IMAGE EVALUATION
TEST TARGET (MT-3)

6"

Photographic
Sciences
Corporation

23 WEST MAIN STREET
WEBSTER, N.Y. 14580
(716) 872-4503

Ca

Technical and Bibliographic Notes/Notes techniques et bibliographiques

The Institute has attempted to obtain the best original copy available for filming. Features of this copy which may be bibliographically unique, which may alter any of the images in the reproduction, or which may significantly change the usual method of filming, are checked below.

L'Institut a microfilmé le meilleur exemplaire qu'il lui a été possible de se procurer. Les détails de cet exemplaire qui sont peut-être uniques du point de vue bibliographique, qui peuvent modifier une image reproduite, ou qui peuvent exiger une modification dans la méthode normale de filmage sont indiqués ci-dessous.

- [ ] Coloured covers/ Couverture de couleur
- [ ] Covers damaged/ Couverture endommagée
- [ ] Covers restored and/or laminated/ Couverture restaurée et/ou pelliculée
- [ ] Cover title missing/ Le titre de couverture manque
- [ ] Coloured maps/ Cartes géographiques en couleur
- [ ] Coloured ink (i.e. other than blue or black)/ Encre de couleur (i.e. autre que bleue ou noire)
- [ ] Coloured plates and/or illustrations/ Planches et/ou illustrations en couleur
- [ ] Bound with other material/ Relié avec d'autres documents
- [ ] Tight binding may cause shadows or distortion along interior margin/ La reliure serrée peut causer de l'ombre ou de la distorsion le long de la marge intérieure
- [ ] Blank leaves added during restoration may appear within the text. Whenever possible, these have been omitted from filming/ Il se peut que certaines pages blanches ajoutées lors d'une restauration apparaissent dans le texte, mais, lorsque cela était possible, ces pages n'ont pas été filmées.
- [ ] Additional comments:/ Commentaires supplémentaires:

- [ ] Coloured pages/ Pages de couleur
- [ ] Pages damaged/ Pages endommagées
- [ ] Pages restored and/or laminated/ Pages restaurées et/ou pelliculées
- [x] Pages discoloured, stained or foxed/ Pages décolorées, tachetées ou piquées
- [ ] Pages detached/ Pages détachées
- [x] Showthrough/ Transparence
- [ ] Quality of print varies/ Qualité inégale de l'impression
- [ ] Includes supplementary material/ Comprend du matériel supplémentaire
- [ ] Only edition available/ Seule édition disponible
- [ ] Pages wholly or partially obscured by errata slips, tissues, etc., have been refilmed to ensure the best possible image/ Les pages totalement ou partiellement obscurcies par un feuillet d'errata, une pelure, etc., ont été filmées à nouveau de façon à obtenir la meilleure image possible.

This item is filmed at the reduction ratio checked below/
Ce document est filmé au taux de réduction indiqué ci-dessous.

10X	12X	14X	16X	18X	20X	22X	24X	26X	28X	30X	32X
								✓			

The copy filmed here has been reproduced thanks to the generosity of:

Library of the Public
Archives of Canada

The images appearing here are the best quality possible considering the condition and legibility of the original copy and in keeping with the filming contract specifications.

Original copies in printed paper covers are filmed beginning with the front cover and ending on the last page with a printed or illustrated impression, or the back cover when appropriate. All other original copies are filmed beginning on the first page with a printed or illustrated impression, and ending on the last page with a printed or illustrated impression.

The last recorded frame on each microfiche shall contain the symbol → (meaning "CONTINUED"), or the symbol ▽ (meaning "END"), whichever applies.

Maps, plates, charts, etc., may be filmed at different reduction ratios. Those too large to be entirely included in one exposure are filmed beginning in the upper left hand corner, left to right and top to bottom, as many frames as required. The following diagrams illustrate the method:

L'exemplaire filmé fut reproduit grâce à la générosité de:

La bibliothèque des Archives
publiques du Canada

Les images suivantes ont été reproduites avec le plus grand soin, compte tenu de la condition et de la netteté de l'exemplaire filmé, et en conformité avec les conditions du contrat de filmage.

Les exemplaires originaux dont la couverture en papier est imprimée sont filmés en commençant par le premier plat et en terminant soit par la dernière page qui comporte une empreinte d'impression ou d'illustration, soit par le second plat, selon le cas. Tous les autres exemplaires originaux sont filmés en commençant par la première page qui comporte une empreinte d'impression ou d'illustration et en terminant par la dernière page qui comporte une telle empreinte.

Un des symboles suivants apparaîtra sur la dernière image de chaque microfiche, selon le cas: le symbole → signifie "A SUIVRE", le symbole ▽ signifie "FIN".

Les cartes, planches, tableaux, etc., peuvent être filmés à des taux de réduction différents. Lorsque le document est trop grand pour être reproduit en un seul cliché, il est filmé à partir de l'angle supérieur gauche, de gauche à droite, et de haut en bas, en prenant le nombre d'images nécessaire. Les diagrammes suivants illustrent la méthode.

1	2	3

1
2
3

1	2	3
4	5	6

ADVANCE PROOF—(*Subject to revision*).

This proof is sent to you for discussion only, and on the express understanding that it is not to be used for any other purpose whatever.—(*See Sec. 47 of the Constitution*).

Canadian Society of Civil Engineers.

INCORPORATED 1887.

TRANSACTIONS.

N.B.—This Society, as a body, does not hold itself responsible for the facts and opinions stated in any of its publications.

A MICROMETER ATTACHMENT FOR THE TRANSIT INSTRUMENT, WITH EXAMPLES OF ITS USE IN SURVEYING, LEVELLING, ETC.

BY W. T. THOMPSON, A.M.CAN.SOC. C.E.

The accompanying photograph represents a 6 inch reiteration transit, with micrometer attachment, the latter was constructed to my order by Mr. James Foster of Toronto, and in connection with the transit telescope affords the means of measuring with great accuracy small vertical angles between the limits of 0.8 and 3.

It consists of a metal box firmly attached to the vernier plate of transit in a plane at right angles to the horizontal axis of telescope, and containing a micrometer screw, with divided head and vernier, and two movable nuts N and I, the former has 40 threads to the inch, and bears against the vertical clamping bar B being kept in close contact by the spring S.

The head of screw is divided into 100 parts, and is read by the vernier V to the $\frac{1}{1000}$th part of a revolution, and as each complete revolution moves the nut N through $\frac{1}{40}$th of an inch, the $\frac{1}{1000}$th part will move it through the $\frac{1}{40000}$th of an inch, and as the length of the clamping bar B from centre of axis to point of contact with nut N is $6\frac{1}{2}$ inches, this will move the telescope through an angle of 0. 8," which is the smallest that can be measured with this micrometer.

The index nut I is for recording the number of revolutions made by the screw; it has 20 threads to the inch, and the edge of box is divided into 20 parts to an inch, so that each turn of the screw carries the index nut through one division; therefore, in making any observation, the number of complete revolutions is read off from the scale, and any fractional part from the divided head and vernier.

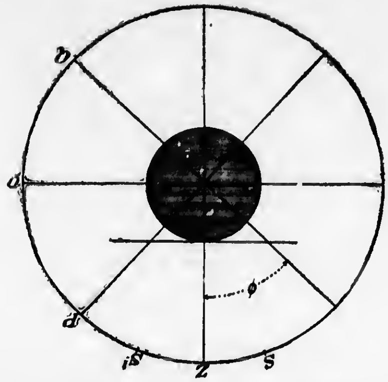
The clamping bar B consists of two parts so arranged that the telescope may be moved in altitude either by the micrometer or by the ordinary tangent screw T, so that when desired the micrometer may be set at zero or any reading, and the telescope accurately set on any object by the tangent T.

In measuring distances with this micrometer, the writer has used for a base a light round rod 30 links in length, about 2 inches in diameter at the bottom, tapering to 1 inch at the top, and provided with a universal spirit level to ensure verticality, with 3 targets, one 5 links from the bottom, one 10 links above this, and one at top of rod, giving a clear distance of 25 links between the outside targets. The targets were formed of bright tin and black rubber tacked on the rod, as shewn in the margin.

The tin reflecting light and the black rubber absorbing it, the division between them was very distinct.

The lower targets 10 links apart were only used in measuring short distances, the outer targets 25 links apart being used in all other cases.

If a distance of say 40 chains be measured on a piece of level ground or upon the ice, and the number of turns of the micrometer screw required to move the horizontal wire of the telescope from one target to another be denoted by n, then as the base is very short as compared with distances to be measured, it may be considered to represent the



arc which subtends the angle at the instrument, and this angle will vary inversely with the radius or distance. Therefore at one chain the number of turns of the screw would be represented by $40\,n = N$. If now the rod be held at any unknown distance denoted by **X** chains, and the number of turns of the screw is observed $= n'$ then $X = \frac{N}{n'}$ where the base subtending n' is very small as compared with its distance from the instrument, and the effect of differential refraction is assumed to be constant.

As, however, at different distances from the instrument the difference of refraction of the targets will vary slightly, it is necessary, in order to prepare an accurate table for reducing the observed readings to distances, to note the actual readings at each chain of distance from 5 chains up to 50 chains, and interpolate the readings for differences of 10 links. The distances corresponding to any observed readings can then be at once obtained by inspection. The condition of the atmosphere at the time should be noted, and on different days, if one or two distances are chained, and the observed readings compared with those given by the table, we shall be able to apply corrections to the tabular distances due to different atmospheric conditions.

The horizontal wire of the telescope should be very fine and the object glass and eye-piece must be very carefully focused. It is also important that the axis should be secured with moderate pressure in the Ys, and to obviate as far as possible the tendency to rise, the spring S must be slightly bent so as to grip the stud against which it bears.

The telescope used has an objective of 1.5 inches clear aperture and 10.5 inches focus, and the eye-piece a magnifying power of 32 diameters.

With this instrument and the 25 link target rod described, distances up to 40 chains may be measured, with an error seldom exceeding ½ link per chain, and with a more powerful telescope it is probable even closer results could be obtained.

We shall now give some examples of the use of this attachment in surveying and engineering operations.

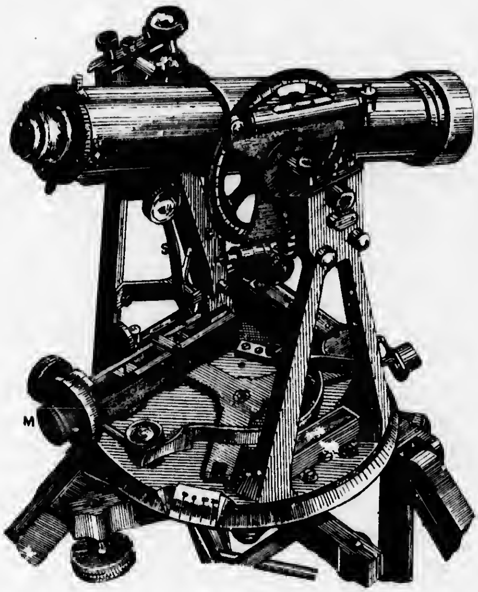
I.

A method of traversing with the transit and micrometer attachment In regard to traverse surveys, the Manual of Survey for Dominion Lands provides as follows:—

"The use of the micrometer for such work will be allowed, provided that the closing error does not exceed one chain in one hundred chains. The micrometer must be of an approved pattern, and must be submitted to the Surveyor General before being used on the survey."

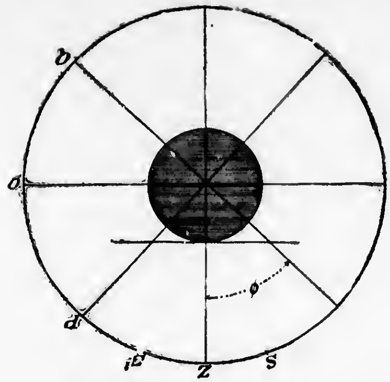
The micrometer attachment described complies with the requirements, and in connection with the transit affords the means of making traverse surveys with great facility.

The method used by the writer is as follows: the instrument being set up on the shore of a river or lake, and either on one of the survey lines or at a point fixed in position with reference to the same. It is



set up at the starting point of the survey, and carefully levelled, the direction of the line is fixed by readings of the horizontal circle, the bubble of telescope level brought to zero and reading of micrometer noted, then the lower target being adjusted to the height of the telescope, the rod-man proceeds along the line and holds the rod at all points where any marked changes of inclination occur, the distance to each point being determined from readings on the targets, also the difference between the micrometer reading for level zero and the reading on the lower target gives the difference of level by consulting our table.

We may also obtain the direction, distance, and difference of level of points on either side of the line referred to the Instrumental Stations, and without planting any stakes except at these stations, collect the necessary data for preparing a plan, profile and cross sections of the line, from which a location can be decided on, which would then be chained, staked and levelled in the usual way.



arc which subtends the angle at the instrument, and this angle will vary inversely with the radius or distance. Therefore at one chain the number of turns of the screw would be represented by $40\ n = N$. If now the rod be held at any unknown distance denoted by X chains, and the number of turns of the screw is observed $= n'$ then $X = \frac{N}{n'}$ where the base subtending n' is very small as compared with its distance from the instrument, and the effect of differential refraction is assumed to be constant.

As, however, at different distances from the instrument the difference of refraction of the targets will vary slightly, it is necessary, in order to prepare an accurate table for reducing the observed readings to distances, to note the actual readings at each chain of distance from 5 chains up to 50 chains, and interpolate the readings for differences of 10 links. The distances corresponding to any observed readings can then be at once obtained by inspection. The condition of the atmosphere at the time should be noted, and on different days, if one or two distances are chained, and the observed readings compared with those given by the table, we shall be able to apply corrections to the tabular distances due to different atmospheric conditions.

The horizontal wire of the telescope should be very fine and the object glass and eye-piece must be very carefully focused. It is also important that the axis should be secured with moderate pressure in the Ys, and to obviate as far as possible the tendency to rise, the spring S must be slightly bent so as to grip the stud against which it bears.

The telescope used has an objective of 1.5 inches clear aperture and 10.5 inches focus, and the eye-piece a magnifying power of 32 diameters.

With this instrument and the 25 link target rod described, distances up to 40 chains may be measured, with an error seldom exceeding $\frac{1}{2}$ link per chain, and with a more powerful telescope it is probable even closer results could be obtained.

We shall now give some examples of the use of this attachment in surveying and engineering operations.

I.

A method of traversing with the transit and micrometer attachment

In regard to traverse surveys, the Manual of Survey for Dominion Lands provides as follows:—

"The use of the micrometer for such work will be allowed, provided that the closing error does not exceed one chain in one hundred chains. The micrometer must be of an approved pattern, and must be submitted to the Surveyor General before being used on the survey."

The micrometer attachment describe dcomplies with the requirements, and in connection with the transit affords the means of making traverse surveys with great facility.

The method used by the writer is as follows: the instrument being set up on the shore of a river or lake, and either on one of the survey lines or at a point fixed in position with reference to the same. It is carefully levelled, at the horizontal circle reading for the north point noted. Then the rod-man proceeding along the shore holds the rod at all points where marked deviations occur, the position of each point being fixed in direction and distance from the instrumental station, by readings of the horizontal circle and micrometer. At suitable points new stations are taken and the survey continued in the same manner. The notes are entered in the field book under the following headings, and written from the bottom upwards, the topography being shewn in margin. If a repetition instrument is used, the two columns headed H.C.R. and H.C.R. on N are not required.

Stn.	H.C.R.	H.C.R on N	Azimuth	Mic Readings S — L	Distance	Remarks.

It is convenient to have rod-man travel uniformly from left to right, viz., in the direction given by the hands of a watch, and any topography will then be shewn in left hand margin.

If the initial station be called O, then the points fixed from it may be conveniently designated O_1, O_2, O_3, etc., O to 1: 1_1, 1_2, 1_3, etc. The reduced notes are placed in three columns, under the headings: Station, Azimuth, Distance, and from this data the points are plotted on a scale of 20 chains to an inch, and the shore line defined by joining these points.

No matter how irregular the shore line may be, a perfect representation of it can be obtained by this method, and in much less time than would be required by the system of survey lines and offsets.

Regarding the areas of the broken quarter sections, it may be stated that as a water boundary is a variable one, depending on variations of the water level, extreme accuracy in determining these areas is not necessary, and the planimeter or some graphical method will usually give sufficiently close results.

II.

To determine differences of level and establish grades on preliminary railway and other surveys.

The telescope must be provided with a good spirit level, and the horizontal wire adjusted to define a horizontal line when the bubble is at zero.

Then if we note the point on a rod at the distance of say 500 feet where this line strikes, and turn the micrometer screw through one revolution, the distance between the two points on the rod being measured, 1-5th of it is the rise or fall in 100 feet for one turn of the screw, and we can now prepare a table giving the number of turns required for various grades, also of the rise or fall in feet at different distances, these tables should include the effect of curvature and refraction.

We also require a target rod consisting of two pieces sliding upon each other, as shewn in margin, in order that the piece carrying the targets may be pushed up or down, so that the lower target can be set at the height of the telescope above the ground, and clamped in position. The distance between the targets may be 5 or 6 feet, and a table for reducing observed micrometer readings to distances can be prepared in the manner already described.

We are now prepared for surveying and obtaining the levels and distances along any preliminary line without the use of the chain or any other instrument.

The mode of proceeding will be as follows: The instrument being set up at the starting point of the survey, and carefully levelled, the direction of the line is fixed by readings of the horizontal circle, the bubble of telescope level brought to zero and reading of micrometer noted, then the lower target being adjusted to the height of the telescope, the rod-man proceeds along the line and holds the rod at all points where any marked changes of inclination occur, the distance to each point being determined from readings on the targets, also the difference between the micrometer reading for level zero and the reading on the lower target gives the difference of level by consulting our table.

We may also obtain the direction, distance, and difference of level of points on either side of the line referred to the Instrumental Stations, and without planting any stakes except at these stations, collect the necessary data for preparing a plan, profile and cross sections of the line, from which a location can be decided on, which would then be chained, staked and levelled in the usual way.

III.

A very important use to which this attachment can be applied is the determination of the latitude by measuring small differences of zenith distance of North and South stars by a method somewhat similar to that by the zenith telescope.

For this purpose a very sensitive spirit level must be attached to the vertical clamping bar B in a plane at right angles to the horizontal axis of telescope, and the bubble should be adjusted to read zero when the index nut I is at the centre of the scale; this level should read to say 3," for one *mm* space, so as to readily show a displacement of $\frac{1}{4}''$. The time, azimuth, and approximate latitude may be readily obtained from observations on Polaris and another star in the same vertical plane.

Then with the approximate latitude or declination of the zenith point, we select from a Star Catalogue, such as the Berliner Jahrbuch, a pair of stars between the 2nd and 5th magnitudes, which culminate as nearly as possible at equal distances to the north and south of the zenith, and within say 30 degrees of it, differing not more than 2 degrees in zenith distance, nor more than say 30 minutes in right ascension.

The observer should be supplied with a chronometer or watch adjusted to sidereal time.

Shortly before the time of transit of the first star the telescope will be brought into the meridian plane by readings of the horizontal circle, and the vertical finding circle set for the mean zenith distance of the two stars. The latitude level will then be brought to zero by turning the micrometer screw and reading of same noted; the screw will then be turned to the right or left, according as it is necessary to depress or elevate the telescope, to set it at the zenith distance of the star, and when it appears in the field, the horizontal wire will be set upon it, and a precise bisection made when it reaches the middle wire, the micrometer reading will then be noted, the screw reversed and level again brought to zero, the micrometer reading again noted and mean of the two readings taken as the true reading for level zero at the instant of the star's transit. The instrument is then turned 180°, in Azimuth, and similar observations taken on the other star.

With this micrometer, a right hand motion of the screw will increase the readings and zenith distances. If, therefore, we denote the reading on the star nearest the zenith by m and the reading for level zer for same star by m_0, then the arc measured by the micrometer is represented by $m_0 - m$; and if we denote similar readings for the other star by m_1 and m_0, then the arc measured will be represented by $m_1 - m_0$; and the sum will represent the total change of inclination of the telescope, or difference of apparent zenith distances $= m_1 - m + m_0 - m_{01}$ which must be reduced to seconds of arc by multiplying by R the number of seconds in one revolution of the screw; this will be determined from observations on Polaris near its elongation, or by measuring the difference of declination of close stars at their transit over the Meridian; the value will vary slightly with the number of turns, and should be tabulated for different intervals. Then using the value corresponding to the observed interval, we shall have for the apparent difference of zenith distance $(m_1 - m + m_{01} - m_0)R'' = (z - z')$, in seconds of arc, where z denotes the zenith distance of southern and z' of northern star.

In the diagram let P denote the North Pole, Z the Zenith, EQ the Equator, S the Southern, and S' the Northern Star; S E and S' E = S and S' their declinations, Z S, and Z S', their true zenith distances = Z and Z', and r and r' their refractions.

Then denoting the latitude ZE by ϕ. We have $\phi = (S + Z) = (S' - Z')$. Therefore $2\phi = S + S' + Z - Z'$, and since $Z = Z + r$, and $Z' = Z' + r'$, inserting these values, our formula becomes

$$\phi = \left(\frac{S + S' + Z - Z' + r - r'}{2}\right) = \left(\frac{S + S' + r - r'}{2}\right) + \frac{Z - Z'}{2}$$

inserting the value of $Z - Z$, as measured by the micrometer, the final formula is

$$\phi = \left(\frac{S + S'' + r - r''}{2}\right) = \left(\frac{m_1 - m + m_0 - m_{01}}{2}\right) R''$$

in which the sign of the second term is the same as that of $(Z - Z')$, viz., if the southern star has the greater zenith distance it will have the + sign, and *vice versa*.

By consulting a Star Catalogue it will be seen that in most latitudes several pairs of stars between the 2nd and 5th magnitudes, and differing not more than 30 minutes in R, A, nor more than 2 degrees in declination, would be available for observation with a good transit telescope.

This method would be found useful in determining latitudes in exploratory surveys, in connection with micrometer work, and should give the latitude within 2″ or 3″.

WM. T. THOMPSON.