reading becomes

$$F \times \frac{5'(5'-F+B)}{(5')^2-(F-B)^2}.$$

Now as $(5')^2$ when expressed in seconds is 90,000, and $(F-B)^2$ is very seldom as large as 100, this latter term may be dropped without introducing any very appreciable error, and the expression becomes

$$F \times \frac{5'-F+B}{5'};$$

$$\text{or} \qquad F\left\{1-\frac{F-B}{5'}\right\};$$

$$\text{or} \qquad F-\frac{F}{5'} \times \text{(difference)}.$$

Where the error of run is considerable, the absolute method of reduction should be used; but wherever the error introduced by using the approximate form is negligible it is much to be preferred on account of its simplicity of application. The differences between the results obtained by using these two methods for all errors of run as high as ten seconds and under the most unfavourable conditions; i.e., when $F = 5'$, are given in the following table. Where F is less than 5′ the difference will be less in the same proportion.

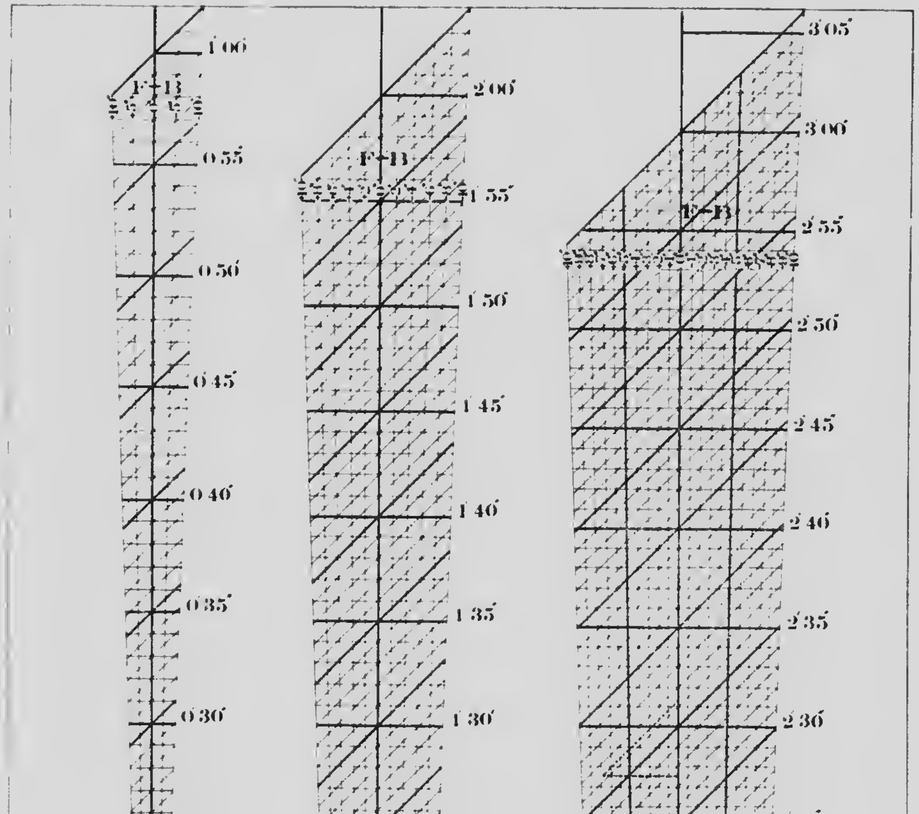


FIGURE 9A. Abacus for Correcting Micrometer Value for Error of Run.

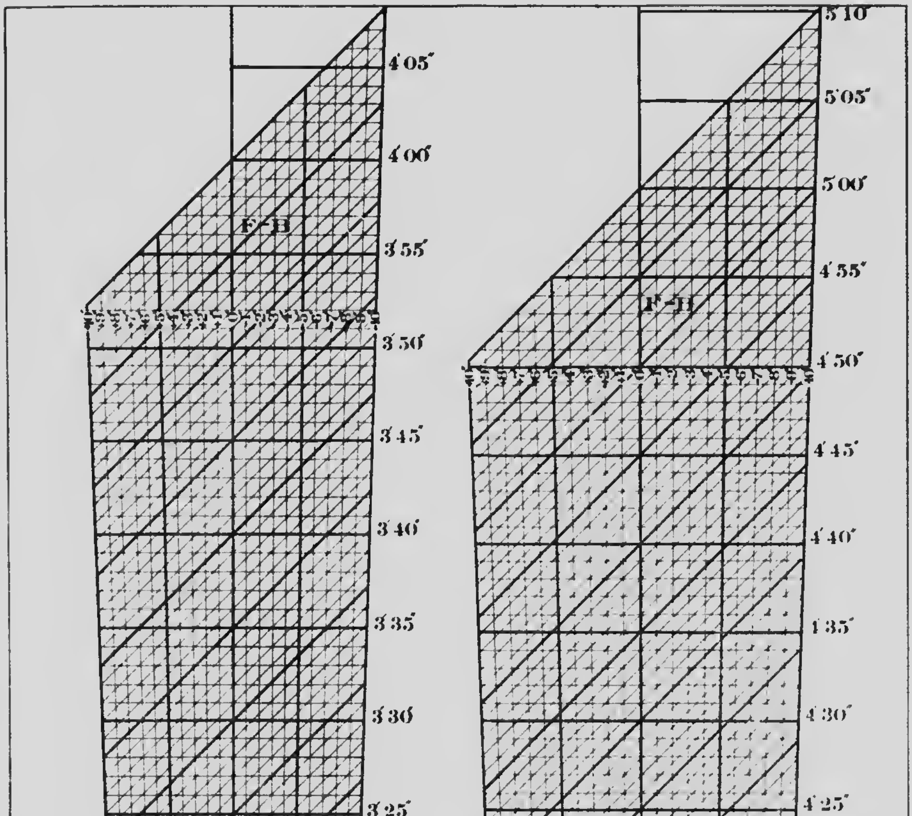


Figure 9A. Abacus for Correcting Micrometer Value for Error of Run.

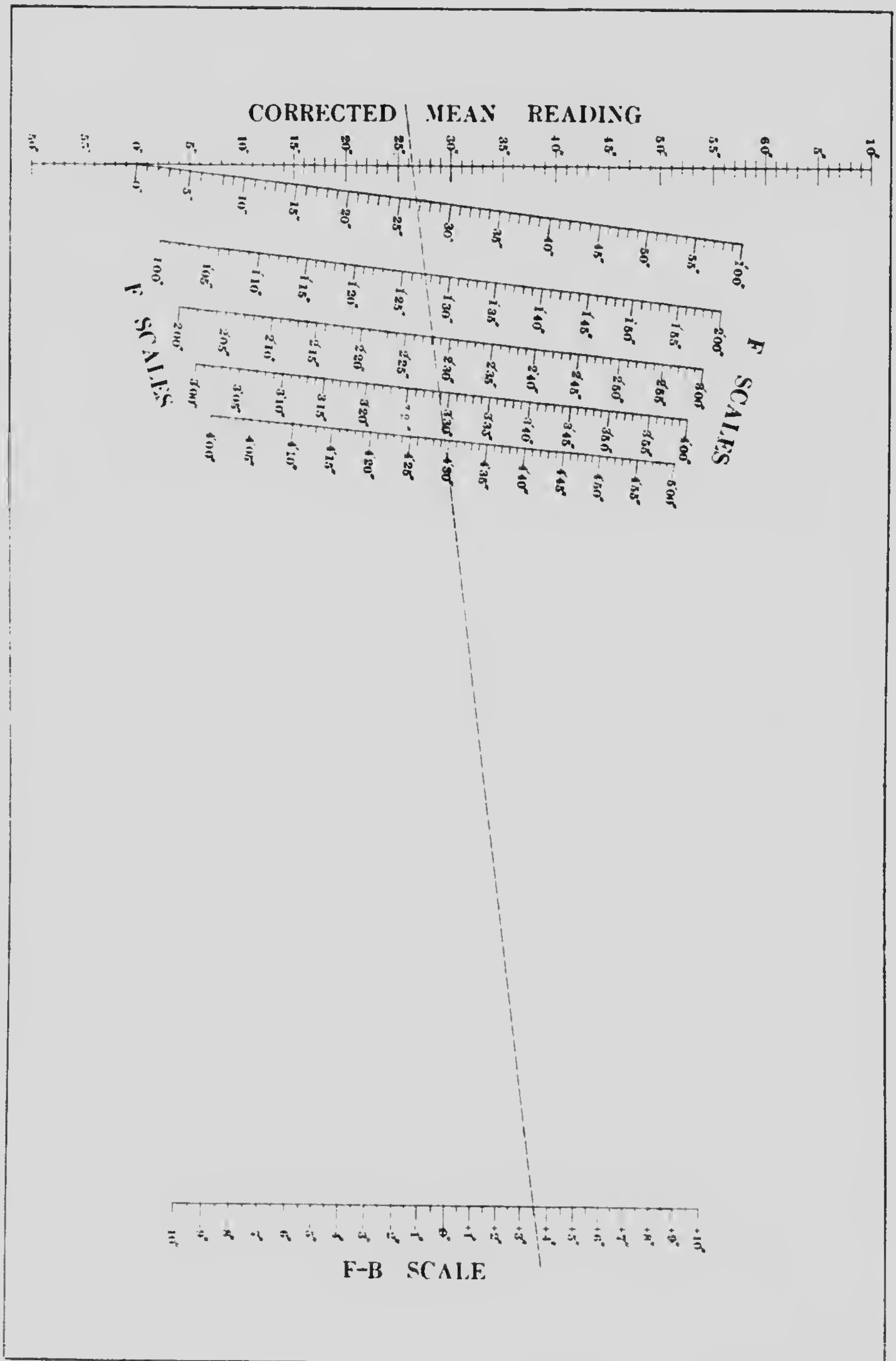


FIGURE 9R. Nomogram for Correcting Micrometer Value for Error of Run.

COMPARISON OF FORMULAE.

F = 5 minutes.

F − B	Approx.	Absolute	F − B	Approx.	Absolute
+1″	4′ 59″·00	4′ 59″·00	+ 6″	4′ 54″·00	4′ 51″·12
2	58·00	58·01	7	53·00	53·16
3	57·00	57·03	8	52·00	52·21
4	56·00	56·05	9	51·00	51·26
5	55·00	55·08	10	50·00	50·31

The most convenient method of deriving the corrected mean reading is that supplied by the "Abacus for Correcting Micrometer Value for Error of Run," fig 9A, the method of procedure being as follows:

1. For each microscope, calculate the mean value of F, of B and of F − B.
2. Locate the value of F on the central vertical line of the diagram.
3. If F − B is positive, proceed diagonally downwards to the left until the value of F − B is reached, and then proceed horizontally to the central vertical line and read off the corrected mean value.
4. If F − B is negative, proceed diagonally upwards to the right until the value of F − B is reached, and then proceed horizontally to the central vertical line and read off the corrected mean value.

This abacus was calculated from the absolute formula, and consequently applies to all readings irrespective of their magnitudes giving the result correct to a fifth of a second.

Example: Mean values of F, and of F − B are found to be 2′ 31″·3 and +7″·7, respectively. Required the value of F corrected for error of run. This is found to be 2′ 27″·5, as indicated on the chart by the dotted line.

Another very convenient method of deriving the corrected mean reading is that supplied by the "Nomogram for Correcting Micrometer Value for Error of Run," fig. 9B, the method of procedure being as follows:

1. For each microscope calculate the mean value of F, of B and of F − B.
2. Locate the value of F − B on the F − B scale.
3. Locate the value of F on one of the five F scales.
4. By means of a straight-edge project the line joining the two points—point F—B on the F—B scale, and point F on the F scale—to cut the corrected mean value scale; when the point of intersection on this latter scale gives the corrected mean value desired.

This nomogram was calculated from the absolute formula and consequently applies to all readings irrespective of their magnitudes, giving the result correct to a fifth of a second.

Example: Mean values of F and of F—B are found to be 2′ 28″·0 and +3″·5, respectively. Required the value of F corrected for error of run. This is found to be 2′ 26″·3, as indicated on the nomogram by the broken line.

It should be noted that it is not necessary to draw any line on the nomogram to obtain a solution; all that is necessary is to lay a straight-edge on the nomogram so as to touch the two points indicating the given data, when the point of intersection on the left hand scale at once gives the corrected mean value.

The left hand or corrected mean value scale is graduated in seconds only, so that only the seconds of F are changed, except in the two following cases:

(*a*) When the solution obtained on the corrected mean value scale falls above 60″, increase the minutes of F by 1′.

(*b*) When the solution obtained on the corrected mean value scale falls below 0″, decrease the minutes of F by 1′.

MICROSCOPE OBJECTIVE.—The objective 62, fig. 8, mounted in its cell 63, is screwed into the tube 64 which in turn is permanently screwed into the draw tube 65. Two pins 66 projecting from the draw tube 65 through slots 67 in the supporting tube 68 enable the distance between the objective and the limb being altered at will by turning the two capstan nuts 69. The objective may be centered by turning the capstan ring 68.

MICROSCOPE REFLECTOR.—A plaster-of-Paris reflector 70 mounted in a metal tube throws an even, soft light upon the graduations of the horizontal circle. This reflector is capable of rotation about the axis of the microscope, thus permitting daylight being used when the reflector is turned outwards; and artificial light, which is supplied by means of a small incandescent electric lamp, when the reflector is turned inwards. As the plaster-of-Paris reflector possesses a white matt surface, the horizontal circle graduations, when viewed through the microscope, appear perfectly black upon a silvery or white surface, and there is no metallic glitter whatever.

MICROSCOPE MAGNIFICATION.—The image of a five-minute interval, which spans 0·004654 of an inch, when projected upon the microscope diaphragm spans a space covered by one revolution of the micrometer screw, or one forty-fifth of an inch. The magnification of the objective is therefore equal to $\frac{1}{45}$ divided by 0·004654, or 4·77 diameters.

As the distance between the field and eye lenses of the eye-piece is about three-quarters of an inch, and the focal length of each lens is about one inch, the equivalent focal length of the eye-piece, ff^1 divided by $(f+f^1-a)$, is 0·80 inch. Therefore the magnification of the eye-piece is 10·0 divided by 0·80=12·5 diameters.*

The magnification of the microscope is then $4·77 \times 12·5=60$ diameters — nearly.

ILLUMINATING THE LIMB.—Illumination of the limb, when daylight is not sufficient, is obtained by small incandescent electric lamps provided for that purpose, run off a battery and controlled by means of a rheostat which varies the intensity of the light. It is necessary to see that the reflectors are turned into their proper positions.

The same result is achieved in the daytime by turning the reflectors outward and utilizing daylight. In places surrounded by trees and other obstructions to light, the limb is apt to appear dark and indistinct. Under these conditions the illumination may be improved by reflecting the light from the sun or sky onto the reflectors by means of a mirror or a sheet of white paper, the field book, for instance.

In all cases it must be borne in mind that the light reflected onto the limb should be, as nearly as possible, radial. The effect of having the light strike the graduations from either side is to materially alter their apparent positions, thus invalidating the micrometer readings.

THE PRINCIPLE OF MICROSCOPE ADJUSTMENT. — The arc measured by the microscope of this instrument is a space of the value of five minutes, which is the space covered by the run due to one revolution of the micrometer screw.

Now in order that the micrometer screw may be competent to measure a five minute space without excess or defect, it is clear that the image of the latter must be magnified so as to occupy precisely the length covered by one revolution of the screw. Suppose that an object, such as the divided limb of the circle for instance, is placed exactly at the stellar focus of the object lens; then the rays passing through the lens become parallel, and the image is formed at an infinite

*10·0 inches is assumed to be the distance of distinct vision for the observer's eye.

distance. But if it be placed beyond the stellar focus, an image is formed within the tube, and the two points where the divided limb and its image are situated are called conjugate foci; the latter of which recedes upwards as the former approaches the object lens.

If the distance of the limb from the objective be called f, and the distance of its image from the same lens be called F, then the length of the image will exceed that of the object in the ratio F:f, or F f will represent the magnified state of the image. Hence it is clear that the expression F f will have an increased value either when F is augmented or f diminished. This is the fundamental principle to be attended to in adjusting the runs, viz.; If the object glass be protruded, it will approach nearer to the limb whereby the size of the image will be increased, and will require more traverse of the micrometer screw of the microscope to measure it; and this will also be the case if the whole microscope be made to descend towards the limb.

CONDITIONS OF ADJUSTMENT.—Before describing the method of performing the adjustment, it may be necessary further to premise that the microscope is in correct adjustment when the following conditions are strictly fulfilled, viz.; when the image of the divided limb and the micrometer lines are so distinctly visible together that no parallax can be detected by varying the position of the eye, in which state of good vision one revolution of the screw must exactly measure one of the five minute spaces of the limb, or two revolutions measure two five minute spaces.

ELIMINATION OF PARALLAX.—If, on removing the paper used in focussing the eye-piece, the limb is not visible, the microscope must be moved bodily up or down by means of the capstan nuts 2. It can easily be found out whether the microscope requires to be lowered or raised to produce distinct vision, because, if, on screwing-in the eye-piece distinct vision is obtained, there is far parallax and the microscope must be lowered, and *vice versa*.

After this experiment the eye-piece must be carefully restored to the position adapted to distinct vision of the micrometer lines till the limb may be seen distinctly. Having rendered the graduations on the limb visible simultaneously with the micrometer lines, bring one of the graduations to the centre of the field, and superimpose the micrometer lines upon it. Now move the eye to and fro, and if the image remains steady there is no parallax; but if the graduation appears to shift its place relatively to the micrometer lines, then notice in which direction it moves and correct the parallax by raising or lowering the microscope, as the case may be.

ADJUSTING THE RUN. The microscope having thus been freed from parallax it will be necessary next to place a graduation of the limb, 0° for instance, under the centre of the microscope, and then measure with the micrometer the space between 359° 55′ and 0° 5′. If due care be taken to note the way in which the graduation on the micrometer drum runs from 0′ to 1′ to 2′, etc., it will be found that one cut or stroke, 359° 55′, will be arrived at by revolving the micrometer drum in the same direction as the numbering on the drum; while the other stroke, 0° 5′, will be reached by a motion of the micrometer contrary to the order of graduation.

Subtract the reading of the latter from the reading of the former, and the difference will be the number of minutes and seconds measured by the micrometer. If this falls short of ten minutes, the magnifying power is too small, and the object glass must be protruded by means of the capstan nuts 69, fig. 8, in order to augment the image; but if the measured interval exceeds ten minutes, the object glass must be raised to diminish the image.

Now in the former case, protruding the object glass will throw the image higher up the microscope, and produce near parallax to correct which the whole microscope must be moved again higher up and farther from the limb, and this again will diminish the run so that the first correction should be a little overdone to counteract the subsequent adjustment for parallax; and the whole process must be repeated two or three times until the two mutually interdependent conditions, correctness of run and freedom from parallax, are very closely satisfied.

FURTHER PRECAUTIONS.—It must be remembered, however, that the divisions of the limb are themselves affected by errors of graduation, to eliminate the effects of which it is desirable to take a mean of several ten minute spaces. Moreover the plane of the circle may not be exactly at right angles to the axis of rotation in which case all parts of the circle will not be at the same distance from the object lens, and there will be a difference of run occasioned by the circle approximating nearer to, or receding farther from, the microscope. It is also to be remembered that the excellence of the observations depends, not on a single microscope, but on the joint operation of the two; so that although each may be near the truth, still the sum of their errors may be large; whereas, if the errors neutralize each other, the magnitude of the individual errors would not be of so much importance. To produce, therefore, the greatest degree of accuracy, the adjustment must be perfected with due regard to the foregoing considerations.

FINAL CORRECTION OF ONE MICROMETER MICROSCOPE.—In general, with an instrument as supplied, unless the microscopes have been dismantled, or taken off for the purpose of being cleaned, or for any other similar reason, the adjustments will be found already near to the truth, and all that is required is an alteration occasionally of the run of a single microscope, so as to compensate for the errors of both. Now, as the value of one micrometer has the weight of only one-half in producing the mean, therefore the correction to be applied to an individual microscope must amount to twice the mean of the errors of the two microscopes or simply to the sum of the two errors.

For instance, if the mean value of the two micrometers amounts to $10'+6''$ for a $10'$ interval; then $2\times6''=12''$ is the correction to be applied to a single microscope to reduce the mean of the two to $10'$, and this correction is much more easily applied to one microscope than is a smaller correction to each.

TO OBTAIN THE MEAN VALUE OF ALL RUNS.—The method to be used is as follows: Set one microscope to $0°$, so that a degree stroke will fall nearly under the notch of each microscope. Now as the micrometer in observing is limited to an excursion of $5'$ on each side of zero, it is unnecessary to go beyond that extent on either side. It is also unnecessary to read the degree stroke in the notch, because the sum of the $5'$ spaces will be given at once by the reading of the extremes; consequently it will suffice to measure the $10'$ space under each microscope, repeating each measure several times for the purpose of nullifying errors in setting.

Now turn the instrument to $90°$, $180°$ and $270°$ in succession, and measure the $10'$ spaces in each position as before. The mean value of each micrometer will thus be obtained from the mean of the four $10'$ spaces at each of the cardinal points of the circle, and therefore the mean value of the runs of the two microscopes in combination will be obtained from eight independent $5'$ spaces, which is sufficient.

If the combined errors of the microscopes amount to more than $2''$ in $10'$, it will be advisable to correct the microscope which is most erroneous by a quantity equal to this combined error. This correction, if it be only a few seconds, will not require any change in the object glass, because it will generally be quite sufficient to raise or lower the whole microscope until the required value of the runs is correctly obtained.

The *rationale* of this proceeding is that the microscope is more sensitive as regards the value of the run than it is with respect to parallax and distinct vision. On account of the spherical aberration of the lenses, the exact position of the point of distinct vision is not sharply defined, and within a small limit the run may be varied sensibly without producing any appreciable parallax. This pecularity will, perhaps, be rendered clearer by applying numerical values to the expression F/f which represents the magnified state of the image. Now F/f equals 5·2/1·1; and let the microscope be raised 0·01 of an inch, which will make f equal to 1·11 inch. This will reduce the image at the focus in the ratio of 5·2:5·15 in which ratio the run will be affected also. Consequently, because 5·2/5·15 equals 300/297, the run will be reduced by 3″. Therefore the descent or ascent of such a microscope will produce a variation of 3″ for each 0·01 of an inch perpendicular change; while the latter quantity would be hardly perceptible in the shape of parallax. In performing this adjustment the rules for avoiding parallax as given above should be adhered to strictly.

EXAMPLE.—The following example will render this subject quite clear, and it is only necessary to add that the runs should be taken frequently, and duly recorded according to the subjoined form.

In the first test the mean error was 5″·63, and the microscope most in error was B, the image being too small. Therefore this microscope was lowered, and as the correction to be applied was twice 5″·63, or 11″·26 in all, it was endeavoured to make this microscope read 10′ by lowering it as nearly as possible by 0·04 of an inch. When this had been done a second test was made, and the error of run was found to be practically eliminated, being only 0″·33.

ADJUSTMENT FOR RUN OF MICROMETER MICROSCOPES

Transit, T & S 124. Temp., 62° F. Date, Feb. 27th, 1913. Observer, W.H.H.

Position	Reading.	Microscope A			Microscope B			Remarks
		F	B	F–B	F	B	F–B	
360°	1	4′60″	4′59″	9′61″	4′51″	4′62″	9′49″	The runs were taken from 55′ to 5′, the *front* or *forward* readings being those taken when the micrometer is turned in the direction of *increasing* readings on the *drum*; and the *back* or *backward* readings being those taken when the micrometer is turned in the direction of *decreasing* readings of the *drum*.
	2	58	59	59	52	61	51	
	3	58	58	60	51	63	48	
	4	59	58	61	51	63	48	
	5	60	59	61	51	62	49	
90°	1	64	64	60	54	68	46	
	2	63	64	59	52	67	45	
	3	62	64	58	53	67	46	
	4	63	62	61	52	66	46	
	5	65	64	61	53	67	48	
180°	1	60	60	60	55	67	48	
	2	59	59	60	56	66	50	
	3	59	60	59	57	66	51	
	4	59	61	58	55	67	48	
	5	58	59	59	56	67	49	
270°	1	56	55	61	55	63	52	
	2	57	56	61	55	63	52	
	3	55	56	59	56	66	50	
	4	57	55	62	55	64	51	
	5	55	56	59	55	64	51	

Mean of each.................	9′59″·95	9′48″·80
Final Mean....................	9′54·37	
Error on 10′ run..............	5·63	

FINAL ADJUSTMENT OF POSITION.—The foregoing operations are very liable to disturb the lateral adjustment of the microscope. Its adjustment over the proper division is readily effected by moving the notch, for which purpose there is a screw 16, fig. 8, at the reverse end of the micrometer box. If the comb be moved care must be taken to set the zero of the micrometer drum to correspond approximately with the notch.

For this purpose set the micrometer lines in the centre of the notch, and loosen the small screw in the centre of the milled head 59; then, holding the milled head stationary with one hand, rotate the drum 60 with the other hand until the zero on the drum comes opposite to the micrometer index 111, after which tighten up the small screw.

The drum retains its place only by friction, therefore it is necessary to use care, when working the micrometer, not to lay hold of the drum, but to use the milled head exclusively.

DISTANCE BETWEEN MICROSCOPES. The microscopes should be fixed 180 degrees apart, but on account of the errors of graduation it is advisable, in order that the minutes appertaining to microscope A may also answer for microscope B, that the latter should be set to read 30″ or 40″ in excess, whereby the minutes given by A will also answer for B, provided care be taken to add 60″ to the readings of the latter when they fall into the next minute above.

Suppose B is set to read 40″ more than A; then if the reading of A is 0° 3′ 50″, that of B will be recorded as 90″ which number of seconds is referable to 0° 3′. If this precaution be not taken, the minutes, and sometimes the degrees, may require to be registered separately for each microscope; because, on account of errors of graduation, readings would frequently be obtained as shown in the following examples which would prove very inconvenient for registry:

A.	B.
0° 00′ 10″	359° 59′ 50″
62° 11′ 05″	10′ 45″

FINAL TESTS. There remain a few other points which should receive attention: for instance, it is clear that the micrometers should act in a direction tangential to the circle; therefore if during the foregoing adjustments, the direction of the micrometers should be changed accidentally, all that is necessary is to turn the microscopes around gently in the collars, until the micrometers are brought to act in the proper direction, when the collar screws should be tightened to render the microscopes' positions permanent. To get the tangential direction correctly, the two parallel lines of the micrometer should be made parallel to a degree division on the limb.

TELESCOPE EYE-PIECE MICROMETER

DESCRIPTION OF TELESCOPE EYE-PIECE MICROMETER.—A front view of the eye-piece micrometer with the cover removed is shown in fig. 10, and a side view and part section in fig. 11.

In the eye end of the telescope tube there is mounted, by means of four small screws 110, fig. 11, the annular part 127, which carries the collimation linear guides 128 rigidly attached by six screws 129. The bearing 130, which accommodates the micrometer body 131, may be shifted laterally in a direction perpendicular to the plane of the illustration of fig. 11 by turning the two capstan collimation screws 109; and the micrometer body may be rotated in this bearing to any desired angle, being brought to rest at each ninety degree interval by the spring catch 71 engaging in one of the four equally spaced notches on the ring

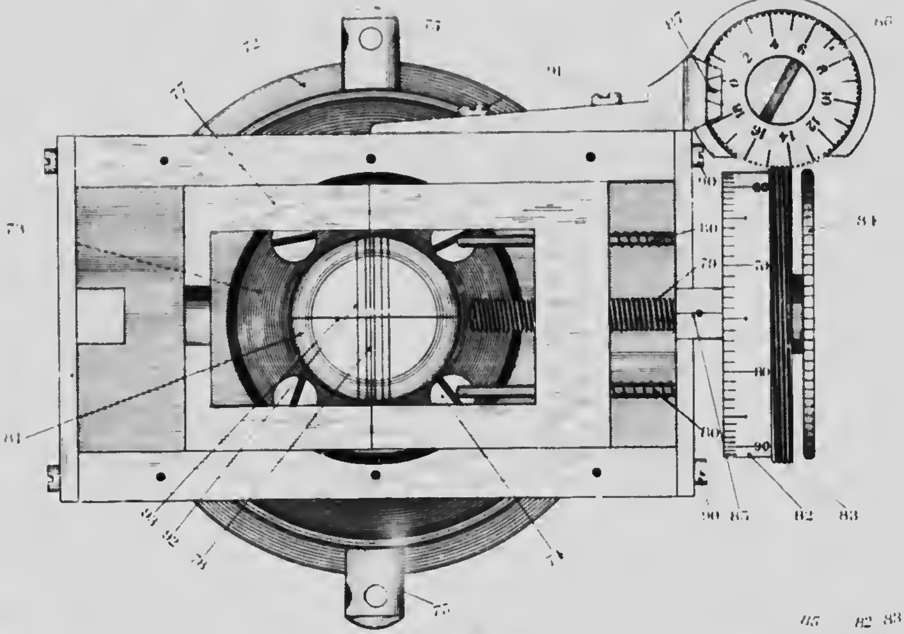


FIGURE 10. Front View of Eyepiece Micrometer with Cover Removed.

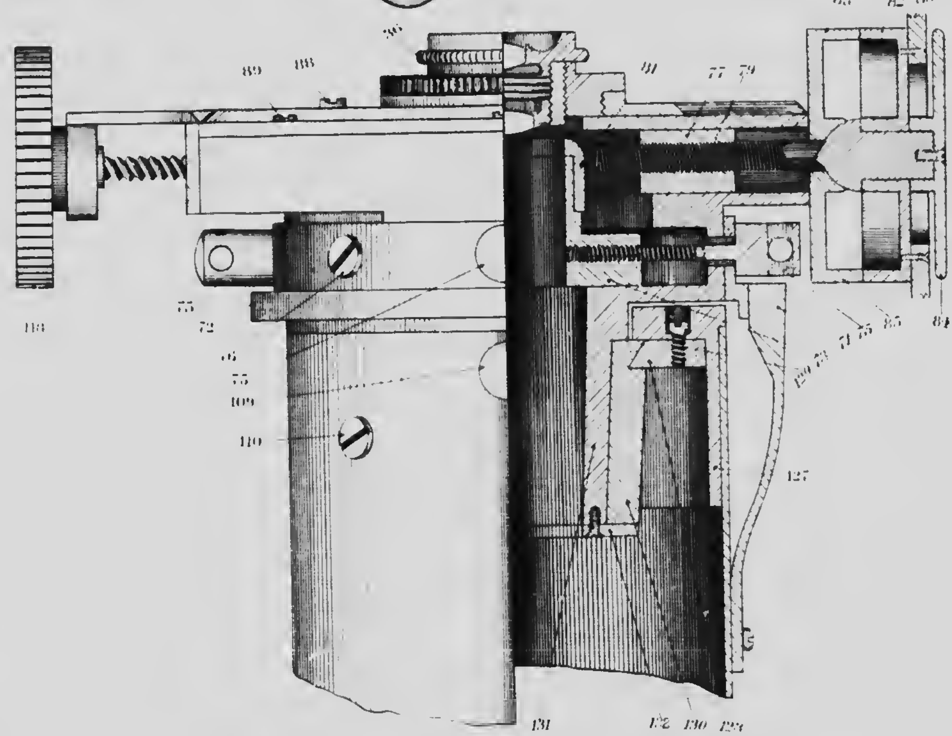


FIGURE 11. Side View and Part Section of Eyepiece Micrometer.

72, the micrometer body being held in place by the washer 132. A diaphragm holder 73 is attached to the micrometer body by the four screws 74, fig. 10, and these screws permit of small lateral and angular displacements in one fixed plane only, which is perpendicular to the axis of the telescope. Movement of this diaphragm holder is accomplished by operating the four capstan screws 75; while relative adjustment between the micrometer and the telescope is effected by changing the position of the ring 72 with regard to the micrometer by adjusting the four small screws 76, fig. 11. The micrometer carriage 77, fig. 10, supports the movable thread 78. The micrometer screw 79 has one hundred threads to the inch, one revolution corresponding to about 166 seconds of arc. It engages with the carriage 77 which supports the movable thread, and as the screw is rotated this carriage travels back or forth, the movable thread lying in almost the same plane as the diaphragm.

Looseness or play between the threads of the micrometer screw and the threads of the carriage is prevented by the two springs 80. A diaphragm of one horizontal and five parallel vertical spider threads is mounted on the ring 81 which slips over an annular projection formed on the holder 73, and is held in place merely by friction. Thus this diaphragm may be adjusted to any angle by merely turning with the fingers. Attached to the external end of the micrometer screw are the graduated drum or head 82, the gear 83, and the milled head 84.

The micrometer drum is divided into one hundred equal parts, every tenth part being numbered; and tenths of these parts, or thousandths of a drum revolution may be readily estimated by eye. Two index marks 85 may be used for making readings on the drum. The milled head 84 is rigidly attached to the micrometer screw, but the micrometer drum may be rotated while the micrometer screw remains stationary if the small screw in the centre of the milled head be first slackened back.

Instead of the toothed comb usually found on micrometers, which is intended for keeping track of the number of complete revolutions of the micrometer screw, there is used the counter or recorder 86. The omission of the comb has about doubled the field of view, which is a matter of great value for all lines of work.

This counter 86 is divided into twenty equal parts, every second part being numbered, and is read by means of the index mark 87. A revolution of the micrometer screw is communicated to the counter through the gear 83, and causes the counter to rotate one division, or one-twentieth of a revolution.

A cover tightly closes the micrometer box, and is applied by six small screws.

Removal of the shutter is effected by taking out the screw 88, figs. 1 and 11, and unscrewing the shutter until it freely slides out; and by withdrawing the six screws 89, the cover may be lifted off. When the cover is lifted off, as is shown in fig. 10, the micrometer proper may be removed by taking out the two small screws 90, and slackening off the two screws 91.

TO REMOVE COMPLETE MICROMETER FROM TELESCOPE.—Remove the two capstan collimation screws 109, figs. 1 and 11, and the four small screws 110 on the telescope tube; when the complete eye-piece micrometer may be removed from the telescope.

TELESCOPE DIAPHRAGM.—Fig. 10. The diaphragm consists of five parallel spider threads 92, fifteen seconds of time, or three minutes forty-five seconds of arc, apart. A movable thread 78 attached to the carriage of the micrometer screw is parallel to the above; and the whole series is crossed centrally at right angles by the single transverse thread 93.

REPLACING THE SPIDER THREADS.—When necessary to replace any of the spider threads, proceed as follows:

Take out the screw 88, figs. 1 and 11, and then, by unscrewing the head 118, the shutter may be removed. By removing the six screws 89, the cover plate may be taken off. Next the two screws 90, fig. 10, are withdrawn, and the two screws 91 slackened off, when the movable thread carriage 77, as well as the drum 82, may be taken out together. This permits the mounting of a movable thread.

The dia[illegible]agm ring 81, may be lifted off the holder 73 to which it is attached by means [illegible]ion only, due to a tight-fitting joint. In replacing a thread on the diaphragm ring 81, it is necessary that the shellac be applied to the extreme ends of the thread only, on the lower part of the ring, in order not to interfere with the movable thread which moves very close to the threads of the diaphragm.

DIAPHRAGM ILLUMINATION.—Artificial illumination of the diaphragm is obtained by the small incandescent electric lamp 31, fig. 2, mounted near the end of, and in line with the transverse axis. The light from this lamp passes through a small lens, and after traversing the centre of the hollow pivot, it strikes upon the small polished silver mirror 30, fig. 7, mounted at the intersection of the two axes of the telescope and inclined at an angle of forty-five degrees to each; from whence it is reflected to the diaphragm in the eye-piece micrometer, forming black lines upon a bright field.

MAKING THE THREADS HORIZONTAL AND VERTICAL.—The instrument is carefully levelled and the micrometer rotated until the transverse thread is apparently horizontal and the spring catch 71, figs. 2 and 11, engages in a notch on the ring 72. The movable thread 78, fig. 10, is now brought nearly to the centre of the field of view and carefully set so as to bisect some distant, well-defined point. By means of the tangent screw on the transverse axis clamp the thread is made to traverse this point; and if, at any part of its travel it deviates from this point, the thread is not in adjustment. The small screws 76 and the capstan screws 75, figs. 2 and 11, are loosened; the spring catch 71 and the ring 72 held in place, and the whole micrometer carefully rotated until the movable thread is truly vertical, when the small screws 76 are tightened.

The next adjustment is to make the threads of the diaphragm truly vertical and horizontal. By loosening and moving the four capstan screws 75, fig. 10, the diaphragm holder 73 may be rotated (the screws 74 allowing it to move only in the one plane perpendicular to the axis of the telescope) until the vertical threads 92 are parallel to the movable thread 78, when the screws are tightened. The construction is such that when the five threads 92 are vertical, the transverse thread 93 is horizontal. It follows, therefore, that if the threads are horizontal and vertical in one position of the micrometer, they will be the same in all positions, for the spring catch stops the drum at each ninety degrees.

CENTERING THE DIAPHRAGM.—The axis of revolution of the eye-piece system must pass through the intersection of the central threads of the diaphragm.

Rotating the micrometer until the spring catch engages in a notch and the transverse thread is horizontal, the middle vertical thread is directed on a distant point, and the telescope firmly clamped in altitude and in azimuth. On revolving the micrometer 180 degrees it will be found, if the adjustment be not good, that the middle thread no longer bisects the distant point

The distance from the point to the middle vertical thread is measured with the micrometer, and the movable thread set midway between the two. The diaphragm is then moved by means of the two horizontal capstan screws 75 until the middle vertical thread of the diaphragm coincides with the movable thread. This adjustment should be repeated until the middle vertical thread bisects the point both before and after reversal.

The transverse thread 93, now has to be centered. Direct this thread on a distant point and clamp the telescope in altitude and in azimuth. Bisect the point by the transverse thread and then rotate the micrometer 180 degrees. If the thread fall to one side of the point, it must be brought halfway back by means of the two capstan screws 75 at right angles to it. This adjustment should be repeated until the transverse thread bisects the point both before and after reversal.

The shifting of the adjusting screws may have slightly affected the position of the diaphragm with regard to the vertical, so that it may have to be turned again until the threads are horizontal and vertical.

Instead of a distant point, the cross threads of another transit or level may be used with advantage. This transit or level should be adjusted to stellar focus and placed so that the two telescopes are near together, in approximately the same straight line and with the objectives facing one another. Under these conditions the auxiliary instrument is used as a collimator.

COLLIMATION.—The error of collimation is corrected by shifting the axis of revolution of the eye-piece system by means of the two capstan screws 109, figs. 1 and 11, situated back of the micrometer. It is done by the usual methods and requires no explanation.

TO ADJUST THE MICROMETER DRUM.—The micrometer drum 82, fig. 10, is rotated until zero comes opposite the index mark 85. The screw in the centre of the milled head 84 is loosened; and then, holding the drum stationary, the milled head is rotated until the movable thread is superimposed upon the middle vertical thread of the diaphragm, when the screw in the centre of the milled head is tightened up. The two screws 91 are now loosened and the counter 86 rotated until zero comes opposite the index mark 87; when the screws are tightened until the counter engages with the gear 83 loosely and without undue friction.

In making a latitude observation the long diagonal eye-piece is used, and the telescope is nearly vertical. Under these conditions the drum and the counter may be read by index marks similar to 85 and 87, but situated on the opposite side. In this case, therefore, it is obvious that as the back and front index marks 85 are half a revolution apart, the drum will not read zero when the movable thread is superimposed upon the middle vertical thread of the diaphragm. Therefore it is necessary to readjust the drum when reading by means of the back index marks, which may be done as already explained.

METHOD OF READING MICROMETER.—So long as the movable thread is to the left of the middle thread of the diaphragm, the counter and drum are read exactly as indicated by the index marks. Thus, in fig. 10, the reading is 19·745 revolutions. When, however, the movable thread is to the *right* of the middle thread of the diaphragm, it is necessary to *add on twenty complete turns* to those indicated by the counter.

TELESCOPE FOCUSSING SCALE.—At the objective end the draw tube carries a small scale which slides over a zero mark on the main tube. The scale is graduated in divisions of five-hundredths or one-thousandths of the focal length; and if, when the instrument is adjusted to stellar focus, the reading on this scale be noted, it is an easy matter to set the telescope again to this focus at any subsequent time.

STELLAR FOCUS.—Correct focussing is most important for all astronomical work. Indifferent focussing may easily involve the loss of one magnitude in stars visible. If the correct position of the draw tube for stellar focus be not known, it may be determined as follows:

Focus approximately both the object glass and the prismatic eye-piece. A little before sunset on a day when the air is steady, direct the telescope on the Pole Star and bisect it by the middle vertical thread. If the star remains bisected when the eye is moved to and fro, there is no parallax and the thread is truly in the focus of the object glass.

If the star appears to move in the *same* direction as the eye, there is far parallax and the object glass must be *racked in*. If, on the other hand, the star appears to move in the direction *contrary* to the eye, there is near parallax, and the object glass must be *racked out*. When it has been brought into correct focus, note the reading on the small scale on the side of the telescope tube.

Now adjust the eye-piece until the star appears as a very fine and bright point.

The stellar focus for the micrometer thread must be determined independently and in the same manner, the difference in scale readings for these two foci being equal to the axial distance between the diaphragm and the micrometer thread.

Stellar focus is determined at the Surveys Laboratory and the scale reading is supplied with the instrument.

A small error in setting the telescope to stellar focus, which is easily made and hardly perceptible by any decrease in the sharpness of the star image, will cause an appreciable variation in the value of the micrometer. Therefore a magnifying glass should be used when setting the telescope by scale to stellar focus.

An error of 0·01 of an inch in setting the telescope to stellar focus will alter the micrometer value by 0·13 of a second of arc per revolution.

MICROMETER VALUE AFFECTED BY FOCUS.—The value of one turn of the micrometer screw may be defined as the angle subtended by the pitch of the micrometer screw, at the distance of the objective focus; and consequently this value varies inversely with the objective focus. The value supplied with the instrument is the average value throughout the run of the micrometer screw when the telescope is set to stellar focus on the micrometer thread; and any variation in this focus will produce a corresponding inverse variation in the micrometer screw value.

When using the instrument on short sights, the focus used will be quite materially different from stellar focus, and therefore the value of the micrometer screw must be modified to agree with this new focus.

There are two methods by which the new micrometer value may be determined, as follows:

1st Method. When the new focus is read off the telescope scale.

Let D = Micrometer value at stellar focus F.

Let D_1 = Micrometer value at new focus F_1.

$$\text{Then } D_1 = \frac{FD}{F_1}.$$

2nd Method. When the distance from the objective to the picket is known.

Let F_2 = this distance.

$$\text{Then } F_1 = \frac{FF_2}{F_2 - F}.$$

$$\text{And } D_1 = \frac{D\,(F_2 - F)}{F_2}.$$

DETERMINATION OF MICROMETER VALUE AND EQUATORIAL INTERVALS.—The mean value of one turn of the micrometer screw when the telescope is set to stellar focus on the micrometer thread, and the equatorial intervals of the five parallel vertical threads are carefully determined at the Surveys Laboratory. When necessary to make a redetermination in the field it may be done by any one of the methods described in text books on astronomy, preferably by observing a circumpolar at culmination or elongation.

SPECIAL LEVELS

LATITUDE LEVEL.—For latitude determinations a special level is applied to the vertical circle. The bubble of this large level 45, fig. 7, has a run of about twenty-five seconds to the inch, and is provided with a large air chamber at its zero end. It is graduated with twenty-five divisions to two inches, one division thus representing about two seconds of arc; and this graduation runs from one end of the tube to the other, every tenth division from 0 to 50 being numbered. The vial lies loosely in its metal sheath and is encased on its under side in a wrapping of white paper. At each end it is supported in a wye and held in place by a small spring which presses downward on the vial, the points of contact being protected by small cork pads. This method of mounting the vial prevents any strain in the metal sheath, due to changes in temperature, from being communicated to the vial itself. The latitude level vial and the stride level vial are of the same size so as to be interchangeable in case of accidents.

In the case of latitude observations there is used a combined lamp holder and reflecting mirror 34, fig. 7, which fastens to a standard by a bayonet joint. This lamp illuminates the vertical circle and the latitude level; and the reflecting mirror enables the observer to read the bubble without moving from the eye end of the telescope. Care must be observed to set the mirror at such an angle as will avoid any parallax in reading the bubble.

STRIDE LEVEL.—The stride level 32, fig. 7, is mounted in the same manner as the latitude level and has a run of about sixty seconds to the inch, and a large air chamber at its zero end. It is graduated continuously from one end to the other, every tenth graduation from 0 to 50 being numbered, and as there are twenty-five graduations to two inches, one division has a value of about five seconds of arc.

DETERMINATION OF LEVEL VALUE.—The determination of the value of one division of the levels is made at the Surveys Laboratory. Should it be necessary to make a determination in the field, it may be done in any of the usual ways described in text books on surveying. The following method will be found very convenient for field determinations:

Apply the latitude level to the vertical circle in the usual way and clamp it to the circle. Then by rotating the tangent screw of the transverse axis clamp, the readings on the vial will be made to vary. This variation can be measured by means of the micrometer, the transverse thread being placed vertical, and settings being made on some distant, well defined point or on the cross threads of another transit or level used as a collimator.

A determination of the value of one division of the stride level may be made in the same manner by placing the vial of the stride level in the metal sheath of the latitude level and applying to the vertical circle. This is possible because the stride and latitude level vials are the same size.

SYSTEM OF ILLUMINATION

DISTRIBUTION OF LAMPS.—The instrument is equipped with a complete system of illumination consisting of miniature incandescent electric lamps of one-quarter candle power, thus permitting of full use of the instrument for performing all classes of work when the ordinary daylight becomes too faint, and supplying the light necessary for making time and latitude observations at night. These lamps are distributed as follows: One for each of the two micrometer microscopes for reading the horizontal circle; one in a lamp holder 21, fig. 7, which may be attached to a standard by a bayonet joint, and is used for reading the vertical circle; one in a lamp holder 34 which carries the reflecting mirror for the latitude level, this lamp holder being attached to a standard by a bayonet joint; one in each of the two lamp holders 31 which may be attached to each of the standards at the ends of the telescope transverse axis by pin-and-socket joints, and illuminate the diaphragm by sending the light through a lens of about one inch focal length in the transverse axis onto the small silver mirror 30, which may be placed at the intersection of the two telescope axes and adjusted to an angle of forty-five degrees to each, thus reflecting the light to the eye-piece and giving black threads on a bright field; and lastly, one mounted at the side of the micrometer box, which may be used to illuminate the threads when observing faint stars so as to give bright threads on a black field, as an alternative to the above.

BATTERY.—These lamps are run off a battery of two, three, or four of the four cells supplied, about three volts being quite sufficient. The cells are of the semi-dry type, that is, they remain inactive until filled up with water; but after being filled with water they remain active until worn out. The battery of four cells is in a wooden case with metal carrying handle. This type of cell is very much superior to the ordinary dry cell, possessing higher voltage, greater amperage and much longer life.

VOLT-AMMETER.—A Kent pocket automatic volt-ammeter in a leather case serves to test the single cells of the battery so that those which are exhausted may be replaced. To make a test, hold the instrument in the left hand with the thumb over the button, but not pressing it; rest the plate marked "Carbon" on the carbon of the battery, which is the centre terminal, and place the end of the flexible lead on the zinc, or the outer terminal. The voltage is then indicated on the lower or green scale of the instrument.

To obtain the amperage reading, simply press the button, without changing the position of the meter, and the indication is on the upper or red scale. It should be carefully borne in mind that when the button of the instrument is pressed to obtain a reading of the amperes, the cell is short-circuited, and should this condition exist for any appreciable time, it will result in the destruction of the cell. When the cells are in good condition they should give the following readings, approximately, when tested:

1·5 volts.
12 amperes.

RHEOSTAT.—The rheostat and lamp leads are shown at 22, fig. 7; and longitudinal sections and switch positions are given in fig. 12. This rheostat consists of a coil of forty-two turns of No. 21 B. & S. gauge German silver insulated wire 98, wound upon a vulcanized rubber core 99, the whole being enclosed in an outer brass casing upon which travels the ring 100 supporting the contact spring 101. The contact spring is held out by a small screw, and slides in a groove, the insulation of the wire in this groove being removed so that any proportion of the resistance may be utilized by sliding the ring to the proper position.

One end of the rheostat resistance wire is led down inside to the clamp 102. Wires from each of the pairs of the three lamp leads, as well as the neutral wire 103 from the other three wires of the lamp leads are also brought down inside; the three lamp wires joining onto the three terminals which are mounted in the cover and terminate in the contacts 104; and the neutral wire 103 joining onto the clamp 102. At the bottom there is mounted the switch ring 105 which carries the switch 106. This ring can be rotated to bring the switch into contact with any one of the three contacts 104.

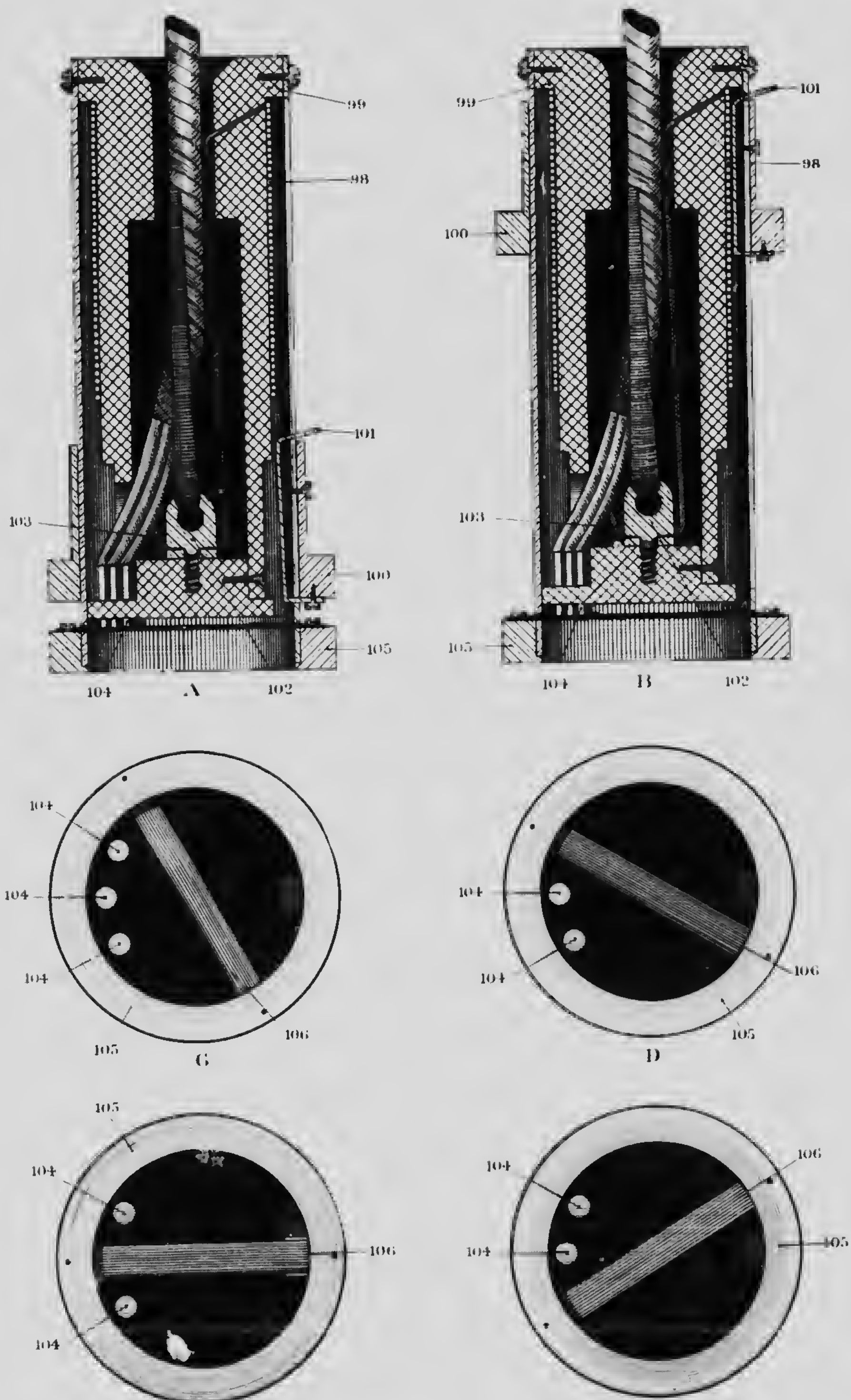


FIGURE 12. Longitudinal Sections and Switch Positions of Rheostat.

The rheostat affords a means of selecting any one of the three lamps for illumination, and regulating the intensity of the light supplied by this lamp. Sliding down the ring contact-maker increases the resistance and dims the light until when the ring reaches the bottom contact is broken and the lamp extinguished; this is shown at "A." Sliding up the ring contact-maker decreases the resistance and increases the light until when the ring reaches the top practically all the resistance is cut out and the lamp receives the full voltage of the battery; this is shown at "B."

At "C" the switch is shown in the "off" position, and at "D," "E," and "F" it is shown adjusted for illuminating the first, second and third lamps, respectively. A long pair of battery leads 23, fig. 7, serves to make connection between the rheostat and the battery.

Before connecting up the battery it is necessary to make sure that the contact ring is at the bottom of the rheostat so that the circuit may be open. The switch is then turned until it presses on one of the contacts, then the contact ring is moved up to make contact with the resistance wire. When this has been done one of the lamps will be found to be glowing dimly; and then to obtain the required brightness all that is necessary is to move the contact-maker up very gently and carefully. If moved up too far the lamp may burn out.

When the light is no longer required the ring must be brought down to the bottom of the rheostat, thus disconnecting the lamp. It is necessary to use considerable care in the manipulation of these extremely small lamps or otherwise they will be destroyed.

METHODS OF USE

RUNNING THE LINE

PRODUCING THE LINE.—The instrument as intended for running lines is shown in fig. 1. Where the ground is soft, it may be necessary to drive in three hubs until firm ground is reached, and the tripod feet are then set upon these hubs.

The transverse axis clamp is omitted, the telescope being held in altitude only by the friction of the clips 112, and adjusted by the action of the hand; and in order to prevent mistakes it is preferable to turn the micrometer so as to have the transverse thread vertical, instead of the usual five parallel threads.

DEFLECTING THE LINE.—An instrumental method of laying off the angle of deflection of a base line at a township corner is afforded by using the eye-piece micrometer.

In flat country, place the movable thread at a distance from the middle thread of the diaphragm equal to one-half the deflection angle, and direct the telescope to intersect the back picket. Then place the movable thread at the same distance on the opposite side of the middle thread, and use it to set the forward picket. In sloping country the deflection angle must be multiplied by the cosine of the angle of inclination.

TELEMETRIC MEASUREMENT OF DISTANCE.—The angle subtended by a divided rod held vertically or horizontally can be measured with the micrometer, and the distance calculated in the usual way. Instead of a rod, a short base may be laid out on the ground at right angles to the line of sight. The micrometer may be turned until the transverse thread is parallel to the slope of the base and the angle subtended can be measured with the micrometer, the calculated distance requiring no other correction than reduction to the horizon.

OBSERVING AZIMUTH

SETTING UP THE INSTRUMENT.—The instrument as intended for observing azimuth is shown in figs. 3 and 4.

Where the ground is soft it may be necessary to drive in three hubs and mount the tripod as already described. This method of setting up the tripod will tend to prevent any movement of the ground, due to movement of the observer, from being communicated to the instrument. It is very convenient to have one of the tripod legs facing towards the star whose azimuth is to be observed. For ease in levelling it is advisable to lock the instrument in a position such that two of the levelling screws are on an east-and-west line, the third facing towards the north or south.

If observing on the horizontal circle, the eye-piece micrometer is turned to bring the transverse thread vertical. If observing with the eye-piece micrometer, the micrometer is turned to bring the transverse thread horizontal. The first case is illustrated in fig. 3, and the second case in fig. 4.

It is customary to make all azimuth observations during the daytime, when natural light is quite sufficient.

If the light should be poor, however, owing to surrounding trees or to a dull sky, the lamps on the horizontal circle may be used with advantage. This necessitates connecting up the batteries to the rheostat by means of the battery leads 23, fig. 7, and then connecting one of the rheostat leads to the plug on the horizontal circle, the rheostat being supported from the plumb-bob hook, or from a tripod leg pin. The two lamps on the horizontal circle are on one circuit, and hence they are both illuminated at the same time. Should the batteries be weak, it may happen that the two lamps cannot be operated together satisfactorily. In this case the lamp not required may be "plugged out" or disconnected. The plugs are so arranged as to make it possible to use either lamp separately, or both together.

Should the light be extremely poor, the vertical circle lamp holder 21, and the transverse axis lamp holder 31, may be used; each supporting a lamp connected to a lead from the rheostat.

Observations for azimuth may be made in any of the following ways:

1. Reading the angle on the horizontal circle by the micrometer microscopes. This applies to angles of any size.

2. Reading the angle by the eye-piece micrometer. This applies only to small angles lying near the meridian.

3. Reading the angle between the meridian and a point near the meridian by the eye-piece micrometer; and then reading the angle between the point near the meridian and the point whose azimuth is to be determined on the horizontal circle by the micrometer microscopes by the method of reiteration—a combination of methods 1 and 2.

OBSERVING AZIMUTH ON HORIZONTAL CIRCLE.—It is assumed that the sidereal time is known to within a minute or so. It is also assumed that the position of the observing station with respect to the system of surveys, and the approximate direction of the meridian are known.

The followng programme is the one usually adopted, see fig. 3:

1. Point on the reference object, tighten the azimuth clamp 115, and make a bisection by turning up the tangent screw 116. Then read each microscope three times on both the forward and backward divisions.

2. The altitude and azimuth of the Pole Star are obtained from the Astronomical Field Tables* for the sidereal time and place of observation; the altitude being set on the vertical circle, and the azimuth being laid off on the horizontal circle. When this is done there is no difficulty in perceiving the star. Next place the striding level on the pivots with the zero of graduation to the east.

*Published by the Topographical Surveys Branch, Department of the Interior, Ottawa.

Then make an accurate setting on the star by means of the azimuth tangent screw, the bisection being made by a screwing-up rotation; and note the time of bisection on the sidereal chronometer. If the star be near culmination and moving rapidly, place the thread slightly in advance, and note the time of transit.

Read the striding level, then reverse it on the pivots and read it again. After the second reading it should be removed altogether.

Each of the micrometer microscopes should now be read three times on both the forward and the backward divisions.

3. Transit the telescope, reverse the instrument 180 degrees in azimuth, and repeat 2.

4. Repeat 1.

A complete observation as above, under favourable conditions should give a result correct to within a very few seconds. This is clearly shown in the following specimen observations, the individual results being:

1st observation	359° 59′ 29″
2nd "	30
3rd "	31

The maximum deviation from the mean has the small value of 1″·0.

OBSERVING AZIMUTH WITH EYE-PIECE MICROMETER.—It is assumed that the sidereal time is known to within a minute or so. It is also assumed that the position of the observing station with respect to the system of surveys, and the approximate direction of the meridian, are known.

The following programme is the one usually adopted, see figure 4:

1. Point on the reference object, tighten the azimuth clamp 115, set the micrometer thread at a distance from the middle thread of the diaphragm equal to about one-half of the angle to be measured, and make a bisection by turning up the azimuth tangent screw 116. Then make a bisection by moving the micrometer head 84, and read the counter 86, and the drum 82. Repeat this bisection and reading, and for clearness of vision adjust the eye-piece directly over the micrometer thread by operating the head 118. This adjustment serves merely to bring the micrometer thread into the centre of the field of view, and does not in any way alter the reading.

2. The altitude of the Pole Star is obtained from the Astronomical Field Tables for the sidereal time and place of observation and set on the vertical circle. When this is done, there is no difficulty in perceiving the star.

Next place the striding level on the pivots with the zero of graduation to the east.

Then make an accurate bisection of the star with the micrometer thread by turning the head 84, the bisection being always made by a screwing-up rotation. Read the counter and drum and note the time of bisection on the sidereal chronometer. If the star be near culmination and moving rapidly, place the thread slightly in advance and note the time of transit.

Read the striding level and reverse it on the pivots. Then repeat the bisection of the star as before. Then read the striding level again and remove it.

3. Set the micrometer thread in the symmetrical position on the opposite side of the middle thread of the diaphragm, transit the telescope, set it to the altitude of the star, reverse the instrument 180 degrees in azimuth and repeat 2.

4. Repeat 1.

A complete observation as above, under favourable conditions, should give a result correct to within a very few seconds. This is shown in the following specimen observations, the individual results being:

1st observation........................	1° 24′ 33″
2nd "	32
3rd "	33
4th "	33

The maximum deviation from the mean has the small value of 0″·7.

SPECIMEN AZIMUTH OBSERVATION

Place 9.58 chs. N. of N.E. cor. sec. 1 tp. 101-18-5

R. O. 66.94 " " " " " " 12 " " "

Date July 8, 1913 Observer J. A. Fletcher D.L.S.

Position	Pointing No.	Horizontal Circle Readings											
		Reference Object						Polaris					
		Microscope A			Micro. B			Microscope A			Micro. B		
			F.	B.		F.	B.		F.	B.		F.	B.
Circle Right Drum Right	1	179° 59'	16"	16"	01'	51"	51"	179° 23'	08"	10"	25'	43"	44"
	2		16	15		51	50		09	11		44	44
	3		15	16		52	52		08	10		45	44
Mean		179° 59' 15.7"			01' 51.2"			179° 23' 09.6"			25' 44.0"		
Circle Left Drum Left	1	359° 59'	24"	24"	01'	54"	54"	359° 19'	20"	20"	21'	50"	51"
	2		24	24		53	55		20	20		50	52
	3		24	25		54	54		20	20		51	52
Mean		359° 59' 24.2"			01' 53.9"			359° 19' 20.0"			21' 50.8"		

	Circle Right	Circle Left	
Mean H. C. R. of Pol.	179° 24' 27"	359° 20' 35"	Mean chron. time
Level correction	- 3	- 1	Chron. error
Corrected H. C. R. of Pol.	179 24 24	359 20 34	Sidereal time
" H. C. R. of R. O.	180 00 33	360 00 39	R. A. of Polaris
Angle Pol. to R. O.	0 36 09	0 40 05	*t* in time
			t in arc
Pol. from collimation log.			Log tan *F*
One turn micrometer log.			Log tan & sec *L*
Altitude Pol. log. sec.			Log cos & sin *t*
Sum			Sum
Pol. fr. coll. reduced to horiz'al			Log $\frac{1}{1-m}$
Level correction			Log tan *Z*
Microm. angle Pol. fr. coll.			Log *T*
R. O. from collimation log.			Log *a* (sec's.)
One turn micrometer log.			Azimuth of Pol.
Altitude R. O. log. sec.			Angle Pol. to R. O.
Sum			Azimuth of R. O.
Microm. angle R. O. from coll.			Mean
Angle Pol. to R. O.			Convergence
			Bearing of R. O.
Direction of deflection		Amount	

ON HORIZONTAL CIRCLE.

Instrument .... T.+S. 121

One turn of micrometer ...... 166.″22

One division of striding level ... 4.″94

Chron. Time	Micrometer Readings		Level		
	Polaris	R. O.	W.	E.	Corrn.
$12^h\ 19^m\ 37^s$			28.5 10.0	9.3 29.3	−1.5 × 1.9
			+18.5	−20.0	− 3″
$12^h\ 12^m\ 38^s$			29.0 10.0	9.7 29.3	−0.6 × 1.9
			+19.0	−19.6	−1″

Circle Right		Circle Left	
$12^h\ 19^m\ 37^s$ + 47		$12^h\ 12^m\ 38^s$ + 47	
12 20 24 1 27 59		12 13 25 1 27 59	
10 52 25 163° 06′ 15″		10 45 26 161° 21′ 30″	
$\bar{2}.30653$ 0.19995 $\bar{1}.98084_n$	$\bar{2}.30653$ 0.27273 $\bar{1}.46334$	$\bar{2}.30653$ 0.19995 $\bar{1}.97660_n$	$\bar{2}.30653$ 0.27273 $\bar{1}.50467$
$\bar{2}.48732_n$	$\bar{2}.04260$ $\bar{1}.98686_n$	$\bar{2}.48308_n$	$\bar{2}.08393$ $\bar{1}.98699_n$
	$\bar{2}.02946_n$ 5.31441		$\bar{2}.07092_n$ 5.31441
	3.34387_n		3.38533_n
	359° 23′ 13″ 0 36 09		359° 19′ 32″ 0 40 05
	359 59 22	359° 59′ 29″	359 59 37
Place			

SPECIMEN AZIMUTH OBSERVATION

Place *9.58 chs. N. of N.E. cor. sec. 1 tp. 101-18-5* ....

R. O. *66.94 " " " " " " 12 " " "* ....

Date *July 8, 1913* .... Observer *J. A. Fletcher D.L.S.*

Position	Pointing No.	Horizontal Circle Readings											
		Reference Object						Polaris					
		Microscope A			Micro. B			Microscope A			Micro. B		
			F.	B.		F.	B.		F.	B.		F.	B.
Circle Right Drum Right	1	179° 59′	16″	16″	01′	52″	53″	179° 30′	36″	35″	33′	10″	10″
	2		15	17		53	53		34	35		10	11
	3		15	17		51	52		34	35		10	11
Mean		179° 59′ 16″.5			01′ 52″.2			179° 30′ 34″.7			33′ 10″.4		
Circle Left Drum Left	1	359° 59′	23″	26″	01′	54″	56″	359° 33′	56″	59″	36′	26″	26″
	2		23	25		55	56		56	59		25	26
	3		23	26		54	[illegible]		56	59		27	27
Mean		359° 59′ 25″.4			01′ 54″.8			359° 33′ 58″.4			36′ 26″.1		

	Circle Right	Circle Left	
Mean H. C. R. of Pol..........	179° 31′ 53″	359° 35′ 12″	Mean chron. time
Level correction..........	− 6	+ 6	Chron. error
Corrected H. C. R. of Pol......	179 31 47	359 35 18	Sidereal time
" H. C. R. of R. O......	180 00 34	360 00 40	R. A. of Polaris
Angle Pol. to R. O....	0 28 47	0 25 22	t in time
			t in arc
Pol. from collimation.........log.			Log tan P
One turn micrometer.........log.			Log tan & sec L
Altitude Pol...............log. sec.			Log cos & sin t
Sum			Sum
Pol. fr. coll. reduced to horiz'al..			Log $\frac{1}{1-m}$
Level correction			Log tan Z
Microm. angle Pol. fr. coll........			Log T
R. O. from collimation...... log.			Log a (sec's.)
One turn micrometer...... log.			Azimuth of Pol.
Altitude R. O. .log. sec.			Angle Pol. to R. O.
Sum			Azimuth of R. O
Microm. angle R. O. from coll			Mean
Angle Pol. to R. O.			Convergence
			Bearing of R. O.
Direction of deflection..........		Amount..............	....

ON HORIZONTAL CIRCLE.

Instrument .... T.&S.121 ....

One turn of micrometer ...... 166".22 ....

One division of striding level ...... 4".94 ....

Chron. Time	Micrometer Readings		Level		
	Polaris	R. O.	W.	E.	Corrn.
12h 33m 38s			28.6 11.0	9.5 30.2	−3.1×1.9
			+17.6	−20.7	·6"
12h 40m 04s			31.0 10.1	11.8 29.4	+3.3×1.9
			+20.9	−17.6	+6"

Circle Right		Circle Left	
12h 33m 38s + 47		12h 40m 04s + 47	
12 34 25 1 27 59		12 40 51 1 27 59	
11 06 26 166° 36′ 30″		11 12 52 168° 13′ 00″	
$\bar{2}$.30653 0.19995 $\bar{1}$.98803 n	$\bar{2}$.30653 0.27273 $\bar{1}$.36475	$\bar{2}$.30653 0.19995 $\bar{1}$.99075 n	$\bar{2}$.30653 0.27273 $\bar{1}$.31008
$\bar{2}$.49451 n	$\bar{3}$.94401 $\bar{1}$.98664 n	$\bar{2}$.49723 n	$\bar{3}$.88934 $\bar{1}$.98656 n
	$\bar{3}$.93065 n 5.31441		$\bar{3}$.87590 n 5.31442
	3.24506 n		3.19032 n
	359° 30′ 42″ 0 28 47		359° 34′ 10″ 0 25 22
	359 59 29	359° 59′ 30″	359 59 32

Place ....

SPECIMEN AZIMUTH OBSERVATION

Place *9.58 chs. N. of N.E. cor. sec. 1 tp. 101-18-5*

R. O *66.94 " " " " " " 12 " " "*

Date *July 8, 1913* Observer *J. A. Fletcher D.L.S.*

Position	Pointing No.	Horizontal Circle Readings											
		Reference Object						Polaris					
		Microscope A			Micro. B			Microscope A			Micro. B		
			F.	B.		F.	B.		F.	B.		F.	B.
Circle Right Drum Right	1	179° 59′	20″	22″	01′	50″	50″	179° 47′	59″	60″	50′	24″	24″
	2		20	20		50	49		59	59		25	24
	3		20	21		49	51		59	58		24	24
Mean		179° 59′ 20.″9			01′ 49.″8			179° 47′ 59.″0			50′ 24.″3		
Circle Left Drum Left	1	359° 59′	24″	26″	01′	54″	56″	359° 42′	23″	24″	44′	49″	49″
	2		23	25		54	54		24	22		49	50
	3		23	25		54	54		22	22		49	48
Mean		359° 59′ 25.″1			01′ 54.″2			359° 42′ 22.″8			44′ 49.″0		

	Circle Right	Circle Left	
Mean H. C. R. of ☆	179° 49′ 12″	359° 43′ 36″	Mean chron. time
Level correction	− 1	+ 4	Chron. error
Corrected H. C. R. of Pol.	179 49 11	359 43 40	Sidereal time
" H. C. R. of R. O	180 00 35	360 00 40	R. A. of Polaris
Angle Pol. to R. O.	0 11 24	0 17 00	t in time
			t in arc
Pol. from collimation...... log.			Log tan P
One turn micrometer .... log.			Log tan & sec L
Altitude Pol.... .... log. sec.			Log cos & sin t
Sum			Sum
Pol. fr. coll. reduced to horiz'al..			Log $\frac{1}{1-m}$
Level correction			Log tan Z
Microm. angle Pol. fr. coll.... .			Log T
R. O. from collimation.........log.			Log a (sec's.)
One turn micrometer.........log.			Azimuth of Pol.
Altitude R. O... ..log. sec.			Angle Pol. to R.O.
Sum			Azimuth of R. O.
Microm. angle R. O. from coll...			Mean
Angle Pol. to R. O..............			Convergence
			Bearing of R. O.
Direction of deflection..............		Amount..............	....

ON HORIZONTAL CIRCLE.

Instrument. T. + S. 121.

One turn of micrometer 166.″22

One division of striding level 4.″94

Chron. Time	Micrometer Readings		Level		
	Polaris	R. O.	W.	E.	Corrn.
$13^h\ 05^m\ 23^s$			29.7 11.0	10.6 30.0	−0.7 × 1.9
			+18.7	−19.4	−1″
$12^h\ 55^m\ 38^s$			31.0 10.9	12.0 30.0	+2.1 × 1.9
			+20.1	−18.0	+4″

Circle Right		Circle Left	
$13^h\ 05^m\ 23^s$ + 47		$12^h\ 55^m\ 38^s$ + 47	
13 06 10 1 27 59		12 56 25 1 27 59	
11 38 11 174° 32′ 45″		11 28 26 172° 06′ 30″	
$\bar{2}.30653$ 0.19995 $\bar{1}.99803_n$	$\bar{2}.30653$ 0.27273 $\bar{2}.97795$	$\bar{2}.30653$ 0.19995 $\bar{1}.99587_n$	$\bar{2}.30653$ 0.27273 $\bar{1}.13767$
$\bar{2}.50451_n$	$\bar{3}.55721$ $\bar{1}.98634_n$	$\bar{2}.50235_n$	$\bar{3}.71693$ $\bar{1}.98641_n$
	$\bar{3}.54355_n$ 5.31442		$\bar{3}.70334_n$ 5.31442
	2.85797_n		3.01776_n
	359° 47′ 59″ 0 11 24		359° 42′ 38″ 0 17 00
	359 59 23	359° 59′ 31″	359 59 38
Place			

GENERAL REMARKS ON OBSERVING AZIMUTH. When observing for azimuth, as in angular measurements generally, care should be taken, when turning the instrument in azimuth by hand, to use the same forward or backward motions when performing the same operations in different observations. This tends to neutralize the effect of any yield in the instrument stand to that part of the impulse of revolution which passes down through the foot screws to the instrument base. The clamp screws which tighten the nuts of the levelling screws should always be screwed up tight to eliminate the azimuthal errors which would otherwise occur.

The reference object, which is usually a picket, should be at a distance such as to be equivalent to infinity, so far as the focus is concerned. Otherwise, when observing on the horizontal circle, the telescope will be set at stellar focus when making a setting on the star, and at a different focus when making a setting on the reference object; and this changing of the focus may produce a slight change in the line of collimation. Also, when observing with the eye-piece micrometer, a new value of the micrometer screw will have to be calculated if the observation is taken at a focus different from stellar focus. This leads to an undesirable multiplication of the work of calculating the azimuth, and so should be avoided.

When observing with the eye-piece micrometer, it should be remembered that the reference object must be within about one hundred minutes of the star, as the micrometer does not embrace an angle larger than this.

If the star is near upper or lower culmination, and moving rapidly, instead of making a bisection, it is preferable to set the thread just in front of the star and note the time of transit.

Under favourable conditions the telescope is capable of finding Polaris at any hour of the day; it will generally be necessary, however, to use the high power inverting eye-piece, of which the magnification is about thirty-seven diameters. Stars of the third magnitude may be observed at twilight when there is still enough light from the sky for reading the graduations. Picking up the star in the daytime may sometimes be a little difficult. A small movement back and forth of the instrument in azimuth or altitude may aid materially in doing so.

Whenever possible it is preferable to make the observation in daylight; but the instrument is equipped with a complete system of illumination by means of which it may be freely used when daylight fails.

As the sidereal time of observation on the star is required in calculating the azimuth, the error of the chronometer must be known. An error of one second in the time of observation, in the latitude of the western provinces, when Polaris is observed near upper or lower culmination, may produce an error in azimuth as large as half a second of arc. The chronometer error, therefore, must be known with precision; and this necessitates an observation for time during or just before or after the observation for azimuth.

The observation for time may be made by any of the methods described in the standard text books on astronomy. The eye-piece micrometer permits of the instrument being set in the meridian with great ease. From the central fixed thread of the diaphragm move the micrometer thread through an angle equal to the azimuth of Polaris at that time, divided by the secant of the altitude. Then make a setting of the micrometer thread on the star by turning the azimuth tangent screw. This puts the instrument in the meridian, when all that is necessary is to observe the time of transit of one of the time stars given in the Astronomical Field Tables.

During a series of observations it is customary to make all the individual observations by following out the same predetermined programme. This conduces to speed and accuracy in observing.

As little time as possible should be lost between observing the reference object and observing the star. Otherwise there may be a movement of the instrument during the interval. Also care should be taken not to touch any part of the instrument with the hand, except those parts which are absolutely necessary. When handling the stride level, lift it by the wooden handle only; for if the metal or glass be touched with the hand, errors may be introduced.

The observations are made in such fashion, "circle right" and "circle left" as to eliminate any error in the collimation.

Complete instructions as to the reduction of the azimuth observations are given in the Manual of Surveys.

OBSERVING LATITUDE

SETTING UP THE INSTRUMENT.—The instrument as intended for observing latitude by Talcott's method is shown in figs. 5 and 6.

Where the ground is soft it may be necessary to drive in three hubs and mount the tripod as already described. Another method is to dig three holes fifteen or eighteen inches deep and fill in with dry sand well rammed, and set the tripod feet on these sand cores. A third method is to use the stump of a tree sawn flat at a convenient height so that it may be used as a pier, the tripod being dispensed with.

The base is rotated until the latitude arc 108 is facing towards the east, with two of the levelling screws on an east-and-west line and the third one faciag towards the north. These conditions are possible because the latitude arc is placed at 30 degrees from one of the levelling screws. The latitude arc is always under the zero of the horizontal limb and therefore microscope A should read in the neighbourhood of 360 degrees, and microscope B in the neighbourhood of 180 degrees.

The instrument should be levelled up very carefully by means of the latitude level, so that when rotated in azimuth the bubble of the latitude level remains at, or departs but slightly from, the central position.

The instrument must be capable of rotation in azimuth exactly 180 degrees, and at either end of its swing the telescope must lie exactly in the plane of the meridian. This condition is brought about by means of the latitude stop clamp 47. The first necessity is to obtain a reference object of which the azimuth is accurately known, and by means of this to place a picket in or near to the meridian. The azimuth of this mark is divided by the secant of its altitude and by the value of the micrometer screw, and the micrometer thread set to give this reading. If now the micrometer thread be set on the mark by means of the azimuth tangent screw, the central thread of the diaphragm will lie in the meridian plane.

The latitude stop clamp 47 is now mounted on the arc 108 and firmly clamped by the nut 122, the capstan screw 123 not quite touching the projection 124, fig. 5. Then the capstan screw is rotated until it makes contact with the projection. The telescope is now transitted, the micrometer thread set to an equal distance on the other side of the middle thread of the diaphragm, and the instrument rotated about 180 degrees in azimuth, and clamped. By means of the azimuth tangent screw the micrometer thread is again superimposed on the reference mark, and then the other capstan screw 125 is rotated to make contact with the other projection. The telescope should now lie in the meridian plane at either extremity of its swing. The eye-piece micrometer must be rotated to bring the transverse thread vertical and the drum in the "up" position.

Latitude observations are always made at night, and therefore all readings must be made by artificial light. This necessitates connecting up the batteries to the rheostat 22 by means of the battery leads 23, fig. 7; and then connecting one of the rheostat leads to the transverse axis lamp 31, a second to the lamp 46 on the latitude mirror holder 34, and the third to the lamps on the horizontal circle.

SPECIMEN AZIMUTH OBSERVATION

Place *East Pier, New Observatory, Ottawa* ....

R. O. *Collimator* ....

Date *November 19, 1912* .... Observer *J. A. Fletcher D.L.S.* ....

Position	Pointing No.	Horizontal Circle Readings											
		Reference Object						Polaris					
		Microscope A			Micro. B			Microscope A			Micro. B		
			F.	B.		F.	B.		F.	B.		F.	B.
Circle Right Drum Right	1												
	2												
	3												
Mean													
Circle Left Drum Left	1												
	2												
	3												
Mean													

	Circle Right	Circle Left	
Mean H. C. R. of Pol.			Mean chron. time
Level correction			Chron. error
Corrected H. C. R. of Pol. ..			Sidereal time
H. C. R. of R. O.			R. A. of Polaris
Angle Pol. to R. O..			t in time
			t in arc
Pol. from collimation .. log.	0.65992	0.62273	Log tan P
One turn micrometer... log.	2.22042	2:22042	Log tan & sec L
Altitude Pol. 46°24′ log. sec.	0.16139	0.16139	Log cos & sin t
Sum	3.04173	3.00454	Sum
Pol. fr. coll. reduced to horiz'al .	0° 18′ 21″	0° 16′ 50″	Log $\frac{1}{1-m}$
Level correction	+ 9	− 1	Log tan Z
Microm. angle Pol. fr. coll	0 18 30	0 16 49	Log T
R. O. from collimation ...... log.	0.64296	0.77349	Log a (sec's.)
One turn micrometer .. log.	2.22042	2.22042	Azimuth of Pol.
Altitude R. O. 0° ..log. sec.			Angle Pol. to R.O.
Sum	2.86338	2.99391	Azimuth of R. O.
Microm. angle R. O. from coll	0° 12′ 10″	0° 16′ 26″	Mean
Angle Pol. to R. O. ..	0 30 40	0 33 15	Convergence
			Bearing of R. O.
Direction of deflection...........		Amount...........	....

WITH EYEPIECE MICROMETER.

Instrument........ T+S. 124

One turn of micrometer........ 166."12

One division of striding level........ 4."75

Chron. Time	Micrometer Readings		Level		
	Polaris	R. O.	W.	E.	Corrn.
23^h 02^m 51^s	24.551	15.603	26.9	3.0	−7.4 × 1.3
03 11	.588	.606	6.8	30.5	
23 03 01	24.570	15.605	+20.1	−27.5	−9"
23^h 09^m 39^s	15.858	25.939	28.2	4.7	+1.0 × 1.3
10 40	.752	.933	4.1	27.8	
23 10 10	15.805	25.936	+24.1	−23.1	+1"

Circle Right	Circle Left
23^h 03^m 01^s	23^h 10^m 10^s
+ 15 52	+ 15 52
23 18 53	23 26 02
1 28 39	1 28 39
21 50 14	21 57 23
327° 33′ 30″	329° 20′ 45″

$\bar{2}.30460$	$\bar{2}.30460$	$\bar{2}.30460$	$\bar{2}.30460$
0.00641	0.15374	0.00641	0.15374
$\bar{1}.92631$	$\bar{1}.72952_n$	$\bar{1}.93463$	$\bar{1}.70744_n$
$\bar{2}.23732$	$\bar{2}.18786_n$	$\bar{2}.24564$	$\bar{2}.16578_n$
	0.00757_n		0.00771_n
	$\bar{2}.19543$		$\bar{2}.17349$
	5.31439		5.31439
	3.50982		3.48788
	0° 53′ 55″		0° 51′ 15″
	0 30 40		0 33 15
	1 24 35		1 24 30
		1° 24′ 33″	

Place ....

SPECIMEN AZIMUTH OBSERVATION

Place *East Pier, New Observatory, Ottawa*

R. O. *Collimator*

Date *November 19, 1912* Observer *J.A. Fletcher D.L.S.*

Position	Pointing No.	Horizontal Circle Readings											
		Reference Object						Polaris					
		Microscope A			Micro. B			Microscope A			Micro. B		
			F.	B.		F.	B.		F.	B.		F.	B.
Circle Right Drum Right	1												
	2												
	3												
Mean													
Circle Left Drum Left	1												
	2												
	3												
Mean													

	Circle Right	Circle Left	
Mean H. C. R. of Pol.			Mean chron. time
Level correction			Chron. error
Corrected H. C. R. of Pol.			Sidereal time
" H. C. R. of R. O.			R. A. of Polaris
Angle Pol. to R. O.			*t* in time
			t in arc
Pol from collimation log.	0.79761	0.68178	Log tan *P*
One turn micrometer log.	2.22042	2.22042	Log tan & sec *L*
Altitude Pol. 46°27′ log. sec.	0.16179	0.16179	Log cos & sin *t*
Sum	3.17982	3.06399	Sum
Pol. fr. coll. reduced to horiz'al	0° 25′ 13″	0° 19′ 19″	Log $\frac{1}{1-m}$
Level correction	+ 7	− 3	Log tan *Z*
Microm. angle Pol. fr. coll.	0 25 20	0 19 16	Log *T*
R. O. from collimation log.	0.67089	0.89542	Log *a* (sec's.)
One turn micrometer log.	2.22042	2.22042	Azimuth of Pol.
Altitude R. O. 0° log. sec.			Angle Pol. to R. O.
Sum	2.89131	3.11584	Azimuth of R. O.
Microm. angle R. O. from coll.	0° 12′ 59″	0° 21′ 46″	Mean
Angle Pol. to R. O.	0 38 19	0 41 02	Convergence
			Bearing of R. O.
Direction of deflection............		Amount..............	....

WITH EYEPIECE MICROMETER

Instrument T.+S. 124

One turn of micrometer 166.″12

One division of striding level 4.″75

Chron. Time	Micrometer Readings		Level		
	Polaris	R. O.	W.	E.	Corrn.
23h 22m 59s	26.248	15.310	27.2	3.7	−5.5×1.3
23 24	.303	.317	6.4	30.0	
23 23 11	26.275	15.313	+20.8	−26.3	−7″
23h 30m 11s	15.221	27.860	28.9	5.1	+2.7×1.3
49	.167	.860	3.8	27.5	
23 30 30	15.194	27.860	+25.1	−22.4	+3″

Circle Right		Circle Left	
23h 23m 11s		23h 30m 30s	
+ 15 52		+ 15 52	
23 39 03		23 46 22	
1 28 39		1 28 39	
22 10 24		22 17 43	
332° 36′ 00″		334° 25′ 45″	
$\bar{2}$.30460	$\bar{2}$.30460	$\bar{2}$.30460	$\bar{2}$.30460
0.00641	0.15374	0.00641	0.15374
$\bar{1}$.94832	$\bar{1}$.66295 n	$\bar{1}$.95523	$\bar{1}$.63511 n
$\bar{2}$.25933	$\bar{2}$.12129 n	$\bar{2}$.26624	$\bar{2}$.09345 n
	0.00797 n		0.00810 n
	$\bar{2}$.12926		$\bar{2}$.10155
	5.31440		5.31440
	3.44366		3.41595
	0° 46′ 17″		0° 43′ 26″
	0 38 19		0 41 02
	1 24 36		1 24 28
		1° 24′ 32″	
Place			

SPECIMEN AZIMUTH OBSERVATION

Place *East Pier, New Observatory, Ottawa*

R. O. *Collimator*

Date *November 19, 1912* Observer *J. A. Fletcher D.L.S.*

Position	Pointing No.	Horizontal Circle Readings											
		Reference Object						Polaris					
		Microscope A			Micro. B			Microscope A			Micro. B		
			F.	B.		F.	B.		F.	B.		F.	B.
Circle Right Drum Right	1												
	2												
	3												
Mean													
Circle Left Drum Left	1												
	2												
	3												
Mean													

	Circle Right	Circle Left	
Mean H. C. R. of Pol.			Mean chron. time
Level correction			Chron. error
Corrected H. C. R. of Pol.			Sidereal time
" H. C. R. of R. O.			R. A. of Polaris
Angle Pol. to R. O.			*t* in time
			t in arc
Pol. from collimation log.	*0.91100*	*0.76125*	Log tan *P*
One turn micrometer log.	*2.22042*	*2.22042*	Log tan & sec *L*
Altitude Pol. *46° 29′* log. sec.	*0.16205*	*0.16205*	Log cos & sin *t*
Sum	*3.29347*	*3.14372*	Sum
Pol. fr. coll. reduced to horiz'al	*0° 32′ 45″*	*0° 23′ 12″*	Log $\frac{1}{1-m}$
Level correction	*+ 8*	*− 0*	Log tan *Z*
Microm. angle Pol. fr. coll	*0 32 53*	*0 23 12*	Log *T*
R. O. from collimation log.	*0.65734*	*0.94895*	Log *a* (sec's.)
One turn micrometer log.	*2.22042*	*2.22042*	Azimuth of Pol.
Altitude R. O. *0°* log. sec.			Angle Pol. to R. O
Sum	*2.87776*	*3.16937*	Azimuth of R. O.
Microm. angle R. O. from coll	*0° 12′ 35″*	*0° 24′ 37″*	Mean
Angle Pol. to R. O.	*0 45 28*	*0 47 49*	Convergence
			Bearing of R. O.
Direction of deflection		Amount	

WITH EYEPIECE MICROMETER.

Instrument .... T.+S. 124

One turn of micrometer .... 166.″12

One division of striding level .... 4.″75

Chron. Time	Micrometer Readings		Level		
	Polaris	R. O.	W.	E.	Corrn.
$23^h\ 41^m\ 03^s$	28.133	15.452	27.2	3.6	−6.1 × 1.3
20	.161	.461	6.7	30.2	
23 41 12	28.147	15.457	+20.5	−26.6	−8″
$23^h\ 47^m\ 03^s$	14.258	28.893	28.7	5.0	+0.2 × 1.3
39	.199	.889	5.0	28.5	
23 47 21	14.229	28.891	+23.7	−23.5	+0″

Circle Right	Circle Left
$23^h\ 41^m\ 12^s$	$23^h\ 47^m\ 21^s$
+ 15 52	+ 15 52
23 57 04	24 03 13
1 28 39	1 28 39
22 28 25	22 34 34
337° 06′ 15″	338° 38′ 30″

$\bar{2}.30460$	$\bar{2}.30460$	$\bar{2}.30460$	$\bar{2}.30460$
0.00641	0.15374	0.00641	0.15374
$\bar{1}.96436$	$\bar{1}.59001$ n	$\bar{1}.96910$	$\bar{1}.56134$ n
$\bar{2}.27537$	$\bar{2}.04835$ n	$\bar{2}.28011$	$\bar{2}.01968$ n
	0.00827 n		0.00836 n
	$\bar{2}.05662$		$\bar{2}.02804$
	5.31441		5.31441
	3.37103		3.34245
	0° 39′ 10″		0° 36′ 40″
	0 45 28		0 47 49
	1 24 38		1 24 29
		1° 24′ 33″	

Place ....

SPECIMEN AZIMUTH OBSERVATION

Place *East Pier, New Observatory, Ottawa*

R. O. *Collimator*

Date *November 19, 1912* Observer *J. A. Fletcher D.L.S.*

Position	Pointing No.	Horizontal Circle Readings											
		Reference Object						Polaris					
		Microscope A			Micro. B			Microscope A			Micro. B		
			F.	B.		F.	B.		F.	B.		F.	B.
Circle Right Drum Right	1												
	2												
	3												
Mean													
Circle Left Drum Left	1												
	2												
	3												
Mean													

	Circle Right	Circle Left	
Mean H. C. R. of Pol.			Mean chron. time
Level correction			Chron. error
Corrected H. C. R. of Pol.			Sidereal time
" H. C. R. of R. O.			R. A. of Polaris
Angle Pol. to R. O.			t in time
			t in arc
Pol. from collimation log.	0.96595	0.74060	Log tan P
One turn micrometer log.	2.22042	2.22042	Log tan & sec L
Altitude Pol. 46° 31′ log. sec.	0.16232	0.16232	Log cos & sin t
Sum	3.34869	3.12334	Sum
Pol. fr. coll. reduced to horiz'al	0° 37′ 12″	0° 22′ 08″	Log $\frac{1}{1-m}$
Level correction	+ 8	− 1	Log tan Z
Microm. angle Pol. fr. coll.	0 37 20	0 22 07	Log T
R. O. from collimation log.	0.72099	1.06536	Log a (sec's.)
One turn micrometer log.	2.22042	2.22042	Azimuth of Pol.
Altitude R. O. 0° log. sec.			Angle Pol. to R. O.
Sum	2.94141	3.28578	Azimuth of R. O.
Microm. angle R. O. from coll	0° 14′ 34″	0° 32′ 11″	Mean
Angle Pol. to R. O.	0 51 54	0 54 18	Convergence
			Bearing of R. O.
Direction of deflection		Amount	

WITH EYEPIECE MICROMETER.

Instrument T.+S. 124

One turn of micrometer 166″.12

One division of striding level 4″.75

Chron. Time	Micrometer Readings		Level		
	Polaris	R. O.	W.	E.	Corrn.
23ʰ 56ᵐ 45ˢ 57 03	29.238 .253	14.738 .741	26.7 6.2	3.0 29.9	−6.4×1.3
23 56 54	29.246	14.740	+20.5	−26.9	−8″
24ʰ 02ᵐ 40ˢ 03 36	14.541 .453	31.628 .621	28.0 4.0	4.4 27.6	+0.8×1.3
24 03 08	14.497	31.624	+24.0	−23.2	+1″

Circle Right		Circle Left	
23ʰ 56ᵐ 54ˢ + 15 52		24ʰ 03ᵐ 08ˢ + 15 52	
24 12 46 1 28 39		24 19 00 1 28 39	
22 44 07 341° 01′ 45″		22 50 21 342° 35′ 15″	
$\bar{2}.30460$ 0.00641 $\bar{1}.97575$	$\bar{2}.30460$ 0.15374 $\bar{1}.51200$ n	$\bar{2}.30460$ 0.00641 $\bar{1}.97963$	$\bar{2}.30460$ 0.15374 $\bar{1}.47603$ n
$\bar{2}.28676$	$\bar{3}.97034$ n 0.00849 n	$\bar{2}.29064$	$\bar{3}.93437$ n 0.00856 n
	$\bar{3}.97883$ 5.31441		$\bar{3}.94293$ 5.31441
	3.29324		3.25734
	0° 32′ 44″ 0 51 54		0° 30′ 09″ 0 54 18
	1 24 38	1° 24′ 33″	1 24 27
Place	....	....	....

The lamps on the horizontal circle are used for the purpose of checking up the instrument position occasionally to see that it has not departed from the adjustment for the meridian. They are both on the one circuit, but only one is necessary for checking purposes, and consequently the second one may be "plugged out."

For illuminating the micrometer thread, the small silver mirror 30 should be mounted at the intersection of the two axes of the telescope, and adjusted to the proper angle for reflecting the light received through the hollow transverse axis on to the diaphragm.

It is now assumed that the instrument is in perfect adjustment, supported rigidly upon the tripod and all the necessary fittings and accessories mounted in place.

OBSERVING LATITUDE.—Assume that two stars N and S have been selected from the Star Charts* to form one of the pairs on the observing list and assume that N transits first. If Zn and Zs be their approximate zenith distances, to the nearest minute only, the telescope should be set $\frac{Zn + Zs}{2}$ to the north, and this will ensure that N will transit within the field of view. But the field is fairly large and the traversing eye-piece shows only a part of it at a time. The observer must know whereabouts to look for the star, and therefore the eye-piece is brought to the approximate micrometer setting by operating the head 118. Should the difference of zenith distance between the two stars be considerable, it is advisable to set the micrometer thread at the approximate point of transit before the star comes into the field of view, especially if the star should be near the equator and moving rapidly. The distance from the middle fixed thread of the diaphragm will be $\frac{Zn - Zs}{2}$. When the north star has the greater zenith distance it will transit at $20 \cdot 000 + \frac{Zn - Zs}{2R}$ micrometer turns, and the south star will transit at $20 \cdot 000 - \frac{Zn - Zs}{2R}$, where R is the value of one turn of the micrometer. The micrometer settings for all stars on the observing list are thus calculated.

The micrometer reading increases with increase of zenith distance. If the star is nearer the zenith than the spot pointed to by the central axis of the telescope, it will appear to cross the field at a point farther from the vertical axis of the instrument as the observer looks through the diagonal eye-piece.

On the observing list the mean zenith distance of the extreme stars to be observed at any one setting is calculated and subtracted from 90 degrees, thus giving the mean altitude to which the vertical circle vernier is set. The transverse axis clamp 44 is then loosened and the telescope swung in altitude until the bubble of the latitude level comes about to the centre of its run, when the transverse axis clamp is tightened; the bubble of the latitude level then being brought as closely as possible to the centre of its run by operating the tangent screw 126, fig. 6. The instrument is then swung north or south, as the case may be, until it rests against the latitude stop; and the micrometer and eye-piece set to the approximate position of the star's transit. As the star enters the field the micrometer thread is brought nearly to bisect it, the bisection being made throughout the period during which the star is traversing the diaphragm and the last motion of the micrometer head always being in the screwing up direction.

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*Published by the Topographical Surveys Branch, Department of the Interior, Ottawa.

As soon as this is done, both ends of the level bubble are read, the north end always being read first, then the micrometer drum is read, estimating the nearest tenth of a division by eye. This completes the observation on the first star.

If the second star transits on the other side of the zenith, the instrument is rotated in azimuth till it rests against the other side of the latitude stop clamp. The level bubble should come to rest at about the middle of the vial, but should the reading differ materially from the previous one, the bubble should be brought back by means of the transverse axis tangent screw and by the levelling screw facing north, half the correction being made by each method. The second star is then observed in the same manner as was the first.

The vertical circle tangent screw 121 which moves the level in regard to the telescope must never be touched between observations of stars of a pair or group.

The specimen observation is composed of twenty-three pairs of stars. It was first calculated with an assumed micrometer value, and then from the resulting latitudes the micrometer error was found and the latitudes recalculated. The positive and negative weighted micrometer differences were balanced. The probable errors were calculated; the probable error of the whole determination being $\pm 0''.16$, and the probable error of a single pair $\pm 0''\cdot 70$, which is a criterion of the accuracy of the instrument. This observation was taken as a check on the line chainage.

Observed latitude of line.............	58° 25′ 37″·30
Correction for sea level..............	−0·08
Correction for variation of latitude....	0·00*
Corrected latitude...................	58° 25′ 37″·22
Theoretical latitude.................	58° 25′ 37·33
Error of line =	0″·11
=	0·17 chs.

*"Astronomische Nachrichten" No. 4749.

Place 31·577 chs. W. of NE. cor. sec. 35, tp. 108-18-5.

Date Aug. 20, 1913.

Observer J. A. Fletcher, D.L.S.

No.	Star.		N or S	Micrometer.		Level.		
				Reading.	Diff. Z. D. in turns.	N.	S	Diff. N-S. in div.
1	B.J. B	675 4518	N. S.	22·273 19·568	− 2·705	23·8 5·0	4·0 24·7	−1·9
2	B.J. B.	675 4522	N. S	22·273 19 068	− 3·205	23·8 5·0	4·0 24·7	−1·9
3	Green. B.	9001 4647	N. S	20·175 20·920	+ 0·745	31·2 13·2	10·9 33·8	−4·9
4	B.J. B.	700 4747·8	N. S	23·178 18·738	− 4·440	29·2 12·0	8·9 33·0	−6·9
5	B.J. B.	700 4749	N. S	23·178 19·997	− 3·181	29·2 12·0	8·9 33·0	−6·9
6	B.J. B.	707 4822	N. S	22·429 19·588	− 2·841	30·8 10·9	9·9 31·8	−2·0
7	Green. G.	2689 4859	N. S.	19·308 22·572	+ 3·264	26·0 6·8	4·8 28·0	−4·0
8	B.J. B.	729 4958	N. S.	16·061 25·507	+ 9·446	34·0 11·9	12·7 33·2	+1 6
9	A. G	6332 5039	N. S.	19·748 21·615	+ 1·867	27·0 4 2	5·2 26·0	+2·0
10	G. G.	5127 5163	N. S.	17·050 24·738	+ 7·688	30·5 10·0	8·9 32·0	−2·6
11	Green. B.	7488 5137	N. S	27·794 13·998	−13·796	27·2 7·1	5·5 29·0	−3·4
12	B. B.	5184 5218	N. S.	20·079 18 143	− 1·936	28 9 8·3	7·0 30·2	−2·6
13	B. B.	5225 5218	N. S.	23·668 18·143	− 5·525	28·0 8·3	5·9 30·2	−4·6
14	Green B.	1891 5411	N. S	21·309 20·281	− 1·028	29·0 7·5	6·3 30·0	−2·2
15	G. G.	6004 5968	N. S	17·807 24·621	+ 6·814	29·7 8·7	6·8 31 3	−3·5
16	B. B.	5614 5639	N. S	14·641 22·532	+ 7·891	30·8 9·8	7·9 32 8	−3·9
17	B. B.	5619 5639	N. S	27·198 22·532	− 4·666	31 1 9 8	8·2 32·8	−3·3
18	Green B.	9977 [illegible]	N. S	21·729 25 725	+ 3·996	29·6 8 8	6·8 31 8	−4·2
19	Green G.	9977 6147	N. S	21·729 16·689	− 5·040	29·6 10 0	6·8 33·1	−6·7
20	B. B.	5727 5742	N. S.	23·317 21·467	− 1·850	32·2 12·3	9·4 35·4	−6 1
21	B. B.	5727 5751	N. S	23 317 17·631	− 5·686	32·2 12·2	9·4 35·3	−5·9
22	Green. B.J.	9991 843	N. S	16·731 24 765	+ 8·031	25·7 6·1	2·6 29·[illegible]	−7·0
23	Green B.J.	2021 852	N. S	22·282 19 579	− 2·703	31·2 9·7	8·0 32·9	−3·4

OBSERVATION—(*Talcott's method.*)

Instrument T. & S. 121.

One division of level = 3″·62.

One turn of micrometer = 166″·217.

Declinations.	Sum and Half Sum	Corrections. Micrometer.	Corrections. Level.	Corrections. Refraction	Latitude.
° ′ ″	° ′ ″	′ ″	″	″	° ′ ″
76 58 37·73	116 58 45·40	− 3 44·81			58 25 36 10
40 00 07·67	58 29 22·70	− 3 44·58	−1·72	−0 07	36·33
76 58 37·73	117 00 09·28	− 4 26·36			36·47
40 01 31·55	58 30 04·64	− 4 26·09	−1·72	−0·09	36·74
65 30 42·35	116 49 22 51	+ 1 01·92			38·77
51 18 40·16	58 24 41 26	+ 1 01·85	−4 43	+0·02	38·70
77 28 55·50	117 03 46·68	− 6 09·00			37·99
39 34 51·18	58 31 53·34	− 6 08·63	−6·21	−0·11	38·36
77 28 55·50	117 00 18·82	− 4 24·37			38·71
39 31 23·32	58 30 09·41	− 4 24·10	−6·24	−0·09	38·98
59 17 02·72	116 59 08·20	− 3 56·11			36·11
57 42 05·48	58 29 34·10	− 3 55·87	−1·81	−0·07	36·35
76 25 06·14	116 42 17·81	+ 4 31·27			36·64
40 17 11·67	58 21 08·90	+ 4 30·99	−3·62	+0·09	36·36
73 11 48·00	116 25 00·80	+13 05·04			37·13
43 13 12·80	58 12 30 10	+13 04·25	+1·45	+0·24	36·34
59 58 14·57	116 46 03·52	+ 2 35·16			38·77
56 47 48·95	58 23 01·76	+ 2 35·01	+1·81	+0·04	38·62
59 12 13·81	116 30 05 07	+10 38·91			39·31
57 17 51·26	58 15 02·54	+10 38·29	−2·35	+0·18	38·66
67 37 40·36	117 29 32·92	−19 06·56			36·49
49 51 52·56	58 44 46·40	−19 05·41	−3 08	−0 33	37·64
61 49 02·86	116 56 41·39	− 2 40·00			37·41
55 07 38·53	58 28 20·70	− 2 10·74	−2·35	−0·04	37·57
61 59 00·76	117 06 39·29	− 7 39·17			36·18
55 07 38·53	58 33 19·64	− 7 38·71	−4·16	−0·13	36·61
71 05 07·40	116 54 06·62	− 1 25·44			35·85
45 48 59·22	58 27 03 31	− 1 25·35	−1·99	−0·03	35·94
62 03 42 66	116 32 26·40	+ 9 26·30			36·49
54 28 43·74	58 16 13·20	+ 9 25·73	−3·17	+0·16	35 92
60 17 28·40	116 29 34·08	+10 55·81			39·50
56 12 05·68	58 14 17·01	+10 55·15	−3·53	+0·18	38·84
60 52 10·56	117 01 16·24	− 6 27·78			37·24
56 12 05·68	58 32 08·12	− 6 27·39	−2·99	−0 11	37·63
64 12 21·85	11[illegible] [illegible] 16 51	+ 5 32 10			36·66
52 27 54·66	[illegible] [illegible] 08·26	+ 5 31·77	−3·80	+0 10	36·33
64 12 21·85	117 05 26·87	− 6 58·87			38·39
52 53 05·02	58 32 43·44	− 6 58·44	−6·06	−0·12	38·82
60 19 52·32	116 56 35·75	− 2 33·75			38·57
56 36 43·43	58 28 17·88	− 2 33·60	−5·52	−0·04	38·72
60 19 52·32	117 07 10·15	− 7 52·55			37·06
56 47 17·83	58 33 35·08	− 7 52·08	−5·34	−0·13	37·53
64 41 26·32	116 29 10·45	+11 07·69			36·76
51 [illegible]7 44·13	58 [illegible]4 35·22	+11 07·02	−6·34	+0·19	36·09
78 22 46 09	116 58 47·82	− 3 44 64			36·12
38 36 01·73	58 29 23·91	− 3 44·42	−3·08	−0·07	36·34

BALANCE OF WEIGHTED MICROMETER DIFFERENCES

Positive Differences.				Negative Differences.			
Pair.	Micrometer Difference.	Weight.	Weighted Difference.	Pair.	Micrometer Difference.	Weight.	Weighted Difference.
3	0·745	1	0·745	1	2·705	2/3	[illegible]·803
7	3·264	1	3·264	2	3·205	2/3	2·137
8.	9·446	1	9·446	4	4·440	2/3	2·960
9.	1·867	1	1·867	5	3·181	2/3	[illegible]
10.	7·688	[illegible]	[illegible]	6	2·841	1	[illegible]·841
15.	6·814	1	6·814	11	13·796	1	[illegible]
16.	7·891	[illegible]	[illegible]	12	1·936	2/3	[illegible]
18.	3·996	[illegible]	[illegible]	13	5·525	2/3	[illegible]
22.	8·034	[illegible]	[illegible]	14	1·028	1	[illegible]
..				17	4·666	2/3	3·111
				19	5·040	2/3	3·360
..				20	1·850	2/3	1·233
...				21	5·686	2/3	3·791
..				23	2·703	1	2·703
Sums	...	[illegible]	[illegible]			10 2/3	[illegible]·858

$$D_p = \frac{45\cdot783}{8\frac{1}{3}}, \qquad D_n = \frac{45\cdot858}{10\frac{2}{3}}.$$

Where Dp = weighted mean positive micrometer difference.
and Dn = " " negative " "

Since the sum of the weighted positive micrometer differences is equal to the sum of the weighted negative micrometer differences, any error which may exist in the micrometer screw value is eliminated from the final mean latitude.

DETERMINATION OF MICROMETER CORRECTION

Latitudes from Positive Differences

Pair	Latitude	Weight	Weighted Latitude.
	°		°
[illegible]	8·7[illegible]	1	8·[illegible]
[illegible]	6·64	1	6·64
8	7·13	1	7·13
9	8·[illegible]	1	8·77
10	9·31	1	9·31
15	6·49	1	6·49
16	9·50	2/3	6·33
18	6·66	2/3	4·44
22.	6·7[illegible]	[illegible]	6·76
[illegible]		[illegible]	[illegible]

Latitudes from Negative Differences

Pair.	Latitude	Weight	Weighted Latitude.
	°		°
[illegible]	6·10	2/3	4·07
[illegible]	[illegible]·47	[illegible]	4·31
[illegible]	[illegible]·99	[illegible]	5·33
[illegible]	8·71	2/3	5·81
[illegible]	6·11	1	6·11
[illegible]	6·49	1	6·49
[illegible]	7·41	2/3	4·94
[illegible]	6·18	2/3	4·12
[illegible]	5·[illegible]	1	5·85
[illegible]	7·[illegible]	2/3	4·83
19	8·[illegible]	2/3	5·59
20	8·[illegible]	2/3	5·71
[illegible]	7·06	2/3	4·71
[illegible]	6·12	1	6·12
[illegible]		[illegible] 2/3	73·99

Lp [illegible] $= \frac{73 \cdot 99}{10\ 2/3}$.

Lp [illegible] mean positive latitude.
Ln [illegible] negative [illegible]

Let [illegible] micrometer correction required.

$$\text{Then } [\text{illegible}] = 2\left\{\frac{\text{Ln} - \text{Lp}}{\text{Dn} - \text{Dp}}\right\};$$

$$= -0'' \cdot 168.$$

New micrometer value $= 166'' \cdot 217 - 0'' \cdot 168 = 166''$ [illegible]

This micrometer correction to the latitude was recalculated [illegible] this new value and entered below the first values, and this change produced a corresponding change in the latitude which was entered in the same way.

PROBABLE ERROR

Pair.	L.	p	pL.	v	v²	pv²
	″		″	″		
1	36·33	2/3	24·22	0·97	0·94	0·63
2	36·74	2/3	24·49	0·56	0·31	0·21
3	38·70	1	38·70	1·40	1·96	1·96
4	38·36	2/3	25·57	1·06	1·12	0·75
5	38·98	2/3	25·99	1·68	2·82	1·88
6	36·35	1	36·55	0·95	0·90	0·90
7	36·36	1	36·36	0·91	0·88	0·88
8	36·34	1	36·31	0·96	0·92	0·92
9	38·62	1	38·62	1·32	1·74	1·74
10	38·66	1	38·66	1·36	1·85	1·85
11	37·64	1	37·64	0·31	0·12	0·12
12	37·57	2/3	25·05	0·27	0·07	0·05
13	36·64	2/3	24·43	0·66	0·14	0·29
14	35·94	1	35·94	1·36	1·85	1·85
15	35·92	1	35·92	1·38	1·90	1·90
16	38·84	2/3	25·89	1·54	2·37	1·58
17	37·63	2/3	25·09	0·33	0·11	0·07
18	36·33	2/3	24·22	0·97	0·94	0·63
19	38·82	2/3	25·88	1·52	2·31	1·54
20	38·72	2/3	25·81	1·42	2·02	1·35
21	37·53	2/3	25·02	0·23	0·05	0·03
22	36·09	1	36·09	1·21	1·46	1·46
23	36·31	1	36·31	0·96	0·92	0·92
Sums.		19	708·62			23·51
Mean			37·30			

$$\text{Probable error of a single pair} = \sqrt{\frac{0{\cdot}455 \times S[pv^2]}{n - 1}} = \pm 0''{\cdot}70.$$

$$\text{Probable error of final latitude} = \sqrt{\frac{0{\cdot}455 \times S[pv^2]}{(n - 1)\ S\ [p]}} = \pm 0''{\cdot}16.$$

GENERAL REMARKS ON OBSERVING LATITUDE.—The level should be read with as little delay as possible after the intersection of the star has been made. If the bubble is seen to be moving when the reading is being made, the fact should always be recorded and the observation as a rule should be rejected. Great care should be taken to avoid errors due to parallax, and this necessitates care in adjusting the silver mirror to the proper angle.

The great advantage of this mirror is that it enables the level being read without requiring any movement of the observer from the eye end of the telescope. If the observer were to walk around to the side of the instrument to make the level reading, the action might cause two kinds of errors, viz.: the elapsed time might be sufficient for the bubble to have changed its position from what it was when the intersection was made, and the mere fact of the observer walking around the instrument might be sufficient to cause the level bubble to shift, due to a change in the distribution of pressure on the ground surrounding the tripod.

If the central axis is truly vertical, the reversal in azimuth will not alter the level reading. Therefore, if the reading is seen to change, the earliest opportunity should be taken of relevelling the instrument. If the amount of the bubble's movement and its direction have been noted, the readjustment of the verticality of the axis in the meridian is made in a moment by producing a movement of half the amount and in the opposite direction with the levelling screw facing towards the north. The bubble is then brought to the centre of its run by operating the tangent screw of the transverse axis clamp.

It is very important to keep the level correction as small as possible, for in the final computation the stars are so arranged as to eliminate the effect of the value of the micrometer screw upon the final deduced value of the latitude, but no such like arrangement is available at the same time for eliminating any error in the value of the level bubble. Changes in the temperature produce changes in the value of this bubble, and under changeable atmospheric conditions, the value must vary appreciably.

The use of the transverse axis clamp tangent screw before observing the second star is slightly objectionable, as it may be the cause of altering the strains in the telescope tube and producing flexure, or changing such flexure as existed during the observation of the first star. There is less danger in this, however, than in allowing the level correction to be large.

When operating the micrometer and shutter heads, great care must be observed that no longitudinal strains be applied.

The latitude stars in the "Catalogue of Stars for 1910·0"* were obtained from the standard catalogues and ephemerides, and the abbreviated names of these catalogues with their catalogue numbers are given in the "Catalogue of Stars for 1910·0" for the individual stars. Consequently when it is necessary to make any adjustments during an observation and these adjustments necessitate the dropping of a few stars, those stars which have been derived from the catalogues of least weight should be omitted.

The stars are observed in pairs, one culminating north of the zenith and the other south. The difference of zenith distances should not exceed 15 or 20 minutes.

The difference of right ascensions of the two stars forming the pair should not exceed five minutes, as changes may take place in the instrument if a longer time elapse; and besides, a sufficient number of stars will not be observed during a period if the stars are far apart. The interval should not be less than one minute, as the instrument must be read and reversed in azimuth for the second star, which will require at least that length of time.

Stars down to the 6·5th magnitude may be observed with this instrument. But stars smaller than this or larger than the 2nd magnitude should be avoided as much as possible as it is difficult to make the bisections with sufficient accuracy.

OBSERVING TIME AND LONGITUDE

The instrument as intended for observing time and longitude is shown in fig. 2. Where the ground is soft it may be necessary to mount the instrument as already described. The tripod should be set up with two legs on a north-and-south line, and the third leg facing towards the east or west.

For ease in levelling it is advisable to lock the instrument in a position such that two of the levelling screws are on an east-and-west line, and the third facing towards the north or south.

The micrometer diaphragm is adjusted so as to have the transverse thread horizontal and the five parallel threads vertical, and the eye-piece is set over the middle thread by operating the milled head 118.

The two lamp holders and lamps 31 are mounted on the standards for illuminating the diaphragm in both positions of the telescope, i.e.; "circle east" and "circle west"; and the lamp holder and lamp 21 used for reading the vertical circle and level; these three lamps being connected up to the three leads of the rheostat 22 which may be suspended from the plumb-bob hook or from a leg pin.

If a stationary reference object of known azimuth be available, it will be possible to place a picket in or near to the meridian. Otherwise the azimuth of the reference mark should be determined by observation on Polaris. The azimuth of the mark which lies near the meridian is then divided by the secant of the angle of elevation or depression and by the value of the micrometer screw, and the micrometer thread set this distance from the middle thread of the diaphragm.

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*Published by the Topographical Surveys Branch, Department of the Interior, Ottawa, 1914.

The micrometer thread is then set on the mark and this operation places the middle thread of the diaphragm in the meridian.

Observations for time are made by the usual standard methods described in text books on astronomy. Should it be necessary to transit the telescope in changing from a star of north to one of south zenith distance, for example, or *vice versa*; it may be done in the usual way after folding back the long diagonal eye-piece at the hinged joint.

It is customary to observe half the stars in the position "circle west" and half in the position "circle east," which necessitates a reversal of the telescope in the wyes. This may be done as with an astronomical transit, but the lamp holder and lamp 21 will also have to be changed from one standard to the other.

The transits of the stars are observed on the five vertical threads of which the equatorial intervals are determined at the Surveys Laboratory. Otherwise they may be measured by means of the micrometer. The inequality of the pivots is also determined at the Surveys Laboratory. The other constants of the instrument for calculating the local sidereal time must be calculated from the time stars themselves in each individual observation. Reduction of the observation may be made by any of the standard methods.

INDEX OF NUMBERED PARTS.

1. Screws Holding Micrometer Eye-piece.
2. Capstan Nuts for Shifting Microscope.
3. Capstan Screws for Clamping Microscope.
4. Draw Tube of Microscope Eye-piece.
5. Field Lens of Microscope Eye-piece.
6. Eye Lens of Microscope Eye-piece.
7. Glass Diaphragm of Microscope.
8. Focussing Nut of Microscope.
9. Reflecting Prism of Microscope.
10. Cover of Reflecting Prism.
11. Screws Holding Prism Cover.
12. Retaining Screw of Microscope Eye-piece.
13. Slot in Draw Tube of Microscope.
14. Top of Micrometer Box.
15. Screws Holding Top of Micrometer Box.
16. Screws Holding End of Micrometer Box.
17. Diaphragm Carriage.
18. Horizontal Lines of Microscope Diaphragm.
19. Vertical Lines of Microscope Diaphragm.
20. Index Plate of Microscope.
21. Lamp Holder and Lamp for Reading Vertical Circle.
22. Rheostat and Lamp Leads.
23. Battery Leads.
24. Large Screw Driver.
25. Small Screw Driver.
26. Wrench for Tripod Nuts.
27. Key for Shifting Tripod Head.
28. Plumb-bob.
29. Stride Safety Holder.
30. Telescope Mirror and Case.
31. Lamp Holders and Lamps for Illuminating Diaphragm.
32. Stride Level.
33. Camel Hair Brush.
34. Lamp Holder and Reflecting Mirror Used in Observing Latitude.
35. Long Diagonal Eye-piece.
36. High Power Inverting Eye-piece and Covers.
37. Prismatic Eye-piece and Cover.
38. Low Power Inverting Eye-piece.
39. Small Vertical Circle Level.
40. Large Adjusting Pin.
41. Small Adjusting Pin.
42. Light Sun Glass.
43. Dark Sun Glass.
44. Transverse Axis Clamp.
45. Latitude Level.
46. Spare Lamps.
47. Latitude Stop Clamp.
48. Bottle of Lubricant.
49. Bottle of Watch Oil.
50. Spare Latitude or Stride Vial.
51. Spare Vertical Circle Vial.
52. Spare Plate Vial—Large.
53. Spare Plate Vial—Small.
54. Instrument Cover.
55. Telescope Plug.
56. Sun Shade.
57. Steel Spring.
58. Micrometer Screw of Microscope.
59. Milled Head of Microscope.
60. Drum of Microscope.
61. Springs.
62. Objective of Microscope.
63. Cell of Microscope Objective.
64. Tube Supporting Objective Cell.
65. Draw Tube of Microscope Objective.
66. Pins on Draw Tube.
67. Slots in Supporting Tube.
68. Capstan Ring for Centering Objective.
69. Capstan Nuts Operating Draw Tube.
70. Plaster of Paris Reflector.
71. Spring Catch.
72. Ring.
73. Diaphragm Support.
74. Screws Holding Diaphragm Support.
75. Capstan Screws for Centering Diaphragm.
76. Screws.
77. Micrometer Carriage.
78. Movable Thread.
79. Micrometer Screw.
80. Springs.
81. Diaphragm Ring.
82. Drum.
83. Gear.
84. Milled Head.
85. Index Marks.
86. Recorder.
87. Index Mark.
88. Screw.
89. Cover Screws.
90. Screws.
91. Screws.
92. Five Parallel Spider Threads.
93. Transverse Thread.
94. Focussing Nut.
95. Focussing Nut.
96. Draw Tube.
97. Supporting Tube.
98. Rheostat Resistance Wire.
99. Rubber Core.
100. Brass Casing.
101. Contact Spring.
102. Ring Clamp.
103. Neutral Wire.
104. Contacts.
105. Switch Ring.
106. Switch.
107. Instrument Clamp.
108. Latitude Arc.
109. Capstan Collimation Screws.

INDEX OF NUMBERED PARTS—*Concluded.*

110 Screws Holding Micrometer Eye-piece to Telescope.
111 Index of Microscope Drum.
112 Clips.
113 Clamping Screws.
114 Levelling Screws.
115. Horizontal Clamp.
116 Horizontal Tangent Screw.
117 Focussing Head.
118 Shutter Head.
119 Vertical Circle.
120 Reader.
121 Vertical Tangent Screw.
122 Clamping Nut.
123 Capstan Screw.
124 Projection on Upper Plate.
125 Capstan Screw.
126 Transverse Axis Clamp Tangent Screw.
127 Annular Base of Eye-piece Micrometer.
128 Collimation Linear Guides.
129 Screws Holding Collimation Linear Guides.
130 Bearing of Telescope Micrometer.
131 Micrometer Body.
132 Retaining Washer.