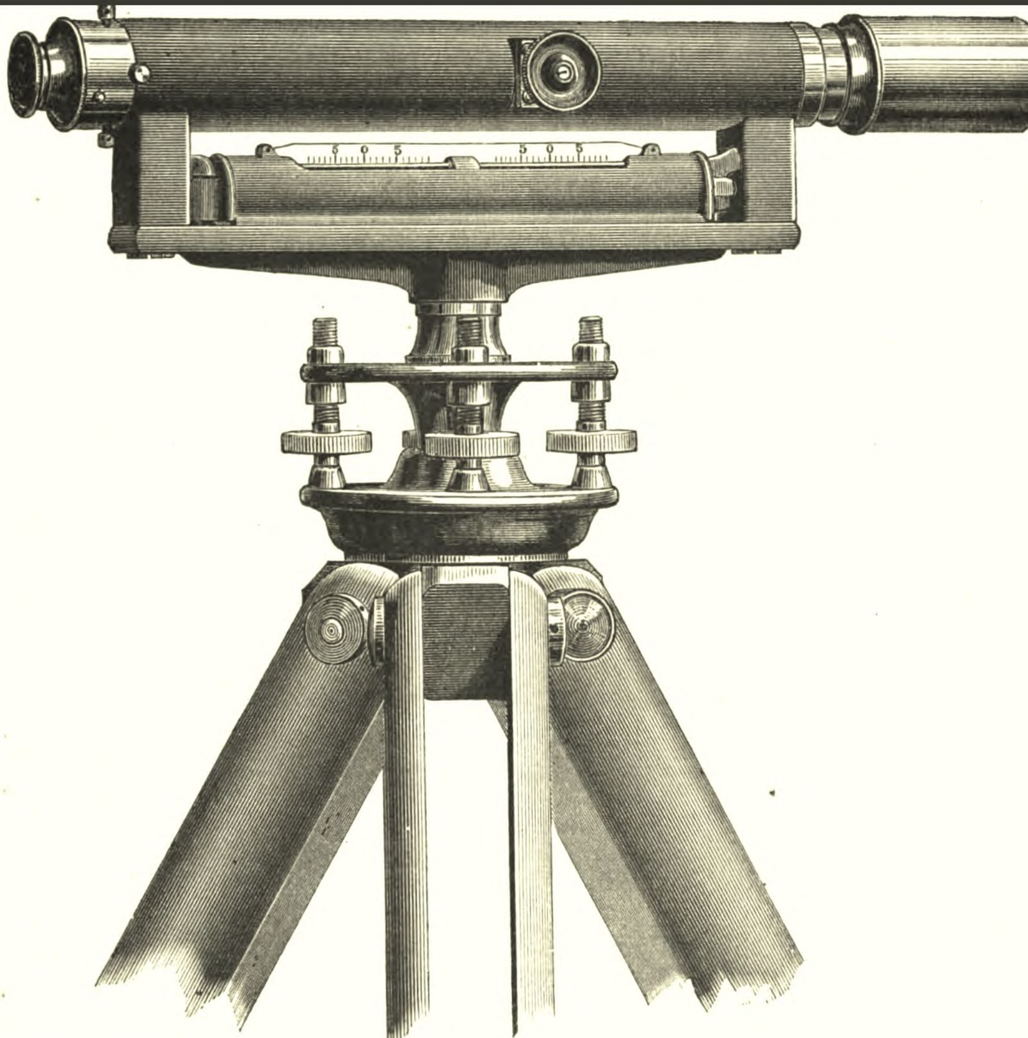

# Handbook and illustrated catalogue of the engineers' ...

C.L. Berger & sons

ESTABLISHED 1871.

ASTRONOMICAL INSTRUMENTS.

ENGINEERS' TRANSITS. ENGINEERS' LEVELS.

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# HAND-BOOK AND ILLUSTRATED CATALOGUE

OF THE

# Engineers' and Surveyors'

# INSTRUMENTS,

MADE BY

# BUFF & BERGER,

NO. 9 PROVINCE COURT, : : : BOSTON, MASS.



1884.

**PRICE 60 CENTS.**

McIndoe Bros., Printers, 40 Oliver St., Boston, Mass.

This Catalogue and Price List supersedes all former editions.

We make no deductions from Catalogue Prices.

Customers ordering from a distance will please remit by registered letter, money order, or draft, made payable to us, or the goods will be sent C. O. D., the expense of collection to be borne by the purchaser.

Small articles can be sent per mail, at the purchaser's risk when the cost of postage, one cent for every ounce, is remitted in addition to the price.

We furnish packing boxes at cost prices.

Please be careful to add the County and State to your address

# Testimonials.

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**Engineers and Surveyors living at a distance, who do not know the quality of our work, we wish to refer to the following, which speak for themselves:**

*Office of City Surveyor, City Hall,*
*Boston, Oct. 14th,* 1876.

**The Surveying Instruments, manufactured by Messrs BUFF & BERGER, have been used in this department for several years past, and have given excellent satisfaction, both for accuracy and thoroughness in their manufacture.**

THOMAS W. DAVIS, City Surveyor.

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*Boston Water Works, (additional supply.) Engineer's Office,*
*South Framingham, Mass., Oct.* 19, 1876.

Messrs. BUFF & BERGER, Boston.

Gentlemen: — Four transits and five levels made by you are in use in this department, and they have always given good satisfaction. For their general working qualities they compare favorably with other good instruments, and they can be particularly recommended as being very stiff and steady, although light in weight.

Yours truly,

A. FTELEY, Resident Engineer.

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*City of Cambridge, Office of City Engineer, City Hall,*
*Cambridgeport, Oct.* 24, 1876.

Messrs. BUFF & BERGER,

Gentlemen: — The four instruments made by you for the Engineering Department of Cambridge, viz: two Transits and two Levels, have been in constant use and have given perfect satisfaction. With the eighteen inch Y Level, very close results have been obtained. The Dumpy Level has proved a very useful as well as a reliable instrument.

The Transits with the Gradienter screw attachment are in all respects equal to your guarantee, and have proved to be valuable and reliable in all respects.

Very truly yours, W. S. BARBOUR, City Engineer.

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*Canada Central Railway Extension.*
*Renfrew, Ontario, May* 22, 1876.

Messrs. BUFF & BERGER, Boston, Mass.

Gentlemen: — In April of 1875, this Company purchased of you one of your transits, and it has been in use ever since. It is but justice to you to state that I prefer it for Railway work to any other that has come under my notice of late years The material is good; your "improvements" are rightly named, and the workmanship is excellent. We have found that its work is accurate. In regard to stability of tripod, reliability of instrument in its adjustments, and strength combined with lightness, it gives thorough satisfaction. Both myself and assistants consider it a first-class instrument.

Wishing you the success that the merit of your work deserves, I am,

Yours, etc., ROBERT L. HARRIS, Engineer Can. Cent. R'y Ext.

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*Office of U. S. Lake Survey,*
*Detroit, Mich., Sept.* 27, 1876.

Messrs. BUFF & BERGER, Boston, Mass.

Gentlemen: — In reply to your question of the 23d inst., I would say, that a more complete examination of your Astronomical Transit. No. 2, has been made, and I find that the difference of the diameters of the pivots is 0.''000021, a mean of 96 determinations. The greatest difference in elevation of top of pivot at circle of contact in wyes, is in east pivot "Telescope direct." This difference amounts to 0.''000026, a mean of 39 determinations. The greatest difference in the value of one division of level, between limits 41 A end and 39 B end, is 0'.1. The cast iron frame is steady and seems to have sufficient strength. No deflection (flexion) has been noticed in the telescope. The collimation has been very steady, indicating stable object-glass and wires. The object-glass is very good. The instrument keeps its adjustment well. As a whole the instrument is very good.

Respectfully yours,

C. B. COMSTOCK,
Maj. of Engineers and Bvt. Brig. Gen'l, U. S. A

## Letter of J. B. Davis, Prof. of Civil Engineering, University of Michigan.

*University of Michigan, Eng. Dept.,*
*Ann Arbor, Sept. 15th,* 1879.

Messrs. Buff & Berger.

Gentlemen: — Your letter of the 10th is before me. In reply I say, that I intended long since to have given you some account of the engineers' transit No. 177, furnished by you for this department of the university. As a recompense for the delay, however, I can now say more about this transit than I could when first received. It has been in use now a year, and the following points are apparent.

*General Designs and Details.* Good. Many of the details are well worked out in a manner only to be fully appreciated by actual field service. I particularly like the plate camp.

*Tripod.* Excellent. * * * *

*Bearings and Connections.* All work very smooth and uniformally. This shows excellent shop-work.

*Plates and Verniers.* Verniers very perfect This instrument is designed to read to 30″. The graduations are so perfect that I can read the plate to 10″. * * * * * * * *

*Telescope.* Very satisfactory.

*Adjustments.* These were found correct as far as tested, when the instrument arrived after 700 miles travel by express, and numerous observations in the field show that they have remained so till now. These adjustments are, the plate levels, the line of sight at right angles to transit axis, the telescope level and vertical circle.

*Result of a year's trial.* This is the best instrument of its grade I ever used, and I have had experience with those of a half dozen or more different makers.

Respectfully yours,

J. B. DAVIS.

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## Extract of Report on Triangulation connected with the Re-Survey of Boston Upper Harbor for the Massachusetts Board of Harbor Commissioners, 1877-78.

By FRANCIS BLAKE, Jun., Assistant U.S. Coast Survey.

*Boston, Mass., March,* 1878.

Mr. C. P. Patterson, Superintendent United States Coast Survey.

Sir: — By an Act of the Massachusetts Legislature of 1877, an appropriation for the re-survey of Boston Upper Harbor was made, to be expended under the direction of the honorable Board of Harbor Commissioners of the Commonwealth.

In September last, in response to a request of the Board, you were pleased to instruct me to execute the triangulation connected with this re-survey; and I now have the honor of making a final report on its execution, and of transmitting to you its records, computations, and final results.

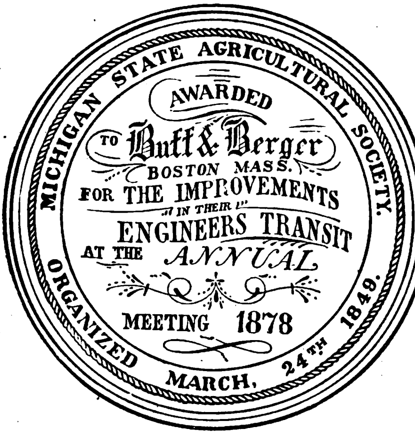
* * * * * * * * * * * * * * * * * * *

At the beginning of the work the Coast Survey theodolite No. 12 was used It is a repeating instrument, made by Gambey of Paris: its horizontal circle is six inches in diameter, and is graduated to be read to ten seconds of arc by two equidistant verniers. The superior construction of this instrument is well known; but, owing to its low telescopic power, it was not suitable for use on the longer lines of our work. Most of the angular measurements were made with a new theodolite, constructed for the Board, with special reference to the work, by Messrs. Buff & Berger of Boston. It is a repeating instrument, with a horixontal circle eight inches in diameter, graduated to be read to ten seconds of arc by two equidistant verniers; but is easily read to five seconds by estimation. The object-glass has a clear aperture of an inch and a half, and a focal length of about eleven inches, which allows the telescope to be revolved in its bearings without making the wye standards of an unusual height.

There are two achromatic eye-pieces, the magnifying powers of which are twenty-two and thirty diameters. The one of lower power was used throughout the work. The intersection of the spider-lines is such that the vertical angles are of sixty degrees

The angles of the main triangle, Blue Hill, Prospect Waltham, and Powderhorn,* were measured with this instrument; and, when corrected for spherical excess, they "close" that triangle within forty-nine hundredths of a second of arc. Their probab'e errors, as computed bv the method of least squares, are 0″.32 at Blue Hill, 0″.23 at Prospect Waltham; and 0″ 46 at Powderhorn. These results have been given elsewhere in this report; but I repeat them here, as perhaps the best proof that can be given of the superior construction of the Buff & Berger theodolite.

* Distance from Blue Hill to Prospect Waltham=22722.78 meters.
Distance from Powderhorn to Blue Hill=22100.29 meters
Distance from Powderhorn to Prospect Waltham=18426 69 meters.


SILVER MEDAL.



SILVER MEDAL.



SILVER MEDAL.



# GOLD MEDAL.

**Report of Judges of the Thirteenth Exhibition of the Mass. Charitable Mechanic Association, Boston, 1878.**

Buff & Berger, Boston, Mass.—Engineering and Surveying Instruments.—These contributors are justly classed among the best manufacturers in this country. They made a very full exhibition of their instruments, with the exception of astronomical instruments, which they manufacture only to order, and therefore do not keep a supply on hand. The following were the principal instruments of their own manufacture exhibited: Transit for triangulation, engineers' large transit, engineers' small transit, transit for mining and reconnoissance, Y-level, dumpy level, reading level, engineers' ordinary spirit level, plummet lamps. There were also many other smaller articles and instruments with the above for exhibition only, and not invoiced for award. These mechanicians show great skill in the manufacture of their instruments, uniting high accuracy and finish with lightness, combined with stiffness and strength. They have. within a few years, made many inportant and valuable improvements; and, by seeking advice and suggestions from engineers and scientific men, keep in advance of many other manufacturers in this respect. A full description of *all* the improvements made by them cannot be given, but among the more recent ones may be mentioned the following: 1. The gradienter screw. This attachment is said to have been first introduced by Prof. Stampfer of the Vienna Polytechnic School. It is attached to the clamp of the telescope, and is used for establishing grades with great rapidity, and for determining horizontal distances, thus dispensing with stadia wires for the last-mentioned purpose. Also a new attachment of a horizontal gradienter to the vernier plate of the instrument, to be used with a horizontal rod for determining distances. These micrometer screws can also be used in the reading of angles where closer results than are ordinarily obtained with verniers are desirable. 2. New form of standard to mount telescope on, securing greater lateral stiffness without increasing the weight. 3. New manner of mounting the telescope axis and its bearings, to obtain a high degree of accuracy in ordinary instruments. 4. New method of completely protecting from dust the telescope axis, by placing covers over the bearings. The covers can be readily removed when it is necessary to reverse the telescope by taking it out of the Y-s and turning it end for end, as in a theodolite. Ordinarily the telescope reverses between the standards. Their telescopes are achromatic, of high power, with large object-glasses and improved eye-pieces. The graduations of their instruments are made with great care and accuracy, and in the best class of instruments are on solid silver. **Award a Gold Medal.**

Prof. JOHN TROWBRIDGE, of Harvard University.
THOMAS W. DAVIS, City Surveyor, of Boston.
J. AVERY RICHARDS, Bay State Iron Company.
WILLIAM C. HIBBARD, Mechanical Engineer.
OSCAR GASSETT, Practical Electrician.
Prof. CHARLES R. CROSS, of Institute of Technology.
JAMES H. STEVENS, Practical Electrician.

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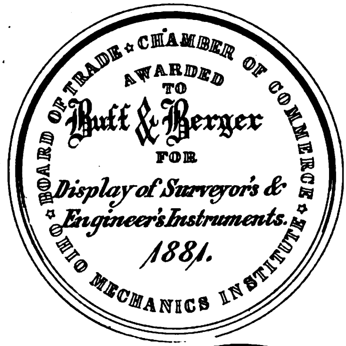
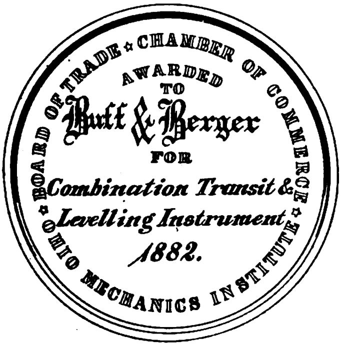
**Report of Judges of the Twelfth Exhibition of the Mass. Charitable Mechanic Association, Boston, 1874.**

In the construction of all their instruments, Messrs. Buff & Berger use a harder composition than is ordinarily used, and they use but one metal for all portions of an instrument, except centers, which are of a still harder metal. Many of the pieces usually attached by screws are cast and finished as a whole, reducing the liability of becoming loose or detached. By means of ribs they also are enabled to combine strength with less weight in the instrument. The clamp and tangent screws with spiral springs, the larger aperture for the object-glass of the telescope, the split-leg tripod and shifting center attached to the instrument, and the attachment to the transit of "Spofford's Equal Arc-Meter," together for the excellent workmanship and nicety of adjustments, are all commendable improvements. **Award a Silver Medal.**


CINCINNATI INDUSTRIAL
EXPOSITION


BOARD OF TRADE ✩ CHAMBER OF COMMERCE
AWARDED
TO
Buff & Berger
FOR
Display of Surveyor's &
Engineer's Instruments.
1881.
OHIO MECHANICS INSTITUTE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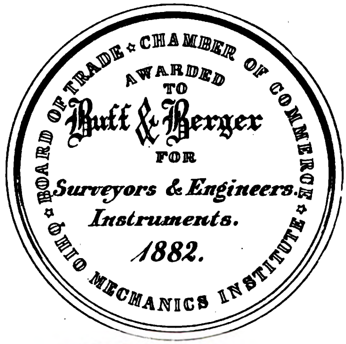
CINCINNATI INDUSTRIAL
EXPOSITION


CINCINNATI INDUSTRIAL
EXPOSITION


BOARD OF TRADE ✩ CHAMBER OF COMMERCE
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Buff & Berger
FOR
Surveyors & Engineers.
Instruments.
1882.
OHIO MECHANICS INSTITUTE


BOARD OF TRADE ✩ CHAMBER OF COMMERCE
AWARDED
TO
Buff & Berger
FOR
Instrument for
General Surveying.
1882.
OHIO MECHANICS INSTITUTE


CINCINNATI INDUSTRIAL
EXPOSITION

One of the most interesting and most carefully arranged exhibits shown at the recent exposition of railway appliances was that made by Messrs. Buff & Berger, of Boston, the well known manufacturers of surveying, engineering and astronomical instruments. The articles shown by them were all of the very best material and manufacture, and showed all the latest improvements. One of the best evidences of the appreciation of this exhibit by the railway public could have been seen in the active and general interest shown in it by the great number of people who visited the exposition. There were in the exhibit twenty-one surveying instruments, each different from the other and each representative of its kind, embodying all the latest improvements; besides a dozen or more instruments of a kindred class, including various appurtenances used in civil and mining engineering. The value of this exhibit is stated by the firm named to be over $4,000. That the results of the expenditure of money and time which this firm represented at the exposition will be satisfactory in increased business we have no question.—*Railway Age, July* 26, 1883.

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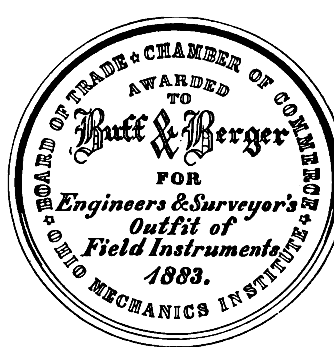

ASTRONOMICAL INSTRUMENTS.

ENGINEERS' TRANSITS. ENGINEERS' LEVELS.

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# HAND-BOOK AND ILLUSTRATED CATALOGUE

5092

OF THE

# Engineers' and Surveyors'

# INSTRUMENTS,

MADE BY

# BUFF & BERGER,

NO. 9 PROVINCE COURT, : : : BOSTON, MASS.

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**PART I.**

A FULL DESCRIPTION OF THE INSTRUMENTS AND CONCISE DIRECTIONS HOW TO TAKE CARE OF AND ADJUST THEM.

**PART II.**

ILLUSTRATED CATALOGUE AND PRICE LIST OF ENGINEERING, SURVEYING AND ASTRONOMICAL INSTRUMENTS, MANUFACTURED AND SOLD BY BUFF & BERGER.

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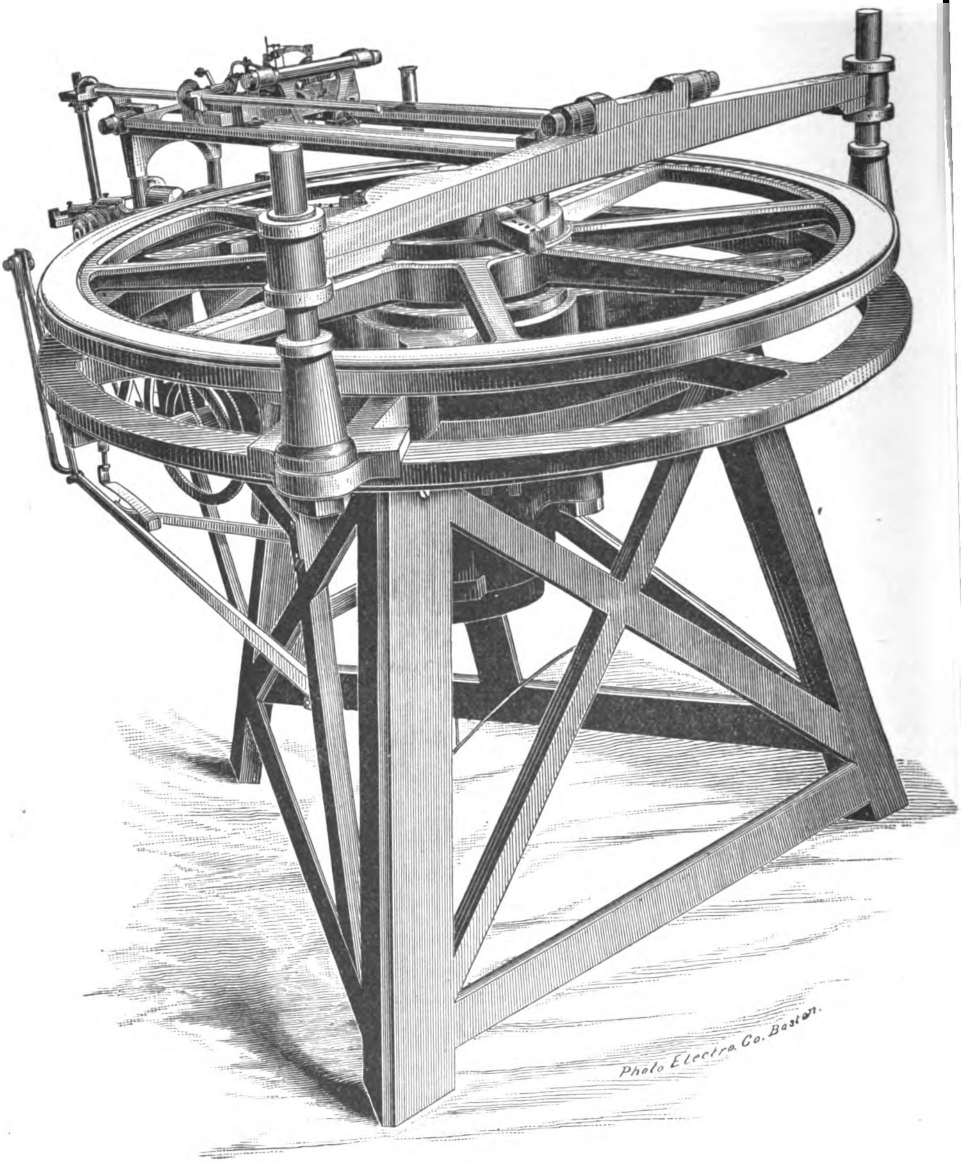



**Buff & Berger's Large Automatic Dividing Engine.**

# PREFACE.

THE Instruments enumerated in this Catalogue and described in the Manual, are those of our regular manufacture. Full supplies of Engineers' and Surveyors' Instruments will be kept on hand, but the demand of late has been so great as to exhaust our supply. Instruments varying from our customary designs, or those of rare inquiry, will be made to order only.

While the cuts given represent the instruments as they have been made by us, we nevertheless make changes from time to time, as experience and the progress of engineering show them to be desirable.

Our long experience in the manufacture of Engineering and Astronomical Instruments, enables us to unite in our Instruments the high accuracy and finish of the European makers, with the *lightness*, combined with *strength*, *steadiness*, *practicability* and *portability* required by American engineers.

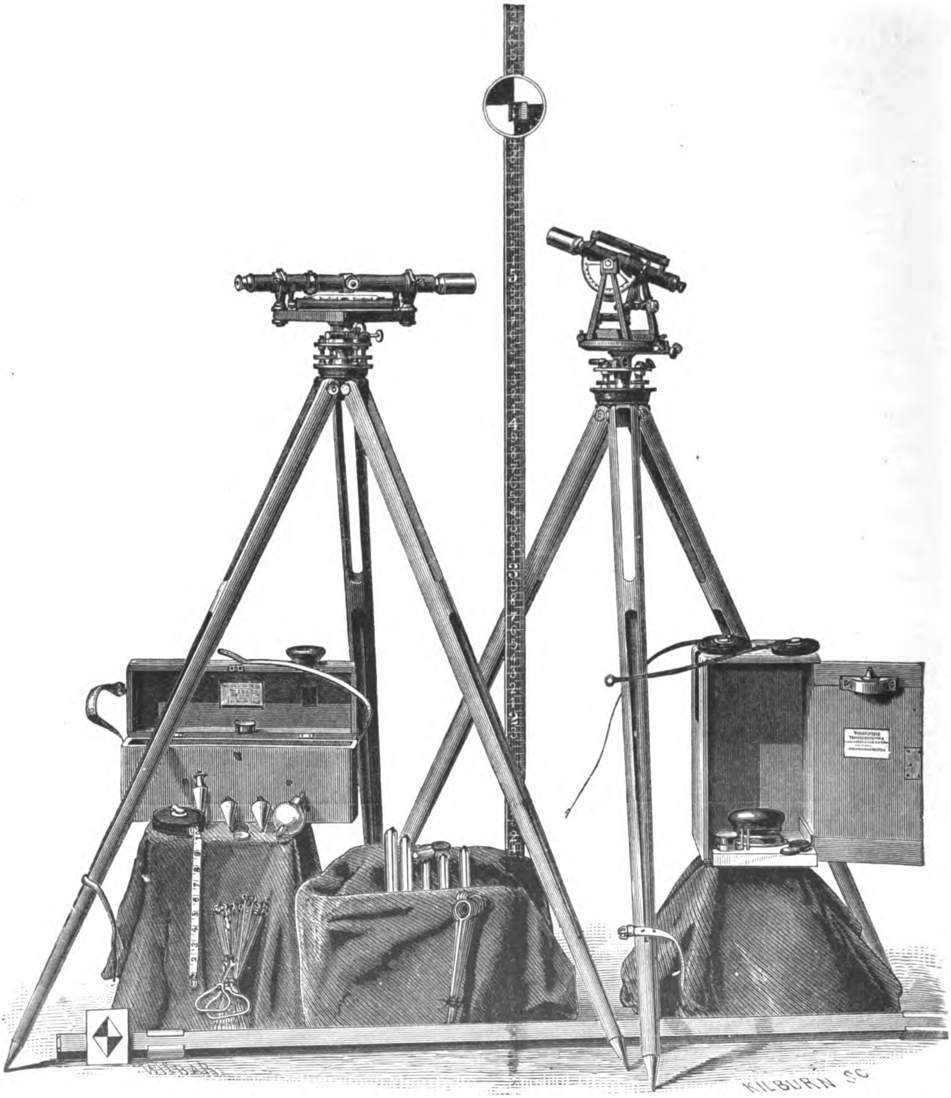
Having added to our dividing engine with a circle of two feet in diameter, one built by the late J. H. Temple, Boston, Mass., with a circle of three feet in diameter, we now possess **two automatic dividing engines,** capable of giving very satisfactory graduations. One is famous for its accuracy and great simplicity in its automatic part, the other as being a master-piece in the perfection of its every part, and as being the crowning effort of a man both eminent as a mechanician and as an instrument-maker.

A careful selection of skilled workmen, increased facilities of steam power, and the application of the most improved tools and machinery, enables us to offer at a moderate cost a very superior article. We make no pretence at manufacturing cheap Instruments,—our prices are as low as is consistent with thoroughness of workmanship and the best materials. We may here add that every instrument issued by us has its most important parts made by us in person. We include under this head, the dividing and centering of all graduations, the fitting of the centers, telescope, etc., and the final adjustment of the whole instrument.

We wish to remark that all of our telescopes are provided with such magnifying powers as will suffice to develope the full capacity of the particular instrument to which it is adapted. We make our telescopes of as large aperture as possible, and we thus secure brilliancy without the loss of accuracy consequent upon a low magnifying power; and in general the magnifying power, aperture, spirit levels and graduations are so related that a slight change in one of these points will be indicated by a change in the pointing of the telescope easily detected by the eye.

With the aid of this Catalogue, Engineers at a distance can now avail themselves of our instruments, and can rely upon being as well served as though they called on us personally.

BUFF & BERGER.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## PART I.

# DESCRIPTION

OF THE

# Essential Features of Our Instruments.

### Graduation.

This very important part of a good instrument we guarantee *exact* and *accurately centered*, opposite verniers reading the same. The lines are straight, thoroughly black and uniform in width. There are two double verniers in every transit to read angles with great rapidity as well as to make four separate readings at every sight, when extreme accuracy in the repetition of angles is required. The horizontal circle is graduated from 0° to 360° with *two* sets of figures, running in opposite directions (unless ordered differently,) and the verniers are marked **A** and **B**. The figures are large and distinct, and to avoid mistakes in reading, the figures of these two sets of graduations, and those on the verniers, are *inclined* in opposite directions, thus indicating the directions in which the verniers should be read.

Instruments intended for mining and mountain use can have the verniers so placed that they may be read without changing the position of the engineer after sighting through the telescope.

Glass covers protect the arc and verniers from exposure. For ease in reading the verniers, we have added to most of our instruments *two plates* of *ground* glass, which cast a very clear light on the verniers, in any position. We recommend this addition to all of our more complete transits. The cost will be $3 additional.

The graduations on our transits are either on brass and silvered, or else graduated on *solid silver*. The former we can only recommend for the more ordinary instruments, since imperfections in the brass or composition castings frequently impair the graduations, and the silvering is apt to tarnish with time and exposure.

To graduate on *solid silver* adds $10 to the first outlay for the instrument, but its many advantages, great permanency and smoothness of surface render it the only satisfactory surface for fine graduations.

### The Telescope.

All of its lenses are ground especially for us, by the best opticians. The telescope is perfectly *achromatic*, and designed to furnish a *large, flat* field of view with *high power* and yet without loss of light. For this purpose the curves of all our lenses are ground by special formulæ. The telescopes show objects right side up, unless ordered otherwise.*

The object-glass has a very large aperture, and is focussed by rack and pinion,† but the eye-piece is focussed by simply turning its head to the right or left in an improved screw-like manner.

By a method of construction peculiar to ourselves, we are enabled to guarantee the line of collimation correct for *all distances* without making use of the very objectionable adjustment for the object-slide by means of inner rings, which time and experience has proven to wear loose too readily, thus rendering this adjustment worse than none at all.

The eye-pieces are thoroughly achromatic, and their lenses are mounted in such a perfect manner (a method also peculiar to us) as to require no further adjustment with regard to the axis of telescope.

*It should be remembered that the focal length of the object glass is limited in engineering instruments and that a high power is obtained only at the sacrifice of light. To obtain the fullest satisfaction, telescopes intended for close work, as in stadia measurement, etc., should invariably be ordered to be inverting. The brilliancy with which objects appear in such a telescope, owing to the amount of light gained by saving two lenses in the eye-piece is very marked as compared with one of the same power and focal length showing objects erect.

†This rack and pinion motion is now so placed upon our telescopes that it is more easy of access by either hand than when placed at the side, as shown in most of our cuts.

The telescope of the transit reverses at both the eye and object ends, and is thoroughly balanced when focussed for a mean distance.

The telescope of the wye and dumpy level is also balanced *each way* from the center of the vertical axis when *focussed for mean distance* and with the *sun-shade attached to it.*

## Spirit-Levels.

The Spirit Levels used in our instruments are carefully ground, filled and tested by us in person.

Those for the highest class of engineering work are sometimes provided with an air chamber by which the length of the bubble can be regulated according to temperature. The levels for astronomical instruments have air chambers, and are filled with ether, but in field instruments ether is not admissable, owing to the high degree of expansion and contraction in that fluid with changes of temperature. For these we use a composition fluid that we have found to be more sensitive and quick-acting than that used in instruments we have seen of other makers.

Our astronomical levels are so ground that a depression through one second of arc causes a displacement of the bubble through about $\frac{1}{20}$ of an inch. The curvature or sensitiveness of our levels for field instruments we adapt carefully to the instruments and the kind of work to which they are to be applied. With too sensitive a level the position of the bubble would be too uneasy to work with, while too low a sensitiveness would not reveal the full qualities of an instrument. Persons ordering instruments of us will confer a favor by stating for what purpose they are intended, whether for water works, for railroads, or for general use, so that we can use our judgment for their benefit.

## Gradienter Screw.

[*Description to be found elsewhere* ]

This is attached to the clamp of telescope of all of our transits except the plain transit. This attachment was first introduced by Prof. Stampfer, of the Vienna Polytechnic School. It does not add to the weight of the instrument, and once used we have found it to be universally approved by our customers. By means of it *grades* can be established, and *horizontal distances*, *vertical angles* and *differences of level* can be measured with great rapidity. Indeed this attachment to an engineer's transit is one of the most useful introductions in practical engineering. It is so universal in its application to railroad and general work, that when once used it *will afterwards form an indispensible part of an engineer's outfit.*

## Fixed Stadia Wires for Distance Measurements.

We have specially devised an optical and mechanical apparatus for the purpose of placing fixed, or non-adjustable stadia wires so accurately upon the diaphragms of our telescopes that their distance apart will read 1′ : 100′ * on any leveling rod, as with the gradienter screw, thus dispensing with a special rod.

It is well known that adjustable stadia wires are so apt to change their distance apart with every change of temperature, that no reliance can be placed upon them unless previously adjusted. With fixed stadia wires, annoyances of this kind are obviated—*they are reliable at all times.*

As regards the degree of accuracy attainable by the use of fixed stadia wires, experiments with our powerful telescopes, made optically as perfect as the most advanced optical and mechanical skill enables us, warrant to say that with some experience and proper care the results obtained will approximate and even equal those obtained by chain measurements. The price for this accessory in any new instrument is only $3.00, but if inserted into a telescope sent to us for that purpose, we must charge $10.00. We advise to order both the gradienter screw and the fixed stadia wires, as each in itself, separately or jointly, will prove of great value.

* In all stadia work, the constant, which is the distance from the center of the instrument to a point in front of the object glass equal to its focal length, must be added to every measurement. Thus the constant in our transit No. 1, with inverting telescope, measured from centre of the instrument, is 1.3 feet; same instrument, telescope erecting, 1.15 feet. Transit, size as in No. 2, telescope inverting, 1.15 feet; same instrument, telescope erecting, 0.94 feet. In our 18-inch Wye level, telescope erecting, this constant is 1.78 feet.

## Tangent Screws.

These are provided with strong *spiral springs* of german silver, which take up all the dead motion, no matter how long the screw may be in use, or how worn. They are *less* liable to get out of order, by blows or accidents, than any of the existing tangent screws, and require *little* or *no* attention on the part of the engineer. There is no *strain* on either plate when the instrument is clamped, so that the levels are unaffected. They are set and turned with the *greatest ease*, following the movements of the finger instantaneously with mathematical precision, and do not *scratch* the plate in revolving instrument. We confidently recommend this form of construction to those who have not used our instrnments, as the best possible; superseding the usual methods by means of two opposing screws, or ball tangent screw, greatly in point of convenience and accuracy, and equalling them in point of steadiness. By this construction we are also able to fit our upper and lower circle plates so snugly that it is impossible for dust to enter between them. Our leveling instruments have the clamp and tangent screws so placed that they can be reached by either hand with the same readiness.

## The Compass.

The Compass circles are graduated to half degrees in quadrants from 0° to 90°. The needles are made of superior steel, and tempered all over. A coil of fine wire attached to the end pointing South balances the needle for our latitude, which must be re-balanced if the instrument is used further north or south of this latitude, and must be entirely reversed if used on the southern hemisphere of our earth. At a cost of $10.00 a variation plate can be placed upon our surveyors' transit to set off the variation of the needle for any particular locality. A stationary pointer just above the graduated ring at the South end, and protected by the glass-cover of the compass, indicates the line joining the vertical plane of the line of collimation of the telescope. By means of a milled-headed nut, also at the South end of compass, serving both as a handle and as a clamp-screw, the graduated ring can be turned past this pointer towards East or West as the case may require.

## Tripod.

The form we adopt for our instruments is an improvement over what is commonly termed the "split leg" tripod, used extensively in Europe, which unites the *greatest strength and steadiness* with the least weight. The tripod-head is cast in a single casting, to avoid all small screws, as well as to attain greater stiffness. For the legs we use the best fine grained white ash, taking particular pains that the grain of the wood runs in the direction of the leg. They are still further guarded against all possible accidents by having wooden tongs inserted at their top. When folded, our tripod is better adapted than the ordinary form, for carrying on the shoulder without irritating the place on which it rests. The good qualities of this over the ordinary round leg tripod provided as that is with unyielding brass cheeks to "tighten" the legs, are so great that there is but one opinion regarding its real advantages, and we gladly bear the greater expense incurred in its manufacture.

Our levels and transits both fit the same tripods, which can be distinguished only by their different lengths — the level tripod being two inches longer.

## Shifting Tripod.

We have also adapted to *all* our engineers' transits the *shifting tripod* or *shifting center*, by which, after an approximate setting of the tripod, the transit can be immediately brought over a point on the ground. This device we also attach to our instruments with three leveling screws in a most perfect and simple manner, and without impairing their steadiness and portability.

## Adjustable Plumb-Bob.

We furnish with all our transits a small brass chain and hook, which are connected to the centers of the instruments. The cord of the plumb-bob can be readily attached or detached from this hook, and by means of a neat, small and simple device, (also furnished with every instrument,) the plumb-bob can be adjusted over the ground at any height, with hardly any effort on the part of the engineer.

## Illumination of Cross-Wires.

**For Mining and Tunnel Transits.**

This consists of a small hole drilled through the transverse axis of the telescope, and closed at each end with small glass plates, to prevent dust entering the telescope. In the center of the telescope is placed a small adjustable reflector, by means of which the cross-wires can be very readily illuminated in the mine or tunnel by the reflection of the light of a lamp placed on a small table, which is attached to the standard. This lamp is provided with a ground lens. This method of illuminating wires is the best known to astronomers; it is the easiest to operate without assistance, or a change of lamp or position of the telescope. It can be applied to all our transits.

[*See Wood Cut Astronomical Instruments.*]

## Arrangement for Offsetting at Right Angles.

Upon unscrewing the small adjustable reflector in the center of the telescope, which is explained in the foregoing paragraph, a perfect line of sight is had at right angles to the telescope. By simply sighting through the axis, offsets may be conveniently established without disturbing either clamp or telescope when the eye is brought close to the instrument; its application is, however, limited to even ground. To use it on an uneven ground it is necessary to place the eye at a distance of twelve or fifteen inches from the instrument. The head should then be moved until the eye is in line with the openings of the transverse axis. An offset can then be aligned irrespective of the height of the instrument.

## Quick Leveling Attachment.

This we can apply to any of our Mining and Mountain Transits and Leveling Instruments. It adds about 1 lb. to the weight and $8.00 to the cost of an instrument.

## Protection to the Object-Slide, &c.

A rain and dust guard for the object-slide is now furnished with all of our telescopes, and to insure smooth working of the object slide and telescope tube both are made of a non-friction metal. The graduation of the horizontal circle, the centers and such other important parts that are liable to injury by the action of dust and water in the field-use of an instrument, are entirely protected.

## General Construction.

In regard to the general construction of our instruments, the dead weight is removed wherever it is shown to be not essential to the stiffness of the instrument; but we have at the same time strengthened the parts most likely to be injured by an accident or fall. Thus the *base of the standards*, the *vernier plate* and *circle*, the *parallel plates* for leveling screws, the *telescope axis*, the *flanges* of *centers*, *cross-bar of level*, etc., are made especially rigid and provided with ribs. Instead of finishing the smaller pieces of an instrument separately and then joining them with small screws, or solder, each screw or joint being a *weak* place in an instrument, we have adopted the opposite principle, (at an increased expense to us,) and aim to unite as many pieces as possible in a single casting, which casting, by means of *ribs* is made as light as consistent with strength.

We also call attention to the exceptionally *hard bell-metal* and *phosphor bronze* used for our centers and telescope axis, which are *long* and *unyielding*, and the remaining parts are of a *composition metal*, which is itself *harder* than hammered brass, or red composition, used ordinarily for centers, etc. It is more difficult to work, but we avoid the objectionable softer brass in its use. Experience has proven that soft, or *hammered* yellow brass is unfit for a good field or astronomical instrument, since it is more liable to fretting and yielding generally, and in the hammered state its unequal expansion and contraction at different temperatures may be so marked as to impair the reliability of the adjustments.

## The Finish.

It is a well-known fact that the black finish has one objection. It absorbs the heat readily, and therefore is apt to expand an instrument unequally, and thereby deranges its adjustments. We therefore consider it necessary to finish certain parts of an instrument in a bright but *not glaring finish*—including the upper plate, the standards and the telescope in the transit; the cross-bar and the telescope in the wye level, etc. All other portions may be finished and bronzed before lacquering. This finish gives a very fine appearance to the whole instrument; it wears better than black, and is in better taste.

Customers desiring to have their instruments finished entirely in bronze, however, can do so by notifying us of their wishes.

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## Cloth-Finish.

It is so called because the parts of an instrument so finished have the feeling to the hand of being covered with cloth of a very close texture,—there is no further resemblance to cloth however.

The principle is borrowed from astronomical instruments, where it is necessary to cover the surfaces with some non-conducting material in order to avoid disturbances in instrumental adjustments caused by suddenly varying temperatures.

We have adopted this principle with the view of securing the same results for our finer transits, wye and dumpy levels. Some of these levels are sensitive to a depression of a single second of arc.

Instruments finished in this manner heat up or cool down very gradually, causing the minimum derangement of the adjustments, and being of a dark brown color, this finish unites all the advantages of a bright finish with the convenience of having a dark colored instrument to use in the sunshine.

As regards durability, it will not quite equal the bright finish, but is superior to the bronze or black; this fact, coupled with the ease with which it can be restored at any time, leads us to recommend it in all cases where engineers do not care so much for an elegant appearing instrument after a number of years, as for an instrument in which every precaution is taken to avoid the influence of sudden changes of temperature.

In finishing an instrument in this manner, we are not obliged to polish its surfaces so finely, and thus can offer our transits with standards finished in this manner at $5 less than when finished in the other ways.

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## Packing.

In putting our instruments in their cases, none of them separate above the leveling screws. They stand *erect*, and are *ready for use* upon unlocking the case.

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**In conclusion,** we wish to say that we aim to secure in our engineers' instruments—

1. *Simplicity in manipulation.*
2. *Lightness, combined with strength.*
3. *Accuracy of division.*
4. *Achromatic telescope, with high power.*
5. *Steadiness of adjustments under varying temperatures.*
6. *Stiffness; to avoid any tremor even in a strong wind.*

And we would add, that since all our leveling, tangent and gradienter screws are cut with precision in our engine lathes, and then run through a size plate to ensure uniformity and perfect smoothness, that we are able to replace any such part of our instruments by mail. The spiral springs, and most other small parts of the instrument, can be supplied in the same manner.

# Care of Instruments.

Do not allow the legs of your tripod to play loose on the tripod head; keep nuts and bolts always well tightened up against the wood. Examine the shoes from time to time, and sharpen them if necessary, also screw the shoes tight, if wear and tear loosen them. Be sure your instrument is well secured to its tripod before using it. Bring all four leveling screws to a seat before shouldering instrument. Let the needle down upon its pivot as gently as possible, and allow it to play only when in use; if too far out from its course check movements of needle carefully by means of lifter. Never permit playing with the needle, especially not with knives, keys, etc. Be sure to arrest the needle after use, and screw it well up against the glass cover before shouldering instrument. Do not clean the glass cover or the lenses with a silk handkerchief; breathe over the compass-glass and reading lens if one is used, after cleaning. Examine the buttons of your coat with regard to iron that may be concealed in them, also beware of nickel-plated watch chains, etc. To clean the object-glass and the lenses use a fine camel hair brush. If dust, or sticky or fatty matter cannot be removed with the brush, take an old clean piece of soft linen, and carefully wipe it off. Do not unscrew the object-glass unnecessarily,—this is apt to disturb the adjustment of line of collimation. The lens nearest the eye of eye-piece, as well as the front side of the object-glass, need careful brushing with *fine brush* from time to time.

If dust settles on cross-hairs and become troublesome, unscrew the eye-piece and object-glass, and gently blow through the telescope tube, cover up both ends and *wait a few minutes* before inserting the eye-piece and object-glass. Be sure to have the object-glass cell *screwed well up against its shoulder*, and then examine the adjustment of line of collimation (see adjustment of line of collimation.) Do not grease the object-slide of telescope, or screws that are exposed to dust; use a stiff tooth brush to clean slides or threads if dusty.

To take out the eye-piece, unscrew the screw at the end of the main tube, take hold of the eye-piece and pull it out.

To focus the cross-hairs, take hold of the *eye-piece cap* and turn it in a screw-like manner until cross-hairs appear distinct, and as if fastened on the object when the head is being moved.

Should there be any fretting in the telescope slide, take it out, and endeavor to smooth the rough part with the back of a pocket knife.

To clean the threads of leveling or tangent screws when *working hard*, use a stiff tooth brush to first clean the threads of all dust, then apply a little oil, and work the screw in and out with alternate brushing to remove dirt and all oil until it moves perfectly free and smooth.

Screws for the adjustment of cross-hairs should not be strained any more than necessary to insure a firm seat; all straining of such screws beyond this simply impairs the accuracy of instrument and reliability of adjustment.

When in the field always carry a Gossamer water-proof for the instrument in your pocket, to put over it in case of a shower or dust cloud. On reaching office, after use of instrument, dust it off generally with another fine brush; examine the centers and all other principal movements to see if they run perfectly free and easy, and oil them if necessary; also examine the adjustments. This will save expense and many hours of vexation in the field.

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## Care of Centers and Graduation.

As the centers, the telescope axis and the graduations require greater care to preserve their fine qualities, perhaps it is not amiss to say a few words concerning their treatment.

Upon finding that the centers do not revolve as free as usual after exposure of the instrument in an extremely hot or cold weather, they should be cleaned as soon as time permits, and then proceed as follows:

Unscrew the milled-head nut at the extreme end of the cylindrical tube containing a spiral spring, which is opposite the upper tangent screw. Do it somewhat cautiously, or the spring will fly out. Then unscrew a small cylindrical case, which also has a milled edge, and which is at the bottom of the centers. This case contains a small triangular spring to balance the upper weight of the instrument within a few lbs. Be careful to keep the face of this spring up in its case, which is best indicated by a bright point in its center. After unscrewing the nut attached to the inner center, a gentle pressure upwards will lift the vernier plate out from the lower part of the instrument. Take a fine camel hair brush, and with it clean the graduation, the verniers and the inner part of the instrument,—but do not rub the graduation, *especially not its edge*,—then take a stick of about the same taper as the inner center, wrap some wash-leather slightly soaked in fine oil around it, and clean the insides of the sockets as carefully as possible; then remove this piece of wash-leather and wrap a fresh piece *without* oil around the stick and clean dry. Proceed similar with the centers and their flanges.

Before applying fresh and pure watch oil, however, care should be taken that not a particle of dust or other foreign matter is left in the sockets, on the centers, or on the graduation. This caution having been taken, the fresh oil should be well distributed on all the bearing parts. It will be well to also examine the arm of the clamp screw of the circle and telescope axis, and if necessary clean by removing washer. After the instrument is thoroughly cleaned and oiled, the nuts and springs screwed back to a *firm* seat, the instrument must turn perfectly free and yield at the slightest touch of the hand.

## Care of Telescope Lenses.

As dust and moisture, as well as perspiration from the hands, will settle on the surface of the lenses of a telescope, it becomes necessary that they should be cleaned at times. A neglect to keep the lenses free from any film, scratches, etc., greatly impairs the clear sight through the telescope. To remove the dimness, produced by such a film, proceed thus: — Brush each lens carefully with a camel's hair brush, wipe gently with a clean peace of chamois leather moistened with alcohol, and wipe dry using a clean part of the chamois skin on every portion of the lens, to avoid grinding and scratching. When perfectly transparent brush again to remove any fiber that may adhere to the lens. The tubes in which the lenses fit should be brushed, and if damp should be dried; this done, restore each lens to its original place as marked. To remove dampness in the main tube of the telescope. take out the eye-piece, *cover the open end with cloth* and leave the instrument in a dry room for some time.

If an instrument has been exposed to a damp atmosphere, or water has penetrated the telescope, moisture may settle between the crown and flint glass of which the object-glass is composed. If such is the case expose the instrument to the sun for a few hours, but if in the winter, leave it in a warm room some distance from the stove, the moisture will then generally evaporate. However, if not successful, unscrew the object-glass from the telescope, and heat it slightly over a stove or open fire. If a film settles between these glasses nothing can be done except sending the instrument to the maker. The two glasses form one lens only and must not be disturbed, as upon their relation to each other the definition and achromaticity of the telescope depends. Of course, if at any time the object-glass has been unscrewed from the telescope, the adjustment of line of collimation must again be verified before the instrument is used.

## Repair of Instruments.

We are often applied to for correcting new and repairing old instruments made by other makers. We will here remark, that as workmanship, material and construction of different makers' instruments vary from one another, it is oftentimes impossible to repair them in an entirely satisfactory manner without going into an unwarrantable great expense, or without making such alterations as would practically make a new one. We will always guarantee in such cases to put the instrument in as good order and adjustment as the character of its construction, workmanship and material, the extent of damage and the general wear will permit, and that all repairs are promptly and conscientiously. The charges will be according to time consumed, and as low as is consistent with good work. Parties sending instruments should point out in detail whatever parts they wish to have repaired; but the best course to be persued is to have the instrument *put in thorough order and adjustment*, implying — as it does — that the firm should make such warrantable repairs as will make it as servicable as possible. This course is always more expensive, but the most satisfactory to insure good work, and it is also the cheapest in the end.

# Engineers' Instruments and Their Adjustments.

WRITTEN ESPECIALLY FOR THIS CATALOGUE, BY

LEONARD WALDO,

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## General Remarks.

### THE OPTICAL PART.

In the construction of telescopes for engineers' instruments, several difficulties present themselves. To be portable, the telescope must be of small aperture, and of short focus. To make it of short focus and yet retain sufficient aperture to give the light necessary with the eye-pieces used, requires especial care on the part of the maker, both in securing the true curves for the crown and flint glass lenses, which make up the achromatic object-glass, and in adapting an eye-piece which will secure a flat field, with the least distortion.

Of the many forms of eye-pieces known, Messrs. BUFF & BERGER, after careful experiments with the formulas suggested by the distinguished astronomer, Sir George B. Airy, and the late Mr. Kellner, of Wetzlar, (the two best formulas known,) have adopted the latter. Mr. Kellner's formula employs four lenses, mounted separately, and so arranged as to secure a flat field of the sharpest definition, to the very edge.

The magnifying power of the telescope depends upon the relation between the focal length of the object-glass and the focal length of the eye-piece, considered as a single lens: Thus—

If $\mathbf{F}$ = focal length of the object-glass.

$\mathbf{f}$ = " " " eye-piece.

Then $\frac{\mathbf{F}}{\mathbf{f}}$ = magnifying power of telescope.

It is readily seen that the magnifying power may be increased or diminished by altering the focal length **f**, of the eye-piece; but if the maker increases the power too much, since only a fixed amount of light can enter the object-glass, this fixed amount of light is spread over too much surface in the field of view, and the object seen is therefore too faint. If the maker gets the magnifying power too small, then the engineer has a difficulty in pointing the telescope accurately. Some other points in regard to the magnifying power will be referred to in the description of the transit telescope. Messrs. BUFF & BERGER have found about twenty-four diameters to be the most satisfactory power for their Engineers' Transit Telescopes; and for levels the powers increase in proportion to the size of the instruments.

Very much depends upon the optical part of any instrument, and very little has been put into the hands of the practical engineer by which he may rigidly test it. The following suggestions may be found convenient.

The telescope should come sharply into focus, and a very little movement of the focussing screw, either way, should cause the image to blur. When it is sharply focussed, covering any part of the object-glass without altering the focus, should not alter the sharpness of definition but merely cut off light. The pencil of light which enters the object-glass, should come out at the eye end. To ascertain this, see whether a pointer which you place just in contact with the edge of the object-glass, can be wholly seen in the small disc of light which you will notice at the small opening of the eye end when you draw your head back some inches from the telescope, and point the telescope towards the sky. If the pointer cannot be seen up to the very edge, then the maker has inserted a diaphragm which cuts off light from the object-glass, and, very probably, to conceal the faults in making. In this case the real aperture of the telescope is found by moving the pointer over the object-glass until its point is just visible, and measuring from the inner edge of the brass cell holding the object-glass to the pointer. Twice this distance subtracted from the distance between the two edges of the brass cell, will give the real or clear aperture of the telescope. The clear aperture, divided by the diameter of the small circle of light at the eye end, when the telescope is focussed on a distant object, will give the magnifying power of the telescope. Thus the clear aperture of a telescope, measured by means of a pair of dividers and a scale, was 1in. 35, while the diameter of the circle of light at the eye end, was, 0in. 06. In this case, the magnifying power of the telescope was $\frac{135}{6} = 22.5$ diameters.

Another way to determine the magnifying power, is to measure the angular distance between two points with a transit, and then measure the same distance with the telescope of which the power is to be ascertained, placed so that the transit must point into its object-glass and see the same angular distance through the second telescope *inverted*. Then calling the first angle **A**, and the angle as seen diminished through the introduction of the second telescope inverted **a**, we have the magnifying power of the second telescope $= \frac{\tan. \frac{1}{2} A}{\tan. \frac{1}{2} a}$. Thus the angle subtended by a window sash, several hundred feet away, was measured by a transit instrument direct, and found to be, 1° 58′ 50″. When a Y level, previously focussed on a distant object, was set before the transit, with its object-glass towards the transit, the same sash was measured and the angle was found to be but 3′ 30″. In this case, therefore,

$$\text{the magnifying power of Y level} = \frac{\tan.\left(\frac{1°58'50''}{2}\right)}{\tan.\left(\frac{3'30''}{2}\right)} = \frac{\tan. 0°59'25''}{\tan. 0°\ 1'45''} = 34.0 \text{ diameters.—}$$

Or, for an approximation, a card cut one inch wide may be set up across a room by the side of a measure graduated to inches. Then, the number of inches on the measure seen by one eye, covered by the image of the white card seen through the telescope by the other eye, will give, roughly, the magnifying power.

It is difficult, without months of use, to fully test an instrument in all its parts; but in choosing an instrument the engineer should bear in mind that the making of the transit and the level are considered to be feats of mechanical skill. It should be remembered that there is no machine so delicate that it can *finish* the essential parts of an instrument. The last stages in its making must depend upon the personal skill of some mechanic, who has a reputation for that particular work; and we are sorry to add, that so difficult is it to secure the mechanical skill and patience required in the finishing of the interior parts, the only essential ones, and so easy is it to add the lacquer and polish of the outside, that the market is full of instruments sold at a price enough lower than the best makers can work, to seem to effect a large saving of the first cost; but such a saving is money borrowed at the highest rate of interest, when the cost of annual repairs is considered. It is better at the outset to buy of a maker who is noted for the conscientious accuracy of his work. An imperfect rack motion; a screw turned home on the wrong thread; a wabbling of the object-slide or eye-piece; a slight space between the edge of the vernier and the limb of the circle; in fact, any mechanical defect, no matter how slight it may seem, may be taken as a pretty sure indication that the work has been slighted in other parts as well, and should have a strong influence in guiding the selection of an instrument, in the absence of a test by work in the field.

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## The Engineer's Transit.

In the first part of this catalogue, Messrs. BUFF & BERGER have pointed out the peculiarities and improvements in this instrument, as constructed by them. In speaking of the adjustments of these instruments it is well for the engineer to remember that the construction is aimed to be such that if the telescope and levels are carefully adjusted they may remain so for even a number of years to come, if the instrument suffers no rough usage.

## Description of the Telescope.

The object-glass is achromatic, that is, made of two lenses, one of crown and one of flint glass, with the curves computed from special formulæ, so that the telescopes may have as large an aperture as possible with its short focal length. The engineer will appreciate the slightest gain in the diameter of the object-glass, since the amount of the light received from any object varies as the square of that diameter. Thus an object-glass 1¼ inches in diameter, will admit half as much light again as an object-glass one inch in diameter.

The magnifying power must be proportional to the aperture. If the magnifying power is too high for the aperture, ordinary objects will appear too faint; and if the magnifying power is too low, the objects will be seen so small that the engineer cannot point upon them with sufficient accuracy.

The magnifying power should be such that the least perceptible motion of the bubble of a level, or change in the reading of the verniers, should cause sufficient movement of the cross-wires over the object in the field of view to be readily noticeable. A higher power than this is worse than useless, since objects are less brilliant. A lower power would not develope the full capacities of the instrument. Messrs. Buff & Berger adapt therefore the magnifying powers of their instruments to the sensitiveness of the levels, and the fineness of the graduations.

The cross lines in the telescope are *bona fide* spider webs, except where platinum wires have been specially ordered. In case they should be broken, they may be restored in the following manner: clean the reticule frame of all foreign matter; put it on a sheet of white paper, with the cuts on its surface uppermost. Prepare a little shellac by dissolving it in the best alcohol and waiting until it is of the consistency of oil. From the spider's cocoon, which the engineer has prudently secured at some previous time, select two or three webs, each about two inches long and of the same appearance. Attach each end of these webs to a bit of paper or wood to act as weights, and immerse them in water for five or ten minutes. Remove one web from the water, and very gently pass it between the fore finger and thumb nails, holding it vertically to remove any particles of moisture or dirt. Stretch the web carefully over two of the opposite cuts in the reticule frame. Fasten one end by a drop of the shellac, let fall gently from a bit of pointed wood or the blade of a penknife. Wait a moment for this drop of shellac to harden. See that the web is taut across the frame, and apply another drop of the shellac to the opposite cut with its enclosed web. Wait several minutes before cutting off the two ends of the web, and then proceed in the same manner with the web which is to be placed at right angles to this one.

The easiest eye-piece to make is a two-lens negative eye-piece, used by astronomers; but unfortunately the objects would be seen inverted. It is necessary in practice to use an eye-piece of four lenses to give an erect image, with a flat and colorless field of view; and the construction of this eye-piece is especially difficult in the case of such short telescopes as are used for engineering instruments.

The best results are, however, obtained with telescopes showing objects inverted. It requires but little practice to get accustomed to its use, and in preparing a self-reading level rod the engineer should so place the figures that they will show erect when seen through an inverting telescope.

## The Graduations.

Engineers' transits have various graduations on their circles, according to the requirements of the different branches of civil engineering. These various graduations are read by opposite verniers, which may be either single or double. American instruments have usually double opposite verniers, commonly reading the circle to single minutes or to thirty seconds. For a higher grade of work, required in the larger cities and on extended land surveys, they should, however, read to twenty or ten seconds.

The customary graduations of Buff & Berger's instruments are, First,—the circle divided to half degrees, the verniers reading to single minutes. Second,—the circle divided to twenty minutes, the verniers reading to thirty seconds. Third,—the circle divided to fifteen minutes, the verniers reading to twenty seconds. Fourth,—the circle divided to ten minutes, the verniers reading to ten seconds.

To express the relation between the vernier and circle divisions, let $d$ = the value of one division of the circle; $d'$ = the value of one division of the vernier; $d-d'$ = the least count of the vernier, or, in other words, the smallest reading of the circle. $n$ = the number of spaces of the vernier which correspond to $(n-1)$ spaces of the circle.

We then have the three formulas;

$$(1.)\qquad n=\frac{d}{d-d'}$$

$$(2.)\qquad d'=\frac{n-1}{n}d$$

$$(3.)\qquad d-d'=\frac{1}{n}d$$

Thus, for example, suppose the circle was divided to 15′, and it was desired to read to 20″. Here, $d = 15'$

$d-d'$, or, the least count = 20″

Then, by formula (1)

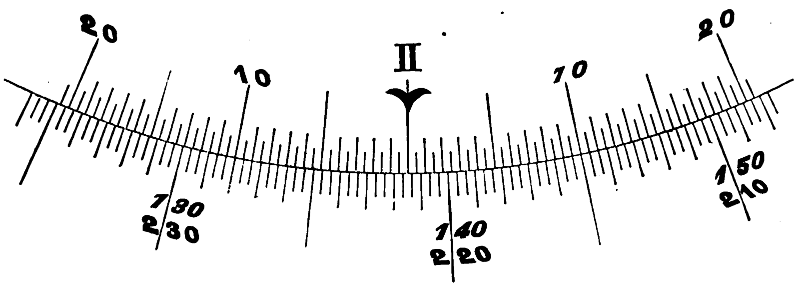
$$n=\frac{15'}{20''}=\frac{15\times 60''}{20''}=45$$

Therefore, 45 spaces of the vernier must correspond to 44 or $(n-1)$ spaces of the circle.

Suppose again the arc to be divided to 20′, and to be read to 30″. In this case we have

$$n=\frac{20\times 60}{30}=40$$

Therefore, 40 spaces of the vernier must correspond to 39, or $(n-1)$ spaces of the circle. These are the graduations which Messrs. Buff & Berger usually adopt for engineers' transits.




The cut shows a portion of the circle and vernier, to illustrate the method of reading to thirty seconds.

The lines marked 130, 140, and 150 denote 10° each. The shorter lines half way between them denote 135° and 145°. The next shorter lines denote whole degrees, while the shortest lines are one-third of a degree, or 20′ apart.

The vernier comprises the upper series of lines. Of this series only that half lying to the right of the vertical arrow, or zero, and having the figures 10 and 20 inclined in the same direction as the 130, 140, and 150 of the arc, is to be used in connection with these figures. The vernier is double,—one half to be used with one set of graduations of the arc, the other half to be used when angles are laid off in the opposite direction, and then the lower set of figures, 210, 220, and 230 are used.

It is to be especially remembered that the figures on the vernier are inclined in the same direction as the figures on the arc to which they belong.

To read the vernier, first note the whole degrees, and 20′ spaces lying between the last 10 degree division and the zero division of the vernier.

Thus in the cut, using the upper line of figures, the zero of the vernier has passed the 130° division, and moved on until it is between the 20′ and 40′ space beyond the 138° mark. The first part of our reading will therefore be 138° 20′.

Second, look along the vernier, beginning from the zero point, and in the direction in which the graduation of the arc runs, until one line of the vernier is found which seems to be a prolongation of an opposite line on the arc.

Consider each of the vernier spaces between the vernier zero and such a line, as equal to 30″ of arc.

Add the number of minutes and seconds thus obtained to the first reading. The result will be the reading of the circle.

Thus we notice that the vernier zero is a trifle over half-way of the distance between the 20′ and 40′ marks of the arc.

And looking along the vernier to the right, we notice that the lines of the vernier gradually approach the lines on the arc until the twentieth line of the vernier is precisely opposite a line on the arc. Of course, since each vernier space denotes 30″, the alternate ones made a little longer in the cut will denote single minutes, and on the vernier therefore the twentieth line would correspond to 10′ 00″, and since our first reading was between 20′ and 40′, this vernier reading is to be added to that first reading.

Thus,

| | | |
|---|---|---|
| 138° | 20′ | |
| | 10′ | 00″ |
| 138° | 30′ | 00″ |

will be the reading of the vernier, using the *upper* graduation.

In the same manner we proceed to the *left* in reading the lower graduation, in which the figures are inclined to the left. Thus in the cut, we should find the zero point of the vernier is beyond the 221° 20′ mark, and the line of the vernier, which is seemingly a prolongation of a line of the arc, corresponds to 10′ 00″. Then we have

| | | |
|---|---|---|
| 221° | 20′ | |
| | 10′ | 00″ |
| 221° | 30′ | 00″ |

for the reading of the vernier, using the *lower* graduation.

Practically, in reading the vernier, the engineer decides which line is in coincidence by the position of the lines on both sides.

He first notices, roughly, what fractional part of a space on the limb lies between the vernier zero and the last graduation mark it has passed. This enables him to look immediately to that part of the vernier in which the coincidence occurs.

Thus in the figure the vernier zero is about half way between 221° 20′ and 221° 40′, the engineer therefore immediately looks about half way along the vernier and finds the 10′ 00″ division to be the one sought.

When the graduation is to thirty seconds, the engineer will find that if he only chooses, he can work to minutes with this graduation quite as rapidly as with a transit graduated to minutes, by simply disregarding the shortest lines of the vernier.

The second vernier, which is distant 180°, or exactly opposite the one read first, may also be read. Not so much to eliminate any eccentricity of the circle and verniers as to afford a valuable check upon the angle measured.

Greater accuracy in the measurement of any angle may be obtained by the principle of repetition. In this case, before and after an angle has been repeated a number of times, all four of the verniers should be read, and if, for example, the graduations proceed from right to left, the left hand side of each double vernier should be read as usual; but in the right hand side the line now marked 20 on the vernier should be considered 0, and the arrow on the vernier 20. Then, with this convention, only the minutes and seconds of the second vernier should be used.

But it should be here remarked that the repetition of angles is not now held in such repute by our best engineers, as it was before the present perfection of the art of graduating and centering the circles and verniers of engineering instruments.

The engineer who has not used them will find the ground-glass shades a great convenience in reading the vernier. They are so placed as not to be readily broken, and they shed a clear, white light upon the graduations.

Graduations on solid silver are much to be preferred to graduations on any known brass alloy. The surface of the silver can be worked very plane, since it is of uniform texture. The graduations can be cut with the utmost uniformity in width of line and spacing.

## The Centers.

Quite as important as the graduation, is the exact fitting of what the makers call the *centers* of the instrument; *i.e.*, the two vertical metal axis, about which the circle and the vernier plate turn.

Both axes must be exactly concentric with the center of the graduated circle, and the center of the horizontal axis of the telescope in any position of the instrument. The most sensitive level about the instrument should not show any displacement when the circle-plate is held, and the lower plate moved by the hand.

In the construction of the inner center, the hardest bell-metal should be used, and for the outer center a red composition metal of the best quality. To insure a true concentricity of the axis, and consequently of the limb and vernier, it is necessary that they should each be turned in a dead center lathe, each about its own axis. In fitting the centers, they should turn without the slightest play, and yet with very little friction.

Messrs. Buff & Berger take the precaution of casting the outer center, circle, and vernier plate in the same mould, to avoid any difference in the composition of the metal.

The upper plate should not be hammered, since this would also effect an unequal expansion of the metals in extreme temperatures, causing the vernier to read too long or too short.

After the plates are put together, the vernier and limb should revolve in the same plane, to avoid parallax. The space between the limb and vernier should have the appearance of a uniform, fine, black line.

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## The Compass.

In running old lines, and as a check in running new ones, the compass is frequently a very important part of the transit. Its needle should be tempered throughout, and of hard steel, to retain its magnetism. It should be thin, and yet at the same time have enough surface to be strongly magnetic. It should be swung upon a jewelled center, and so nicely fitted that when at rest, with the instrument levelled, the two extreme points should just clear the graduation of the compass box, and read precisely 180° different in any part of the graduated arc. The pivot on which it swings should be conical, and hardened so that it may swing upon a sharp point, without having this point weak.

The needle should also be so sensitive, that when drawn from its pointing by the outside attraction of a piece of iron held in the hand a foot or so away, it will settle to the same reading several times in succession.

This sensitiveness depends upon the form and sharpness of the pivot, the strength of its magnetism, and its bearing on the jewelled center.

If it should be found that a needle has lost its sensitiveness, it is probably not so much owing to its loss of magnetism, as to a dulling of the pivot. Since this may happen when the engineer is without access to the maker, and an instrument otherwise be in good condition, it should be remarked that the pivot can be sharpened after removing the needle, by taking a fine oil-stone, and while turning the instrument with one hand, grinding the pivot, with the oil-stone in the other; being careful to incline the grinding surface about 25° to the pivot. The pivot is originally turned and sharpened in a lathe, and in grinding by hand, great care should be taken to preserve its conical form.

The two extreme points which lie next the graduation, together with the point of suspension, should lie in one straight line.

The center of gravity of the needle should be as far below this line as possible.

The quivering of a needle so constructed is not annoying, since the center of its quivering motion is in the line through its two extreme points, which are, therefore, stationary.

To determine whether the transit itself has any iron in it to disturb the needle, it is a good plan, after setting the instrument so that both compass-needle and vernier reads 0°, to go round the circle, setting the vernier ten degrees ahead each time, and noting whether the compass-needle also describes an arc of precisely ten degrees. If it does not, there is some local attraction.

The graduations on the compass box should begin at the North point, and run 90° in both directions; then decrease to 0° again at the South point. In order that the needle reading may indicate the direction of the telescope, the line joining the zeros of the ordinary compass ring must be in the same vertical plane, with the line of collimation of the telescope; and the letters denoting the cardinal points, East and West, must be transposed; *i. e.*, when the letter N is towards the North, the letter W should be towards the East. Of course the needle indicates magnetic north, and in the case of instruments unprovided with means of setting off the local variation of the needle, all the readings of the needle must be corrected for this local deviation.

## Spirit-Levels.

The spirit levels, as regards their sensitiveness, should be in strict keeping with the optical power, and the graduations of the instrument, but the quality should be of the best. A level-bubble should move uniformly over the same distance, when the telescope is made to point on two objects alternately, differing slightly in altitude, by the leveling screws alone. In change of temperature the bubble should lengthen symmetrically from the center; and no matter what its length, it should move quickly, without any of the hitching, which is caused usually by a little dirt introduced when it is filled.

Of the three levels attached to the complete transit, the telescope level is the most sensitive. It should be sensitive enough for ordinary leveling, such as good railroad work. The level in front, or at right angles to the standards, should be sensitive enough to make a line plumb by it to any height; while the third level on the standard is used in leveling up the instrument, and to establish the zero point for the vernier correctly when vertical angles must be measured.

The test of the fitness of the various levels for the capacity of the instrument should lie in this: that after carefully bi-secting an object in the field of view, in such a position of the instrument that all the levels can be read, and then slightly deranging them all with the leveling screws, the bi-section will be accurately made after restoring the levels to the exact position they before occupied, by the leveling screws alone.

## Leveling Screws.

Messrs. Buff & Berger usually cut their leveling screws with 32 threads to an inch provide the usual four screws in opposing pairs. The plates once set firmly apart by tightening two of these screws on the *same side*, the leveling of the instrument is easily accomplished by turning the two screws of an *opposing* pair so that both thumbs shall move toward each other (when the bubble will go toward the right), or both thumbs away from each other, when the bubble will move toward the left. Instruments intended for triangulation, *i. e.*, reading to 10″ or less, should however be supported on three, instead of upon four screws. In this case the instrument is rapidly leveled by bringing one level parallel to two of the screws, the other level will now be at right angles to it. Level both levels at the same time by turning one of the screws to which the first level is parallel and the screw which is at right angles to this level. Of course the instrument may now be reversed to guard against non-adjustment of the levels.

## Three Leveling Screws versus Four.

To the student of the progress in Engineers' field instruments, the question often presents itself as to the comparative merits of an instrument provided with three, over one having four leveling screws. It should be here remarked that the greater portability existing in instruments provided with four leveling screws still commends itself to all using the more customary class of instruments. However, the finest class of field instruments, requiring spirit-levels corresponding to the fineness of graduation, cannot be advantageously manipulated with four leveling screws. The results thus obtained would be little better than those obtained with a more ordinary instrument. To insure the full benefit of a finer instrument, such as used in triangulation, the maker will prudently apply three leveling screws. mounted on *a basis larger* then is usual in instruments with four screws. So, while four leveling screws have the advantage of greater compactness and less weight three screws have the advantage for closer setting, giving better results. The maker will therefore adapt either the one or the other kind to his instruments as the case may require.

## Quick Leveling Attachment.

[*For illustration see elsewhere.*]

As all devices of this kind detract more or less from the stability of an instrument, it seems they never have been regarded with much favor by the engineering profession at large. There are cases, however, where the use of such a device, in a mountainous country, or in underground work of a close character, becomes very desirable. Messrs. Buff & Berger's device, unlike devices of a similar kind forming a part of the instrument proper, consists of a coupling with a ball and socket joint which can be screwed between the instrument and tripod. As this intermediate piece forms no part of the instrument itself it can be readily attached or detached at will, thus adapting the instrument to the circumstances and to the class of work in hand. For this purpose the threads of this coupling or quick-leveling attachment, and those of the instrument and tripod are identical; and as all their transits and levels with four leveling screws are interchangeable on any of their tripods, one such coupling is sufficient for an engineer's outfit. In fact one extra tripod permanently provided with this quick-leveling attachment may be kept ready for occasional use in an office where there are a number of their instruments.

To use this quick-leveling attachment proceed as follows:—Screw it to the instrument, and then screw both to the tripod in the usual manner, taking care that the coupling becomes firmly fastened thereto. Now to operate it, slightly unscrew the instrument from its hold upon the flange of the coupling by means of the milled edges provided for this purpose, and move it approximately into a level plane, then again screw the instrument firmly to the coupling same as before. This being accomplished, move the instrument over the given point on the ground by means of the centering arrangement described later on, and level up carefully by the leveling screws alone. It will be seen that this quick-leveling attachment is operated entirely independent of the leveling screws or centering arrangement. Of course, when this device is to be used for several days in succession, it is not necessary to detach it from the tripod every time the instrument is to be removed. In such cases the instrument only should be detached from the coupling. Whenever it becomes desirable to detach the coupling from the tripod, it can best be performed by allowing the instrument to remain fastened to the coupling, then by taking hold of the milled edge of the coupling unscrew in the usual manner. In cases where the coupling has been permanently attached to a tripod, the small screws connecting it to the tripod head must first be removed.

To secure the greatest possible stability to the instrument, the outside diameter of the hollow hemisphere is equal to the distance between the leveling screws of the instrument; and to secure a smooth and ready action, leather washers are provided in the socket which act against the hemisphere. However, when the instrument is clamped to the flange of the coupling these washers recede, and the metal surfaces are brought into direct contact with each other.

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## The Gradienter Screw.

This very convenient attachment consists simply in a screw working against the clamping arm suspended from the horizontal axis, and on the opposite side from the vertical arc. A strong spiral spring is set directly opposite the screw, and presses the clamp arm against the end of it. This screw is cut with great care in a lathe. It has a large silvered head graduated into fifty equal parts. As the screw is turned, the head passes over a small silvered scale, so graduated that one revolution of the screw corresponds to one space of the scale.

Obviously then, the number of whole revolutions made by the screw, in turning the telescope through a vertical arc, can be ascertained from this scale. The clamp arm of the telescope has its clamping screw just above the horizontal axis, in the usual manner. When this screw is free, the telescope may be revolved; but when it is clamped, the telescope can only be moved by the gradienter screw, which thus takes the place of the ordinary vertical tangent screw. The screw is cut with such a value of a single revolution, as to cause the horizontal cross-line of the telescope to move over a space of $\frac{1}{100}$ of a foot, placed at a distance of 100 feet, when the screw is turned through one of the smallest spaces on its graduated head; and since there are fifty such spaces on the head, it follows that one revolution of the screw is equivalent to $\frac{50}{100}$ of a foot, at a distance of 100 feet. The numbered graduations on the screw head are then each equivalent to $\frac{1}{10}$ of a foot in 100 feet; and two entire revolutions of the screw would be twice $\frac{5}{10}$, or 1 foot to the 100. It is readily seen that grades can be established with great rapidity with this screw. It is only necessary after setting the gradienter screw to zero, and leveling and clamping the telescope, to move it up or down as many spaces of the head of the gradienter screw as there are hundredths of feet to the hundred, in the grade to be established. Thus, to establish a grade of 1ft 85, the screw head is turned through three whole spaces of the scale, which corresponds to 1.ft 50, and through three of the numbered divisions, and five of the shortest ones to make up the entire reading of 1.ft 85.

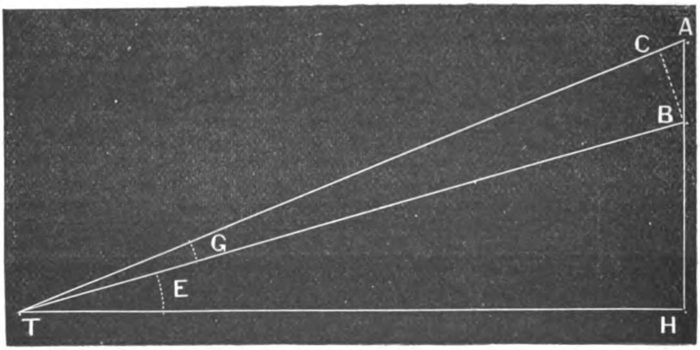
For measuring distances this screw takes the place of stadia lines, and is more convenient; since for any approximately horizontal distance, the space on an ordinary leveling rod expressed in hundredths of feet, included in two revolutions of the screw, will be the number of feet the level rod is distant from the center of the instrument. Thus the difference between two readings of the level rod was 2ft.965 when the telescope was moved in altitude through two revolutions of the screw. The rod therefore was distant 296.5 feet.

It is unnecessary even that a leveling rod be used. A ranging pole or walking stick, or any arbitrary length which can afterwards be measured, will suffice. Thus a stick, which was afterwards measured and found to be 3ft.38 long, was found to be subtended by $3\frac{8}{50}$ revolutions of the screw at an unknown distance.

In this case the distance was—

$$\frac{3.38}{1.58} \times 100 = 213.9 \text{ feet.}$$

In case, however, the distance to be measured is not approximately in the same level plane with the transit telescope, it is necessary to compute the distance, from the readings of the rod. In taking such readings at an altitude, it is customary to incline the rod towards the telescope, and by trial find the least space subtended by two stadia lines. A skilful rod-man will *plumb* a rod more readily than he can *incline* it at the proper angle, and a reading of the plumb rod can be taken with greater accuracy, and in less time than with the inclined rod; but it ordinarily involves some additional computing to reduce such vertical readings to horizontal distances. With the view of reducing the computation to a simple multiplication, the following table is appended with the trignometrical argument on which it depends. The engineer will notice the solution is not rigorously exact, but is sufficiently so for all cases in practice.



In the above figure,

TH = the transit horizontal sight line.

The angle HTB = the angle of elevation of the telescope to the foot of the rod = E.

" " BTA = the angle subtended by any number of revolutions of the gradienter screw = G.

AB = the length of the rod included by the angle G, when the rod is vertical = R.

CB is drawn perpendicular to TB.

Then, CBA = BTH = E  TAH = 90° — (E + G)

$$\frac{BC}{AB} = \frac{\sin\left(90° - (E+G)\right)}{\sin(90° + G)} = \frac{\cos E \cos G - \sin E \sin G.}{\cos G.}$$

$\therefore$ BC = R (cos E — tan G sin E.)

$\tan G = \frac{nh}{a}$ where $h$ is the height above a horizontal line, subtended by *one* revolution of the gradienter screw at a distance $a$.

$n$ is the number of revolutions made in any given case.

$$BT = \frac{n}{nh} BC = R\frac{a}{nh}\left(\cos E - \frac{nh}{a}\sin E\right)$$

$$\therefore BT = R\left(\frac{a}{nh}\cos E - \sin E\right) \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad I.$$

and

$$HT = BT \cos E$$

$$\therefore HT = R\left(\frac{a}{nh}\cos^2 E - \tfrac{1}{2}\sin 2E\right) \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad II.$$

Formulas I and II are general formulas for *any* gradienter screw. In Buff & Berger's transits the screw is cut and placed so that when $a = 100$, for $n = 2$ and $h = \frac{1}{2}$, by substitution these formulas become,

$$BT = R\,(100 \cos E - \sin E.)$$
$$HT = R\,(100 \cos^2 E - \tfrac{1}{2} \sin 2E.)$$

Where BT = the direct distance from the center of the horizontal axis of the transit to the foot of the vertical rod.

HT = the horizontal distance from the center of the horizontal axis of the transit to the plumb line dropped from the foot of the vertical rod.

R = the space included on the vertical rod by two revolutions of the gradienter screw.

E = the elevation of the foot of the rod above the horizontal sight line of the telescope.

When the angle **E** becomes an angle of *depression* instead of elevation, then the point **B** is the *upper* end of the part of the rod used, **A B.** The distance **B T** in this case is the direct distance between the center of the horizontal axis of the telescope and the upper reading of the vertical rod in the valley.

The distance **H T** is, as before, the horizontal distance between the center of the horizontal axis of the telescope, and the plumb line prolonged in this case upwards from the upper end of the vertical rod. The plumb line in all cases coincides with the direction of the rod.

By means of the following table, it is only necessary to multiply the factor opposite the angle of elevation, by the space included upon a vertical rod by two gradienter screw revolutions, to obtain either the direct or horizontal distance of the center of the horizontal axis of the telescope from the foot of the rod; or the same distance from the upper reading of the vertical rod in the case of an angle of depression.

# Gradienter Screw Table I.

Factors to be multiplied by the space on the vertical rod expressed in feet and decimals, included in two revolutions of the gradienter screw, to find the distance of the foot of the rod from the center of the horizontal axis of the transit telescope.

| Angle of Elevation E. | | Factor for the Direct Distance (100 cos E − sin E) | Factor for the Horizontal Dist. (100 cos ² E — ½ sin 2 E) | Angle of Elevation E. | | Factor for the Direct Distance. (100 cos E − sin E) | Factor for the Horizontal Dist. (100 cos ² F — ½ sin 2 E) |
|---|---|---|---|---|---|---|---|
| ° | ′ | | | ° | ′ | | |
| 0 | | 100.00 | 100.00 | 15 | | 96.33 | 93.05 |
| 1 | | 99.96 | 99.94 | 15 | 30 | 96.09 | 92.59 |
| 2 | | 99.90 | 99.84 | 16 | | 95.85 | 92.14 |
| 3 | | 99.81 | 99.67 | 16 | 30 | 95.60 | 91.66 |
| 4 | | 99.69 | 99.45 | 17 | | 95.34 | 91.17 |
| 5 | | 99.53 | 99.15 | 17 | 30 | 95.07 | 90.66 |
| 6 | | 99.34 | 98.80 | 18 | | 94.80 | 90.17 |
| 7 | | 99.13 | 98.39 | 18 | 30 | 94.51 | 89.63 |
| 8 | | 98.89 | 97.93 | 19 | | 94.22 | 89.09 |
| 9 | | 98.61 | 97.41 | 19 | 30 | 93.93 | 88.54 |
| 10 | | 98.31 | 96.81 | 20 | | 93.63 | 87.98 |
| 10 | 30 | 98.15 | 96.51 | 20 | 30 | 93.32 | 87.41 |
| 11 | | 97.97 | 96.17 | 21 | | 93.00 | 86.83 |
| 11 | 30 | 97.79 | 95.82 | 21 | 30 | 92.67 | 86.22 |
| 12 | | 97.60 | 95.47 | 22 | | 92.34 | 85.62 |
| 12 | 30 | 97.41 | 95.11 | 22 | 30 | 92.01 | 85.01 |
| 13 | | 97.21 | 94.73 | 23 | | 91.66 | 84.37 |
| 13 | 30 | 97.01 | 94.33 | 23 | 30 | 91.31 | 83.75 |
| 14 | | 96.79 | 93.92 | 24 | | 90.94 | 83.08 |
| 14 | 30 | 96.56 | 93.48 | 24 | 30 | 90.59 | 82.43 |
| 15 | | 96.33 | 93.05 | 25 | 00 | 90.21 | 81.76 |

In practically applying this table, it is preferable to take the mean of several readings of the rod in each position of the gradienter screw.*

Thus, with the target near the foot of the rod, and then moved to correspond to two revolutions of the gradienter screw, three readings in each position were as follows:

| | I. | II. |
|---|---|---|
| | Altitude 18° 20′ | |
| | ft. | ft. |
| | 0.625 | 3.380 |
| | 0.627 | 3.376 |
| | 0.625 | 3.378 |
| Means, . . . | 0.626 | 3.378 |
| | | 0.626 |
| Difference, . . . . . . . . . . . . . . . | | 2.752 |

| | | | |
|---|---|---|---|
| Factor for direct distance for 18° | =94.80 | For Horizontal Distance | =90.17 |
| " " " 18°30′ | =94.51 | " " " | =89.63 |
| Differences, . . . | =0.29 | | 0.54 |

Therefore, the factor for 18° 20′ will be for the *direct* distance 94.80,—⅔ of 0.29 = 94.61, and for the horizontal distance, 90.17—⅔ of 0.54=89.81.

Then we have, 2.752 × 94.61 = 260.37 = the *direct* distance.
2.752 × 89.81 = 247.15 = the *horizontal* distance.

This direct distance being the distance from the position of the foot of the rod or the lower target to the center of the horizontal axis of the telescope,† and the horizontal distance, the one usually desired, that distance reduced to a level line.

The mean value of two revolutions of the Gradienter Screw in arc, is 34′ 23″. Hence the value in arc of one of its smallest divisions on the head is 20″ nearly. Vertical angles therefore may be laid off with facility when they are confined to the range of the screw.

* To insure at all times accurate results, the telescope axis should revolve free, but without any looseness in the bearings. The engineer should examine these bearings from time to time, and, if necessary, fresh and pure watch oil must be applied.

To make a measurement with a micrometer screw, its graduated head should be set back slightly, then bring it up to the readings in the same direction in which the measurement must be effected.

† Should the engineer desire the direct distance between the foot of the rod, and *the point over which the plumb-bob is suspended*, it may be found by the following formula.

$$x = \sqrt{d^2 + p^2 + 2pd \sin E}.$$

or putting it in a shape adapted for logarithmic computation,

$$x = \frac{(d-p)}{\cos q}. \quad \text{Where } \tan q = \frac{2 \sin \tfrac{1}{2}(90+E)}{(d-p)} \sqrt{dp}.$$

Where $x$ = the distance from the point under the plumb-bob to the foot of the vertical rod.
$d$ = the direct distance obtained as above.
$p$ = the distance from the center of the horizontal axis is to the point under the plumb-bob.
$E$ = the angle of elevation of the foot of the rod, as above.

The subjoined table affords a ready means of expressing any number of revolutions, and parts of a revolution, in arc; and the converse, of degrees, minutes and seconds, in revolutions of the screw:

## Gradienter Screw Table II.

| To convert a reading of the Screw into Arc. | | | | To convert Arc into a reading of the Screw. | | | |
|---|---|---|---|---|---|---|---|
| Gradienter Screw. | Arc. | Gradienter Screw. | Arc. | Arc. | Gradienter Screw. | Arc. | Gradienter Screw. |
| Rev. Div. | ° ′ ″ | Rev. Div. | ° ′ ″ | ° ′ ″ | Rev. Div. | ° ′ ″ | Rev. Div. |
| 0 0 | 0 0 0 | 2 0 | 0 34 25 | 0 0 0 | 0 0.0 | 0 8 00 | 0 23.5 |
| 0 1 | 0 20 | 3 0 | 0 51 35 | 0 0 10 | 0 0.5 | 0 8 30 | 0 25.0 |
| 0 2 | 0 40 | 4 0 | 1 8 45 | 0 0 20 | 0 1.0 | 0 9 00 | 0 26.0 |
| 0 3 | 1 0 | 5 0 | 1 25 55 | 0 0 30 | 0 1.5 | 0 9 30 | 0 27.5 |
| 0 4 | 1 25 | 6 0 | 1 43 10 | 0 0 40 | 0 2.0 | 0 10 00 | 0 29.0 |
| 0 5 | 1 45 | 7 0 | 2 0 20 | 0 0 50 | 0 2.5 | 0 20 00 | 1 8.0 |
| 0 6 | 2 5 | 8 0 | 2 17 35 | 0 1 00 | 0 3.0 | 0 30 00 | 1 37.0 |
| 0 7 | 2 25 | 9 0 | 2 34 45 | 0 1 30 | 0 4.5 | 0 40 00 | 2 19.0 |
| 0 8 | 2 45 | 10 0 | 2 52 0 | 0 2 00 | 0 6.0 | 0 50 00 | 2 55.5 |
| 0 9 | 3 5 | 11 0 | 3 9 10 | 0 2 30 | 0 7.5 | 1 00 00 | 3 24.5 |
| 0 10 | 3 25 | 12 0 | 3 26 20 | 0 3 00 | 0 9.0 | 2 00 00 | 6 49.0 |
| 0 20 | 6 50 | 13 0 | 3 43 30 | 0 3 30 | 0 10.5 | 3 00 00 | 10 23.5 |
| 0 30 | 10 20 | 14 0 | 4 0 45 | 0 4 00 | 0 12.0 | 4 00 00 | 13 48.0 |
| 0 40 | 13 45 | 15 0 | 4 17 55 | 0 4 30 | 0 13.5 | 5 00 00 | 17 22.5 |
| 1 0 | 17 10 | | | 0 5 00 | 0 15.0 | | |
| 1 10 | 20 40 | | | 0 5 30 | 0 16.0 | | |
| 1 20 | 24 05 | | | 0 6 00 | 0 17.5 | | |
| 1 30 | 27 30 | | | 0 6 30 | 0 19.0 | | |
| 1 40 | 30 55 | | | 0 7 00 | 0 20.5 | | |
| 2 0 | 34 25 | | | 0 7 30 | 0 22.0 | | |

Thus, the telescope being leveled, the gradienter screw was turned through a space of 11$^{rev.}$ 23$^{div.}$ required the arc:

| | | | |
|---|---|---|---|
| 11 revolutions, | = 3° | 9′ | 10″ |
| 20 divisions, | = 0 | 6 | 50 |
| 3 " | = 0 | 1 | 0 |
| The whole arc, . . . | = 3° | 17′ | 00″ |

Conversely, it was desired to turn off a vertical angle of 4° 35′ 40″.

Then we have—

| | | | | | |
|---|---|---|---|---|---|
| 4° | 0′ | 0″ | = 13$^{rev.}$ | 48$^{div.}$ | .0 |
| | 30 | 0 | = 1 | 37 | .0 |
| | 5 | 0 | = | 15 | .0 |
| | | 40 | = | 2 | .0 |
| The space on the head of the screw | | | = 16$^{rev.}$ | 2$^{div.}$ | .0 |

The engineer will bear in mind that the examples given are purposely given in detail: that in practice the operations may be mental ones.

It will be seen that the vertical gradienter can be used for a variety of purposes; measuring distances, grades, differences of levels, vertical angles, and is a useful check against errors of rod or chain measurement.

Messrs. Buff & Berger have also applied the same principle to their horizontal tangent screws. By graduating a silver head attached to these screws sub-divisions of one minute of arc are readily made.

For constant use with these screws it is better to have a rod with two movable targets, or a rod painted with white and black squares as used in the coast survey.

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## Stadia Lines.

The gradienter screw is so universal in its application and can be so readily used for angular, distance or grade measures, that it will generally be found best to have it upon transits designed for current work. There are some cases however where stadia lines are more expeditious in use than the gradienter screw, and give quite as exact results.

Stadia lines, for instance, where an instrument is to be used for distance measures alone, commend themselves for their greater simplicity. For such work, non-adjustable lines, in connection with an inverting eye-piece, give the best results. If the lines are adjustable, in the field usage of an instrument they may alter their distance apart; and there is a rapidity of work with fixed lines, and a rod graduated for telemetrical work, which is not reached in any other way.

These lines may be webs, or platinum, or they may be ruled on glass. The latter are extremely accurate, but the glass on which the lines are ruled intercepts a small amount of light and any dust clinging to the glass somewhat impairs the appearance of the field of view.

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## Plumbing and Centering Arrangements.

It now remains to speak of several conveniences of the instrument under consideration. By a simple mechanical contrivance the plumb-bob when suspended from the instrument can be set immediately at any desired height. It is suspended directly from the *center* of the instrument, and not from the tripod head. This precaution should be taken with every instrument, since otherwise, when there is difficulty in setting up an instrument, and the legs are unsymmetrically placed, the plumb-line will not pass through the center of the instrument.

The instrument is provided with the shifting tripod, better known as the shifting center, by means of which, when the plumb-bob of the instrument is within a fraction of an inch over a point on the ground, it may be brought immediately over it, by moving the body of the instrument on its lower level plate. This is probably the greatest time-saving arrangement which modern makers have introduced in engineers' transits.

## Arrangement for Offsetting at Right Angles.

The most common off-set with the transit is one at 90° to the line of sight. Several methods have been proposed for doing this without disturbing the telescope. Messrs. Buff & Berger have a very neat one; it consists in simply perforating the horizontal axis, so that by drawing the head back fifteen or twenty inches from one end of the axis, the eye may be placed so that the eye, the horizontal axis of the telescope, and a rod set beyond, may be readily placed in the same straight line, at right angles to the line of sight of the telescope, no matter at what altitude the telescope may be pointing.

In off-setting by the arrangement proposed above, the rod is made plumb by lining it with the plumb-line of the instrument itself. The advantage of this method is, that it holds equally well for any inclination of the telescope. The disadvantage is, that the engineer is obliged to leave the eye-end of the telescope at each off-set made. Where the engineer is willing to bring his telescope nearly level before each off-set is made, Messrs. Buff & Berger will adapt a simple combination of two prisms to the telescope, by which the rod may be made plumb, and set at an angle of 90° to the line of sight.

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## Setting Up.

In setting up a transit, push the iron shoe of one leg firmly into the ground, by pressing on the other two legs near the tripod head. Having secured a firm foundation for this leg, separate the other two legs, at the same time drawing the tripod head toward you. Then set the two remaining legs in the same manner as the first one. If the ground is pretty level, merely noticing that the tripod feet are equidistant, will insure that no unsightly appearance will be given to the leveling screws. If the ground is uneven, however, nothing but practice can produce a graceful position of the instrument. The plumb-bob attached to the instrument should swing within say half an inch of the point on the ground, and the plate on which the leveling screws rest, if possible, should be approximately horizontal, when this stage is completed.

Now with the level screws not tightened up, after leveling approximately, bring the plumb-bob exactly over the point on the ground, by moving the body of the instrument on its shifting head. Then complete the leveling of the instrument, and it is ready for work.

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## The Adjustments of the Transit.

In a theoretically perfect transit instrument, the following points are established:

1. The object and eye-glasses are perpendicular to the optical axis of the telescope at all distances apart.
2. The line of collimation coincides with the optical axis.
3. The line of collimation is parallel to the telescope level.
4. The line of collimation passes through, and is perpendicular to the horizontal axis of revolution.
5. The vertical circle is perpendicular to the horizontal axis.
6. The center of its graduated arc lies in the horizontal axis.
7. The arc reads zero when the line of collimation is perpendicular to the vertical axis of the upper plate.
8. The pivots of the horizontal axis of the telescope are circles.
9. The bearings for these pivots are of the same diameter or otherwise exactly similar.
10. The line of collimation moves in a plane perpendicularly above the center of the horizontal graduated circle.
11. The horizontal axis is perpendicular to the axis of the upper plate.
12. The upper plate is perpendicular to its axis.
13. The radial lines which form the graduations of the circle and verniers are equi-distant at the same distance from the axis of the upper plate, and pass through this axis.

14. The levels of the upper plate are perpendicular to its axis.
15. The vertical axis of the upper plate coincides with the axis of the lower plate.
16. The lower plate is perpendicular to its axis.
17. The center of the vernier plate lies in the axis of the lower plate.
18. The axis of the plumb-bob coincides with the vertical axis of the instrument.

Of the above points the maker attends to numbers 1, 2, 4, 5, 6, 8, 9, 11, 12, 13, 15, 16, 17, 18, as a part of the skillful manufacture of the instrument; and the engineer has no facilities for adjusting them, away from the shop. Points numbered 3, 7, 10 and 14 are attended to by the maker when the instrument leaves the shop; but owing to their liability to derangement, from accidental rough usage, the maker leaves it in the hands of the engineer to restore them at any time. It is to these adjustments only that the following remarks are confined.

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## Adjusting.

If the instrument is out of adjustment generally, the engineer will find it profitable to follow the makers in not completing each single adjustment at once, but rather bring the whole instrument to a nice adjustment by repeating the whole series.

After setting up, bring the two small levels each parallel to a line joining two of the opposing leveling screws. Bring both bubbles to the center of the level tubes, by means of the leveling screws. In doing this, place the two thumbs on the inner edges of the two leveling screws, parallel to the bubbles, and the fore fingers of each hand on the outer edge. Turn the leveling screws so that both thumbs move inwards or both outwards. In the former case the bubble will move toward the right, in the latter case toward the left.

Now turn the instrument 180° in azimuth. If the small levels still have their bubbles in the center of their tubes, these levels are adjusted, and the circles are respectively as nearly horizontal and vertical as the maker intended them to be.

If the bubbles, however, are not in the center of their tubes, then bring them half way back by means of the leveling screws, and the remaining half by means of the adjusting screw at the end of each of the level tubes.

It may be necessary to repeat this adjustment several times, but when made, the instrument once leveled will have its small levels in the center of their tubes through an entire rotation of the circle.

There is one adjustment common to all telescopes used in surveying instruments, that of bringing the cross hairs to a sharp focus, at the same time with the object under examination, the adjustment *for Parallax.*

Point the telescope to the sky, and turn the eye-piece until the cross hairs are sharp and distinct. Since the eye itself may have slightly accommodated itself to to the eye-piece, test the adjustment by looking with the unaided eye at some distant point, and while still looking, bring the eye-piece of the telescope before the eye. If the cross hairs are sharp at the *first glance*, the adjustment is made. Now focus in the usual manner upon any object, bringing the cross hairs and image to a sharp focus by the rack-work alone. A point should remain bi-sected when the eye is moved from one side of the eye-piece to the other.

To make the vertical cross-line perpendicular to the plane of the horizontal axis, simply bi-sect some point in the center of the field of view of the telescope, and note whether it continues bi-sected by this cross-line throughout its entire length when the telescope is moved in altitude. If it does not, and the point is to the right of the line in the upper part of the field, the adjustment is made by loosening the four capstan-headed screws, and rotating the reticule in the direction of a left-handed screw, until the cross-line is moved over half the distance between the point and the line. Again, bi-sect the point by means of one of the tangent screws. It should now remain bi-sected throughout the length of the cross-line.

The following method of adjusting particularly the horizontal line has its advantages, and it is given in the words of its propounder, Mr. Gravatt.

"On a tolerably level piece of ground, drive in three stakes at intervals of about four or five chains, calling the first stake *a*, the second *b* and the third *c*. Place the instrument half way between the stakes *a* and *b* and read the staff (leveling rod) A, placed on the stake *a*, and also the staff B, placed on the stake *b*; call the two readings A and B; then, although the instrument be out of adjustment, yet the points read off will be equidistant from the earth's center, and consequently level. (Supposing the instrument to have its vertical axis vertical.) Now remove the instrument to a point half way between *b* and *c*. Again read off the staff B, and read also a staff placed on the stake C, which call staff C (the one before called A, being removed to that situation). Now by adding the difference of the readings on B (with its proper sign) to the reading on C, we get three points say A′, B′, C′, equidistant from the earth's center, or truly level. Place the instrument at any short distance, say half a chain beyond it, and using the bubble to merely to see that you do not disturb the instrument, read all three staffs, call these three readings A″, B″, C″. Now, if the stake *b* be half way between *a* and *c*, then ought

$$C'' - C' - (A'' - A) = 2\left[B'' - B' - (A'' - A')\right]$$

but if not, alter the screws which adjust the diaphragm, and consequently the horizontal line, until such be the case, and then the instrument will be adjusted for collimation."

It is the vertical wire, however, which in the transit is the most important. When that is to be alone adjusted in the field, it is usually done according to the following simple directions: Select two distant points in opposite directions from the instrument, such that the vertical cross-line will bi-sect them both when the telescope is pointed upon one, and then the telescope is reversed around its horizontal axis. After bi-secting the second point selected, revolve the instrument 180° in azimuth, and bi-sect the first point again by means of the tangent screw. Reverse the telescope around its horizontal axis again, and if the second point is now bi-sected the adjustment for collimation of the vertical wire is correct. If it is not bi-sected, move the vertical wire one-fourth of the distance between its present position and the point previously bi-sected. Again bi-sect the first point selected, reverse the telescope and find a new point precisely in the new line of sight of the telescope; these two points will now remain bi-sected when the instrument is pointed upon them in the manner described above, if the adjustment is correctly made. If the two points are not now both bi-sected, the adjustment must be repeated until this is the case.

Perhaps the most elegant method of adjusting for collimation, and one which recommends itself because it is best performed by lamp-light, is the following: set up the transit and level with their object glasses towards each other, and they need not be but a few inches apart. Cover the eye-piece of the level with a piece of white paper, and illuminate this paper with a lamp. By a slight motion of the two telescopes, and use of the transit focussing screw, the cross-lines of the level will be seen sharply defined against the white background of the illuminated paper over the eye-piece. Bring the transit cross-lines so that their intersection is precisely over the intersection of the cross-lines in the level, which had better be turned in its wyes so that its cross-lines make an X with the horizon. If now either instrument is not collimated when the focus of the level is altered by its focussing screw, half an inch or more, and the transit is again sharply focussed on its cross-lines, the intersection of the transit cross-lines will no longer exactly cover the intersection of the level cross-lines. If the level has been carefully adjusted by the methods given further on, then the displacement is wholly due to error of collimation in the transit. This must be corrected by the adjusting screws. When the adjustment is made, the two sets of cross-lines should coincide throughout the entire focussing motion of both telescopes. It must be borne in mind, however, that this method is only applicable to instruments like Buff & Berger's, in which the method of construction precludes the idea of sensible change in the telescope axis, when the focussing screw is turned from one end of its rack-work to the other.

It should be remarked here that whenever the engineer has a level and transit with him at the same time, it is a great convenience to use either one for adjusting the other. It requires a little patience at the outset to point one into the other. so that the cross-lines in both instruments may be black and sharp against a dead white background; but once accustomed to using these methods, the cross-lines are so sharp, and their motions so easily controlled by the screws of the instruments, the engineer usually prefers them.

To determine whether the standards are of the same height, suspend a plumb-bob by means of a long cord from a height say of from thirty to forty feet. The plumb-bob may swing in a bucket of water to keep it steady. Level the instrument carefully, and point upon the plumb-line at its base. If the plumb-line remains bi-sected throughout its entire length when the telescope is moved in altitude, and then the telescope reversed and again made to bi-sect the line throughout its length from its base upward, the adjustment is correct. Otherwise make the adjustment by means of the capstan-headed screw directly under one of the telescope wyes, loosening or tightening the small screws in the pivot-cap at the same time.

To adjust the telescope level in the field, set up the transit in the middle of a tolerably level piece of ground, and carefully level it. At equal distances, in opposite directions from the transit, drive two stakes, so that the readings of a level rod held successively on each of them will be the same when the telescope level bubble is brought to the center of its tube by the vertical tangent screw in each case, and the instrument is turned in azimuth. Take up the instrument and re-set it over one of the stakes; measure the vertical distance from the center of the horizontal axis of the telescope to the top of the stake over which the instrument is set. Set the target of the rod to read this distance, Hold the rod on the distant stake, and bi-sect the target with the horizontal cross-line. With the target thus bi-sected, turn the cylindrical nuts at the object-glass end of the level, till the bubble plays in the middle of its tube. Test the adjustment by re-setting half way between the two stakes, and noting that the bubble remains in the same position, and the rod gives the same reading when the instrument is turned in azimuth alone upon the two stakes. Sometimes it is convenient to use a sheet of water for the same purpose. Two stakes are driven into the water bed at different distances from the transit, until their tops are even with the surface of the water. The transit is leveled up near one of them, and its telescope altered in altitude until a rod held on each successively gives the same reading. Then with the telescope clamped in this position, the adjusting nuts are altered as before until the bubble plays in the middle of its tube.

This adjustment also permits of being made by an auxiliary level in the office. Set up the transit and a level, as described in the adjustment for collimation, and after both instruments are in collimation; take the precaution to set up the instruments so that when the telescopes are approximately level they will point into each other, and the cross-lines may be made to coincide by means of the leveling screws of the transit instrument, after the level has been carefully leveled. Now make the transit bi-sect the intersection of the level cross-lines, and bring the bubble of the telescope level into the middle of its tube by means of the capstan-headed screws· it is obvious the telescope and level axis are both truly level.

It now remains to adjust the vernier of the vertical arc to read zero when the telescope is level, to complete the adjustments of the transit. Bring the telescope level bubble in the middle of its tube, and with the bubble in this position, set the zero of the vernier to coincide with the zero of the vertical arc; loosening the capstan-head screws, which secure the vernier to the standard in so doing,

In reading this vernier proceed to the right or left on the upper line of figures in the direction of the graduation used, and if the coincident line of the vernier is beyond the 15′ line, continue on the lower line of figures on the other half of the vernier, so that the whole graduation from 0′ to 30′ lies in the same direction.

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## The Wye Level.

The description of the telescope of the engineer's transit applies with the following modifications to the telescope of this level.

It has a clear aperture of 1⅜ inches focus, and is 17 or 18 inches long over all, the sun-shade excluded.

The bell-metal collars which rest in the wyes are about 10½ inches apart and 1¾ inches in diameter.

On account of the extreme length of the telescope tube. four capstan-headed screws are provided for centering the eye-piece.

The object-glass focussing screw is in the middle of the tube. The eye-piece is focussed by turning a milled ring at the eye-end. The level attached to the telescope is about 8 inches long, with about 5½ inches exposed, over which is placed the metal scale for reading the position of its bubble. The level-tube is suspended from the telescope-tube in such a manner that at the object-glass end it can be moved in azimuth, with reference to the telescope axis, and at the eye-piece end it can be moved in altitude with reference to the same axis.

Its graduated scale has its graduations set carefully opposite each other on its two sides, and they are numbered from 5 to 0 to 5 at each end of the bubble.

Since it is not necessary to construct a level which shall have absolutely the same value in arc for the same motion of its bubble throughout its length for engineering purposes, the graduated scale is so set that the slight deviations from the arc of a circle may be equally distributed on each side of the zero of the scale. The bubble tube is ground cylindrical.

The level-bar is about 12 inches long over all, and at its two extremities supports the two wyes which rise about 3½ inches from its upper surface. One of these wyes is adjustable in altitude. The level-bar is attached to a long conical center of the hardest bell-metal, which may be clamped to the upper level plate, and then a slow motion in azimuth may be given to the telescope, by a slow motion screw which presses the clamping bar against a stiff spiral spring. With the sunshade on the telescope, the weight is equaly distributed from the center, each way. This is necessary, since a sensitive level, in the nicest work, is affected by any unequal strain, though it may seem to be, practically, imperceptible.

The base, on which the leveling screws rest, has as great a diameter as portability will permit; and the leveling screws are cut with a fine thread. These two points add to the ease with which the instrument may be accurately leveled.

A stop is so arranged that the telescope may be readily set with its horizontal cross-line level, when the instrument is in adjustment.

The instrument complete is not separable when put into its box. Messrs. Buff & Berger believe this condition to be necessary to protect one of the essential adjustments of the level—the adjustment of the wyes—from needless derangement.

This instrument is sometimes made by Messrs. Buff & Berger in a different form. One of the wyes is movable in a vertical line by a milled-head screw. This enables pointing to be made with greater accuracy and facility.

## The Adjustments.

In a theoretically perfect level the following points are established:

1. The object and eye-glasses are perpendicular to the optical axis at all distances apart.
2. The optical axis coincides with the axis of rotation in the wyes.
3. The axis of collimation coincides with the optical axis.
4. The axis of collimation is parallel to the telescope level.
5. The collars resting in the wyes are circles of the same diameter and concentric with the line of collimation of the telescope.
6. The wyes are exactly similar, and similarly placed with reference to the line of collimation of the telescope.
7. The level bubble moves over equal spaces for equal displacements of the telescope in altitude.
8. The level bubble expands or contracts equally from the center in both directions, during changes of temperature.
9. The vertical axis of revolution is perpendicular to the line of collimation of the telescope.

Of the above, the maker establishes points numbered 1, 2, 5, 7 and 8. The remaining points, 3, 4 and 9, are established when the instrument leaves the shop. but being liable to derangement from rough usage, they are made adjustable in the field.

## Adjusting.

After the engineer has set up the instrument and adjusted the eye-piece for parallax, as described under the engineer's transit, the horizontal cross-line had better be made to lie in the plane of the azimuthal rotation of the instrument. This may be accomplished by rotating the reticule, after loosening the capstan-headed screws, until a point remains bi-sected throughout the length of the line when the telescope is moved in azimuth. In making this adjustment, the level tube is to be kept directly beneath the telescope-tube. When made, the small set screw attached to one of the wyes may be set so that by simply bringing the projecting pin from the telescope against it, the cross-lines will be respectively parallel and perpendicular to the motion of the telescope in azimuth.

The first collimating of the instrument may be made using an edge of some building, or any profile which is vertical. Make the vertical cross-line tangent to any such profile, and then turn the telescope half-way round in its wyes. If the vertical cross-line is still tangent to the edge selected, the vertical cross-line is collimated.

Select some horizontal line, and cause the horizontal cross-line to be brought tangent to it. Again rotate the telescope half way round in its wyes, and if the horizontal cross-line is still tangent to the edge selected, the horizontal cross-line is collimated.

Having adjusted the two wires separately in this manner, select some well defined point which the cross-lines are made to bi-sect. Now rotate the telescope half way round in its wyes. If the point is still bi-sected, the telescope is collimated. A very excellent mark to use is the intersection of the cross-lines of a transit instrument.

Center the eye-piece by the four capstan-headed screws nearest the eye end. This is done by moving the opposite screws in the same direction until a distant object under observation is without the appearance of a rise or fall throughout an entire rotation of the telescope in its wyes. The telescope is now adjusted.

Next, bring the level bar over two of the leveling screws, focus the telescope upon some object about 300 feet distant, and put on the sun-shade. These precautions are necessary to a nice atjustment of the level tube. Throw open the two arms which hold the telescope down in its wyes, and carefully level the instrument over the two level screws parallel to the telescope. Lift the telescope out of its wyes, turn it end for end and carefully replace it. If the level tube is adjusted, the level will indicate the same reading as before. If it does not, correct half the deviation by the two leveling screws and the remainder by moving the level tube vertically by means of the two cylinder nuts which secure the level tube to the telescope tube at its eye-piece end. Loosen the upper nut with an adjusting pin, and then raise or lower the lower nut as the case requires, and finally clamp that end of the level tube by bringing home the upper nut. This adjustment may require several repetitions before it is perfect.

The level is now to be adjusted so that its axis may be parallel to the axis of the telescope. Rotate the telescope about 20° in its wyes, and note whether the level bubble has the same reading as when the bubble was *under* the telescope. If it has, this adjustment is made. If it has not the same reading, move the end of the level tube nearest the object-glass in a horizontal direction, when the telescope is in its proper position, by means of the two small capstan-headed screws which secure that end of the level to the telescope tube. If the level bubble goes to the object-glass end when that end is to the engineer's right hand, upon rotating the teleseope level toward him, then these screws are to be turned in the direction of a left-handed screw, as the engineer sees them, and *vice versa*. Having completed this adjustment, the level bar itself must now be made parallel to the axis of the level.

To do this, level the instrument carefully over two of its adjusting screws, the other two being set as nearly level as may be; turn the instrument 180° in azimuth, and if the level indicates the same inclination, the level bar is adjusted. If the level bubble indicates a change of inclination of the telescope in turning 180°, correct half the amount of the change by the two level screws, and the remainder by the two capstan-headed nuts at the end of the level bar, which is to the engineer's left hand when he can read the firm's name. Turn both nuts in the same direction, an equal part of a revolution, starting that nut first which is in the direction of the desired movement of the level bar. Many engineers consider this adjustment of little importance, prefering to bring the level bubble in the middle of its tube at each sight by means of the levelling screws alone, rather than to give any consideration to this adjustment, should it require to be made.

## The Dumpy Level.

The dumpy level differs from the wye level in being attached to the level bar by immovable upright pieces; in having the level tube firmly secured to the uprights of the level bar, in being provided with an inverting eye-piece (unless ordered otherwise), and in the absence of the tangent and slow-motion screws. In regard to the level itself, and the optical power of its telescope, it is fully the equal of the more elaborate wye level.

Compactness is the object aimed at with the dumpy level, and this must be secured at the sacrifice of the parts of the wye level which may be considered more in the light of conveniences than necessaries.

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## Adjusting.

A theoretically perfect dumpy level has the same points established that are mentioned under the head of wye level; but since its construction differs from the wye level, the methods of adjustment are not so convenient, resembling closely the adjustment of the transit telescope and its attached level. After adding the sun-shade and setting up as nearly as level as may be, and setting the eye-piece so to be rid of parallax, the two cross-lines should be set one at right angles to line the telescope axis describes in its horizontal revolution, and the other cross-line parallel to such a line. This is accomplished by loosening the four capstan-headed screws near the eye-piece, and rotating the reticule until a point remains bi-sected when the telescope is moved in azimuth.

To adjust the level, bring the level over two of its foot screws, and bring the bubble to the middle of its tube by means of the foot screws alone. Revolve the instrument 180° in azimuth, and if the bubble remains in the middle it is adjusted, if it does not, then correct half its deviation by the capstan-headed adjusting screw at the eye end, and the remaining half by the two foot screws. Repeat the operation over the other two screws, until the instrument may be revolved in any position, and the level bubble will remain in the middle of its tube,

To adjust the telescope for collimation, any of the methods given for the horizontal cross-line of the transit telescope (see page 28) will apply to the dumpy level. The usual method is to use a sheet of water, or where that is not available, two stakes which are driven with their surfaces in the same level plane.

To make the adjustment with the stakes, set up the level half way between two points lying very nearly in a horizontal line, and say 300 feet apart. Point upon a rod held at one of them, and bring the level to the middle of its tube. Drive a stake at this point, and take the reading of the rod upon it. Point the telescope in the opposite direction, again bring the level to the middle of its tube, and drive a second stake at the second point selected until the rod held upon the second stake gives the same reading as when held upon the first stake. The tops of these two stakes now lie in the same level line.

Take up the level and set it within a few feet of the first stake. Read the rod upon the first stake, and then upon the second. If the two readings agree, and the level is in the middle of its tube, the collimation is correct. If the two readings do not agree, correct nearly the whole of the disagreement shown when the rod is held on the distant point, by means of the upper and lower capstan-headed screws near the eye end of the telescope, and repeat the operation until both rods read the same with the level in the middle of its tube.

The telescope and uprights are in a single casting, which is finished and fitted to the level bar, so that the line of collimation may be permanently parallel to it.

The dumpy level will then be in adjustment, since the adjustment of its vertical cross-line is of no importance.

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## The Plane Table.

A description of this instrument, as modified in plan by H. L. Whiting, Esq., assistant U. S. Coast Survey, and constructed by Buff & Berger, may be found in the Coast Survey Report for 1865.

**The following description of its adjustments, by A. M. Harrison, Esq., assistant U. S. C. S.,** is taken entire from the same paper:

"Topography is that branch of surveying by which any portion of the land surface of the earth is mapped in plan on a specified scale or proportion of nature. With the plane-table such a map is constructed on the ground by at once drawing upon the paper, which is spread upon the table, the angles subtended by different objects, and determining by intersections their relative positions, instead of reading off the angles on graduated instruments and afterwards plotting the lines by means of a protractor, as is done in other methods of surveying. The practice with the plane-table has in this respect a great advantage in directness and precision. The measurement of distances and of vertical angles are used, in conjunction with the method of intersections, to obtain all the data for representing the horizontal and vertical features on the map, which is drawn in the field with pencil, the details being filled in according to established conventional signs.

"**Adjustments.**—From the nature of the service in some sections of the country the plane-table is often necessarily subjected to rough usage, and there is a constant liability to a disturbance of the adjustments; still, in careful hands, a well made instrument may be used under very unfavorable conditions for a long time without being perceptibly affected. One should not fail, however, to make occasional examinations, and while at work, if any difficulty be encountered which cannot otherwise be accounted for, it should lead directly to a scrutiny of the adjustments.

"1. *The fiducial edge of the rule.*—This should be a true, straight edge. Place the rule upon a smooth surface and draw a line along the edge, marking also the lines at the ends of the rule. Reverse the rule, and place the opposite ends upon the marked points, and again draw the line. If the two lines coincide, no adjustment is necessary; if not, the edge must be made true.

"There is one deviation from a straight line, which, by a very rare possibility, the edge of the ruler might assume, and yet not be shown by the above test; it is when a part is convex, and a part similarly situated at the other end concave, in exactly the same degree and proportion. In this case, on reversal, a line drawn along the edge of the rule would be coincident with the other, though not a true right line; this can be tested by an exact straight edge.

"2. *The level attached to the rule.*—Place the instrument in the middle of the table and bring the bubble to the center by means of the leveling screws of the table; draw lines along the edge and ends of the rule upon the board to show its exact position, then reverse 180°. If the bubble remain central, it is in adjustment; if not correct it one-half by means of the leveling screws of the table, and the other half by the adjusting screws attached to the level. This should be repeated until the bubble keeps its central position, whichever way the rule may be placed upon the table. This presupposes the plane of the board to be true. If two levels are on the rule, they are examined and adjusted in a like manner.

"Great care should be exercised in manipulation, lest the table be disturbed.

"3.—*Parallax.*—Move the eye-glass until the cross-hairs are perfectly distinct, and then direct the telescope to some distant well defined object. If the contact remain perfect when the position of the eye is changed in any way, there is no parallax; but if it does not, then the focus of the object-glass must be changed until there is no displacement of the contact. When this is the case, the cross-hairs are in the common focus of the object and eye-glasses. It may occur that the true focus of the cross-hairs is not obtained at first, in which case a readjustment is necessary, in order to see both them and the object with equal distinctness and without parallax.

# Pearsons' Patent Solar Attachment, as manufactured by Buff & Berger.

The following description of the methods of adjusting and using the Solar Attachment was written principally by the inventor, Mr. H. C. Pearsons of Ferrysburg, Michigan, at the request of Messrs. Buff & Berger.

An illustration of this instrument will be found in the price list.

(1.) *This "Attachment"* is an appliance to the surveyor's transit, for the purpose of finding the astronomical meridian. Combined with that instrument it becomes purely astronomical in its character; hence, a few definitions explaining the character of the work to be done seem to be requsite.

(2.) *The Astronomical Triangle* is a spherical triangle, formed by the intersection of the planes of the three following great circles with the celestial sphere,—viz:

The plane of the observer's meridian. The plane of the great circle containing the sun and the pole at the time of observation; and the plane of the great circle passing through the zenith of the observer and the sun.

The distance from the zenith of the observer to the pole, is the complement of the latitude. The distance from the the sun to the pole, is the complement of the sun's declination,—and the distance from the sun to the zenith of the observer is the complement of the sun's altitude.

(3.) *Line of Bearing or Azimuth.* The trace of the last mentioned plane, on the surface of the earth, is called the line of "bearing" or "azimuth" of the sun.

It is the knowledge of the place, or direction of this line with regard to the equator, that enables us to point out the direction of the meridian, as we shall hereafter see.

The place of this line is variable with the observer's latitude,—with the sun's declination; and with the hour-angle or distance of the sun from the meridian.

The above three elements being known, the "bearing" or "azimuth" of the sun (and hence the place of the meridian) is determinate by the rules of spherical trigonometry; but

(4.) *The Solar Transit determines mechanically* the place of the meridian from *two* of the above named elements. viz: *declination* and *latitude.* The following is a

## Description.

(5.) The *Solar Transit* is a combination of the transit-theodolite with the solar attachment above mentioned.

The theodolite is so thoroughly and fully described in Messrs. Buff & Berger's Manual of Engineering and Surveying Instruments, that further effort in that direction would be superfluous.

(6.) *The Declination Arc* is the essential part of the solar attachment. It consists of an arc of about 30° on each side of a zero-point in its center, and it revolves on an axis which is parallel with the optical axis of the telescope when adjusted to the latitude of the observer.

(7.) *The Polar Axis* is the axis on which the declination arc above mentioned revolves. It takes this name from the fact, that when in position for an observation, it is parallel with the earth's axis, and consequently points to the *Pole* of the equator.

(8.) *The Clamping Arc* is the part carrying the polar axis; it is attached to one extremity of the transverse axis of the telescope by a collar, about which it revolves; and it is provided with a clamp screw by which it can be secured in any position on the collar.

This arc is also provided with a slot near its circumference, by which it admits a bolt with a clamping nut, that clamps the arc to any position on the standard of the transit.

When the "clamp arc" is clamped to the "collar" by means of the clamp screw on its side, the "solar attachment" may be put on to, or taken off from the transverse axis of the telescope, by means of the screw cut on the end of the same, which has its nut in the collar.

(9.) *Two Check-Nuts and a Clamp Screw* are provided on the bolt in the slot of the clamping arc. These nuts are capstan-headed, so that they may be adjusted to the limb of the arc when in a vertical position. The clamp screw is provided with a washer between it and the limb of the arc, so that the latter may not be in danger of being disarranged from the adjustment for latitude when being clamped.

(10.) *The Declination Index* consists of a vernier, by which the declination of the sun is set off on the declination arc.

This vernier is attached to the bar which carries a *lens* (called the *Solar Lens*) at the upper end, and a *silver plate* (called the *Focal Plate*) at the lower end of its bar, which is attached, near its middle, to the center of the declination arc.

(11.) *Equatorial and Hour Lines.* On the face of the focal plate are engraved on silver two sets of lens,—the lines of each pair parallel but perpendicular to other pair,—and embracing by their intersection a small square, called the *Focal Point*, from the circumstance of its being in the focus of the solar lens.

That pair of lines perpendicular to the face of the declination arc, is called the *Equatorial* pair, from the fact of their being parallel with the plane of the equator. That pair which is parallel with the face of the declination arc, is called the *Hour Line Pair*,—it being parallel with the meridian at the equator when the sun is at zero declination, and the instrument is in position for an observation.

(12.) *The Spirit Level* on the clamping arc is for the purpose of setting the polar axis to a truly horizontal position, before elevating this axis for the latitude. To facilitate the adjustment of the polar axis, Buff & Berger furnish a smallstriding level with their solar attachment, which can be placed upon the two projecting ends of the polar axis which are made cylindrical for this purpose. By this level the polar axis is at once made truly horizontal.

(13.) *Adjusting Screws* are also provided, whereby the polar axis may be moved horizontally, so that a vertical plane passing through it shall be strictly parallel with the vertical plane passing through the optical axis of the telescope. The object of this condition is, that when the polar axis is put into the meridian, and up to the latitude by means of the telescope, it shall be strictly parallel with the earth's axis,—*i. e.*, in the pole of the equator.

Also a *Friction Spring* is introduced into the joint on the polar axis, whereby the necessary friction of the declination arc on the same, may be secured so that it shall remain in any given position in which it is placed.

(14.) *A Clamp and Eccentric Lever* are provided at the lower end of the declination index, whereby the index may be clamped approximately to its position on the declination arc, when it may be brought precisely to the reading required, by means of a tangent screw attached to the same clamp.

On the other end of the cross-axis of the telescope is a small weight, attached by a "thread and nut," and removable at will, for the purpose of counter-weighting the above described parts of the solar attachment; practically, however, it is not found that this counter-part will ordinarily be needed.

(15.) *Latitude Arc.* When the vertical arc, or circle of the transit-theodolite, is regarded as a part of the solar attachment, it is called the *latitude arc.* Its office is to set the polar axis up to the latitude of the place of the observer. This is done by first bringing the level bubble of the level on the clamp arc to the middle of its tube, and clamping to the standard. Then bring the bubble of the telescope level to the middle of its tube by means of the tangent on the telescope axis. Then releasing the clamp arc from the standard, after first clamping to the cross-axis of the telescope, the polar axis may be put up approximately to the latitude required, and precisely to its place, by the tangent screw of the telescope axis.

The tangent screw of the telescope may be used to advantage in setting the clamp arc for latitude. After leveling up by means of the plate levels alone, turn the clamp arc until its level is nearly horizontal and clamp it to its collar; then clamp the telescope to its tangent screw and now bring the bubble of the clamp arc precisely to the middle. Clamp the clamp arc to the standard and unclamp its collar. Set the telescope nearly horizontal and bring its level bubble in the center by means of the tangent screw. Clamp the clamp arc again to its collar and release both the clamp arc from the standard and the telescope from its tangent screw, when the telescope may be pointed approximately to the given latitude and then precisely by means of the tangent screw.

The polar axis being in place and securely clamped, the telescope may be released and brought down for use till from the progress of the survey it is necessary to readjust the polar axis to a new latitude.

(16.) *Relation between the parts of the instrument:—*

First. The polar axis must be horizontal when the zero of the latitude arc coincides with the zero of its vernier.

Second. The equatorial lines must be vertical when the axis of the solar lens is horizontal.

Third. The optical axis of the solar lens must be in the plane with the zero line of the declination arc and its vernier.

Fourth. The vertical plane containing the center line of the polar axis must be parallel with that containing the optical axis of the telescope.

In all of the following adjustments, it is assumed that the transit instrument itself has been previously carefully adjusted.

(17.) 1st. *The Adjustment of the Polar Axis.* Level the instrument carefully in some place out of the wind, and where there is plenty of light. Move the clamp arc which carries the polar axis until the polar axis is approximately horizontal. Clamp the clamp arc to the transverse axis of the telescope. Place the small striding level, which can be supplied with each instrument, on the two cylindrical flanges which slightly project beyond the two ends of the case in which the polar axis revolves. Bring the bubble of the striding level to the center of its tube by means of the clamp and tangent screw attached to the telescope axis. Adjust the small striding level, if necessary, by reversing it on the cylindrical flanges on which it rests. This bubble remaining in the middle of its tube, adjust the level on the clamp arc so that its bubble will also be central.

2d. *To adjust the Equatorial Lines of the Silver Plate.* The polar axis being in adjustment, place the declination arc in a nearly horizontal position. Suspend a fine silk thread from some point above the instrument, and cause it to be truly vertical directly in front of the focal plate, by means of a small weight attached to the lower end, which may swing in a cup of water to steady it. Look through the solar lens at this plumb-line, and note whether the lines on the focal plate are parallel to this plumb-line. If they are not, they may be made so by loosening the four small screws which hold the plate.

(18.) 3d. *To make the Optical Axis of the Solar Lens lie in the same plane as the zero lines of the Declination Arc and its vernier.* This may be done in two ways.

*a.* Place the lens bar with the declination arc in a nearly vertical position. Fasten a fine silk thread to that end of the telescope axis which is opposite the solar apparatus, and stretch it over the lens, allowing the thread to fall into the small notch cut in the block in which the lens is mounted, and attach a small weight to the lower end of the thread, which is now allowed to swing vertically. Bring the focal plate as close to this thread as possible without touching it. Clamp the declination arc, and with a magnifying glass bring the equatorial lines on the focal plate so that they will be at equal distances from the vertical thread. This bi-section is to be accomplished with the declination tangent screw, and to avoid parallax, it is necessary to place the eye and the magnifying lens in such a position that the whole length of the space between the equatorial lines appears bi-sected by the vertical thread.

Examine the vernier of the declination arc; if it does not coincide with the zero on the arc, cause it to do so by loosening the two screws with which the vernier is fastened to the lens bar, and shift it the proper amount.

*b.* Suspend a thread, as in the second adjustment, about two feet distant from the instrument. Turn the lens bar as far down as is convenient, with the lens bar in the direction of the thread. Clamp the horizontal circle and see that the bubble of the clamp arc is in the middle of its tube. Upon looking through the lens at the focal plate, it will be found possible by raising the eye slightly above the center of the lens to see the equatorial lines and the thread at the same time. To avoid parallax, the eye should be placed three or four inches from the lens, and the equatorial lines must be seen in the middle of the lens. Make the thread bi-sect the space between the two middle equatorial lines by means of the horizontal tangent screw. Bring the lens bar to a nearly horizontal position, and note whether the middle space is still bi-sected; if not, remove half the displacement by means of the tangent screw of the declination arc, and proceed as before until the same space remains bi-sected at all altitudes. Set the zero of the vernier of the declination arc to coincide with the zero of the arc, and the adjustment is complete.

(19.) 4th. *To make the plane of the Polar Axis parallel to the plane of the Telescope Axis.* Having completed the third adjustment, place the lens bar in a horizontal position. Set the zero of the vernier of the horizontal circle to the zero of its arc. Point the telescope to some well defined point by means of the lower tangent screws. Turn the telescope 90° in azimuth, and note whether the middle space of the equatorial lines, as seen through the solar lens, correspond with the point chosen. (Look through this lens at the point beyond, as described in the preceding adjustment.) If the middle lines do not contain the direction of the point between them, loosen three of the four screws which fasten the polar axis to the top of the clamp arm, and by means of the two opposing capstan-headed screws, or by gentle pressure, move the polar axis until the chosen point is seen between the two lines prolonged. Take care in this adjustment that the untouched screw is one of the two on the left hand side. This adjustment being made, screw the plate firmly to its bearing plate.

It should be remarked that the above adjustments will require to be made but rarely.

(20.) *Verifying the Adjustment of the Equatorial Lines.* This adjustment is made by the manufacturer, and it may be verified as follows:

Having "set in" the bubble of the level on the clamping arc, turn the index or lens bar down to a level position across the telescope, and suspend the silk fibre plumb-line immediately in front of the focal plate, so as to be seen through the solar lens projected on to the focal plate.

As the index is moved slightly to the right or left, by means of the tangent screw of the declination arc, the lines, if truly vertical, will be eclipsed by the plumb-line. If they should incline from it either way, adjust as described above.

(21.) *Verification of Adjustments three and four.* At a few minutes before apparent noon, level up the instrument carefully, and set the latitude arc to some convenient degree near the latitude of the place.

Turn the lens bar into a vertical position, and bring the sun's image from the solar lens, on to the focal point as if looking for latitude.

By means of the tangent screw of the declination arc, keep the sun's image between the focal lines,—moving the whole instrument in azimuth at the same time, to keep the image also between the hour lines—*and note the reading of the declination arc.*

When the sun is about culminating, turn the whole instrument quickly 180° in azimuth,—set off the same point on the other side of zero, on the latitude arc, and bring the sun's image again on to the focal point. The reading of the declination arc *should be the same as before.*

This depends on the principle, that near noon the sun's altitude for a few moments changes so slowly as to appear constant.

(22.) *Repeating the Adjustments.* If on making the above verification, any difference appears in the reversed readings of the declination arc, *the foregoing adjustments should be repeated.* Any discrepancy in any of the preceding adjustments will be developed by this test.

(23.) *Ready for Use.* The foregoing adjustments being satisfactorily made, the instrument is ready for use, (it being taken for granted that the several parts of the transit are in adjustment) but before it can be made available in finding meridian, the requisite data must be prepared;—chief among which are

## Refraction and Declination.

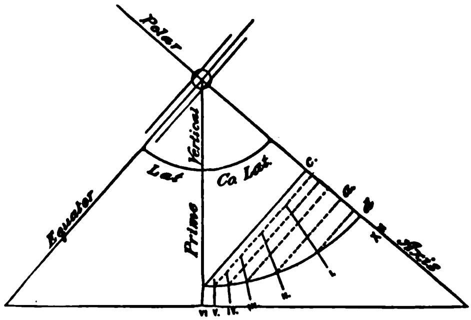
(24.) *Refraction Tables* are prepared, showing the amount of refraction due to the mean state of the atmosphere, indicated by the thermometer (Fahrenheit) at 50°, and the barometer at 30 inches. Corrections are prepared also, for changes indicated by changes of the thermometer and barometer from the mean state, but these are *too small* to be appreciable by the solar transit.

(25.) *Refraction to be reduced for the Time of the Day.* Refraction is applied to the sun's declination, in order to show his apparent place with regard to the plane of the equator; but as the effect of refraction on apparent declination, is different for the different distances of the sun from the meridian, and for different latitudes a *reduction* must be made before it is thus applied.

Mr. William Burt, of "solar compass" fame, has prepared a table of coefficients, or decimals, showing the per cent. of refraction, that must be applied to the declination, for the different hours of the day, and for different latitudes; but as this is only partially correct, we furnish the following explanation.

In the following figure, let the lines marked "equator," "prime vertical," &c., represent the traces of their respective planes on the celestial sphere. Set off any given refraction from ☉ to *d* on the polar axis.

Then when the sun is in the meridian, the *whole* amount of the refraction is effective in projecting the sun's image *below* its true place between the equatorial lines on the focal plate; and the "coefficient" of refraction is *unity*, or ☉ *d*.




But when the declination index is revolved six hours from the meridian, the several lines assume the position as shown in the figure. The vertical plane containing the optical axis of the solar lens, is the prime vertical; and the trace of this vertical plane runs over the face of the focal plate, from XII to VI. And ☉ *c* is now the coefficient showing the part of refraction to be applied to the declination.

But ☉ *c*, is the co-sine of the co-latitude, which is the same as the sine of the latitude. That is to say the *sine of the Latitude* is the *limit* for the reduction of refraction to be applied to the declination.

Between unity and this limit, the coefficient varies with the hour-angle and the latitude, according to the following formula, which is readily deduced by the rules of spherical trigonometry, — and in which L = latitude; H = the hour-angle, and X° = angle passed over by the trace of the vertical plane on the focal plate, in the given time, viz:—

$$\text{Tan } X^\circ = \sin H \cot L$$

The co-sine of this angle X° is the coefficient required. By this formula was *table II* computed.

(26.) *Reduction of Declination.* In finding meridian with the solar transit, it is necessary to set off on the declination arc the declination of the sun, in order to show his relative position with regard to the equator.

The Nautical Almanac furnishes this declination for noon of every day in the year, for the meridian of Greenwich. This must be reduced to the longitude and local time of the place of observation.

It must also be corrected for the effect of refraction before it is set off. An example will illustrate.

Required a declination table for the different hours of the day for Oct. 25, 1878, Lat. 44° N, Long. 97° W.

## Construction.

The difference of time for 97° of longitude, is, say 6½ hours, then, 5½ o'clock, A.M, corresponds to 12 o'clock, noon, at Greenwich. Then taking out the declination for the day, and the hourly difference or change of declination, add the hourly difference for the consecutive hours, thus, (see N. A.)

| | | | | | | |
|---|---|---|---|---|---|---|
| Hourly Diff. Dec. = | | | | 52″ | | |
| (S.) Dec. at 5½ A.M. | = | 12° | 07′ | 39″ | — | 71 |
| " 6 " | = | 12 | 08 | 05 | — | 69 |
| " 7 " | = | 12 | 08 | 57 | — | 71 |
| " 8 " | = | 12 | 09 | 49 | — | 74 |
| " 9 " | = | 12 | 10 | 41 | — | 81 |
| " 10 " | = | 12 | 11 | 33 | — | 89 |
| " 11 " | = | 12 | 12 | 25 | — | 96 |
| " 12 " | = | 12 | 13 | 17 | —1 | 00 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Hourly Diff. = | | | | 52″ | | |
| Dec. brought up, | = | 12° | 13′ | 17″ | — | |
| " 1 P.M. | = | 12 | 14 | 09 | — | 96 |
| " 2 " | = | 12 | 15 | 01 | — | 89 |
| " 3 " | = | 12 | 15 | 53 | — | 81 |
| " 4 " | = | 12 | 16 | 45 | — | 74 |
| " 5 " | = | 12 | 17 | 37 | — | 71 |
| " 6 " | = | 12 | 18 | 29 | — | 69 |
| " 7 " | = | 12 | 19 | 21 | — | 71 |

Having computed the declinations for the several hours, write after each hour the appropriate decimal, or coefficient from table (II,) and prefix the + sign when latitude and declination are of *same name*, or the — sign when *unlike*.

(27.) *Changing the Signs of Refraction.* The reason for the preceding rule for changing the signs of refraction, whenever the name of the declination changes will appear, when we recollect that with the declination and latitude of the same name, an increase of the apparent altitude *increases* the apparent declination, while a contrary effect is produced when these elements have different names. These signs change twice a year, viz: at the equinoxes.

An example will best show the use of these coefficients. Suppose, at an observation at 5 o'clock P.M., in the example of Art. (26,) the refraction was found to be 10′ 48″. The table gives as the coefficient for this hour, .71, multiplying this by 10′ 48″, we have 7′ 40″ to deduct from the computed declination; thus leaving 12° 9′ 57″ to be set off on the declination arc, instead of 12° 17′ 37″.

(28.) *Sun's Image below the Equatorial Lines.* It is the practise of the public land surveyors, to run the sun's image *below* the equatorial lines on the focal plate, by the amount of corrected refraction, instead of taking it from, or adding it to the declination, as above.

This plan facilitates the work somewhat, but it should not be resorted to till after the judgment and the eye are well trained by being made familiar with the preceding process.

Parallel lines, at about 5′ distance apart, are drawn below the equatorial lines, to assist the eye in bringing the sun's image down to its proper place.

## Problem.

(29.) *To find the Latitude.* Having prepared the declination for noon of the day as in Art. (26,) level up the instrument carefully; turn the declination arc into a vertical plane, and approximately into the meridian, by means of the magnetic needle.

Bring the level of the clamping arc, as also the index of the latitude arc to read zero, and clamp the solar "attachment" firmly to the cross axis of the telescope.

Set off the declination, as in the table prepared, clamping the index bar at the same by means of the eccentric lever on the limb of the declination arc.

At a few minutes before apparent noon, bring the solar lens down to "look" at the sun, by canting the telescope on its axis, at the same time moving the instrument in azimuth so as to bring the sun's image on to the focal point.

At first, the sun's image will appear to fall; follow it as long as it does so by means of the tangent screw of the latitude arc. Also, by means of the tangent screw on the horizontal limb of the instrument, keep the image on the focal point between the hour lines of the focal plate.

When the sun's image begins to rise, we know the sun has passed the meridian, *and we may then read the apparent latitude at the vernier of the latitude arc.*

This latitude having been measured from the zenith is *too small* by refraction. Hence, the corresponding refraction being added to the reading of the latitude arc, we have the *true* latitude.

The latitude for other points of the survey, may be found by allowing *92 chs.* of northings or southings for 1′ of latitude.

## Problem.

(30.) *To find Meridian.* As for latitude, level up the instrument carefully, with the zero of the vernier plate clamped to that of its limb.

Turn the face of the declination arc *from the sun*, *i. e.*, in the morning, face the instrument to the west, and in the afternoon, to the east.

Set the level of the clamping arc, as also the index of the latitude arc to read zero, and, clamping the solar attachment to the axis of the telescope, turn the polar axis up to the latitude of the place,—making the solar lens "look" towards the sun,—and clamp the clamping arc to the standard by means of the clamping nut in the slot of its lower limb.

Then, releasing the telescope from the clamping arc, bring it down and measure the altitude of the sun, for the purpose of knowing the refraction,—sighting through a colored glass on the telescope, and reading the altitude on the latitude arc.

Having multiplied the observed refraction by the coefficient for the hour (see Art. 26,) and applied the same to the computed declination, set off the corrected declination on the declination arc, and clamp the index with the eccentric lever on the limb of the arc.

Then, having brought the telescope approximately into the meridian by means of the magnetic needle, turn the instrument in azimuth (on the spindle) to the right or left, at the same time turning the index-bar back and forwards in right ascension, till the sun's image fall precisely on the focal point. *The optical axis of the telescope will then be in the plane of the meridian.*

## Remarks.

(31.) The object of bringing the telescope into the meridian by means of the motion on the spindle, is to have the zero line of the horizontal plate in the meridian, so that the azimuth or bearing of lines can be referred directly to that line.

(32.) If, for any cause, we are obliged to work with an uncertain latitude, it is better to do so with the sun as far from the meridian as practicable, for the following reasons:

It is only when the sun is in the pole of the meridian, that it has its maximum efficiency in pointing out the direction of the meridian. Hence, a large hour-angle, and a small declination, are conducive to the elimination of errors resulting from an incorrect latitude.

Indeed, with the sun precisely in the pole of the meridian, meridian is determinate independantly of latitude.

(33.) In making the several adjustments, or rather in verifying them, the student should have a true meridian established by some other means than by the "solar transit,"—as from the North Star, by some of the methods given in works on surveying. He should compare the results of his observations with this meridian at different times in the day, and under different states of the atmosphere, till he has learned any peculiarity of the instrument and the utmost precision obtainable with it, as well as the ordinary limit of non-precision.

## Degree of Precision Required.

(34.) This, of course, depends on the character of the work to be done. In the U. S. Public Land Surveys,—which are, without question, conducted on the best plan the world can afford,—*only compass lines are required.* As a consequence, a wide margin for non-precision is given.

In sub-dividing a block of townships, the surveyor in coursing a random of 6 miles, is required to make his objective point within 3 chains. Charging the half of this error to lineal measurement, we find the error of coursing *must be within 10′ of the true course.*

(35.) *In Manitoba*, the authorities, having fallen in love with our system of Public Land Surveys, have adopted it; but they require greater precision. They require clear transit lines, projected with the best six-inch silver lined instruments, graduated to 10″.

In coursing a 6 mile random in the sub-division of a township, the surveyor must make his objective point within *one chain*, in order to save reviewing his work, charging, as before, one half of this error to the lineal measurements, we find the maximum error allowed in coursing *to be between 3′ and 4′.*

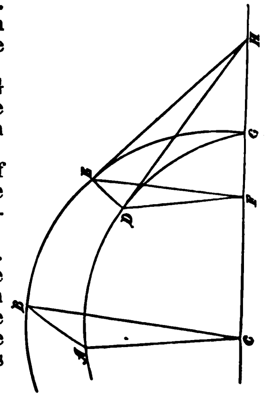
(36.) *With the "New Solar,"* as manufactured by Messrs. Buff & Berger, the surveyor will be surprised and delighted to see the *facility* and *certainty* with which *he can bring his work far within the above limit.*

# Inclination of the Meridian.

(37.) In projecting arcs of a great circle with the "solar transit," it is of the utmost importance that the surveyor be able to tell the inclination of the meridians for any latitude, and for any distance of eastings or westings.

As this problem is not treated in elementary works on surveying, perhaps the few following hints may be of use to the young student.

In the following figure, let the two arcs A G, and B G be two arcs of a quadrant of the meridian, 1° of longitude apart. Let A B = the arc of one degree of longitude on the equator = 69.16 miles.



Let D E be an arc of longitude on any parallel of latitude. Also, let E H and D H be the tangents of those meridians meeting in the earth's axis produced, and corresponding to the parallel of latitude D E.

Then the line E F = D F = cos L = cos A D or B E. Also, the angle D F E = 1°, and the angle D H E = the inclination of the meridians, which is the angle we wish to find, and which we will represent by X°. And because the two triangles F D E and D H E are on the same base E D, and isosceles, their vertical angles vary inversely as their sides; and we have the equation,

$1° \times EF = X° \times EH,$ But
$EF = \cos L$, and $EH = \cot L$, hence
$X° \cot L = 1° \cos L$, or
$X° = \cos L \div \cot L = \sin L,$ . . . . . . . (a)

That is to say,

*The inclination of the meridians for any difference of longitude, varies as the sine of the latitude.*

(38.) Since the sine of the latitude is the inclination in decimals of a degree, for one degree of longitude, if we multiply by 3600″ we shall have the inclination in seconds of arc. Then, if we divide this by the number of miles in one degree of longitude on that latitude, we shall have the inclination due to one mile on that parallel. Thus, for

| | | |
|---|---|---|
| Latitude 43° . . . . . . . | log. sine = | 9.833783 |
| Multiply by 3600″ . . . . . . | ″ = | 3.556303 |
| | | 3.390086 |
| Divide by 50$^{m}$.66, = 1° long. on that L, log. = | | 1.704682 |
| 48″.46 = inclination for one mile of long. | | 1.685404 |

(39.) *The use of the Inclination*, as found by the preceding article, is to show the surveyor how much he must deflect a line of survey from the due east or west, to have it meet the parallel at a given distance from the initial point of the survey,—for it will be remembered that a parallel of latitude is a *curve*, having the cotangent of the latitude for its radius. And the line due east or west is the tangent of the curve.

Thus, on latitude 43°, I wish to project a six-mile line west, for the southerly line of a township.

Remembering that in an isosceles triangle, the angle at the base is less than a right angle by *half the angle at the vertex*, I deflect my line *towards the pole* by the inclination due to *three miles*,—or in this case 48″.46 × 3 = 2′.25″, *i. e.*, *Deflection* = ½ *Inclination*.

(40.) *Table No. III*, which was computed from the formula (a) Art. 37, gives the *Inclination* for one mile, and for six miles on any parallel, from 10° to 60° of latitude; also the *Convergency* for six miles, on any latitude.

(41.) *The Convergency of the meridian* is readily found for any given distance from the corresponding inclination, by multiplying the *Sine* of the inclination by the given *distance*.

Thus, for latitude 43°, the inclination for one mile is 48″.46; the sine of which is .000235. This, multiplied by the number of links in a mile, which = 8000, we have the convergency for one mile, = 1.88 links.

Multiplying this by the number of miles in a township, = 36, and we have the convergency for a township = 67.68 links. In this manner were the convergencies of table III computed.

(42.) *Deflection of Range-Lines from meridian.* The second column of table III shows the surveyor how much he must deflect the range lines between the several sections of a township from the meridian, in order to make the consecutive ranges of sections in a township of uniform width, for the purpose of throwing the effects of "convergency" into the most westerly rangeof quarter sections agreeably to law.

Thus, say between 45° and 55° of latitude, the inclination is practically 1′ for every mile of easting or westing. Then, bearing in mind that in the U.S., the surveys are regarded as projected from the East and South to the West and North; the surveyor must project the *first range-line* between the sections of a township in those latitudes, 1′ *to the left of the meridian.*

The second, 2′; the third, 3′; and so on to the fifth, which must be 5′ to the left of the meridian on the east side of the township.

By this means all the convergency of the township is thrown into the *sixth*, or westerly range of sections, as the law directs.

The fourth column of the above table shows the amount of this convergency. This column is also useful in sub-dividing a block of territory embraced by two "standard parallels" and two "guide meridians" into townships. Thus, starting a meridian from a standard parallel on latitude 43° N, for the western boundary of a range of township,—say the first one west from the guide meridian,—and running North, say 4 townships, the surveyor must make a point that is *East* of the six-mile point on the northern "standard parallel" 4 × 67.7 links = 270.8 links, The second meridian should fall 8 × 67.7 links to the *right* of the twelve-mile point, etc.

(43.) *The Variation of the Needle.* This is easily determined by noting the reading of the needle when the solar transit telescope has been brought into the meridian.

# Table I.

**Mean Refraction of Celestial Objects for Temperature 50°, and Pressure 29·6 inches.**

| Alt. | Refr. | Alt. | Refr. | Alt. | Refr. | Alt. | Refr. | Alt. | Refr. |
|---|---|---|---|---|---|---|---|---|---|
| ° ′ | ′ ″ | ° ′ | ′ ″ | ° ′ | ′ ″ | ° ′ | ′ ″ | ° ′ | ′ ″ |
| 0 0 | 33 0 | 5 30 | 9 8 | 12 0 | 4 23 | 23 0 | 2 14 | 46 0 | 0 55 |
| 10 | 31 22 | 40 | 8 54 | 20 | 4 16 | 20 | 2 12 | 47 0 | 0 53 |
| 20 | 29 50 | 50 | 8 41 | 40 | 4 9 | 40 | 2 10 | 48 0 | 0 51 |
| 30 | 28 23 | 6 0 | 8 28 | 13 0 | 4 3 | 24 0 | 2 8 | 49 0 | 0 49 |
| 40 | 27 0 | 10 | 8 15 | 20 | 3 57 | 20 | 2 6 | 50 0 | 0 48 |
| 50 | 25 42 | 20 | 8 3 | 40 | 3 51 | 40 | 2 4 | 51 0 | 0 46 |
| 1 0 | 24 29 | 30 | 7 51 | 14 0 | 3 45 | 25 0 | 2 2 | 52 0 | 0 44 |
| 10 | 23 20 | 40 | 7 40 | 20 | 3 40 | 20 | 2 0 | 53 0 | 0 43 |
| 20 | 22 15 | 50 | 7 30 | 40 | 3 35 | 40 | 1 58 | 54 0 | 0 41 |
| 30 | 21 15 | 7 0 | 7 20 | 15 0 | 3 30 | 26 0 | 1 56 | 56 0 | 0 38 |
| 40 | 20 18 | 10 | 7 11 | 20 | 3 26 | 20 | 1 55 | 58 0 | 0 35 |
| 50 | 19 25 | 20 | 7 2 | 40 | 3 21 | 40 | 1 53 | 60 0 | 0 33 |
| 2 0 | 18 35 | 30 | 6 53 | 16 0 | 3 17 | 27 0 | 1 51 | 62 0 | 0 30 |
| 10 | 17 48 | 40 | 6 45 | 20 | 3 12 | 30 | 1 49 | 64 0 | 0 28 |
| 20 | 17 4 | 50 | 6 37 | 40 | 3 8 | 28 0 | 1 47 | 66 0 | 0 25 |
| 30 | 16 24 | 8 0 | 6 29 | 17 0 | 3 4 | 30 | 1 45 | 68 0 | 0 23 |
| 40 | 15 45 | 10 | 6 22 | 20 | 3 1 | 29 0 | 1 42 | 70 0 | 0 21 |
| 50 | 15 9 | 20 | 6 15 | 40 | 2 57 | 30 0 | 1 38 | 72 0 | 0 18 |
| 3 0 | 14 36 | 30 | 6 8 | 18 0 | 2 54 | 31 0 | 1 35 | 74 0 | 0 16 |
| 10 | 14 4 | 40 | 6 1 | 20 | 2 51 | 32 0 | 1 31 | 76 0 | 0 14 |
| 20 | 13 34 | 50 | 5 55 | 40 | 2 47 | 33 0 | 1 28 | 78 0 | 0 12 |
| 30 | 13 6 | 9 0 | 5 48 | 19 0 | 2 44 | 34 0 | 1 24 | 80 0 | 0 10 |
| 40 | 12 40 | 10 | 5 42 | 20 | 2 41 | 35 0 | 1 21 | 82 0 | 0 8 |
| 50 | 12 15 | 20 | 5 36 | 40 | 2 38 | 36 0 | 1 18 | 84 0 | 0 0 |
| 4 0 | 11 51 | 30 | 5 31 | 20 0 | 2 35 | 37 0 | 1 16 | 86 0 | 0 6 |
| 10 | 11 29 | 40 | 5 25 | 20 | 2 32 | 38 0 | 1 13 | 88 0 | 0 2 |
| 20 | 11 8 | 50 | 5 20 | 40 | 2 29 | 39 0 | 1 10 | 90 0 | 0 0 |
| 30 | 10 48 | 10 0 | 5 15 | 21 0 | 2 27 | 40 0 | 1 8 | | |
| 40 | 10 29 | 20 | 5 5 | 20 | 2 25 | 41 0 | 1 6 | | |
| 50 | 10 11 | 40 | 4 56 | 40 | 2 23 | 42 0 | 1 3 | | |
| 5 0 | 9 54 | 11 0 | 4 47 | 22 0 | 2 20 | 43 0 | 1 1 | | |
| 10 | 9 38 | 20 | 4 39 | 20 | 2 18 | 44 0 | 0 59 | | |
| 20 | 9 23 | 40 | 4 31 | 40 | 2 16 | 45 0 | 0 57 | | |

# Correction to the Mean Refraction given in the preceding Table.

| Ap. Alt. | | Height of the Thermometer. | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | ′ | 20° ′ + ″ | 24° ′ + ″ | 28° ′ + ″ | 32° ′ + ″ | 36° ′ + ″ | 40° + ″ | 44° + ″ | 48° + ″ | 52° — ″ | 56° — ″ | 60° — ″ | 64° ′ — ″ | 68° ′ — ″ | 72° ′ — ″ | 76° ′ — ″ | 80° ′ — ″ |
| 0 | 0 | 2 40 | 2 18 | 1 55 | 1 33 | 1 11 | 51 | 31 | 10 | 10 | 29 | 48 | 1 7 | 1 25 | 1 43 | 2 1 | 2 19 |
| 0 | 20 | 2 25 | 2 5 | 1 44 | 1 24 | 1 4 | 46 | 28 | 9 | 9 | 26 | 44 | 1 1 | 1 17 | 1 33 | 1 49 | 2 05 |
| 0 | 40 | 2 11 | 1 53 | 1 34 | 1 16 | 58 | 42 | 25 | 8 | 8 | 24 | 39 | 55 | 1 10 | 1 24 | 1 38 | 1 53 |
| 1 | 0 | 1 59 | 1 43 | 1 25 | 1 9 | 53 | 38 | 23 | 8 | 7 | 21 | 36 | 50 | 1 3 | 1 17 | 1 30 | 1 43 |
| 1 | 20 | 1 48 | 1 33 | 1 17 | 1 3 | 48 | 34 | 21 | 7 | 6 | 19 | 32 | 45 | 57 | 1 9 | 1 21 | 1 33 |
| 1 | 40 | 1 39 | 1 25 | 1 11 | 57 | 44 | 31 | 18 | 6 | 6 | 18 | 30 | 41 | 52 | 1 4 | 1 15 | 1 25 |
| 2 | 0 | 1 31 | 1 18 | 1 5 | 53 | 39 | 29 | 17 | 6 | 5 | 16 | 27 | 37 | 48 | 58 | 1 8 | 1 18 |
| 3 | 0 | 1 11 | 1 1 | 51 | 41 | 32 | 22 | 13 | 4 | 4 | 13 | 21 | 30 | 38 | 46 | 54 | 1 1 |
| 4 | 0 | 58 | 49 | 41 | 33 | 26 | 18 | 11 | 4 | 4 | 10 | 17 | 24 | 31 | 37 | 44 | 50 |
| 5 | 0 | 48 | 41 | 35 | 28 | 22 | 16 | 9 | 3 | 3 | 9 | 14 | 20 | 26 | 31 | 36 | 40 |
| 6 | 0 | 41 | 35 | 30 | 24 | 19 | 13 | 8 | 3 | 2 | 7 | 12 | 17 | 22 | 26 | 31 | 35 |
| 7 | 0 | 36 | 31 | 26 | 21 | 16 | 12 | 7 | 2 | 2 | 6 | 10 | 14 | 19 | 23 | 27 | 31 |
| 8 | 0 | 32 | 27 | 23 | 19 | 15 | 10 | 6 | 2 | 2 | 5 | 9 | 13 | 16 | 20 | 24 | 27 |
| 9 | 0 | 28 | 24 | 20 | 16 | 13 | 9 | 5 | 2 | 2 | 5 | 8 | 11 | 14 | 18 | 21 | 24 |
| 10 | 0 | 26 | 22 | 18 | 15 | 12 | 8 | 5 | 2 | 1 | 4 | 7 | 10 | 13 | 16 | 19 | 22 |
| 12 | | 21 | 18 | 15 | 13 | 10 | 7 | 4 | 1 | 1 | 4 | 6 | 9 | 11 | 13 | 16 | 18 |
| 14 | | 18 | 16 | 13 | 11 | 8 | 6 | 4 | 1 | 1 | 3 | 5 | 7 | 9 | 11 | 14 | 16 |
| 16 | | 16 | 14 | 12 | 9 | 7 | 5 | 3 | 1 | 1 | 3 | 5 | 6 | 8 | 10 | 12 | 14 |
| 18 | | 14 | 12 | 10 | 8 | 6 | 5 | 3 | 1 | 1 | 2 | 4 | 6 | 7 | 9 | 10 | 12 |
| 20 | | 13 | 11 | 9 | 7 | 6 | 4 | 2 | 1 | 1 | 2 | 4 | 5 | 6 | 8 | 9 | 11 |
| 25 | | 10 | 8 | 7 | 6 | 5 | 3 | 2 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 30 | | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 35 | | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 0 | 1 | 2 | 3 | 3 | 4 | 5 | 6 |
| 40 | | 6 | 5 | 4 | 3 | 3 | 2 | 1 | 0 | 0 | 1 | 2 | 2 | 3 | 3 | 4 | 5 |
| 45 | | 5 | 4 | 3 | 3 | 2 | 2 | 1 | 0 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 |
| 50 | | 4 | 3 | 3 | 2 | 2 | 1 | 1 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 3 | 3 |
| 55 | | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 3 |
| 60 | | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 2 |
| 65 | | 2 | 2 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 |
| 70 | | 2 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| 80 | | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 90 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Height of Barometer. | | | | | — 28·26 inches. | — 28 56 inches. | — 28·85 inches. | — 29·15 inches. | — 29·45 inches. | + 29·75 inches. | + 30.05 inches. | + 30.35 inches. | + 30·64 inches. | + 30·93 inches. | | | |

### Example I.

What is the correction for refraction for an altitude of 8° 5′, the thermometer standing at 50·0° and the barometer at 29·6° inches?

Answer (by inspection) .. .. .. .. 6′ 25″:

and therefore,

| | | | |
|---|---|---|---|
| Apparent altitude | .. .. | = | 8° 5′ |
| Refraction | .. .. .. | = | — 6 25″ |
| True altitude | .. .. .. | | 7 58 35 |

### Example II.

What is the correction for refraction for the same altitude, the thermometer standing at 44° and the barometer at 29·45 inches?

| | | | |
|---|---|---|---|
| | | | ′ ″ |
| Thermometer correction for altitude 8° 5′ | | = | + 0 6 |
| Barometer | ditto | = | — 0 2 |
| Correction for both is | .. .. .. | = | + 0 4 |
| Mean Refraction | .. .. .. | = | — 6 25 |
| ∴ True refraction | .. .. .. | = | — 6 21 |

| | | | |
|---|---|---|---|
| | | | ° ′ ″ |
| Apparent Altitude | .. .. .. | = | 8 5 0 |
| True refraction | .. .. .. | = | — 6 21 |
| True altitude | .. .. .. | | 7 58 39 |

# Table II.

**Coefficients showing the per cent. of Refraction to be applied to the Sun's Declination.**

| | Hours from the Meridian. | | | | | | | Hours from the Meridian. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lat. | 1 H. | 2 H. | 3 H. | 4 H. | 5 H. | 6 H. | Lat. | 1 H. | 2 H. | 3 H. | 4 H. | 5 H. | 6 H. |
| ° | | | | | | | ° | | | | | | |
| 10 | 56 | 33 | 24 | 20 | 18 | 17 | 36 | 94 | 82 | 71 | 64 | 60 | 59 |
| 12 | 63 | 39 | 28 | 24 | 22 | 21 | 38 | 95 | 85 | 74 | 67 | 63 | 62 |
| 14 | 69 | 45 | 33 | 27 | 25 | 24 | 40 | 95 | 87 | 77 | 70 | 65 | 64 |
| 16 | 74 | 50 | 38 | 31 | 29 | 28 | 42 | 96 | 88 | 79 | 72 | 68 | 67 |
| 18 | 78 | 55 | 42 | 35 | 32 | 31 | 44 | 96 | 89 | 81 | 74 | 71 | 69 |
| 20 | 81 | 60 | 46 | 39 | 35 | 34 | 46 | 97 | 90 | 83 | 77 | 74 | 72 |
| 22 | 84 | 64 | 50 | 42 | 38 | 37 | 48 | 98 | 91 | 85 | 79 | 76 | 74 |
| 24 | 87 | 68 | 54 | 46 | 42 | 41 | 50 | 98 | 92 | 86 | 81 | 78 | 76 |
| 26 | 89 | 70 | 57 | 49 | 45 | 44 | 52 | 98 | 93 | 88 | 83 | 81 | 79 |
| 28 | 90 | 72 | 60 | 51 | 48 | 47 | 54 | 99 | 94 | 90 | 85 | 83 | 81 |
| 30 | 91 | 74 | 63 | 54 | 51 | 50 | 56 | 99 | 95 | 91 | 87 | 85 | 83 |
| 32 | 92 | 77 | 66 | 57 | 54 | 53 | 58 | 99 | 96 | 92 | 88 | 86 | 85 |
| 34 | 93 | 80 | 69 | 61 | 57 | 56 | 60 | 99 | 97 | 93 | 90 | 88 | 87 |

For the construction of the above table, see Article (25).

# Table III.

## Inclination and Convergency of the Meridians.

| Lat. | Inclination for one mile. | Inclination for six miles | Convergency for one township of 36 miles. | Lat. | Inclination for one mile. | Inclination for six miles | Convergency for one township of 36 miles. | Lat. | Inclination for one mile. | Inclination for six miles | Convergency for one township of 36 miles. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | ″ | ′ ″ | LINKS. | ° | ″ | ′ ″ | LINKS. | ° | ′ ″ | ′ ″ | LINKS. |
| 10 | 9.18 | 55 | 13.0 | 27 | 26.52 | 2 39 | 36.9 | 44 | 50.19 | 5 01 | 70.1 |
| 11 | 10.13 | 1 01 | 14.2 | 28 | 27.66 | 2 46 | 38.6 | 45 | 52.00 | 5 12 | 72.6 |
| 12 | 11.07 | 1 06 | 15.5 | 29 | 28.85 | 2 53 | 40.2 | 46 | 53.83 | 5 23 | 75.2 |
| 13 | 12.02 | 1 12 | 16.8 | 30 | 30.03 | 3 00 | 41.9 | 47 | 55.67 | 5 34 | 77.8 |
| 14 | 12.98 | 1 18 | 18.1 | 31 | 31.26 | 3 07 | 43.6 | 48 | 57.67 | 5 46 | 80.6 |
| 15 | 13.96 | 1 24 | 19.4 | 32 | 32.49 | 3 15 | 45.4 | 49 | 59.83 | 5 59 | 83.5 |
| 16 | 14.93 | 1 30 | 20.7 | 33 | 33.83 | 3 23 | 47.2 | 50 | 1 02.00 | 6 12 | 86.5 |
| 17 | 15.92 | 1 36 | 22.0 | 34 | 35.17 | 3 31 | 49.1 | 51 | 1 04.17 | 6 25 | 89.7 |
| 18 | 16.91 | 1 41 | 23.4 | 35 | 36.50 | 3 39 | 50.9 | 52 | 1 06.67 | 6 40 | 93.0 |
| 19 | 17.93 | 1 47 | 24.9 | 36 | 37.83 | 3 46 | 52.7 | 53 | 1 09.17 | 6 55 | 96.4 |
| 20 | 18.94 | 1 54 | 26.5 | 37 | 39.17 | 3 55 | 54.7 | 54 | 1 16.67 | 7 10 | 100.0 |
| 21 | 19.98 | 2 00 | 27.8 | 38 | 40.67 | 4 04 | 56.8 | 55 | 1 14.33 | 7 26 | 103.7 |
| 22 | 21.02 | 2 06 | 29.3 | 39 | 42.17 | 4 13 | 58.8 | 56 | 1 17.17 | 7 43 | 107.6 |
| 23 | 22.10 | 2 13 | 30.8 | 40 | 43.67 | 4 22 | 60.9 | 57 | 1 20.00 | 8 00 | 111.8 |
| 24 | 23.17 | 2 19 | 32.3 | 41 | 45.17 | 4 31 | 63.1 | 58 | 1 22.00 | 8 19 | 116.2 |
| 25 | 24.30 | 2 26 | 33.8 | 42 | 46.85 | 4 41 | 65.4 | 59 | 1 26.66 | 8 40 | 120.9 |
| 26 | 25.38 | 2 32 | 35.4 | 43 | 48.52 | 4 51 | 67.7 | 60 | 1 30.00 | 9 00 | 125.7 |

For the construction and use of the above table, see articles (37,) (38,) (39,) (41,) (42.)

For details of instruction in U. S. Government Surveying, see Hawes' System of "Rectangular Surveying," and Burt's "Key to Solar Compass."

Fig 1

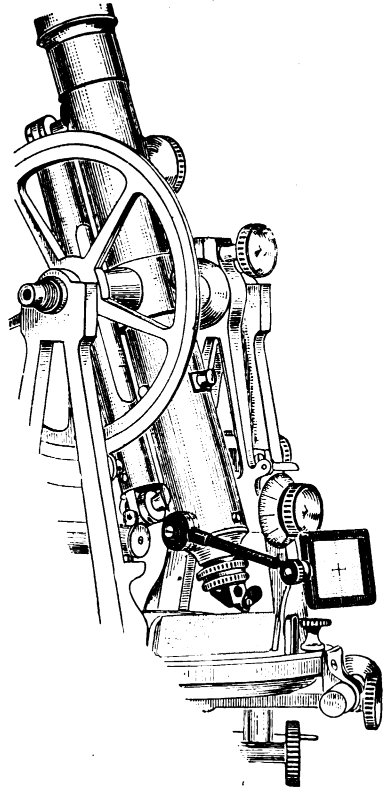


Fig 2.

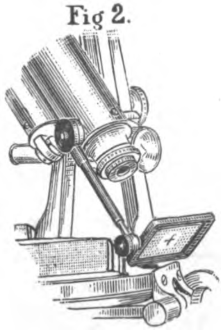
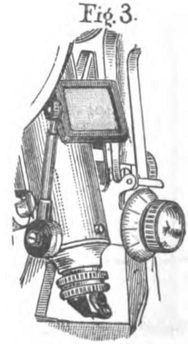


Fig.4.

Fig. 3.



**Davis' Patent Solar Attachment.**

# Transit Solar Attachment.

**For running Meridian or other lines by the Sun.**

Written for this catalogue with special reference to the wants of Public Land Surveyors, for both common and mineral lands, by J. B. Davis, Assistant Professor of Civil Engineering, University of Michigan.

**1. Remarks.** The attachment herein referred to is the Davis and Berger solar screen, prism, and colored shade glass, used for direct solar observation. These inventions have been devised by the Mr. Berger, of the firm of Buff & Berger, and by the writer. They are simply for the purpose of enabling one to make an observation directly upon the sun's centre. This observation being secured by readings of the horizontal and vertical circles, is reduced so as to give the direction of the line of sight of the transit at the instant of the observation. Thus knowing the direction of the line of sight at a given instant it becomes simply necessary to turn off the angle which this line of sight makes with the meridian, to ascertain the position of the meridian. This angle is what is obtained by reducing the observation, as above mentioned. A brief reference to the history of these devices will best explain them. It occurred to the writer to see if an image of the sun could be formed behind the eye-piece of a telescope at the same time an image of the cross-wires was, and the latter image be made to quarter the former, by allowing the sun to shine into the object end of the telescope and thence directly through it. The experiment was made by holding a piece of white paper behind the eye-piece, and adjusting the focus of the eye-piece and object glass. The very first trial was readily successful. The next thing was to see if the position of the instrument could be located by this means as near as the circles would read. By the same simple means it was soon found that a motion given to the telescope by either tangent screw might be so slight that the eye could not detect it upon the circles, but evidence of it would be apparent in the position of the images with reference to each other. This fact at once settled the question of whether this would be a sufficiently delicate means of observation. It showed that the observations would be closer than the circles would read. After some trials and some months rest these facts were brought to the notice of others, and finally were submitted to Mr. Berger for his opinion. He made a screen which the writer exhibited at the first annual convention of the association of Michigan Engineers and Surveyors at Lansing. The matter was further studied by Mr. Berger. The screen was much improved, and the mechanical construction of it brought to the standard of the work done by this firm. Mr. Berger soon conceived the idea of making the screen of ground white glass in a brass frame, as shown in figs. 1 and 2, so one might observe the position of the images directly upon it, and thus secure not only the comfort of an easy position in observing, but the consequent accompanying accuracy. The arm of attachment was perfected from time to time. The screen of ground glass is mounted upon an arm that admits of all adjustments of position, and is so attached to the side of the telescope tube that it can be turned up out of the way when not needed. The reflecting prism can be screwed on to the eye-piece cap for observing at high altitudes. This also is adjustable so as to look in any desired direction from the telescope tube. The diagonal eye-piece also has its movable colored shade glass as above stated. With these attachments observations on the sun at all altitudes may be made in two ways. By looking directly at it through the simple colored glass for low altitudes, or through the prism and its shade glass for high altitudes. The other way is to receive on the screen the images of the cross-wires and the sun and make the image of the cross-wires just quarter the image of the sun by means of the slow motion screws to the circles of the instrument. For this method the colored shade glasses are not to be used. With this complete outfit one may work whichever way seems best.

These devices being perfected have been protected by letters patent, and Messrs. Buff & Berger make and sell them exclusively.

**2. Remarks.** Certain precautions are necessary in the use of this method of finding the true direction of a line as well as in any other. It is not wise to observe the sun, read the circles, note down the readings and leave the instrument standing there while making the reductions. It will get out of place in some way, very likely. Therefore, as soon as the observation is completed and the readings of the circles noted, set the line of sight on some fixed point and read the plate again, noting this reading. Of course the two plate readings will give the horizontal angle from the sun to the line. This will enable the observer, after finding the direction of the line of sight when set on the sun, to readily ascertain its direction as set on the fixed point referred to, thus determining the direction of the line from the point over which the instrument is set to the fixed point. This line may be chosen before beginning the observation, and become the reference line for the work in hand.

**3. Remarks.** For the purposes of reduction the process by equations is used instead of one by rules. The introduction of symbols and signs is a much simpler matter than many suppose. It is nothing but this. We agree that a character of some sort or other shall represent a certain thing and nothing else. Whenever this character occurs, therefore, it simply means the thing we have set it for. That is all there is of symbolical representation. These very words here printed are all symbols. The method is universal. We here, as elsewhere in algebraic processes, make a special application of it. The rules for a case of this kind would be very cumbersome and give the user far more trouble than will be necessary for mastering the few equations given below. The record of the processes is hereby reduced to a few lines, and one has not to go searching through a page for a point here and there, but places his eye at once upon what he wants, where all will be found in a compact form. Of course one needs to read each word and each sign. Nothing must be slurred over or missed. The record as set forth below is exact, complete and reliable.

**4. Remarks.** All computations should be thoroughly checked, and check equations and devices are given. These should always be applied, without fail, as no one can implicitly trust a computation by a single process, unrepeated, even if simple. No one should who is a surveyor or engineer. Several checks are given. One *used* is sufficient, usually. If one distrusts the check because it shows the work to be wrong, it may be of some satisfaction to use another or more than one.

**5. Remarks.** The *directions* prepared below are intended for use, word by word, and step by step. It is hoped that they will prove in convenient form for use as a chart to direct the efforts of the observer in his first use of these attachments and this method. Therefore, it is thought that one may safely do as told, trusting the next step to the next statement. They have been prepared with this view.

**6. Using the Screen.**

***a.* Directions.** Set the instrument so the sun can shine in at the object end of the telescope, and directly through it. Run out the eye-piece and adjust the screen behind it, by its sliding arm, so that a distinct image of the cross-wires can be seen on the screen within the lighted spot made by the shining sun, as shown in fig. 2. Set the object glass so as to clearly define the image of the sun on the screen. Repeat these trials, and adjust the parts of the telescope and screen so that the clearest image of both the cross-wires and the sun will be obtained that the telescope will give. Mark the slide on the arm of the screen and the eye-piece, so they can be easily set thereafter for an observation.

***b.* Remarks.** The eye-piece, when all is in exact position, will be found to be considerably farther out than for an ordinary sight. The marking of the sliding arm and eye-piece will save time in the future. These trials, when made with a new apparatus, should be conducted at leisure and with extra care, for the purpose of fitting the apparatus carefully to the telescope. A few trials may be needed at first in order to accustom the observer to recognize the best definition of the images.

This solar screen is especially adapted to the ordinary surveyors' and engineers' transit telescopes, with erecting eye-pieces. It is not adapted to be used with inverting or astronomical telescopes, because in such telescopes the images are formed at too great a distance behind the eye-piece, and are too large to be received on the screen. Hence, with such telescopes, the colored shade-glasses and reflecting prism should alone be used.

### 7. Using the Colored Shade Glass.

*a.* **Directions.** Attach the colored glass shown in fig. **4,** to the eye-piece, to shield the eye from the sun and look directly at it, setting the cross-wires so as to quarter it.

*b.* **Remarks.** This will be found entirely satisfactory when the sun's altitude is so low as to enable the observer to bring his eye in apposition with the eye-piece of the telescope with ease.

### 8. Using the Diagonal Eye-piece.

*a.* **Directions.** Screw on the prism, as shown in fig. **3,** to the end of the common eye-piece. Look directly through the shade-glass, if observing in that way, turning the prism either way so as to make it convenient to look into it. If any trouble is experienced in finding the sun with it, let the sun first shine through the telescope, the colored shade-glass being turned aside, till the brilliant light perceived in the aperture of this eye-piece shows the telescope to be rightly directed. Cover the aperture with its shade-glass and proceed.

*b.* **Remarks.** By attaching the reflecting prism to the eye-piece of the telescope, the light is reflected at right angles to the the line of sight of the telescope, and it thus becomes what is termed a diagonal eye-piece.

This prism can be used for direct observation when the altitude of the sun is too great to allow the eye to be applied *directly* to the eye-piece of the telescope, and not so great as to bring the eye-piece too far over the plate, but through this range of altitudes the solar screen can be used without the prism, as shown in fig. **2,** and it will usually be found advantageous to do so.

Since the prism in effect withdraws the eye about half an inch further from the eye-piece of the telescope than its natural position, that being about the distance traversed by the light in passing through the prism, the high magnifying power used in Buff & Berger's transit telescopes makes the use of the reflecting prism for *direct* observation a little awkward, and it will usually be found more satisfactory when using the prism to use the solar screen with it.

### 9. Using the Reflecting Prism and Solar Screen combined.

*a.* **Directions.** Attach the prism, and direct the telescope as in **8.** Then, leaving the aperture of the prism uncovered, adjust the solar screen so as to receive the images of the sun and the cross-wires, as shown in fig. **1.**

*b.* **Remarks.** For observing the sun at high altitudes it will be found that in this, otherwise most difficult of all positions, the use of the solar screen combined with the prism will enable the engineer to make his observation with the greatest ease and precision.

### 10. Making the Observations.

*a.* **Directions.** Direct the telescope to the sun, and by means of the slow motion screws, cause the image of the cross-wires to exactly quarter the sun's image. Read both circles and record the readings. Refer the position of the instrument to some fixed line, and once, *after* the above work, by another plate reading. Also note and record the exact instant of time of the observation by the watch.

*b.* **Remarks.** This observation with the watch may be used as hereafter indicated to simplify and lessen the amount of work in making the reductions. A fair watch of ordinary accuracy is sufficient. The entire work can be carried on without a watch at all, but it takes some more figuring.

### 11. Use of the Nautical Almanac.

*a.* **Remarks.** In order to use the observations, made as above directed, it is necessary to find the sun's apparent declination for the time of observation. This is done as directed below.

*b.* **Conditions.** Let all the algebraic signs be carefully observed throughout the work. Use the watch time.

*c.* **Directions.** *For finding the Sun's apparent declination.* Look in the table of Washington Solar Ephemeris against the date of the observation, and take out the following quantities. First, the sun's apparent declination, with its sign, + when N., — when S., from its column. Second, the hourly change, with its sign, from its column. Find from a map or otherwise, the difference in longitude between the place of observation and Washington, as near as one-half hour, or seven and one-half degrees. This is + when W. and — when E. of Washington. Add to this difference of longitude the time of the observation from noon, this time being + when the sun is W. and — when E. of the meridian. Multiply the hourly change by this result, *in hours*, noting all the signs. Apply this product, regarding its sign, to the sun's apparent declination as taken, from the table, for the sun's apparent declination at the time of the observation.

*d.* **Example.** Date, 1881—6—14. Hour, $9^h—26^m—24^s$, A.M. Longitude about 40 minutes East of Washington, considered in time.

⊙'s apparent declination, 1881—6—14.
Washington mean noon, + 23° 18′ 15″
Hourly motion, + 7″

Time of observation from noon, —2 hours 30 minutes, about.
Longitude East of Washington, — 40 minutes.
Total time of correction, —3 hours 10 minutes, $= 3\frac{1}{6}$ hours.

Amount of correction = $-3\frac{1}{6} \times 7'' = -22\frac{1}{6}''$
⊙'s apparent declination from table, + 23° 18′ 15″
⊙'s apparent declination at time of observation, + 23° 17′ 53″ nearly.

## 12. Reducing Observations.

*a.* **Conditions.** Let $h'$ = the sun's altitude, as observed.
Let $\phi$ = the latitude of the place of observation.
Let $\delta$ = the sun's apparent declination at the time of observation, found as above directed.
Let $z'$ = the sun's observed zenith distance.
Let $z$ = the sun's true zenith distance, always +.

Let $k$ and $k'$ be two auxiliary angles used in the reductions.

Let A = the azimuth of the line of sight of the instrument at the instant of the observation, reckoned from the N. point of the horizon, either E. or W. as the sun is E. or W. of the meridian.

Let $t$ = the sun's apparent hour angle at the time of the observation, that is the local apparent time from apparent noon plus the change in the sun's right ascension between apparent noon and the time of the observation. This is + when W. and — when E. of the meridian, or + for P.M., and — for A.M. times. The mean or watch time is sufficient for use in 2.

Let $p$ = an auxiliary angle used in some of the reductions.

Let all signs be faithfully regarded. Let logarithms be used.

*b.* **Directions.** *For finding z from z′.* Use the following equations.

$$z' = 90° - h' \qquad (1)$$
$$z = z' + 55'' \tan z' \qquad (2)$$

*c.* **Directions.** *For finding A when $\phi$, $\delta$ and $z$ are given.*

Find $\tan \frac{1}{2}(k-k') = \cot \frac{1}{2}(\phi+\delta) \tan \frac{1}{2}(\phi-\delta) \cot \frac{1}{2} z$ . . (3)
When $\phi < \delta$ and of the same name find $k = \frac{1}{2} z + \frac{1}{2}(k-k')$ . . (4)
When $\phi > \delta$ and of the same name find $k' = \frac{1}{2} z - \frac{1}{2}(k-k')$ . . (5)
When $\phi$ and $\delta$ have different names find $k' = \frac{1}{2} z - \frac{1}{2}(k-k')$ . . (6)
Then find A from $\cos A = \tan k \tan \phi$ or $\tan k' \tan \phi$ . . . . (7)

**Checks.**

When (4) is used $$\frac{\sin \phi}{\sin \delta} = \frac{\cos k}{\cos k'} \qquad (8)$$

or $$\frac{\sin \phi}{\cos k} = \frac{\sin \delta}{\cos k'} = \cos p \qquad (9)$$

When (5) or (6) is used $\frac{\text{Sin}\ \phi}{\text{Sin}\ \delta}=\frac{\cos k'}{\cos k}$ . . . . . . . . . (10)

or $\frac{\text{Sin}\ \phi}{\cos k'}=\frac{\text{Sin}\ \delta}{\cos k}=\cos p$ . . . . . . (11)

**Find** $\text{Sin}\ p=\sin A \cos \phi$ . . . . . . . . (12)

Sin $p$ and cos $p$ are at the same place in the table.

*d.* **Example.** $\phi=42°\ 16'\ 30''$ N. $z=52°\ 43'\ 30''$

$\delta=18°\ 13'\ 20''$ N. $\frac{1}{2}z=26°\ 21'\ 45''$

$\phi+\delta=60°\ 29'\ 50''$

$\phi-\delta=24°\ \ 3'\ 10''$

$\frac{1}{2}(\phi+\delta)=30°\ 14'\ 55''$

$\frac{1}{2}(\phi-\delta)=12°\ \ 1'\ 35''$

**Checks.**

| | | | |
|---|---|---|---|
| $\text{Cot}\frac{1}{2}(\phi+\delta)=0.2342195$ | $\text{Tan}\ \phi=9.9586273.$ | $\text{Sin}\ \phi=9.8278148$ | $\text{Cos}\ \phi=9.8691875$ |
| $\text{Tan}\frac{1}{2}(\phi-\delta)=9.3284570$ | $-\text{Tan}\ k'=9.2477939.$ | $\text{Cos}\ k'=9.9933068$ | $\text{Sin A}=9.9943079$ |
| $\text{Cot}\ \frac{1}{2}\ z=0.3048785$ | $-\text{Cos A}=9.2064212.$ | $\text{Cos}\ p=9.8345080$ | $\text{Sin}\ p=9.8634954$ |
| $\text{Tan}\frac{1}{2}(k-k')=9.8675550$ | 3894. | At same place in table. | |
| 346 | 318. | | |
| 204 | $A=99°\ 15'\ 22''.5$ | | |
| $\frac{1}{2}(k-k')=36°\ 23'\ 45''$ | | $\text{Sin}\ \phi=9.8278148$ | $\text{Cos}\ k'=9.9933068$ |
| $\frac{1}{2}\ z=26°\ 21'\ 45''$ | | $\text{Sin}\ \delta=9.4951325$ | $\text{Cos}\ k=9.6606232$ |
| $k'=-10°\ \ 2'\ 00''$ | | 0.3326823 | 0.3326836 |
| $k=\ \ 62°\ 45'\ 30''$ | | | |

*e.* **Remarks.** Look out tan $\phi$, cos $\phi$, and sin $\phi$, at one search. Use either check as may be preferred. This operation need not be performed oftener than the demands of the work require, the plate being used mean time.

## 13. Remarks.

The observations and reductions can be always made, according to the process given, without a watch, but the latitude of the place must be known. It must be carried on as the survey proceeds, by measurement, or an observation made to determine it with the instrument. If it becomes necessary to find the latitude it may be done as follows:

## 14. Finding the Latitude by the Sun.

*a.* **Directions.** *For Observations.* Near noon begin to observe the sun a little before it reaches its greatest altitude. By means of the slow-motion screws keep the sun's image exactly in place on the screen, or by direct sight keep the cross-wires exactly on the sun. As it moves upward just carefully follow it, recollecting that the object is to get its greatest altitude. Be careful to stop following it when it turns and begins to descend.

*b.* **Directions.** *For Reductions.* Find $z$, as in **12, *b*.** Find the sun's apparent declination, $\delta$, as in **11, *c*.** Then

$z+\delta=\phi$, the required latitude. . . . . . (13)

Be sure to observe the Algebraic signs, as $\delta$ may be $+$ or $-$.

*c.* **Remarks.** Having the latitude in this way, the observations and reductions may be conducted according to the processes above given. The latitude once carefully ascertained by this or some other method, may be preserved by the distance traversed *north* or *south* of the point of the last observation for latitude. It will at once appear that the measurement and observation may be made to check each other. The method of reducing the *change* in latitude by linear measurement may be as follows:

## 15. Finding the Latitude by Linear Measurement.

*a.* **Conditions.** The latitude of the point measured from, or reckoned from, must be known. The measurements must be reduced to the north and south direction from the reference point. Let reduced distances north be $+$, and those south be $-$. Let all signs be observed. Let the true bearings, or directions of all lines with the meridian of the reference point, be given. Let any number of courses be run in any direction.

*b.* **Directions.** *For reducing the north or south distances.* Multiply the length of each course by the cosine of its bearing, the results being given signs as above indicated, + for northerly courses, and — for southerly courses. Sum these results regarding the signs.

*c.* **Remarks.** This sum will be the distance north or south of the reference point.

*d.* **Directions.** *For reducing feet to minutes of Latitude.* Find the length of a minute of latitude for the place by this equation.

$$m = 6076.36\left(1 + \frac{\text{Sin}\,2(\phi - 45°)}{200}\right) \quad . \quad . \quad . \quad . \quad . \qquad (14)$$

Then divide the traversed distance north or south of the reference point by the value of $m$ found from this equation.

*e.* **Remarks.** The result will be the minutes and decimals of a minute of the new point from the reference point. This value of $m$ will be in feet, hence the north or south distance must be in feet.

**16. Remarks.** The latitude may be dispensed with during a day's work after the first satisfactory observation. It may be for a longer period if the watch is to be depended upon. It will be well to find the latitude, and check the work occasionally, where the watch is used. In order to prepare the watch for this work, proceed as follows:

### 17. Correcting the Watch.

*a.* **Directions.** *For correcting the Watch by a Noon Observation.* Having ascertained the bearing of a line without the aid of the watch, as at first directed, near noon set the line of sight in a meridian. Set the telescope so the sun can be seen in it, or received on the screen as it passes the meridian. Note the time by the watch when the sun's west side comes in apparent contact with the vertical cross-wire. Note the watch time when the east side of the sun just touches the vertical wire. Find the time half way between these two noted times for the time of the meridian passage of the sun's center, or the time of apparant noon, by the watch.

*b.* **Remarks.** The time as above found should differ from exact noon by just the equation of time for that date and time as given in the Nautical Almanac. Observe the sign there attached to the equation of time. The watch may then be set to true time if not correct. That is, it may be set so that the time of the sun's meridian passage will be just the equation of time, with its sign, from exact noon.

*c.* **Remarks.** The watch may also be corrected directly from an observation, reduced as at first directed in **10** and **12.** Here it will be necessary to take the watch time of the observation, as directed in **10.** Having done so, and reduced the observation by **12,** proceed as follows:

*d.* **Directions.** *For correcting the Watch by an observation at any time.* Having found A and $z$, and knowing $\delta$, find $t$ by the following equation.

$$\text{Sin}\, t = \frac{\sin A \sin z}{\cos \delta} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (15)$$

This being in arc, reduce it to time at the rate of four minutes of time to one degree of arc.

*e.* **Remarks.** This result should differ from the watch time of the observation from mean noon, by just the equation of time, *with its sign.* If it does not, set the watch so it would have done so had the observation been made with the corrected watch.

**18. Remarks.** Having corrected the watch by the last method, the value of $t$ in time may be found from the value of $t$ at this observation by noting the time by the watch of another observation, and thence finding the elapsed time. This applied to the first value of $t$ will give its value for the last observation. Thus the value of $t$ may be carried forward as long as the watch runs true. Of course it will occur to many at once that the watch can just as well be used to measure the elapsed time without being corrected. This is too careless. The better way is to keep a careful oversight of the watch by correction. Thereby it may be known how much the watch is to be trusted. It is always best to establish a routine system in these matters, as soon as practicable, and adhere faithfully to it.

**19. Remarks.** When the watch is corrected by either method, it will give the value of $t$ in time directly as follows: Note the time of an observation. Apply to this time the equation of time *with its sign*, as given in the Solar Ephemeris Table of the Nautical Almanac. The result will give the apparent time of the observation from apparent noon, + when the sun is west of the meridian, and — when it is east. This found is the required value of $t$.

## 20. Reducing Observations.

***a.* Conditions.** Let the notation be as before.

Let $t$ = the sun's apparent hour angle at the time of the observation, that is the local apparent time from apparent noon This is + when W. and— when E. of the meridian, or + for P.M., and — for A.M. times.

Let the value of $t$ be found by **18** or **19**, and reduced to arc at the rate of one degree of arc to each four minutes of time, the work being carried out to seconds of arc.

***b.* Directions.** *For finding* A *when* $\delta$, $t$, *and* $z$ *are given.* Find A from the following equations.

$$\text{Sin A} = \frac{\cos\delta \sin t}{\text{Sin } z} \qquad (13)$$

**Check.**

$$\frac{\text{Sin } z}{\cos\delta} = \frac{\sin t}{\sin \text{A}} \qquad (14)$$

***c.* Example.** $\delta = 18° \; 30' \; 20''$ N. $z = 52° \; 43' \; 30''$ $t = 55° \; 46' \; 32''.5$

$$\begin{aligned} \text{Cos } \delta &= 9.9776554 \\ \text{Sin } t &= 9.9174225 \\ &\overline{9.8950779} \\ \text{Sin } z &= 9.9007700 \\ \text{Sin A} &= \overline{9.9943079} \\ \text{A} &= 99° \; 15' \; 22''.5 \end{aligned} \qquad \left.\begin{matrix} 9.9231146 \\ 9.9231146 \end{matrix}\right\} \text{Check.}$$

**20. Remarks.** The value of A as determined in these examples is greater than 90°, because the sun is south of the zenith. The value of $t$ used in the second example was found from the first, hence the exact check. It may be noticed how much less figuring is required in the second example than in the first. It should be noted, however, that more than one check is figured out in the first example, and so more than the *necessary* figures shown. The value of A is carried out with exactness in order that the process may be fully illustrated.

**21. Summary.** Several courses are hereby opened to the surveyor. This is done that he may have the more checks at his command, and so make certain of his work, It may be well to indicate these courses in a catalogued form for easy reference. The courses are

The processes of **10, 12,** and **14** or **15.**

The processes of **10, 12,** and **14** or **15,** and thence
**16, *a*,** or **16, *d*,** and **18** or **19** and **20.**

**22. Cautionary.** Keep the levels and the vernier of the vertical circle in good adjustment. Also keep the adjustment of the axes of the instrument, the transit axis and the vertical axis, in good order.

**23. General Remarks.** It will be seen that in doing solar work with these attachments in the manner explained above, the observation of the sun depends on the ordinary line of sight of the telescope exactly as in all Geodesic work.

For this reason *no extra adjustments are required.* The accuracy of the observation in no way depends on these attachments, which are merely conveniences to enable one to make solar observations with the ease and precision of ordinary terrestrial work.

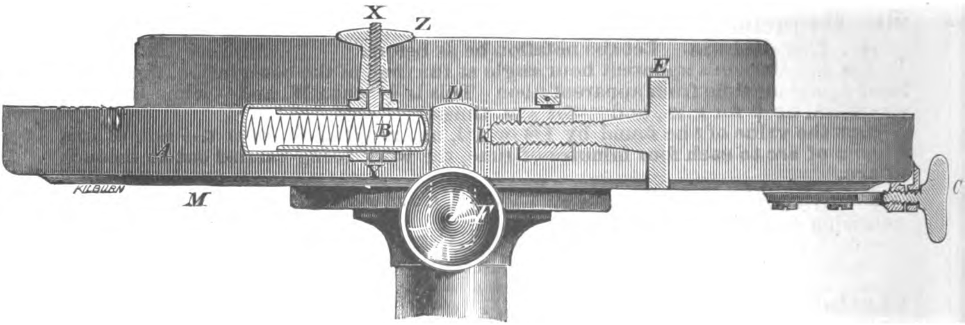
Other Solar Attachments are mechanical devices requiring special adjustments, and considerable care is necessary to keep these adjustments perfect, while they cause some degree of anxiety and doubt in the mind of the engineer as to whether they are quite perfect or not.

With this invention all these sources of anxiety are avoided, the solar observation being made with the telescope of the transit itself, while it has the advantage of being applicable to every surveyors' and engineers' transit, is so light as not to add appreciably to the weight of the instrument, so simple as to require no special provision for its care, and so cheap as to be within the reach of every surveyor.

# Spofford's Equal Arc-Meter.

**Patented, November 28, 1876.**

***Attached to the Engineers' Transit, for the purpose of facilitating the Location of Curves.***




This attachment to the engineer's transit, recently patented by **Mr. N. Spofford**, of Haverhill, Mass., is designed to facilitate the operation of laying out railroad curves, or running out arcs of circles for any purpose where the use of a transit is required.

As these curves are usually run by the method of equal angles, subtended by equal chords, it requires considerable time and no little care on the part of the transit man to set off the angles from the verniers, especially when there are odd minutes in the angle; but with the equal arc-meter attachment it is only necessary to read the angle once. The meter is then carefully set, after which the angle may be repeated any number of times with the greatest rapidity and accuracy, the vernier showing at any time the sum of the angles turned off.

The construction and operation of this device will be readily understood by reference to the annexed engraving, in which **A** represents a front view of the vernier plate of the ordinary engineers' transit. **M**, the main plate or circle. **E**, the vernier tangent screw in section. **B**, spring bolt. **D**, the vertical portion of the radial arm. **F**, clamp screw. These are the ordinary parts of the vernier clamp and tangent device as usually constructed for all surveying instruments; but by the simple addition of clamp-screw **Z**, operating screw eye bolt **X**, **Y**, by means of which spring bolt **B**, is clamped in any desired position, and the supplementary clamp screw **C**, to hold the plates firmly together, it may be used for the purpose of repeating any small angle, independently of the vernier readings.

The operation is as follows:—Suppose the transit set over the tangent point of the curve, clamped at zero. Reverse telescope and align upon the back staff with lower tangent screws; clamp spring bolt **B** with clamp screw **Z**; turn back tangent screw **E**, until space **K**, equals the arc measure of the angle to be repeated. This being very carefully done by the vernier reading, our meter is set and ready for the work. With telescope on the fore staff, suppose we are to deflect to the left; set clamp screw **C**, release clamp screw **F**, and move arm **D** to the right until it comes in contact with point of screw **E**, as shown by dotted lines; set clamp screw **F**, and release **C**, then turn vernier plate and telescope until point of spring bolt **B**. comes in contact with tangent arm **D**; set clamp screw **C**. The chain-man may now be aligned and the first point fixed. The simple repetition of this operation, which the transit man can very easily perform without changing his position at the instrument, sets every stake in the curve as far as the sight extends, and as rapidly as the chain-man can proceed. Clamp screw **C** is removed and carried in the pocket when the meter is not in use; but the clamp is permanently fixed to the main plate, and is a great convenience in setting the verniers at zero.

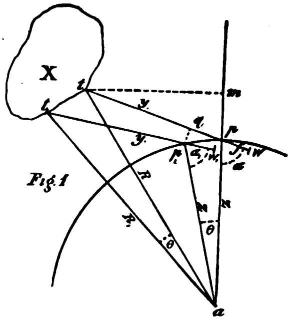
If the engineer desires to run other than circular curves, it may be very easily done by changing the length of the chord for every station.

## The Planimeter.


An instrument for measuring the areas of plane surfaces, by passing a pointer around their periphery. It is of great convenience to all classes of engineers, and practically applicable to a great variety of purposes. To measure the areas of figures that are bounded by irregular lines, such as:—drainage areas; lots bounded by rivers or creeks; contour lines of ponds, etc.; to get the true average of observations taken at irregular intervals; to measure indicator and other diagrams, and for many other portions of engineering work. As these instruments will not only give the area of any figure, but also any multiple of such area, and the sum of any number, or series of such multiples, at one operation, they may be used to very great advantage in the calculation of the cubical contents of solids; as in the calculation of earth-work, etc. See on this point an article by Clemens Herschel, Esq., in the *Journal* of the Franklin Institute for April, 1874. The planimeters graduated by us are rated to read square inches of area, square centimeters of area, any multiple of these areas, and so as to give the cubic yards in any cut or fill, if used according to the directions that will accompany each instrument, Two consecutive measurements of the same area need never differ by more than 0.02 of a square inch; and by repeating the measurement in the same manner that angles are repeated with a transit instrument, the error of observation may be reduced to but a small fraction of one hundredth of a square inch of area.

The above illustration represents the planimeter, as sold by us, ready for use. The total length of the instrument is about nine inches. The graduated bar *g h* can be slid in and out in a socket formed at the top of the frame, the thumb-screw *f* being used for fine movements of this sort; by this means, and by the sensible form of graduation adopted, the planimeter may be made to do the various operations spoken of above. Theory requires that the pointer *d*, which is moved around the periphery of the figure whose area is to be measured, the pivot *k*, at the junction of the two arms *g h* and *i j*, and the main axis *a b*, upon which turns the measuring and counter wheel *c* should all be in one and the same straight line; for this purpose, our instruments have both the pointer *d* and the rear part of the frame which carries the rear bearing of the axis *a b*, adjustable. Each reading of the instrument consists of a record of the number of revolutions of the counter-wheel *c* read to three places of decimals; the whole revolutions are read on the wheel *l*, the tenths and hundredths on the wheel itself, and the thousandth on the vernier *m*. With such simplicity of construction and of operation, the accuracy of work done by this instrument is one of the most surprising things about it. The figures given above in relation to accuracy of work are, however, reliable; being derived from the experience of several years in the use of the planimeter for many kinds of work.

A brass scale sent with our planimeters can be used to prove the correct working of the instrument. To use it drive a fine needle as an axis through one of the small holes of the scale into the paper, then put the tracer into one of the other holes and describe a circle. In this manner large and small circles of known areas can be circumscribed with perfect accuracy. This operation should be repeated in the opposite direction, and if the results agree the instrument is correct. However. if the results differ correction may be made by means of the two adjusting screws by which the tracer can be moved to right or left of the graduated bar, as the case may be.




THE FOLLOWING DEMONSTRATION OF THE WORKING OF THE PLANIMETER IS FROM THE PEN OF WM. D. GELETTE, CIVIL ENGINEER, FORMERLY OF BOSTON, NOW ENGAGED IN THE CONSTRUCTION OF THE SOUTHERN PACIFIC R.R.

**Case I.** When the anchor point is outside of the figure to be measured. Let X be the figure to be measured, and let $a$ be the pole or origin, and R the radius of polar co-ordinates of the point $t$ in Fig. 1. And let $R_1$ be the radius of a second point $t_1$ on the outline of the figure X, and let $\theta$ be the angle $t\,a\,t_1$—then the area of the triangle $t\,a\,t_1 = \frac{R\,R_1 \sin\theta}{2}$. But if $\theta$ be taken so small, that for the small distance $t\,t_1$ the radius R may be taken constant, then area $t\,a\,t_1 = \frac{R^2 \sin\theta}{2}$.

By polar co-ordinates the area $X = \Sigma\,\frac{R^2 \sin\theta}{2}$ . . . . . . . . (1)

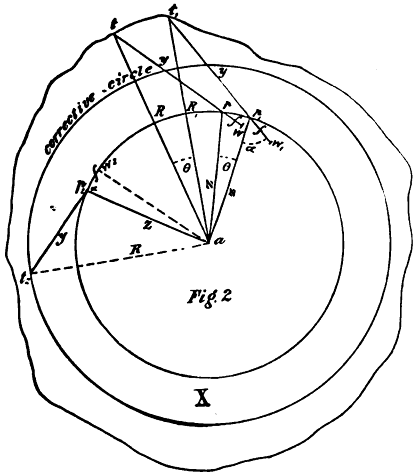
Let $a$ be the anchor point, $t$ the tracing point, and $w$ the point of contact of the flange of the wheel of a polar planimeter, and call $t\,p = y$, $ap = z$, and $p\,w = f$, and the angle $a\,p\,w = \alpha$ then after the motion of the tracing point $t$ to $t_1$ the point $p$ comes to $p_1$, $w$ to $w_1$ and the angle $\alpha$ changes to $\alpha_1$. But when, as in this case, it is supposed that during the small motion $t\,t_1$ the radius R is constant, then for the same length of motion, $\alpha$ will be constant and $p\,a\,p_1$ will $= \theta$.

Expressing R in terms of $y$, $z$, and $\alpha$, we have $R^2 = (t\,m)^2 + (a\,p + p\,m)^2 = (z + y\cos\alpha)^2 + (y\sin\alpha)^2 = z^2 + 2\,z\,y\cos\alpha + y^2\cos^2\alpha + y^2\sin^2\alpha$ But $\sin^2\alpha + \cos^2\alpha = 1$ and $R^2 = z^2 + 2\,z\,y\cos\alpha + y^2$. And the area $t\,a\,t_1 = \frac{R^2 \sin\theta}{2} = \frac{z^2 \sin\theta}{2} + \frac{2\,z\,y\cos\alpha\sin\theta}{2} + \frac{y^2\sin\theta}{2}$ and $X = \Sigma\,\frac{z^2\sin\theta}{2} + \frac{\Sigma\,2\,z\,y\cos\alpha\sin\theta}{2} + \frac{\Sigma\,y^2\sin\theta.}{2}$ But in the summation, owing to the fact that the instrument returns to the same position from which it started, the $\Sigma\sin\theta$ must $= 0$ and wherever combined with constants only, in the above equation will reduce to 0, hence the first and last terms will disappear, but the middle term which contains the variable $\cos\alpha$ will remain, hence,

$X = \Sigma\,z\,y\cos\alpha\sin\theta$ . . . . . . . . . . . . . . (2)

It will be seen by reference to Fig. 1 that $z\sin\theta = p\,p_1$ when $\theta$ is very small, ∴ $z\sin\theta\cos\alpha = p\,p_1\cos\alpha = p_1\,q$ which is the component of the motion of the wheel which is at right angles to its axis, and is therefore the part which represents the rotation of the wheel for a small motion $t\,t_1$ of the tracing point. And this component multiplied by the arm $y$ gives $z\,y\sin\theta\cos\alpha$ which by equation (2) expresses the area of X after summation. But $\Sigma\,z\sin\theta\cos\alpha$ is the resultant rotation of the wheel after the tracing point has completed the circuit of X, hence the area X = distance rolled by the wheel multiplied by the length of the arm $y$. Calling the circumference of the wheel $c$, and the number of resultant number of revolutions made during the measurement $n$, we have $X = y\,c\,n$. . . . . . . . . . . (3)

And if the instrument is graduated so as to record $y\,c\,n$, and we call the record of the instrument $r$, we shall have, $X = r$.



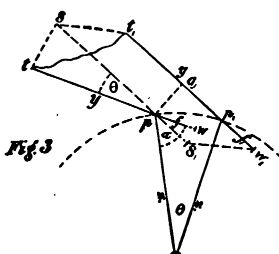

**Case II.** When the anchor point is inside the figure to be measured,—and the rotation of the wheel is forward or plus with reference to the figures on its circumference,—it will be seen that there will be one position of the arms $y$ and $z$, which, while the point $t$ describes a circle around $a$ as a center, (see fig. 2) will produce no rotation of the wheel. The condition under which this will occur will be fulfilled when the angle $t\,w\,a = 90°$, in which case $R^2 = z^2 - f^2 + (y+f)^2 = z^2 + 2\,y\,f + y^2$, and the area of the circle described under these conditions $= \pi R^2 = \pi z^2 + 2\,\pi\,y\,f + \pi\,y^2$ . . . . . . . (4)

Call this the corrective circle. In (fig. 2) the area of $t\,a\,t_1 = \frac{\pi R^2 \theta}{360}$ the area of the whole figure $X = \Sigma\,\pi\,R^2 \frac{\theta}{360}$; as before $R^2 = z^2 + 2\,z\,y \cos\alpha + y^2$ and hence

$$X = \Sigma\,\pi\,z^2 \frac{\theta}{360} + \Sigma\,2\,\pi\,z\,y \cos\alpha \frac{\theta}{360} + \Sigma\,\pi\,y^2 \frac{\theta}{360} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (5)$$

But in the summation the instrument makes a complete revolution around $a$, the sum of $\Sigma \frac{\theta}{360} = 1$, and when combined with constants only, will not appear in the result as a factor. Hence we have

$$X = \pi z^2 + \Sigma \left(2\,\pi\,z\,y \cos\alpha \frac{\theta}{360}\right) + \pi\,y^2 \quad . \; . \; . \; . \; . \quad (6)$$




Now follow out on the diagram in Fig. 3, the motion of the wheel, which corresponds to a motion of the tracing point from $t$ to $t_1$ first dividing that motion into two parts $t\,s$ and $s\,t_1$ swinging the arm $y$ around the point $p$ until it becomes parallel to $t_1\,p_1$ while $z$ remains fixed, produces the first motion and causes the wheel $w$ to roll backward to $s_1$ and as the path of its motion is everywhere perpendicular to its axis, $s_1\,w$ will represent rotation or distance rolled during that motion, but as $s\,p\,t = \theta$ the distance $s_1\,w = 2\,\pi\,f \frac{\theta}{360}$ which is the backward or minus rotation of the wheel.

The second part of the motion is by moving the arm $y$ from $s\,s_1$ to $t_1\,p_1$ during which the wheel moves from $s_1$ to $w_1$ and this motion is part sliding and part rolling, the rolling component is $p\,q$, and causes forward or plus rotation of the wheel, the value of $p\,q$ is $2\,\pi\,z \frac{\theta}{360} \cos\alpha$, and the resultant rotation of the wheel is on completing the circuit $= \Sigma \left(2\,\pi\,z \cos\alpha \frac{\theta}{360}\right) - \Sigma\,2\pi f$; and the area expressed by the wheel as by Case I is

$$\Sigma \left(2\,\pi\,z\,y \cos\alpha \frac{\theta}{360}\right) - \Sigma\,2\,\pi\,y\,f \quad . \; . \; . \; . \; . \quad (7)$$

Comparing the area expressed by the wheel which we will call $r$ with the true area of the figure as given by Eq. 6, we have

$$X = \pi z^2 + \Sigma \left(2\,\pi\,z\,y \cos\alpha \frac{\theta}{360}\right) + \pi\,y^2$$

$$r = \Sigma \left(2\,\pi\,z\,y \cos\alpha \frac{\theta}{360}\right) - 2\,\pi\,y\,f$$

$X - r \quad = \pi z^2 + 2\pi f y + \pi y^2$ which is seen to be identical with the expression in Eq. 4, for the area of the corrective circle. Hence, calling the area of the corrective circle C, we have for Case II

$$X - r = C; \text{ and } X = C + r \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

It will be seen from the above equation that when $z \cos \alpha = f$, the forward rotation of the wheel just balances the backward rotation, and the result is 0 for a reading. This occurs when the tracing point moves on the arc of the corrective circle and the area passed around is $X = C$. When $z \cos \theta$ is less than $f$, then the backward rotation preponderates over the forward rotation, and the result is a minus reading; this is Case III.

**Case III.** When the anchor point is inside the figure to be measured, and the rotation of the wheel is backward with reference to the figures on its circumference. In this case $r$ is negative, and instead of $X = C + r$, we have $X = C - r$. Hence, we have for Case I, $X = r$, Case II, $X = C + r$, Case III, $X = C - r$.

Suppose it to be required to make the instrument record 100 for every square inch passed around by the tracing point. As the wheel is divided on its circumference into 100 divisions, and by the vernier can read tenths of these, then $\frac{1}{10}$ of a revolution will give a reading of 100, make $X = 1$ sq. in., and $n = \frac{1}{10}$ then by Eq. 3, $y\frac{c}{10} = 1$, and $y = \frac{10}{c}$: the length of the arm varies inversely as the reading, so for any other reading we may obtain the length of $y$ by simple proportion. Suppose it is required to read $v$ for every sq. in. passed around, we have

$$\frac{100}{v} = \frac{y}{\frac{10}{c}} \text{ from which } y = \frac{1000}{c\,v}.$$

The range of the arm renders it impossible to set it so that for one sq. in. of area it shall read more than 250, or less than 50, so the value of $v$ must lie somewhere between these limits. Having determined the value of $y$ for any particular scale, the value of C may be found by substituting in Eq. 4; the values of $z$ and $f$ being measured on the instrument.

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## Current Meter.

An instrument used in the hydrography of rivers and harbors for measuring the velocity of the current, at any depth, and generally, at any defined point in the cross-section of a stream. Since the days of Woltman this instrument has undergone many improvements at the hands of experienced engineers, and the illustrations given in the price list, represent it as manufactured by Messrs. Buff & Berger, of Boston, who make it according to two general designs; the one with special regard to the results of a series of careful experiments by Mr. Clemens Herschel, Hydraulic Engineer, Boston, Mass., the other after designs furnished by Gen. Theo. G. Ellis, of Hartford, Conn. The first named experiments were made at Lowell, in 1877 and 1878 under the direction of Mr. James B. Francis, Engineer of "The Proprietors of Locks and Canals on Merrimac River," and warrant to say that velocities as low as 0.17 of a foot per second can be measured.

In designing these meters, it has been the aim to make all parts of the instrument as unchangeable as possible. For this purpose the wheel is furnished with a guard ring, thus connecting the outer ends of the vanes among themselves, and the journal in which runs the main axis is made of an agate, as is also the bearing for the conical pivot at the end of the same axis. The wheel is a geometrically defined body, the vanes being surfaces of an Archimedean screw; hence in case of loss or injury, the wheel can always be replaced by one of exactly the same size, construction and qualities; experience as well as theory having shown that the shape of the wheel is the ruling element in the rate of the instrument. These remarks apply equally to the three kinds of meters shown in the price list. In Figs. I and II the string is shown, by means of which the dial wheels are thrown in and out of gear. One short pull on the string throws them in gear, and the succeeding pull will throw them out again; the next one in, and so on. Fig. I represents the cheaper kind of instrument, in which the dials and gears are not protected while in the water. Fig. II shows a complete protection of both dials and gears, as well as a protection for the main axis and its bearings from impurities while in the water. This protection may be useful in preventing straw, dirt, etc., from clogging the gear. To lessen the friction on the journal the outer rim of the wheel can be provided with an air-chamber, and the size of this is so nicely adjusted that the wheel and its axis would float in the water if detached from the instrument proper.

The electric form of meter shown in Figs. III and IV, is especially adapted for observations upon large rivers, arms of the sea, etc. It has its registering apparatus above the surface of the water, or on the bank of a river, and current measurements may be made with it at any depth, and may be continued for a week, without stopping, or longer, if desired. Half a dozen or more of these meters may be strung on one and the same vertical rod or wire, and *simultaneous* observations then taken of the velocities at different depths below the surface. With the meters shown in the first and second figures, to be used principally in water not over ten or twelve feet deep, a gauging of a quantity equal to 1000 cubic feet per second, has been made in *four minutes*, the calculation of the field notes so taken requiring only about five minutes more without leaving the place of gauging; thus finding the quantity flowing in the stream within ten minutes from the time of commencing to gauge—a speed of work accomplished which has been equalled by no other instrument yet discovered.

The form of current meter shown in Fig. IV, was used upon the gauging of the Connecticut River* by General Ellis, and was designed particularly to avoid the catching of floating substances, such as leaves and grass, upon either the vanes or the axis, and to render the record of the instrument independent of the position of its axis with respect to the line of the current. Also, to get less friction upon the axis so as to measure low velocities accurately.

This current meter is also adapted to be used with an electric register for showing the number of revolutions of the wheel. It is constructed upon the principle of Robinson's Anemometer, turning by the difference of pressure upon opposite vanes of the wheel. The vanes of this meter however, instead of being hemispherical cups with a straight stem, are made conical at the ends, and are hollow and taper to the central hub, so as to offer no obstruction to the slipping off of straws, leaves, or grass as the wheel revolves. The central hub is made tapering so that any object can slide off easily, and it extends over the joints at the ends of the axis, so as to enclose and protect them from floating substances.

The axis runs in agates, through which a fine platinum wire connects with the metal of the frame.

The forward end of the frame which carries the wheel, can be turned and secured in any position so that the wheel can be horizontal, vertical, or at any desired angle.

The electrical connection is made by carrying an insulated wire from near the center of the instrument, where the insulated wire from the battery is attached to it when in use, out to the end of one arm of the wheel frame, where it ends in a fine platinum wire resting upon a ring in the hub of the wheel. This ring is made of alternate interchangeable sections of silver and hard rubber, secured in place by screws, so that their position can be changed to register whole or part revolutions as desired.

There is also a socket and set-screw in the body of the frame near the center, for the return current, which can be carried most conveniently through a plain wire slightly twisted around the insulated wire so as to form one cord. If the instrument is run upon a wire, or has a metalic connection with the surface, the return current can be made through that.

The universal motion at the center of the frame and the tail are of the usual construction.

This meter can be used in connection with any apparatus for registering the revolutions of the wheel by the breaks in the electric circuit.

* For further information on this point see Gen'l G. K. Warren's Report of Surveys and Examinations of Connecticut River.

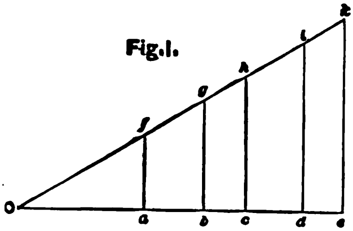
# On Stadia Measurement.

Written especially for this Catalogue by Geo. J. Specht, C. E., San Francisco, Cal.

A transit or theodolite, which is provided with the so-called stadia wires and a vertical circle, furnishes the means to obtain simultaneously the distance and the height of a point sighted at without direct measurement, and with the only use of a self-reading rod, held at the point of which the horizontal and vertical position is to be determined in reference to the instrument-point.

Besides the ordinary horizontal and vertical cross hairs of the diaphragm of the telescope, two extra horizontal hairs are placed parallel with the center one, and equally distant on each side of it, which, if the telescope is sighted at a leveling rod, will inclose a part of this rod or stadia-rod, proportional to the distance from the instrument to the rod. By this arrangement we have obtained an angle of sight, which remains always constant.

Fig. I.




Supposing the eye to be in the point O (Fig. 1), the lines O $e$ and O $k$ represent the lines of sight from the eye through the stadia-wires to the rod, which stands consecutively at $k\,e$, $i\,d$, $h\,c$, $g\,b$ and $f\,a$. According to a simple geometrical theorem we have the following proportion:

$$O\,a : O\,b : O\,c : O\,d : O\,e = a\,f : b\,g : c\,h : d\,i : e\,k,$$

which means that the reading of the rod placed on the different points $a$, $b$, $c$, $d$ and $e$ is proportional to the distances O $a$, O $b$, O $c$, O $d$ and O $e$.

The system of lenses which constitute the telescope do not allow the use of this proportion directly in stadia measurements, because distances must be counted from a point in front of the object glass at a distance equal to the focal length of that lens.

Fig. 2.

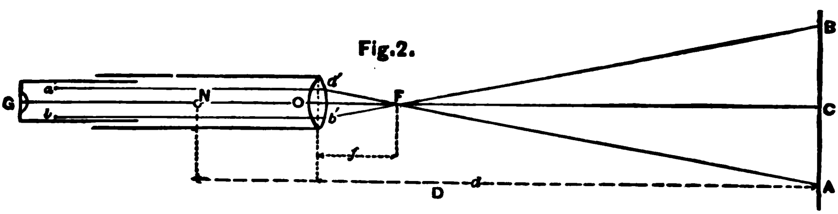



Fig. 2 represents the section of a common telescope with but two lenses, between which the diaphragm with the stadia-wires is placed.

We assume:

$f$ = the focal distance of the object glass.
$p$ = the distance of the stadia-wires $a$ and $b$ from each other.
$d$ = the horizontal distance of the object glass to the stadia.
$a$ = stadia reading (B A).
D = horizontal distance from middle of instrument to stadia.

The telescope is leveled and sighted to a leveling or stadia rod, which is held vertically, hence at a right angle with the line of sight. According to a principle of optics, rays parallel to the axis of the lens, meet after being refracted in the focus of the lens. Suppose the two stadia wires are the sources of those rays, we have, from the similarity of the two triangles, a′ b′ F and F A B the proportion:

$$(d - f) : a = f : p.$$

The value of the quotient, $f : p$, is, or at least can be made, a constant one, which we will designate by the letter $k$; hence we have:

$$(d - f) = F\,C = k\,a.$$

In order to get the distance from the center of the instrument N, we have to add to the above value of F C yet the value $c$.

$$c = O\,F + O\,N.$$

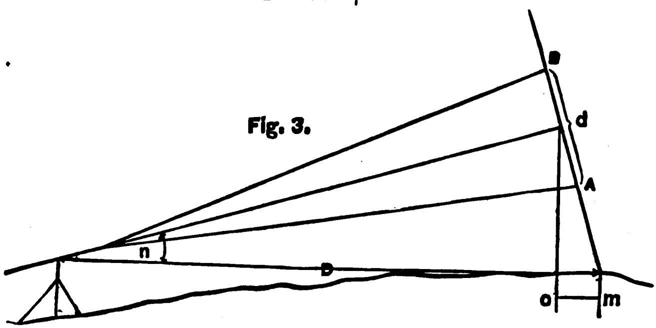
O N is mostly equal to half the focal length of the objectic, hence we have

$$c = f + \frac{f}{2} = 1.5\,f.$$

Therefore the formula for the distance of the stadia from the center of instrument, when that stadia is at right angles to the level line of sight, is:

(1) $$D = k.a + c.$$

Fig. 3.




When the line of sight is not level, but the stadia held at right angle to it, the formula for the horizontal distance is:

(2) $$D = k.a.\cos n + c + \overline{om}.$$

The member $\overline{om} = \frac{a}{2} \sin n$; for $a = 24'$, $n = 45°$ the value of $\overline{om}$ is but 8.4′, and for $a = 10'$, $n = 10°$ it is 0.86′; this shows that $\overline{om}$ in most cases may safely be omitted.

Some engineers let the rodman hold the staff perpendicularly to the line of sight; they accomplish this by different devices, as, a telescope or a pair of sights attached at right angle to the staff. This method is not practicable, as it is very difficult, especially in long distances, and with greater vertical angles for the rodman to see the exact position of the telescopes, and furthermore, in some instances it is entirely impossible, when, for instance, the point to be ascertained is on a place where only the staff can stand, but where there is no room for the man. The only correct way to hold the staff is vertically.

In this case we have the following: (Fig. 4)

$MF = c + GF = c + k.C.D.$
CD must be expressed by AB.
$AB = a.\quad AGB = 2m.$
$CD = 2GF\ \tan.m.$

And finally, after many transformations:

$$D = c.\cos n + a.k.\cos^2 n - a.k.\sin^2 n\ \tan^2 m.$$

The third member of this equation may safely be neglected, as it is very small even for long distances and large angles of elevation (for 1500′, $n = 45°$ and $k = 100$, it is but 0.07′). Therefore, the final formula for distances, with a stadia kept vertically, and with wires equi-distant from the center wire, is the following:

(3) $$D = c.\cos n + a.k.\cos^2 n.$$

The value of $c.\cos n$ is usually neglected, as it amounts to but 1 or 1.5 feet; it is exact enough to add always 1.25′ to the distance as derived from the formula

(3a) $$D = a.k.\cos^2 n$$

without considering the different values of the angle $n$.

In order to make the subtraction of the readings of the upper and lower wire quickly, place one of the latter on the division of a whole foot and count the parts included between this and the other wire; this multiply mentally by 100 (the constant $k$) which gives the direct distance D′.

In cases where it is not possible to read with both stadia wires, it is the custom to use but one of them in connection with the center wire, and then to double the reading thus obtained. With very large vertical angles, this custom is not advisable, as the error may amount to 0.50%.

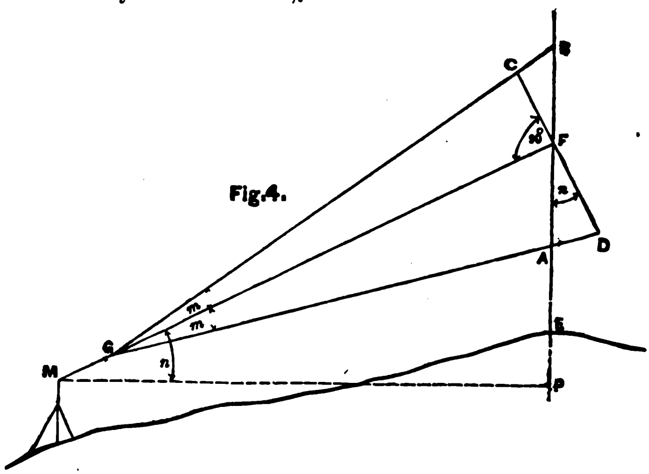



Fig.4.

To find the height of the point where the stadia stands above that one of the instrument, simultaneously with the distance, we have the following:

We assume in reference to figure 4,

$q$ = height of instrument point above datum.

MP = D = horizontal distance as derived from formula (3).

$n$ = vertical angle.

$h$ = FE = stadia reading of the center wire.

Q = height of stadia point above datum; it is

$$Q = q + D \tan n - h.$$

The substraction of $h$ can be made directly by the instrument, by sighting with the center wire to that point of the rod, which is equal to the height of the telescope above the ground (which is in most cases = 4.5′); $q$ will be constant for one and the same instrument point; then the formula:

$$Q = D \tan n;$$

this in connection with formula (3) gives

$$Q = c \sin n + a.k. \cos n. \sin n.$$

or

$$Q = c \sin n + a.k. \frac{\sin 2\,n}{2}$$

The first term of the equation can be neglected, when the vertical angle is not too large; hence the final formula for the height is

$$(5) \qquad Q = \frac{a.k. \sin 2\,n}{2}$$

The position of the stadia must be strictly vertical.

The error increases with the height of $m$; ($m$ = height of center wire on the rod). In shorter distances the result is seven-fold better when the center wire is placed as low as one foot than it is at 10′; in longer distances this advantage is only double.

It is always better to place the center wire as low as possible. If the stadia is provided with a good circular level, the rodman ought to be able to hold it vertically within 500″; that means, that the inclination of the stadia shall not be more than 0.023′ in a 10′ stadia, or 0.034′ in a stadia of 15′ length.

*Determination of the two constant coefficients c and k.* Although the stadia wires are usually arranged so that the reading of one foot signifies a distance of 100 feet, I will explain here, how to determine the value of it for any case. Suppose the engineer goes to work without knowing his constant, and not having adjustable stadia wires. The operation then is as follows:

Measure off on a level ground a straight line of about 1000′ length; mark every 100′, place the instrument above the starting point, and let the rodman place his rod on each of the points measured off; note the reading of all three wires separately, repeat this operation four times; the telescope must be as level as the ground allows; measure the exact height of the instrument. *i. e.*, the height of the telescope axis above the ground. Then find the difference between upper (*o*) and middle (*m*) wire; between middle (*m*) and lower (*u*) wire, and between upper (*o*) and lower (*u*) wire, from the four different values for each difference, determine the average value; then solve the equation for the horizontal distance (1) $D = k.a + c.$, with the different average values, and you find the value of *k* and *c*. In case the stadia wires should not be equi-distant from the center wire, there will be three different constants, one for the use of the upper and middle, one for the use of the middle and lower, and one for the upper and lower wire.

If the stadia wires are adjustable, the engineer has it in his power to adjust them so that the constant $k = 100$, or $k = 200$, which he accomplishes by actual trial along a carefully measured straight and level line.

The constant *c*, which is one and a half times the total length of the object-glass can be found closely enough for this purpose by focussing the telescope for a sight of average distance, and then measuring from the outside of the object-glass to the capstan-head-screws of the cross-hairs. This constant must be added to every stadia sight; it may be neglected for longer distances.

# PART II.

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# Catalogue and Price List

OF IMPROVED

# Engineers' and Surveyors' Instruments,

WARRANTED FIRST-CLASS,

MANUFACTURED BY

**BUFF & BERGER, No. 9 Province Court, Boston, Mass.**

## NOTICE.

**In selecting instruments from catalogues, engineers should not be led so much by a simple comparison of prices, as by the advantage offered in** *superior merits, working capacity, and preservation of fine qualities in case of severe treatment.* **We can cite instances, where transits and levels of our manufacture had severe falls, resulting without injury to any part of instrument — not even disturbing the adjustments.**

***A greater outlay of* $10 *or* $20 *in the purchase of a superior article is a greater saving in time and expense in the end.***

# ENGINEERS' DUMPY LEVEL.

On account of the greater compactness, our dumpy level is best adapted for railroads, water works and reconnoissance, etc., permitting of high accuracy by greater simplicity, and is less liable to derangement of all parts. As regards size, it has all the advantages of the larger engineers' levels, but as it consists of a lesser number of pieces and screws, is superior to these in point of durability and permanency of adjustments. With a properly adjusted dumpy level of our make, (*see adjustment of dumpy level,*) an engineer can perform as high a class of work as he is generally enabled to do with a good wye level, depending, as he does, not so much on *mechanical* perfections, as on his own superior skill and sense of accuracy in making adjustments. The upper part of this instrument is entirely cloth-finished.

The instrument is packed in a mahogany box, containing a sun-shade, a wrench, a screw driver and adjusting pin.

Weight of instrument 10 lbs., weight of tripod from 7 to 7½ lbs.

Gross weight of instrument, packed securely for shipment, in 2 boxes, about 45 lbs.

**Price $100.00.**

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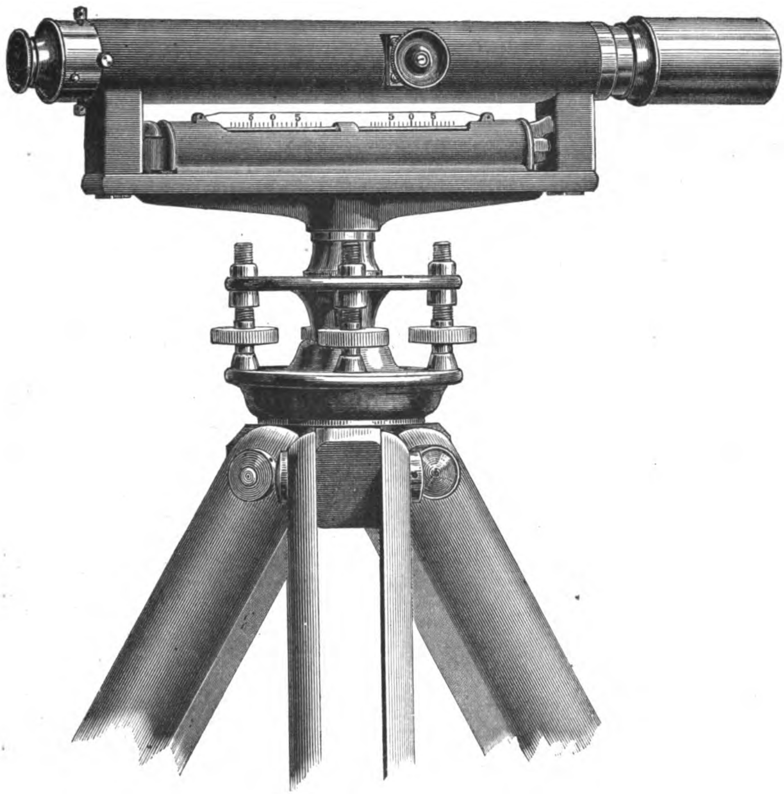
## Extras to Engineers' Dumpy Level.

| | |
|---|---|
| Center of instrument made of steel, . . . . . . . . . | $10.00 |
| " " " " and hardened, runs in a socket of cast iron, . . . . . . . . . . . . . . . . . . . | 20.00 |
| Stadia Wires, fixed, . . . . . . . . . . . . . . . . . | 3.00 |
| Gossamer water-proof bag, to protect the instrument in case of rain or dust, | 1.00 |
| Bottle of Vaseline, to lubricate the level center, . . . . . . . . | 0.25 |



## 15-inch Dumpy Level.

**As made by Buff & Berger.**

NOTE.—The cut represents this instrument with a telescope, showing objects inverted. If ordered with an erecting telescope its length will be 17½ inches. Unlike the round nuts, shown in the cut, the tripod is provided with thumb-nuts with which to fasten the legs against the tripod head, and the instrument has a leveling head similar to those represented in the cuts of our Engineers' Transits and Levels.

# ENGINEERS' WYE LEVEL.

**Leveling Instrument of Precision.**

Eighteen or seventeen-inch powerful telescope; aperture of object-glass 1⅜ inches in diameter; eye-piece provided with an improved *screw arrangement* for the accurate focussing of cross-wires; field of view large and flat; telescope provided with an *adjustable stop* to readily set cross-wires horizontal and perpendicular; *line of collimation true on all distances;* objects erect; *telescope balanced each way from the center when focussed to a mean distance with sun-shade attached to it* to secure the highest accuracy attainable; telescope rings and the center are very stout, long and of the hardest bell-metal; cross-bar is cast hollow and provided with ribs; 8-inch very sensitive spirit level; instrument does not detach from tripod above leveling screws; it packs whole and stands in the case erect. Mahogany case, provided with straps and hooks, contains sun-shade, wrench, screw driver, and two adjusting pins.

Weight of instrument 11 lbs., weight of tripod from 7 to 7½ lbs.

Gross weight of instrument, packed securely for shipment in two boxes, about 48 lbs.

**Price,** *including a protection to the object-slide,* . . . . . **$140.00.**

Telescope and level tube will be cloth-finished, unless ordered to the contrary when an extra charge of $5.00 will be made. However, we strongly advise the cloth-finish. (*See cloth-finish.*)

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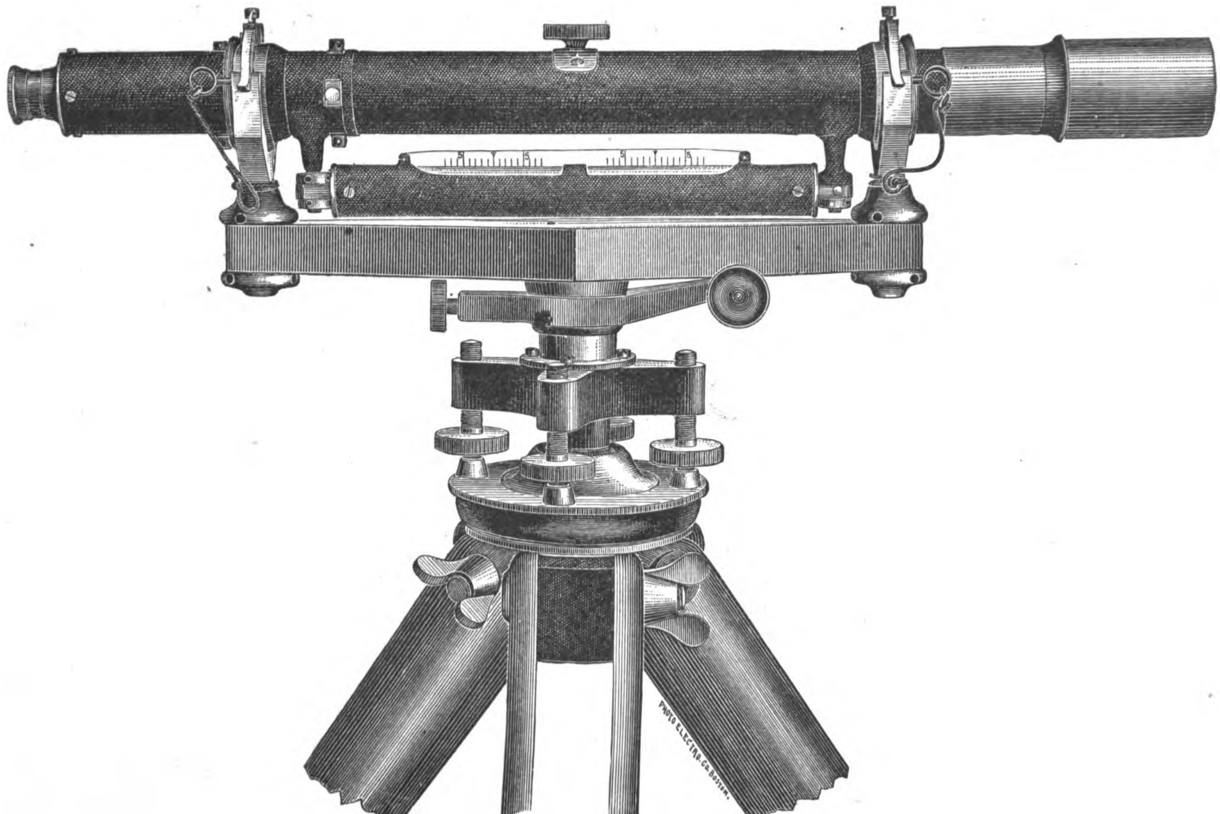
## Extras to Engineers' Wye Level.

| | |
|---|---|
| Center of instrument made of steel, . . . . . . . . . . | $10.00 |
| " " " " and hardened; runs in a socket of cast iron, . . . . . . . . . . . . . . . . . | 20.00 |
| Stadia Wires, fixed, . . . . . . . . . . . . . . . | 3.00 |
| Metal-mirror with universal joint. (This is readily attachable to the instrument and facilitates the reading of the bubble on soft ground without stepping aside.) . . . . . . . . . . . . . . | 10.00 |
| Extra Sun-shade with smaller aperture, for use with the telescope when the sun's rays are too bright for accurate work, . . . . . . | 1.50 |
| *Adjustable Wye, provided with a micrometer screw and a graduated head for the most refined work in hydraulic engineering. To a certain extent this micrometer screw may also be used for gradienter work. . | 25.00 |
| Instrument provided with three leveling screws, . . . . . . | 18.00 |
| Gossamer water-proof bag, to protect the instrument in case of rain or dust, | 1.00 |
| Bottle of Vaseline, to lubricate the level center, . . . . . . . | 0.25 |

*This arrangement renders a leveling instrument more susceptible to rough treatment as compared with an instrument provided only with the ordinary Wye adjustment. On the other hand the greater conveniency with which the bubble can be set, or the telescope pointed independently of the leveling screws, commend it for work of a very close character. Instruments of this description, and those with three leveling screws, will be made to order only, and the time required is from six to nine weeks.




**Engineers' 18-inch Wye Level.**
(Power 35 diameters.)
**As made by Buff & Berger.**

## Engineers' and Surveyors' Transit.

This instrument is designed for engineering work of a high class, such as is required in bridge building, water works, and for city and land surveying. The size of the circle is such that it may be graduated to read to 30″ or 20″ without fatigue to the eye. The telescope is of the best definition, and has a large aperture with perfectly flat field. The eye-piece is achromatic, and gives a large field with plenty of light. We advise our customers to order *solid silver* graduations for this instrument, also ground glass shades over the verniers for reasons given on page 6.

**Transits No. 1—No. 1 c.**— Horizontal circle 6¼ in. (edge of graduation), two double verniers reading to minutes; *two rows of figures* in opposite directions from 0° to 360°; *figures on limb* and *verniers* are *inclined* in the direction they should be read; verniers and graduations are protected with fine plate glass; graduations are silvered; magnetic needle 4½ inches; *adjustment for vertical plane* of telescope; improved *spring tangent screw*; improved *lower tangent screw*; *shifting center* to set the instrument exactly over a given point; improved telescope 11½ inches long; objects erect; aperture 1¼ inches; power of the telescope 24 dia., which qualifies it especially for telemeter work; eye-piece is provided with an improved screw arrangement for the accurate focussing of cross-wires; telescope is *perfectly balanced* and reverses at both ends; spirit-levels *ground* and extra sensitive; line of collimation *correct* on *all distances* without adjustable object-slide; **protection** to object-slide; *long compound centers* with heavy flanges; *improved split-leg tripod provided with thumb-nuts.*

The mahogany case has a leather strap, hooks, etc. It contains a sun-shade, a wrench, a screw driver, an adjustable plumb-bob, a magnifying glass, and several adjusting pins, and weighs from 9½ to 10 lbs.

| | | |
|---|---|---|
| Weight of Plain Transit, (No. 1), . . . . | 13½ lbs. | Weight of tripod from 7 to 7½ lbs. |
| " " Transit with Level Attachment, (No. 1 a) | 14 " | |
| " " Complete Transit, (No. 1 b and No. 1 c) | 14½ " | |

Gross weight of instrument, complete, packed securely for shipment in 2 boxes, about 50 lbs.

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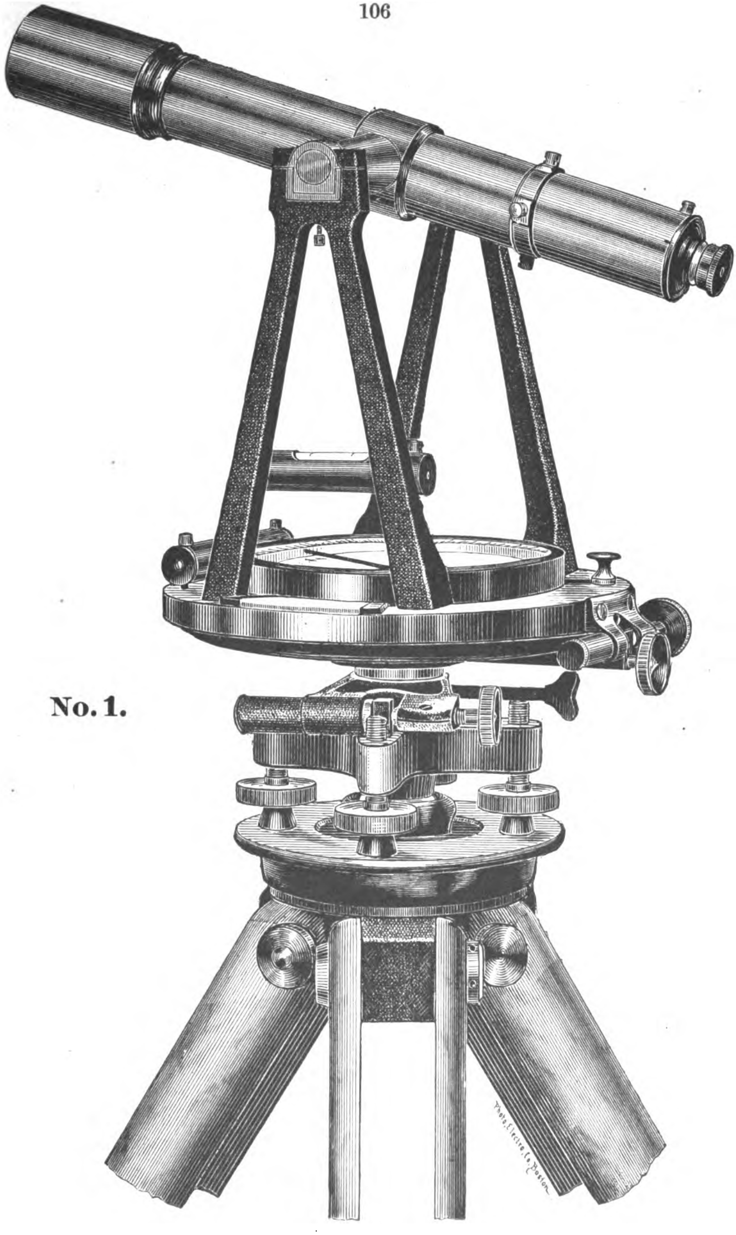
## Extras to Transits No. 1—No. 1 c inclusive.

| | |
|---|---|
| Verniers provided with *ground glass shades*, (see page 6), . . . . . | $3.00 |
| Graduations on horizontal circle, on *solid silver*, . . . . . . . . | 10.00 |
| " " " reading to 30″. . . . . . . | 10.00 |
| " " " " 20″. . . . . . . . | 20.00 |
| Graduation on vertical arc or vertical circle, *on solid silver*, . . . . | 5.00 |
| Gradienter attachment, (see page 20), . . . . . . . . . . . | 5.00 |
| Stadia wires, fixed, . . . . . . . . . . . . . . | 3.00 |
| " " adjustable, . . . . . . . . . . . . . . | 10.00 |
| Arrangement for *offsetting at right angles*, . . . . . . . . | 5.00 |
| Spofford's Patent Equal Arc Meter, . . . . . . . . . . . | 20.00 |
| Variation plate, . . . . . . . . . . . . . . . | 10.00 |
| Gossamer water-proof bag, to cover transit in case of rain or dust, . . | 1.00 |
| Bottle of fine watch-oil to lubricate the centers, etc., of transit, . . | 0.25 |

NOTE.—Sometimes we are asked by those not intimately acquainted with the principles governing a telescope to place a higher power than is customary with the best makers upon a telescope of the size described above. In answer we wish to say that with the power mentioned above very good results in stadia measurement can be obtained, and that while the power could be easily increased, the light and definition of the telescope would become so diminished that it would render the instrument less efficient in more than one respect. In this connection we refer to the various articles written on the telescope in part I. of catalogue. In some cases, however, where the instrument is principally intended for use in stadia measurements, we can increase the aperture of our *inverting telescope* for Transits No. 1 from 1¼ to 1⅜ inches diameter. This increase in aperture will permit of a higher power. Thus two eye-pieces, magnifying respectively 27 and 33 diameters, can be supplied with such a telescope; but the danger of the wires getting broken, or dust blowing into the telescope, etc., in changing the eye-pieces, is so great, that in instruments of the above class the use of two eye-pieces should be as little resorted to as possible. To increase the aperture of the object-glass to 1⅜ inches adds $10.00 to the cost of the instrument, and where both eye-pieces are ordered an extra charge of $5.00 will be made. This change in aperture will add about 10 oz. to the weight of the instrument, and about 1 lb. to the weight of



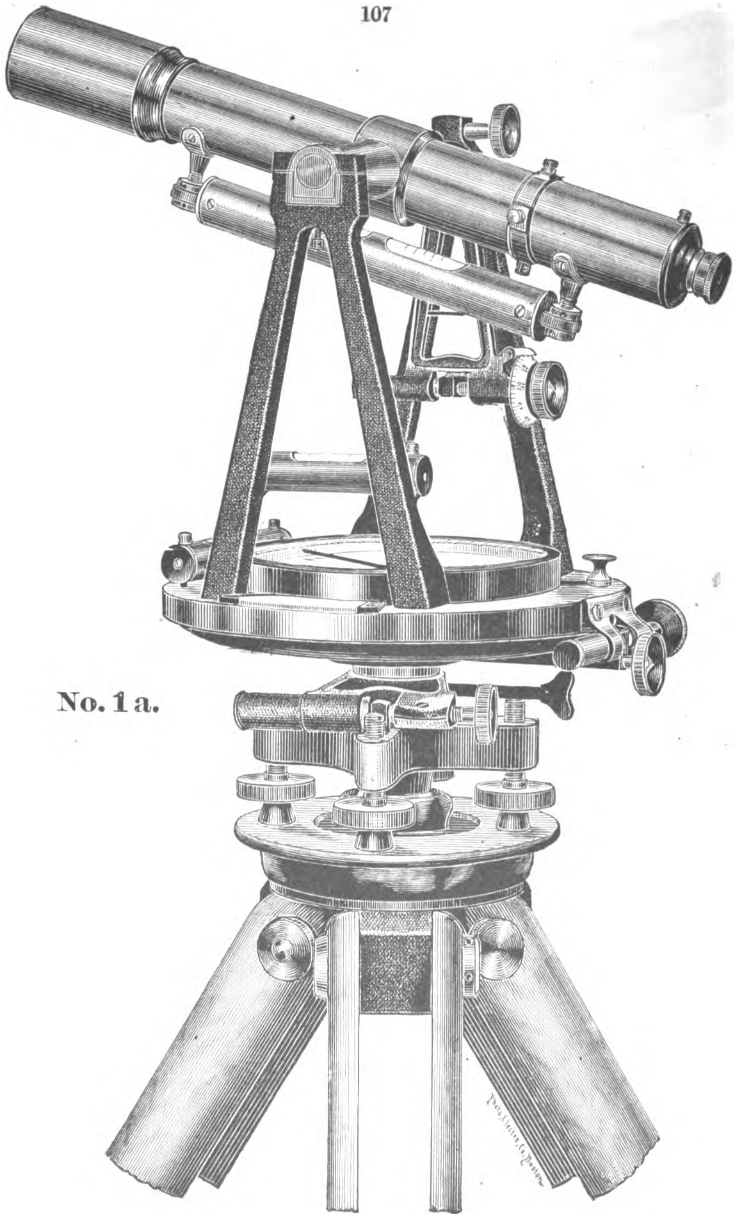

No. 1.

**Plain Transit,**

**Price, as above, $185.00.**

**Standards cloth-finished,** (*see cloth-finish*), . . . . . . . $5.00 less.

**For size and description of this instrument, as well as for *Extras*, see preceding page.**

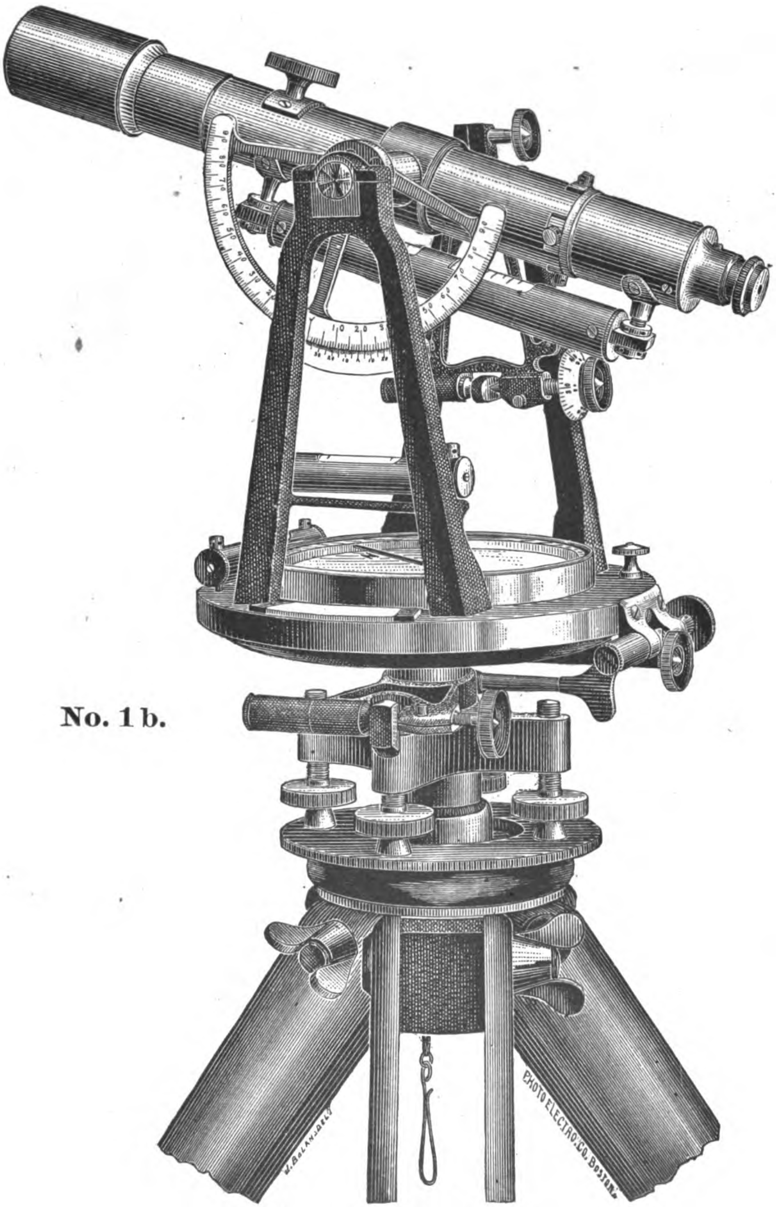



**Transit with Level Attachment to Telescope.**

**Price, as above,** *without gradienter*, **$215.00.**

**Standards cloth-finished,** . . . . . . . . . . $5.00 less.

For size and particulars of this instrument, as well as for *Extras*, see page 105.




No. 1 b.

**Complete Engineers' and Surveyors' Transit.**

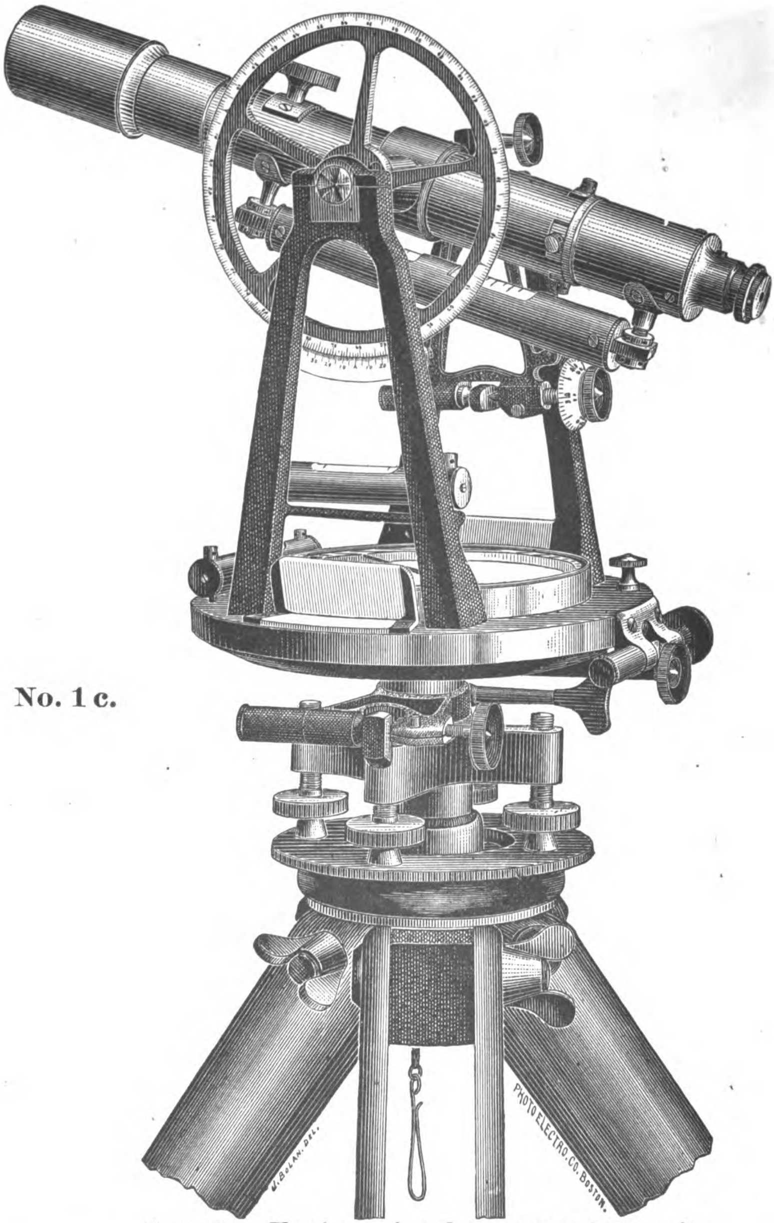
The 5 inch vertical arc is provided with double verniers reading to minutes.

**Price, as above,** *without gradienter*, **$230.00.**

**Standards cloth-finished,** (*see cloth-finish*,) . . . . $5.00 less.

For size and particulars of this instrument, as well as for *Extras*, see page 105.

No. 1 c.



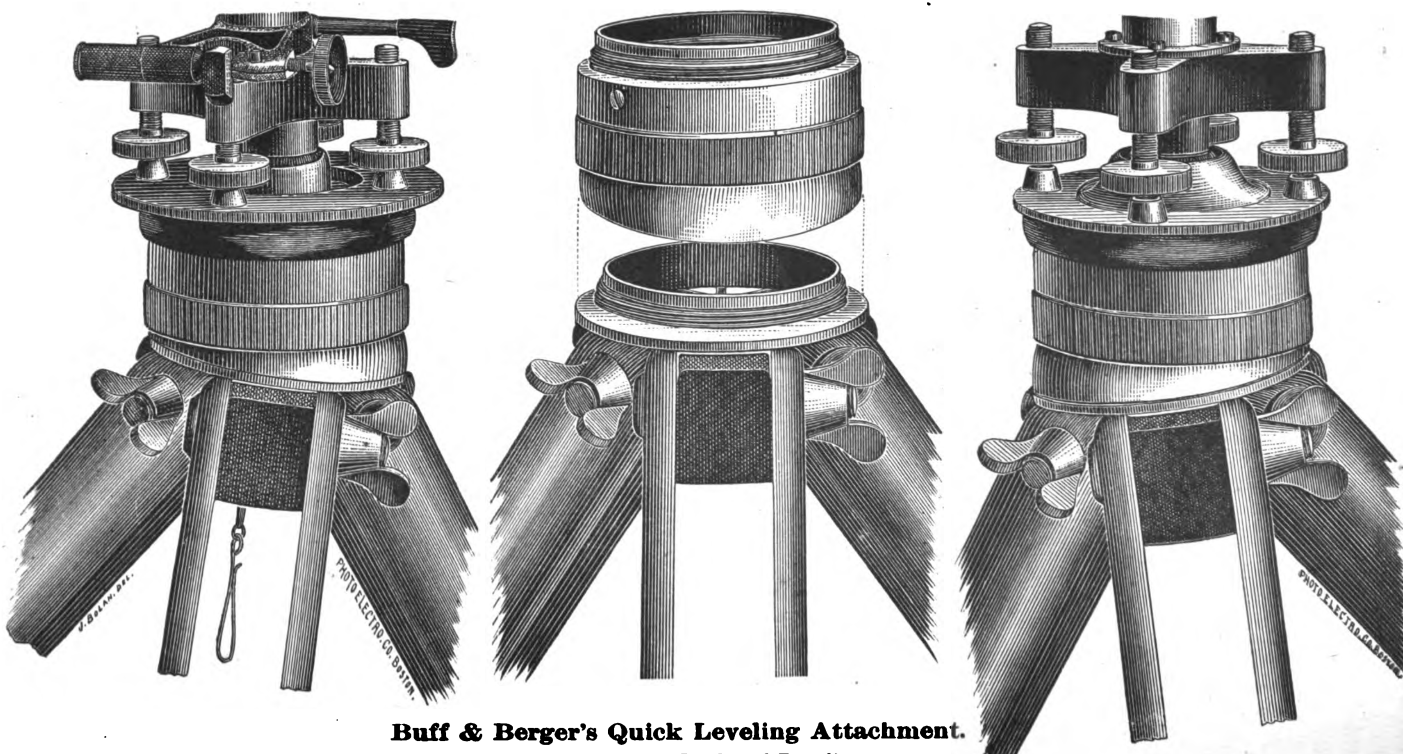

**Complete Engineers' and Surveyors' Transit.**

The 5 inch vertical circle is provided with double verniers reading to minutes.

**Price, as above,** *without vernier shades and gradienter,* **$235.00.**

**Standards cloth-finished,** (*see cloth-finish, page 10*), . . . . **$5.00 less.**

**For size and particulars of this instrument, as well as for *Extras*, see page 105.**

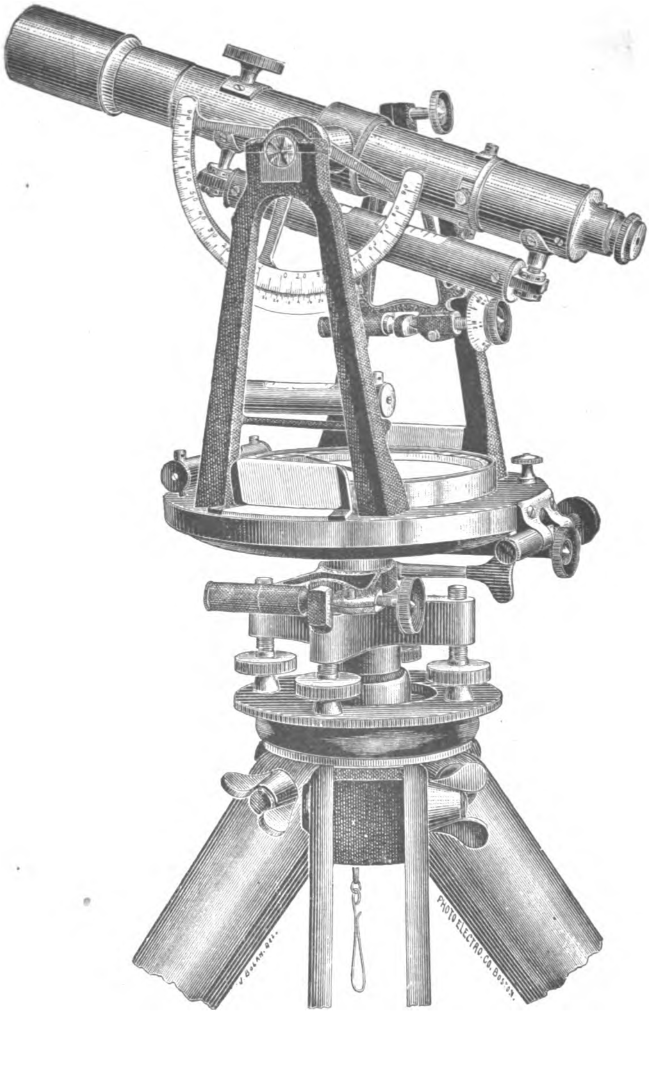



**Buff & Berger's Quick Leveling Attachment.**

**Shown as applied to Levels and Transits.**

(See page 20 of Manual.)

**Price $8.00.**




**Complete Engineers' and Surveyors' Transit.**
**No. 2.**
**As made by Buff & Berger.**

## Small Engineers' and Surveyors' Transit.

**No. 2. Plain Transit.*** The essential features of this instrument are like those *enumerated under No.* **1**, with the exception of size and weight. It is designed to be used in cases *where a lighter instrument is desirable.* All the parts, the graduations, the telescope, etc., are made with as great care as in the larger instruments made by us. We can recommend it as being a very reliable and superior instrument for railroad work, for general land surveying and for mining purposes.

The dimensions are as follows:—

Horizontal limb 5 inches; magnetic needle 3¾ inches; telescope 9 inches; clear aperture 1 inch; power 18 diameter.

The mahogany case has a leather strap, hooks, etc. It contains a sun-shade, a wrench, a screw driver, an adjustable plumb-bob, a magnifying glass, an adjusting pin, and weighs 7 lbs.

Weight of instrument 10 lbs.; weight of tripod from 6½ to 7 lbs.

Gross weight of instrument, packed securely for shipment in 2 boxes, about 40 lbs.

**Price, as above, $185.00.**

**Standards cloth-finished,** . . . . . . . . . . $5.00 less.

---

## Extras to Plain Transit.

| | |
|---|---|
| Spirit-level 5½ inches, with clamp and tangent screw to telescope, | $30.00 |
| Gradienter attachment, | 5.00 |
| Offsetting arrangement, | 5.00 |
| Graduation of horizontal circle on *solid silver*, | 10.00 |
| 5 inch vertical arc, *double* verniers reading to minutes, | 15.00 |
| " " " graduation on *solid silver*, | 20.00 |
| 5 " " circle *double* verniers reading to minutes, | 20.00 |
| 5 " " " graduation on *solid silver*, | 25.00 |
| Glass shades over verniers (to faciliate the reading,) | 3.00 |
| Stadia wires, fixed, | 3.00 |
| " " adjustable, | 10.00 |
| Variation plate, | 10.00 |
| Gossamer water-proof, to protect the instrument in case of rain or dust, | 1.00 |
| Bottle of fine watch oil, to lubricate the center, etc., of transit, | 0.25 |

*A Plain Transit is one without spirit-level, clamp and arc to telescope, see No. 1, page 106.

NOTE.—If a transit is intended for very close stadia work, Transit No. 1, with its larger telescope and higher power will be best suited for that purpose. But in all cases where greater lightness and portability is a factor and where only general good results in stadia measurements, as obtained with a smaller and less powerful telescope, will be deemed satisfactory, size No. 2 should be chosen. We cannot put a telescope of the size as described in Transit No. 1 upon a Transit No. 2. It should be borne in mind that all parts of an instrument are so closely related to each other that the preponderance of any one part would simply impair the efficiency of other parts. A telescope of the size given above, but showing objects inverted, will generally give the desired result.

## Pearsons' Patent Solar Attachment,

A concise description of this attachment to a transit as invented by Mr. H. C. Pearsons, and constructed by us, will be found in our manual. The accompanying illustration represents it as attached to No. 1*and No. 2 of our engineers' and surveyors' transits. Of all the different kinds of solar attachments in use we believe this to be the most efficient ever attached to a transit. Owing to its position on the instrument it can be easily manipulated. Its adjustments are very few and simple, and most important of all they can be readily proven and perfected in a simpler manner than in any of the solar attachments we have seen.

All the settings for position, with the exception of two, are done by means of the level attached to the standard of the instrument, and that attached to the clamp arc of the solar. It is only necessary to make two readings of the graduation, viz: that of the setting for latitude and for declination. After the latitude has been set off, and the clamp arc, carrying the solar, clamped to the standard, the telescope is free to move in altitude without interfering with the position of the solar. While observing, it is only necessary to watch the level on the standard to secure good results.

The following are the essential points of the new solar attachment as made by us.

I. The polar axis can be adjusted to coincide with the zero of the latitude arc with a degree of accuracy mentioned before. This is done by means of a striding level which can be placed on top of two rings as in a Y level. It is then only necessary to adjust the level attached to the clamp arc, when the striding level can be stored away in its box.

II. The solar apparatus is exactly at right angles to the line of collimation.

III. The adjustment of the lens bar, to coincide with the zero of the declination arc, can be made similar to the vertical adjustment in a transit by means of a plumb-line in front of the instrument and, second, can be perfected by means of a plumb-line stretched over the lens bar when in a vertical position.

IV. The solar attachment can be readily attached or detached from the transit without altering any of the foregoing adjustments. When detached from the instrument, the transit is then simply an ordinary complete engineers' transit, with vertical arc, spirit-level, clamp and tangent screw to telescope.

V. Its weight is 1 lb., with the counterpoise 2 lbs.

(*It is not necessary* to use the counterpoise in connection with the solar to do good work. It can be put on, or left off at will.)

VI. We can now furnish a telescope instead of a lens bar with ½ inch aperture and 6 inches focus, provided with a single lens objective and diagonal eye-piece for observing the sun. We also make a focal plate of ground glass instead of a silver one, when desired. The ground glass permits the sun to be seen from the other side of the plate, and the image of the sun is more sharply defined than when accompanied by the glare of the silver surface reflection.

Solar attachment, as above, *solid silver* graduations,

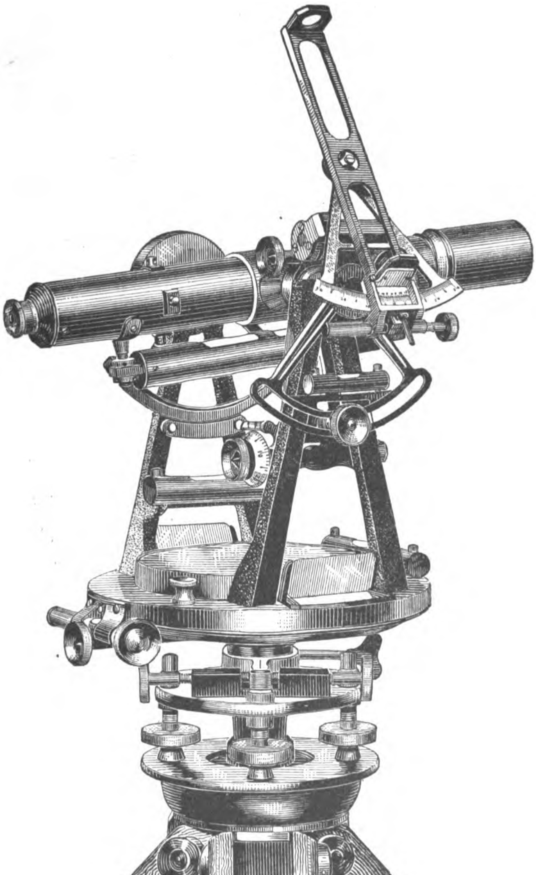
**Price $100.00.**

### Extras to Solar Attachment.

Small striding level for adjusting the polar axis, . . . . . . . . $3.50

Colored glass to apply to the telescope of the transit to observe the sun's altitude, in order to apply the correction for refraction in solar transit work, 2.00

***Pearsons' Solar Attachment can be placed only upon Transits No. 1 b, No. 1 c and No. 2, and then only when ordered with the instrument.**



**Pearsons' Patent Solar Attachment.**

**As made by Buff & Berger.**

**NOTE.—** Instead of a lens bar, as represented in the cut above, a small telescope is now furnished. See preceding page.

## Davis' Patent Solar Attachment.

This invention is destined to supersede all other solar attachments, being by far *the most accurate*, *the most simple*, *and the cheapest* Solar Attachment in use. It can be attached to any engineers' and surveyors' transit which has a good vertical arc, or a good full vertical circle. We frequently attach it to our transits Nos. **1 b** and **2**, for the use of U.S. Deputy Surveyors, and others having occasion to do solar work.

However, as its manipulation involves a few mathematical calculations, differing somewhat from ordinary solar attachments, we advice our patrons to carefully read pages 50 and 51, etc., of manual, where a full description will be found. The screen as shown in fig. **2**, can be applied only to the ordinary erecting telescope. Telescopes, with objects inverted, require attachment as in figs. **3** and **4** only, as no screen can be used with them. These latter attachments are now made by us in a manner superior to that shown in the accompanying figures. They are mounted upon a frame, readily attachable to the eye-piece by means of a clamp, which can be clamped in any position most convenient for the observer. To bring the colored glasses or the prism before the peep-hole of the eye-piece, it is only necessary to revolve them, hence they can be used in rapid succession. It will be seen that these solar attachments, requiring no other adjustments than those common in a Surveyors' Transit, are easy to manipulate, and therefore must insure better results than heretofore obtainable with mechanical devices of any other kind.

| | |
|---|---|
| **Price** of Solar Screen as in figs. **1** and **2**, . . . . . . . . . | $6.00 |
| " " Prism and Colored Glasses, as in figs. **3** and **4**, . . . . . | 12.00 |
| " " Solar Screen with prism and colored glasses combined, for use with an erecting telescope, as explained in manual and shown in fig. **1**, | 18.00 |

If we attach it to instruments which are sent to us for that purpose, we must make an extra charge of **$4.00**.

Fig 1

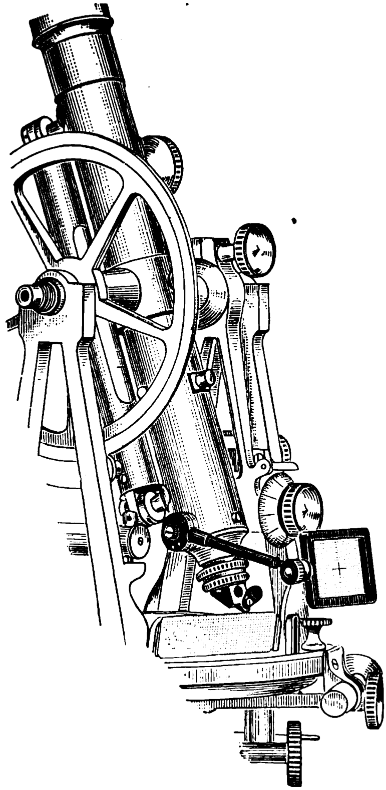


Fig 2.

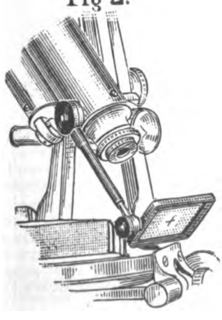
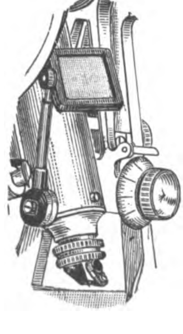


Fig.4.

Fig. 3.



**Davis' Patent Solar Attachment.**

## Mountain Transit.

**No. 3. Mountain Transit.**—Size as in No. **2.** Provided with an extension tripod. This instrument is well adapted for use in mountainous regions, chiefly on account of its smaller size, lightness and great portability. Its work is as accurate as that of larger instruments of its class. Its weight is 10 lbs., with an ordinary tripod complete 16½ lbs., but when provided with an extension tripod three pounds are added to this weight. The graduations are on *solid silver verniers reading to minutes; ground glass shades; 5 inch vertical arc; spirit-level clamp and gradienter to telescope; protection to object slide; extension tripod provided with thumb-nuts, etc.*

The mahogany case has a leather strap, hooks, etc. It contains a sun-shade, a wrench, a screw driver, an adjustable plumb bob, a magnifying glass, an adjusting pin, and weighs 7 lbs.

Gross weight of instrument, packed securely for shipment in 2 boxes, about 45 lbs.

**Price, complete as above, $260.00.**

A reduction of $15.00 from this price is made if the graduations are not on solid silver.

**Standards cloth-finished,** (*see cloth-finish,*) . . . . . $5.00 less

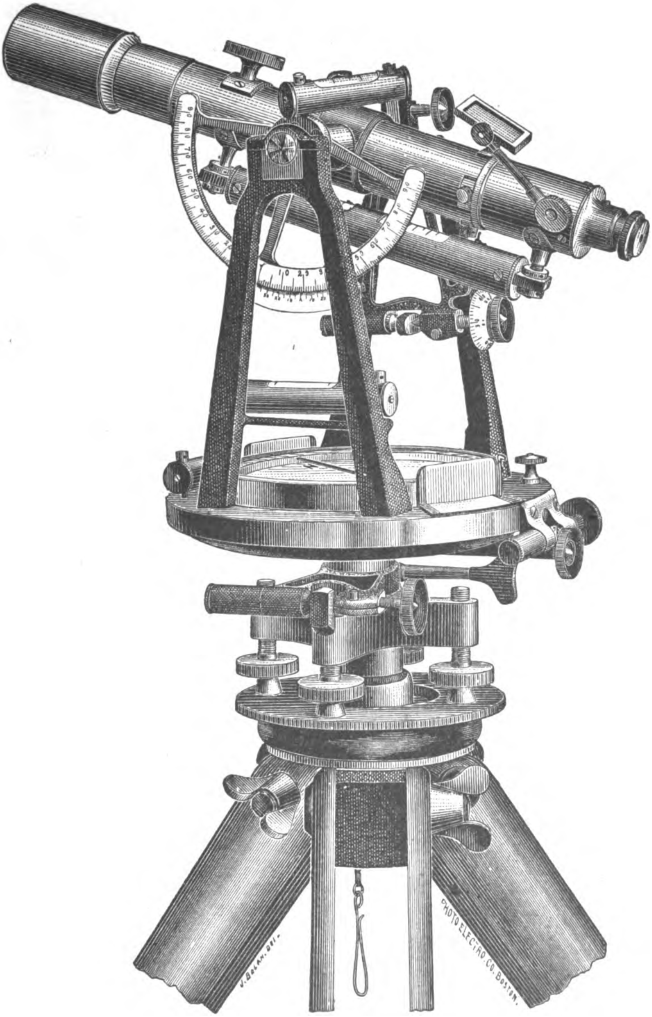
---

## Extras to Mountain Transit.

| | |
|---|---|
| 5 inch full vertical circle, instead of arc, | $5.00 |
| Offsetting arrangement, | 5.00 |
| Stadia wires, fixed, | 3.00 |
| " " adjustable, | 10.00 |
| Variation Plate, | 10.00 |
| Quick leveling arrangement, (see manual), | 8.00 |
| Extra regular tripod, for use with instrument in ordinary practice, | 16.00 |
| Davis' Solar Attachments, all complete, | 18·00 |
| Pearsons' Solar Attachment, all complete, | 105.50 |
| Prism with colored glasses, for observing the sun's altitude, | 12.00 |
| Leather cover over case, to be strapped to the saddle of a horse, | 10.00 |
| Gossamer water-proof bag, to protect the instrument in case of rain or dust, | 1.00 |
| Bottle of fine watch oil, for the centers of transit, | 0.25 |

NOTE.—Although the extension tripod is more slender and somewhat heavier than our regular tripod, its superiority for mountain work is very apparent on account of its adaptation to sudden changes in grades. Still, for general practice, it is desirable to have the regular tripod, insuring, as it does, greater steadiness, and consequently giving increased accuracy. The surveyor will therefore find it to his advantage to order both kinds.

—It will be observed that in the cut the verniers of the horizontal circle are placed at an angle of 35° to the line of sight, thus adapting the instrument to the work in a mountainous country. On the other hand this change in the position of the verniers shortens the level in front of the telescope so much that for very accurate work it cannot be as much relied on as when the level is of standard length and character. To avoid this we place an extra level permanently upon the telescope axis, as shown in the cut. In place of this permanent level we sometimes fit a striding level to the telescope axis similar to that described in the note appended to our Transit No. 11. The price of this striding level in place of the permanent level is $15.00 extra. In all cases where this change in the position of the verniers is not deemed of sufficient importance, we advise to order our Transit No. 2, involving as it does a saving in the cost of the instrument.



**Mountain Transit.**

**Shown with Patent Solar Screen Attachment.***

**As made by Buff & Berger.**

*For illustrations and full description of this Solar Attachment, see pages 49 and 50 of the manual. For Price, etc., see page 113.*

## Mountain, Mining and Reconnoissance Transit.

The annexed cuts represent two complete transits of this class.

No. **4** is in every respect similar to our large engineers' and surveyors' transit, with the exception of size and weight. In the cut the verniers are placed at an angle of 35°, but ordinarily we place them at right angles to the line of sight, which permits of a longer spirit-level in front of the plate. If made in the other way the level will be quite short. This is quite an important feature in so small an instrument, and the longer level should not be sacrificed, unless there are vital reasons to the contrary. The instrument is as carefully made as the larger ones, and, we believe, with careful use capable of very accurate results. For preliminary work of all kinds, as well as to fill in details, it is especially adapted. Owing to the smaller size of the telescope and its high power, we supply the inverting kind. The needle is 2¾ inches long. Sometimes we make this instrument as in No. **4 a;** it is then a transit theodolite. The standards are cast in a single U-shaped piece to gain as much lateral stiffness as possible. The telescope can be reversed over the bearings by removing the upper covers, and also in the usual way through the standards. In this instrument the graduation is covered too, and the verniers are protected by glass, as in No. **4,** but the needle is only 1¾ inches long. Its cost of manufacture, however, is so high, as compared with No. **4,** that we are compelled to make an extra charge of $10.00 when ordered in that style.—However, we believe that No. **4,** having the advantage of a longer needle and containing all the latest improvements possessed by the Engineers' and Surveyors' Transits, will give equal satisfaction in every respect. We therefore advise our friends to order No. **4.** These instruments can be supplied with leather covers over the case, to be strapped to the saddle of a horse.

**No. 4 Mountain, Mining and Reconnoissance Transit.**— The dimensions, etc., are as follows:—

Horizontal limb 4 inches; double opposite verniers reading to minutes; graduations on solid silver; glass-shades over verniers; vertical arc 4 inches; telescope 7½ inches; aperture from $\frac{9}{10}$ to 1 inch; power from 15 to 18 diameters; 4 inch spirit-level, with clamp and tangent screw to telescope; vertical adjustment for the telescope axis; shifting tripod; double centers; two rows of figures from 0° to 360°; split-leg tripod, etc.

The mahogany case has a leather strap, hooks, etc. It contains a sun-shade, a wrench, a screw driver, an adjustable plumb bob, a magnifying glass, an adjusting pin, and weighs 4 lbs.

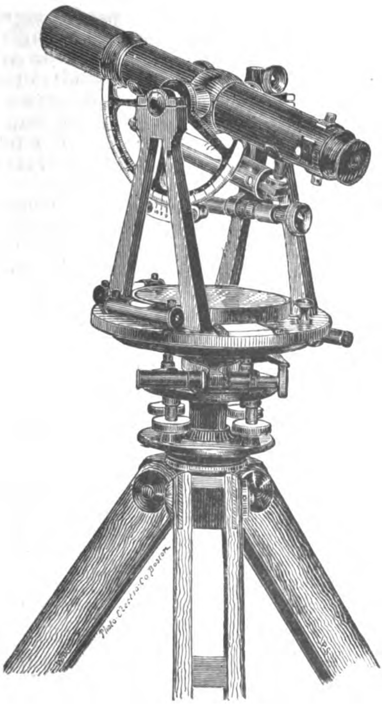
Weight of instrument 5 lbs., weight of tripod 3½ lbs.

Gross weight of complete instrument. packed securely for shipment in 2 boxes, 29 lbs.

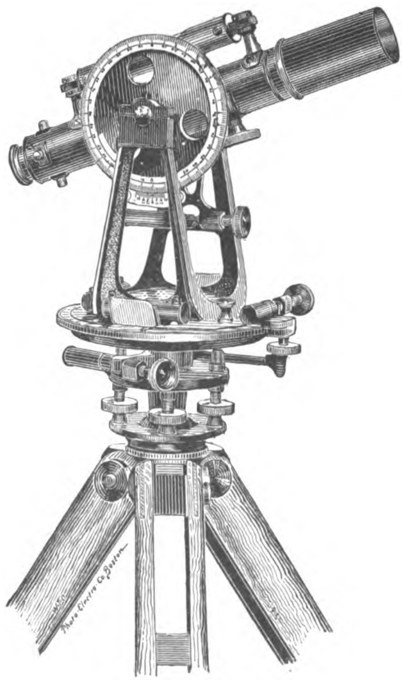
**Price, $228.00.**

### Extras.

| | |
|---|---|
| Adjustable stadia wires, . . . . . . . . . . . . . . . | $10.00 |
| Fixed stadia wires, . . . . . . . . . . . . . . . . . . | 3.00 |
| Prism and colored glasses for solar observations, (improved mounting), . . | 12.00 |
| Extra extension tripod, (weight 4 lbs.; see note to No. **3** mountain transit), | 16.00 |
| Leather cover over case, . . . . . . . . . . . . . . . | 8.50 |
| Silk bag to cover transit in case of rain or dust, . . . . . . . . | 0.80 |
| **Bottle of fine watch oil,** . . . . . . . . . . . . . . . | **0.25** |



No. 4.



No. 4 a.

**Mountain, Mining and Reconnoissance Transit.**

**As made by Buff & Berger.**

## Mining Transits.

All of the foregoing instruments, *particularly No. 2 and No. 4* we recommend for general underground work. (The latter instruments chiefly on account of their greater portability and lightness.) The telescope may be either inverting or erect, and may have a diagonal eye-piece (if inverting,) or a prism attached to the ordinary erecting eye-piece to facilitate sighting in a shaft. We frequently attach to the cross-axis of the telescope a side telescope, which swings free of the plates and permits of vertical sighting *up* or *down* a shaft. This detachable side telescope is placed opposite to the full vertical circle and is parallel with the regular telescope. The horizontal wires of both these telescopes are adjusted to read the same level line. Sometimes we also place directly above and parallel with the line of sight of the main telescope, another one of smaller size, mounted upon standards, firmly attached to the main tube. This second telescope can be reversed in its Wyes end for end, and the distance between the lines of sight of both telescopes is equal to the radius of the horizontal circle. It will be seen that vertical sights, up or down a shaft, can be taken with perfect accuracy and ease. This arrangement, as explained above, has all the advantages of a telescope mounted upon inclined standards, without the faults common in such instruments, as the auxiliary telescope can be taken out of its Wyes when not in use. To avoid errors in reading cardinal points, the compass ring is figured from 0° to 360°, the same as the horizontal circle. Mining instruments should have large vernier openings to admit of as much light as possible, and all graduations should be on solid silver. For the illumination of the cross-wires we place a small reflector in the centre of the cross-axis of the telescope of our larger instruments, but for the smaller kind we attach a reflector in front of the object-glass. The tripod is provided with three adjustable legs to permit of raising or lowering the instrument in unfavorable localities.

**No. 5. Mining Transit** — Dimensions as in No. 1; graduations on *solid silver,* verniers reading to minutes are provided with ground glass shades; 5 inch full vertical circle; spirit-level, clamp and tangent screws to telescope; extension tripod, etc.*

**Price, $253.00.**

**No. 6. Mining Transit.**— Dimensions as in No. 2; graduations on *solid silver,* verniers reading to minutes are provided with ground glass shades; 5 inch full vertical circle; spirit-level, clamp and tangent screw to telescope; extention tripod, etc.*

**Price, $253.00.**

**No. 7. Mining Transit.**— Dimensions, etc., as in No. 6. Instrument has a lamp, which serves as a target, and is interchangeable with the transit above the leveling screws. The lamp is of the same height as the transit and has a leveling head identical with the transit, which is provided with 2 levels.

**Price** of this instrument, with one extra extension tripod for lamp, **$310.00.**

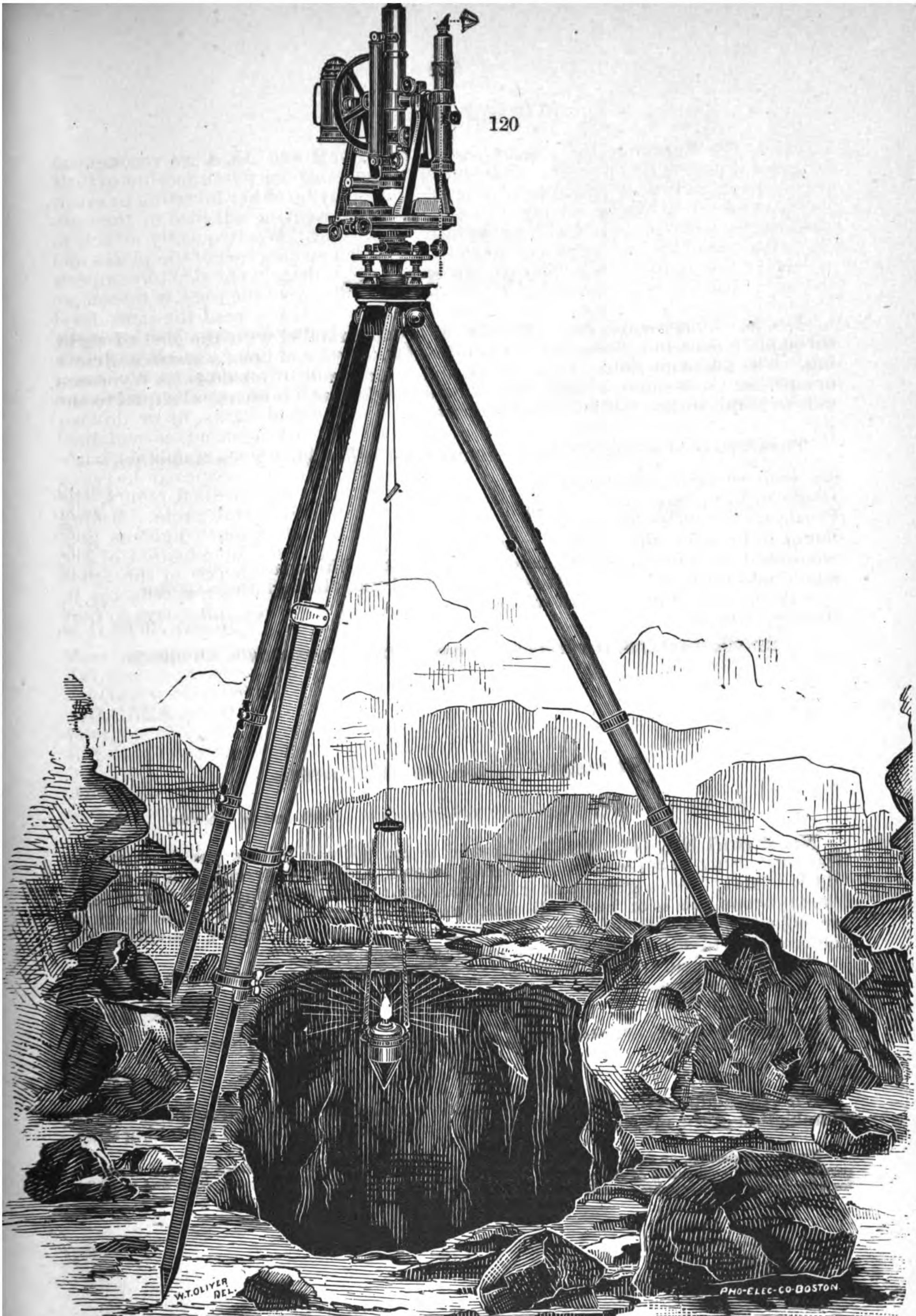
**A reduction of* $15.00 *will be made if the graduations are not on solid silver.*

---

## Extras to Mining Transits.

| | |
|---|---|
| Lamp for mining engineering, of brass, with ground lens, | $7.00 |
| Small table, to attach lamp to standard of transit to illuminate wires. | 3.00 |
| Reflector for illuminating the cross-wires, | 4.00 |
| Small reflector in the center of telescope, holes drilled through the telescope axis for the illumination of wires, | 8.00 |
| Diagonal eye-piece, | 16.00 |
| Prism, attachable to eye-piece, | 8.00 |
| Detachable side telescope, | 35 00 |
| " auxiliary telescope, (as explained above), including standards and counterpoise, etc., | 70.00 |
| Arrangement for offsetting at right angles to telescope, | 5.00 |
| Quick leveling arrangement, | 8.00 |
| Half-length tripod, | 13.00 |
| Extra extension tripod, | 16.00 |
| " split-leg tripod, (see note to No. 3), | 16 00 |
| Plummet lamp (large size), | 10 00 |
| " " (small size), | 8.00 |
| Stadia wires, adjustable | 10.00 |
| " " fixed, | 3.00 |
| Gradienter attachment for No. 5, 6 and 7, | 5.00 |
| Large plumb bob, weight 4 lbs., for use in shafts, | 5.00 |
| Bottle of fine watch oil, | 0.25 |
| Silk bag, to cover Transit. | 1.00 |

**MINING TRANSITS CONSTRUCTED WITH ECCENTRIC TELESCOPE TO ORDER.**




**Complete Mining Transit, with Extension Tripod and Detachable Side-Telescope.**

**As made by Buff & Berger.**

Size as in **Nos. 5, 6** and **7.** For price of instrument and attachments, see preceding page.

## Tunnel Transit.

**No. 8.** Under this heading we wish to say that the general form of the transit-theodolites, described under No. **11** and No. **12**, is best adapted for tunnel engineering. The telescope should be inverting and be provided with a diagonal eye-piece, or a prism. A sensitive striding level should be added to rest on top of the telescope axis to establish the vertical plane correctly.

The EXTRAS in addition to those enumerated under No. **11**, are as follows:—

| | |
|---|---|
| 4½ inch sensitive striding level, | $20.00 |
| Diagonal eye-piece, | 12.00 |
| Prism, attachable to eye-piece, | 8.00 |
| Lamp, of brass or copper, with ground lens, | 7.00 |
| Small table to attach lamp to standard of transit to illuminate wires, | 3.00 |
| Small reflector in the center of telescope, holes drilled through the telescope axis for the illumination of wires, | 10.00 |
| Plummet lamps, | $15.00, 10.00, 8.00 |

**TUNNEL TRANSITS CONSTRUCTED WITH ECCENTRIC TELESCOPE TO ORDER.**

## Straight Line Instruments.

**For running Straight Lines on the Surface of the Earth and in Tunnels.**

**No. 9 and No. 10.** These Instruments are without circles and graduations. They rest either on three or four leveling screws, and are so arranged as to readily adjust exactly over a given center, after an approximate setting with tripod legs. The telescope axis is of hard bell metal, and reverses in its bearings; the bearings are adjustable in vertical plane; striding level is provided with a handle in the center and is highly sensitive. We make two sizes, viz.:—

No. 9. Aperture of object-glass, 1⅜ inches in diameter; focal length 18 inches; objects erect or inverted, etc.

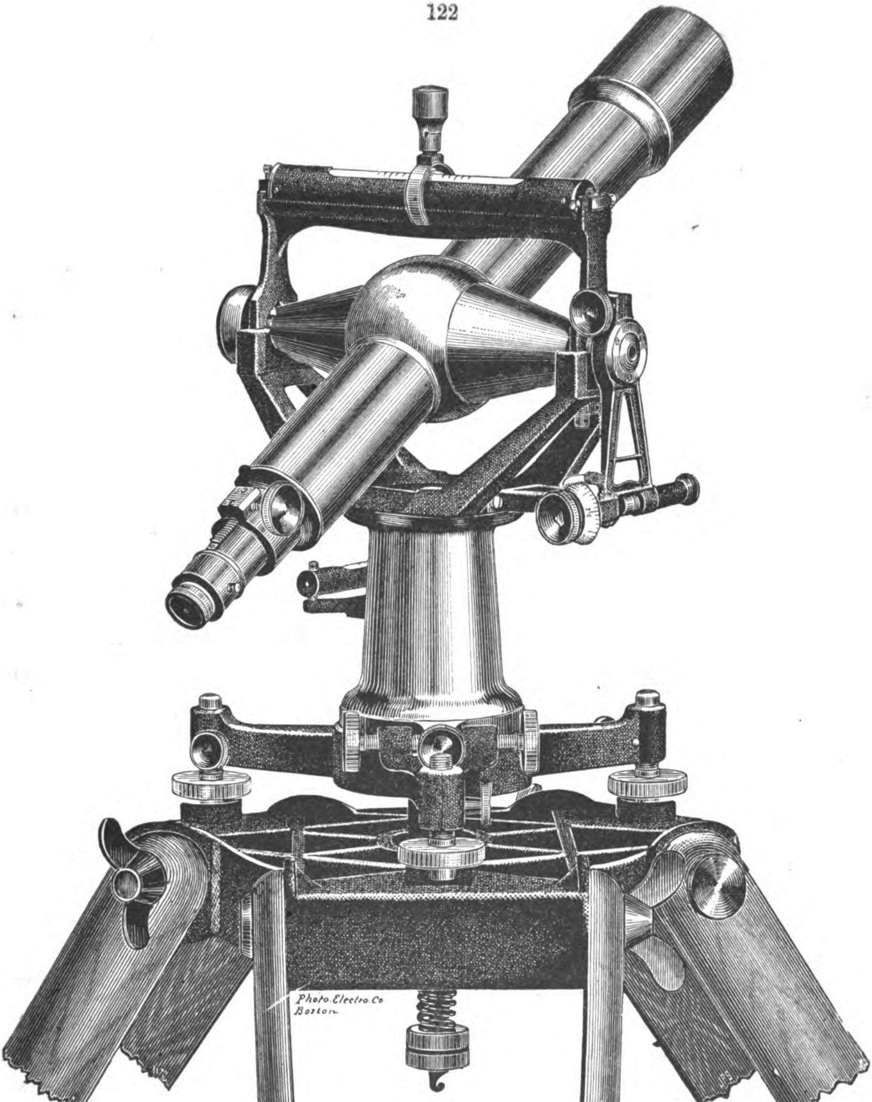
**Price $190.**

No. 10. Aperture of object-glass, 2 inches; focal length 18 inches; etc.

**Price $270.**

With the addition of a glass or spider line micrometer, lamp and reflector for the illumination of the micrometer, both these instruments may be used for taking time.

NOTE.—If desired, an extra striding level can be placed upon two concentric rings of equal diameters parallel to line of collimation of the telescope, thus making a leveling instrument of great power and precision for long sights. This attachment will cost $35.00.




**No. 10.**

**Straight Line Instrument.**

**With Gradienter Attachment.**

# Transit-Theodolite.

**For use in cities, in tunnels, and for triangulation.**

**No. 11.** Of late years it has been found desirable by us to design a transit for use where instruments of ordinary construction would fail to give satisfaction, or do not permit of rapid work where the highest degree of accuracy is required. The instrument as shown in the accompanying illustration has no compass, and therefore, the upper frame mounting the telescope is in one piece, which is provided with ribs, and which rests directly on the top-flange of the inner center. The result of this is that great lateral strength is obtained, which permits of mounting the telescope axis by means of cylinders at each end in wyes. On top of each bearing of the telescope axis is mounted a cap provided with an adjusting screw, with which the necessary friction for the revolving telescope is obtained, and these caps are also provided with two milled-headed screws, which can be removed readily when the telescope is to be reversed for straight line measurements over the bearings. These caps are so arranged as to completely exclude dust from the axis. In this new arrangement the telescope can be reversed as in ordinary instruments through the standards, as well as over the bearings, as is usual in triangulation and for aligning straight lines, and last, but not least, the movement of the telescope in the vertical plane is the most accurate known. Ordinary transits cannot fulfil these functions owing to the peculiar form of the bearings wherein the telescope axis revolves, which bearings are so made to give lateral stiffness to the telescope, on account of the slenderness of the standards resting on the upper plate. Many of these instruments are in use in the survey and triangulation of our largest cities and have given great satisfaction. The instrument is provided with three or four leveling screws. The verniers can be placed at right angles to the line of sight, or as shown in the cut. The dimensions, etc., are:—

Horizontal plate 6¼ inches, *graduation on solid silver* protected as in our regular engineers' instrument; two double opposite verniers, reading to 30″; two rows of figures in opposite directions; long compound centers; 11 inch telescope (inverting or erect); 1¼ inches clear aperture; power 24 diameter; *protection to object-slide;* single spring tangent screws for the upper and lower plates; 4 leveling screws; shifting center, split-leg tripod, case, etc.

Weight of instrument with a 7 inch circle, and all complete, 14 lbs.; weight of tripod 7½ lbs.

**Price, for Plain Transit-Theodolite, $240.00.**

---

## Extras to Plain Transit-Theodolite.

For Extras to Tunnel Transits, see Extras to Mining Transits page 119.

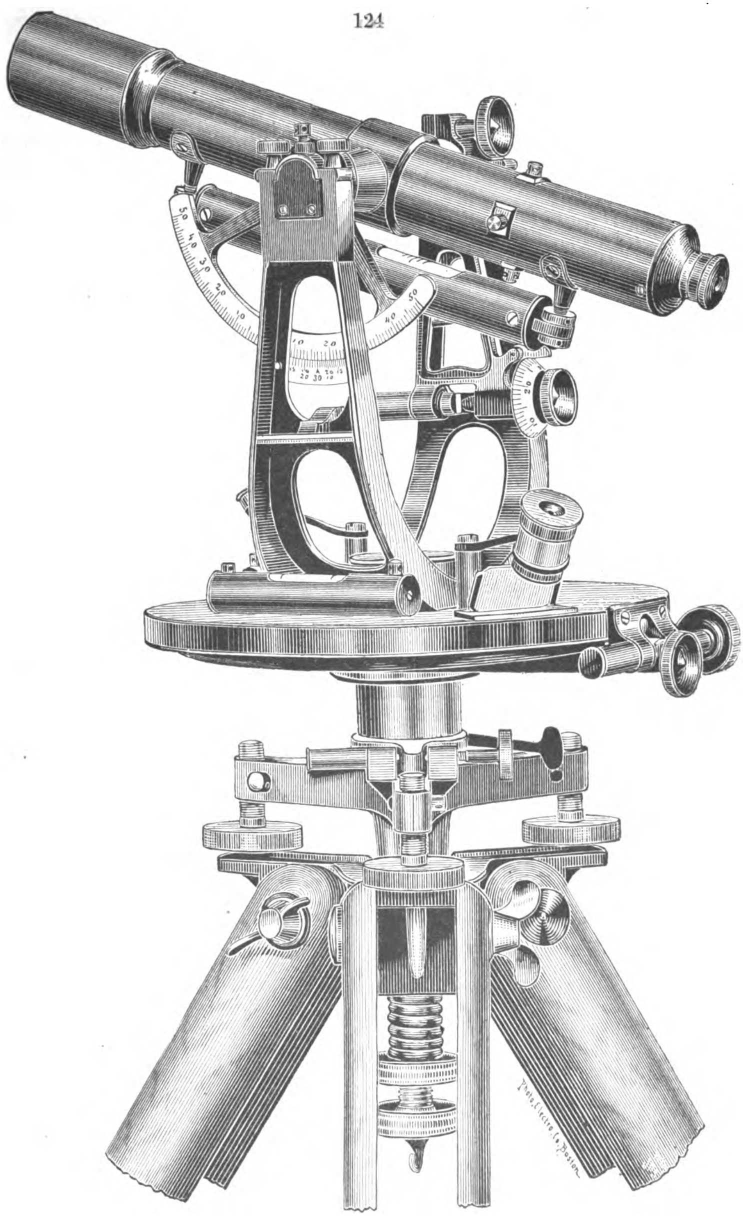
| | |
|---|---|
| Horizontal limb 6¼ inches in diameter, verniers reading to 20″* . . . | $10.00 |
| " " 7 " " " 10″* . . . . | 35.00 |
| Vertical arc 5 " " " minutes, . . . | 20.00 |
| Full 5 inch vertical circle, " " " . . . | 25.00 |
| Two reading glasses, with ground glass shades to verniers, . . . . | 15.00 |
| Instrument provided with 3 leveling screws, as in cut, . . . . . . | 10.00 |
| Shifting center for instrument with 3 leveling screws (improved) . . | 5.00 |
| Stadia wires, fixed, . . . . . . . . . . . . . . . | 3.00 |
| " " adjustable, . . . . . . . . . . . . . . | 10.00 |
| Striding level,** . . . . . . . . . . . . . . . | 20.00 |
| 6 *inch spirit-level with reversible clamp*, tangent and *gradienter* to telescope, | 40.00 |
| Oblong compass, with motion for setting off the variation. (Three-inch needle reads only a few degrees each way from zero.) . . . . . | 20.00 |

*These graduations should always be ordered with reading glasses and ground glass shades *attached* to the instrument.

**Unless ordered to the contrary the striding level of this instrument will not rest directly over the points of contact in wyes as represented in Transit No. 12. For greater convenience it rests on the telescope axis at points between the standards, which has the advantage that the striding level can be left on the axis while the telescope is revolved in the vertical plane. A striding level should always be ordered with an instrument of the class described above.

NOTE.—A Plain Transit-Theodolite is without a level, clamp and arc to telescope.

—For increase of aperture in inverting telescopes see note to Transit No. 1, page 105.



**Complete Transit-Theodolite.**

**For use in cities, in tunnels, and for triangulation.**
**As made by Buff & Berger.**

## 8-inch Transit for Triangulation.

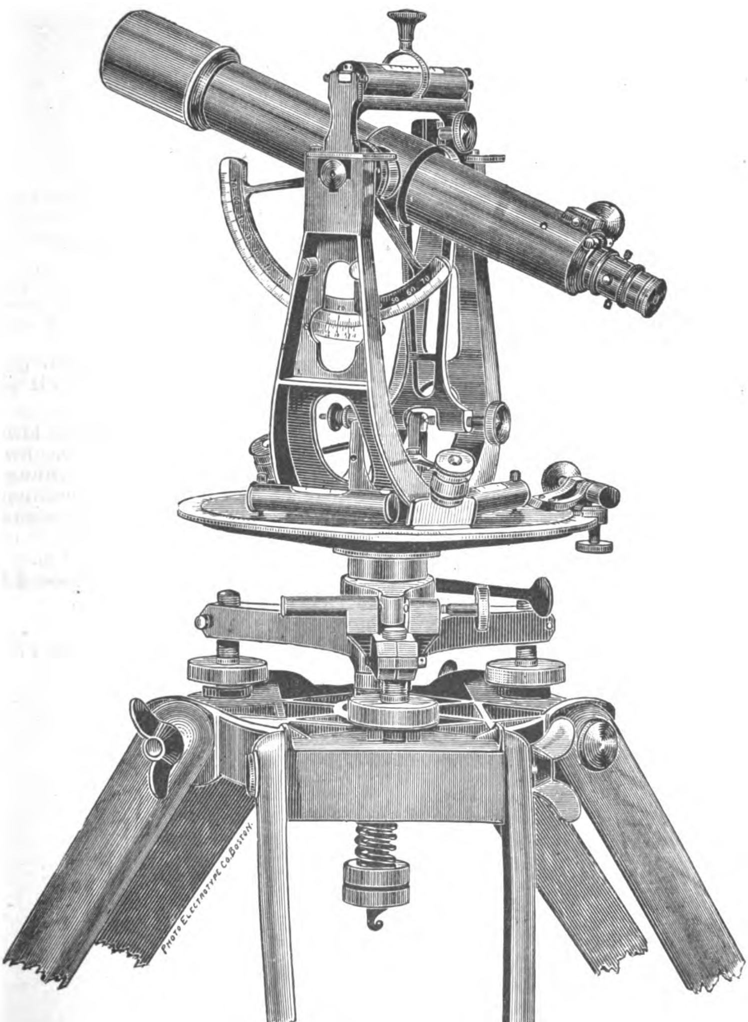
**No. 12.** The form of frame chosen for mounting the telescope is as in the cut, which permits the reversal of the telescope through the standards, as well as over the bearings.

The inverting telescope has a clear aperture of 1½ inches, and is of 11 inches focal length, and has a power of 20, 25 or 30 diameters as ordered. It is provided with a 5 inch vertical arc, graduated to read to minutes, a 4½ inch striding level to rest on the pivots of its axis, a 6 inch spirit-level (parallel to line of collimation) together with a reversible clamp and tangent screw. The horizontal circle is 8 in. in diameter, opposite verniers reading to 10″. Its graduation is open, but it is protected by a rim which is raised above the limb. This instrument has three leveling screws which have a larger base than is usual, and the tripod-head being proportionately large the instrument has great stability.

Weight of instrument 16 lbs.; weight of tripod 12 lbs.

**Price, as above, $450.**

This instrument without arc and clamp to telescope. $50.00 less.



**No. 12.**

**8-inch Transit for Triangulation.**

**As made by Buff & Berger.**

## Transit-Theodolite.

**As made for the U. S. Corps of Engineers.**

Two of these instruments, shown in the accompanying engraving, were designed and constructed for use in the Geographical Exploration and Survey West of the one-hundredth meridian, and exhibited at the Centennial, in the United States Government Building, by Lieut. George M. Wheeler.

**No. 13** and **No. 14** represent this instrument as used in the field for triangulation, and as used for astronomical observations. It is designed to combine in a portable form of construction, the efficiency for field use usually obtained with the larger classes of instruments.

Horizontal limb is 8 inches in diameter, opposite verniers reading to 10″; vertical circle 5 inches in diameter, opposite verniers reading to 20″; object-glass 1½ inches clear aperture; focus 11 inches; powers of two direct eye-pieces respectively 30 and 40 diameters; power of diagonal eye-piece 40 diameters; spirit-level attached to telescope and striding level capable of reading to seconds of arc; three leveling screws; split-leg tripod; low standards are *cast* on vernier-plate; two *extra* standards for astronomical observations; 3½ inch needle; round level for vernier-plate; spider-line micrometer; instrument is ribbed throughout; lamp, arm and adjustable plane reflector; sunshade; adjusting pins; case and strap.

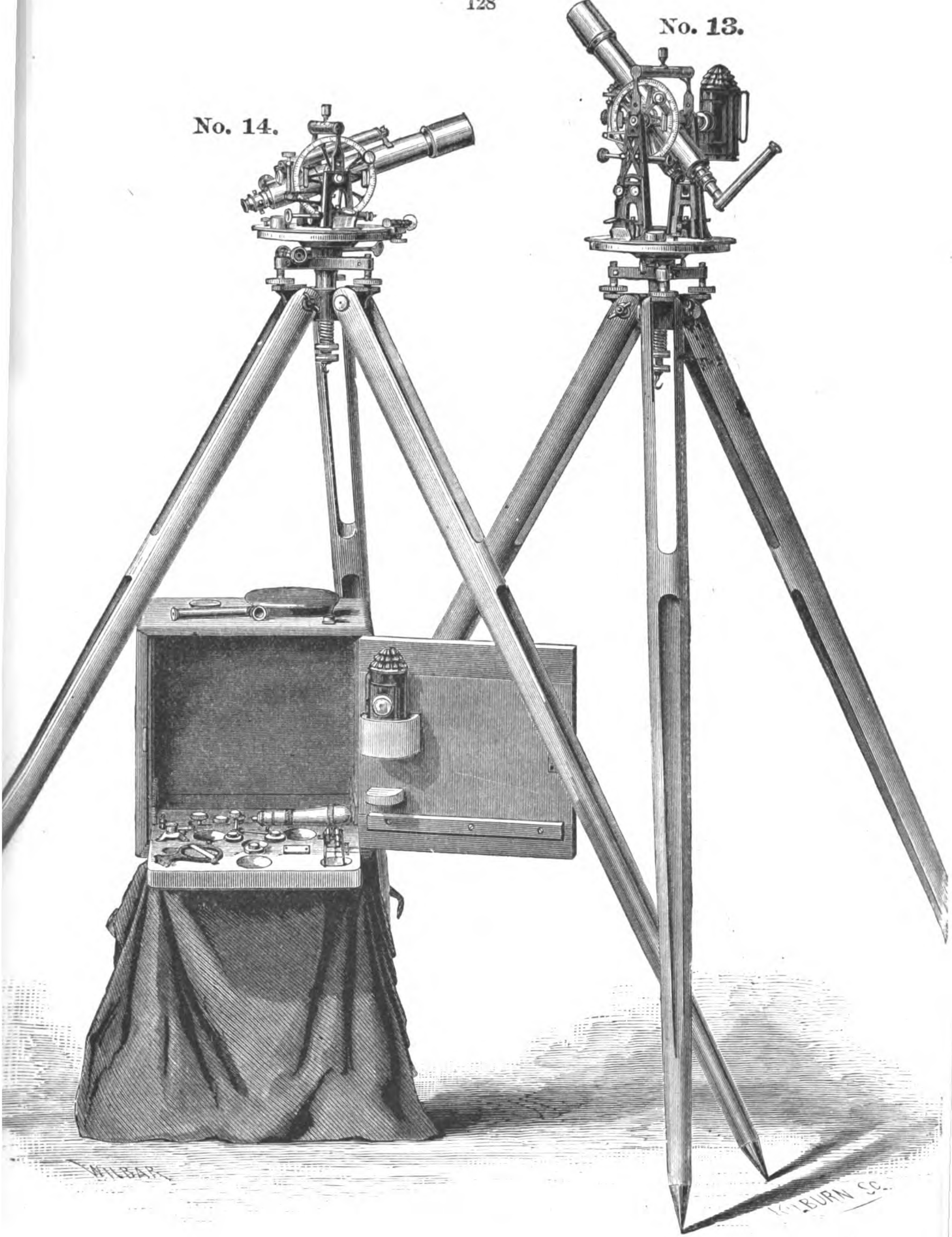
The weight of whole instrument is 14½ lbs.; weight of tripod 8½ lbs.

**Price $650.**

---

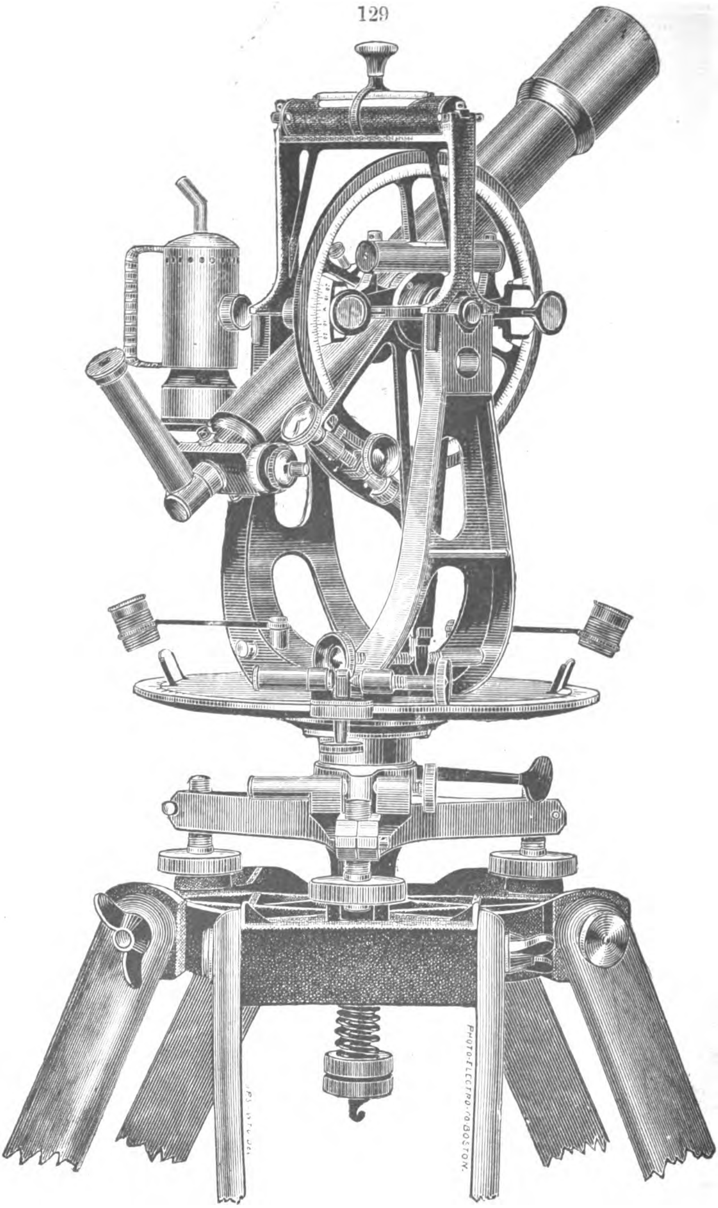
## Theodolite.

**No. 14.** Price of instrument, same in size as that above, arranged for triangulation only, without extra standards, diagonal eye-piece, etc. . **425.**




**Astronomical Transit-Theodolite.**

**As made by Buff & Berger.**

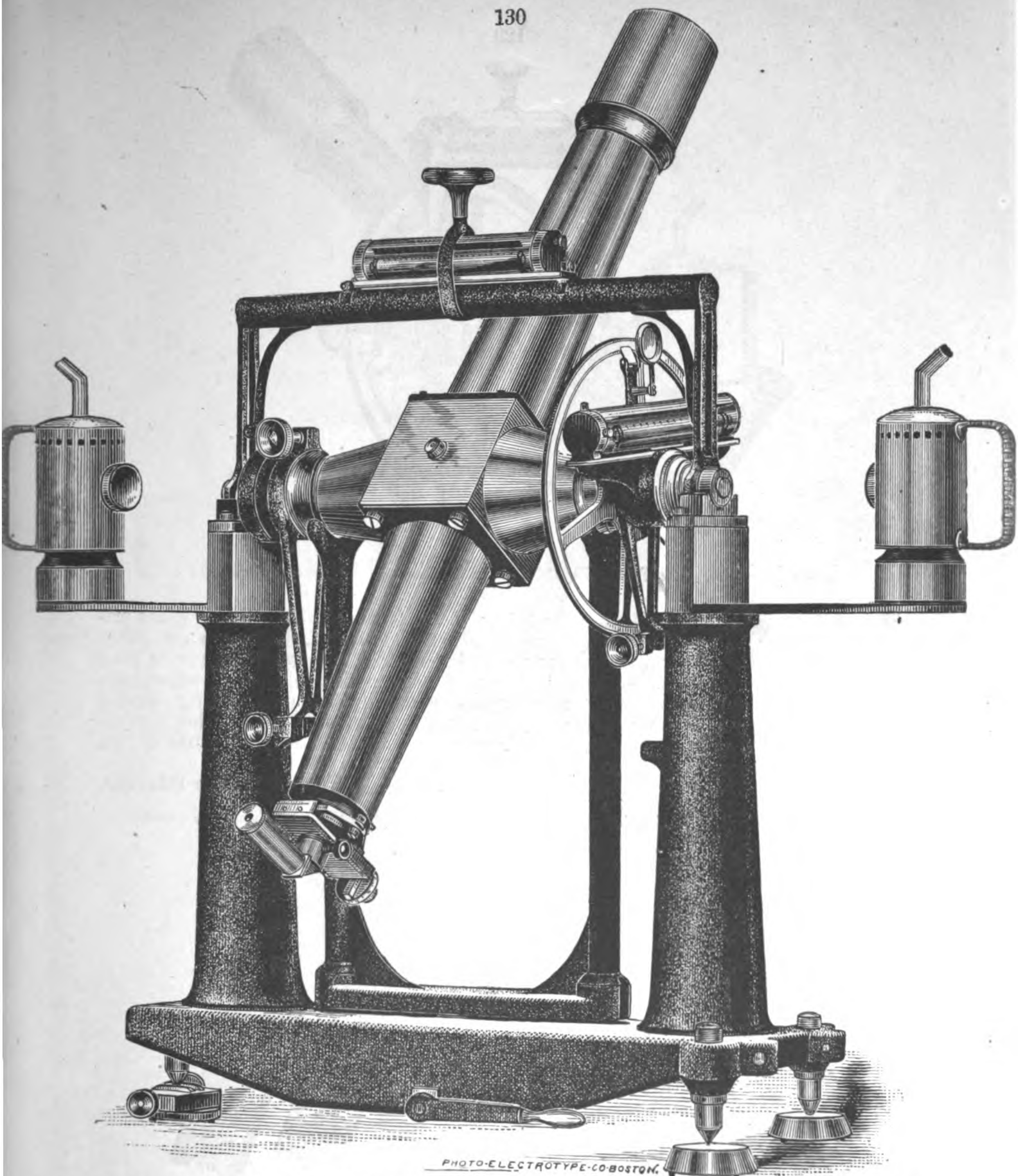



**No. 15.**

**Altazimuth.**

Repeating horizontal circle eight; non-repeating vertical circle 6 inches in diameter. The former can be provided with 2, 3 or 4 verniers reading to 10″, the latter is provided with 2 verniers reading to 20″. The telescope has a clear aperture of 1½ and a focus of 11 inches. Striding level and filar micrometer read to seconds of arc. Mahogany box, etc.

**Price, all complete as in cut, $680.00.**




**Portable Transit Instrument for Latitude Observations.**

**No. 16.** Aperture of object-glass 3 in.; focus 28 in.; spider-line or glass micrometer; micrometer screw reads to seconds of arc; spirit-levels read to seconds of arc; diagonal eye-piece 80 dia.; Ramsden eye-piece 40 dia.; vertical circle 8 in. in dia.; bell-metal pivots, two lamps and arms, adjustable reflector; reversing apparatus; two cases, etc.

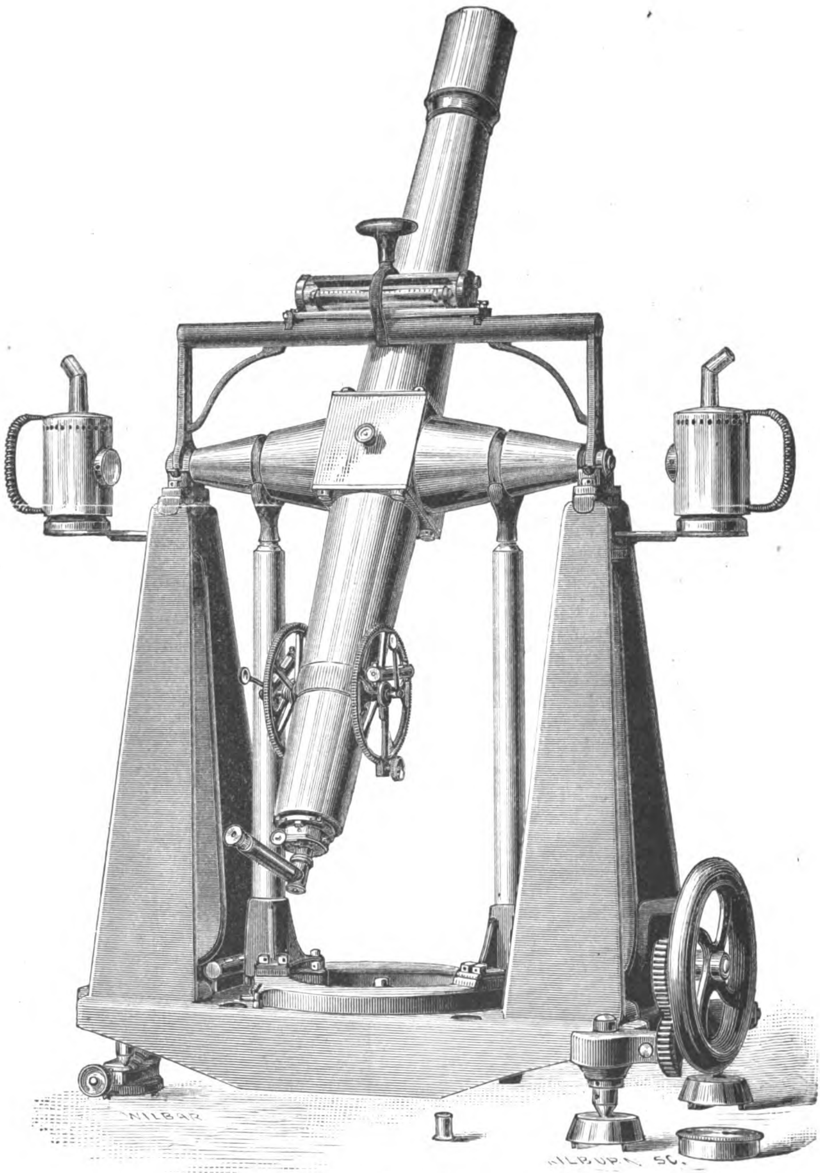
**Price $980.**

## Portable Astronomical Transit Instrument.

**No. 17.** Aperture of object-glass 3 in.; focus 39 in.; spider-line or glass micrometer; diagonal eye-piece magnifies from 90 to 120 dia.; Ramsden eye-piece magnifies 75 dia.; striding level reads to seconds of arc; adjustable mirror to read the level from below: reserve level; pivots of hardened steel; small adjustable plane reflector; two lamps and arms; reversing apparatus; two finding circles each provided with double verniers; cast-iron frame rests on three leveling screws of steel, which are provided with foot-plates—one of them is adjustable to set instrument in the meridian; two cases, etc.

**Price $1300.**

*(Notice of this Instrument, with full description, in Johnson's New Universal Cyclopædia, under article "Transit.")*



**No. 17**

**Astronomical Transit Instrument.**

**As made for U. S. Lake Survey.**

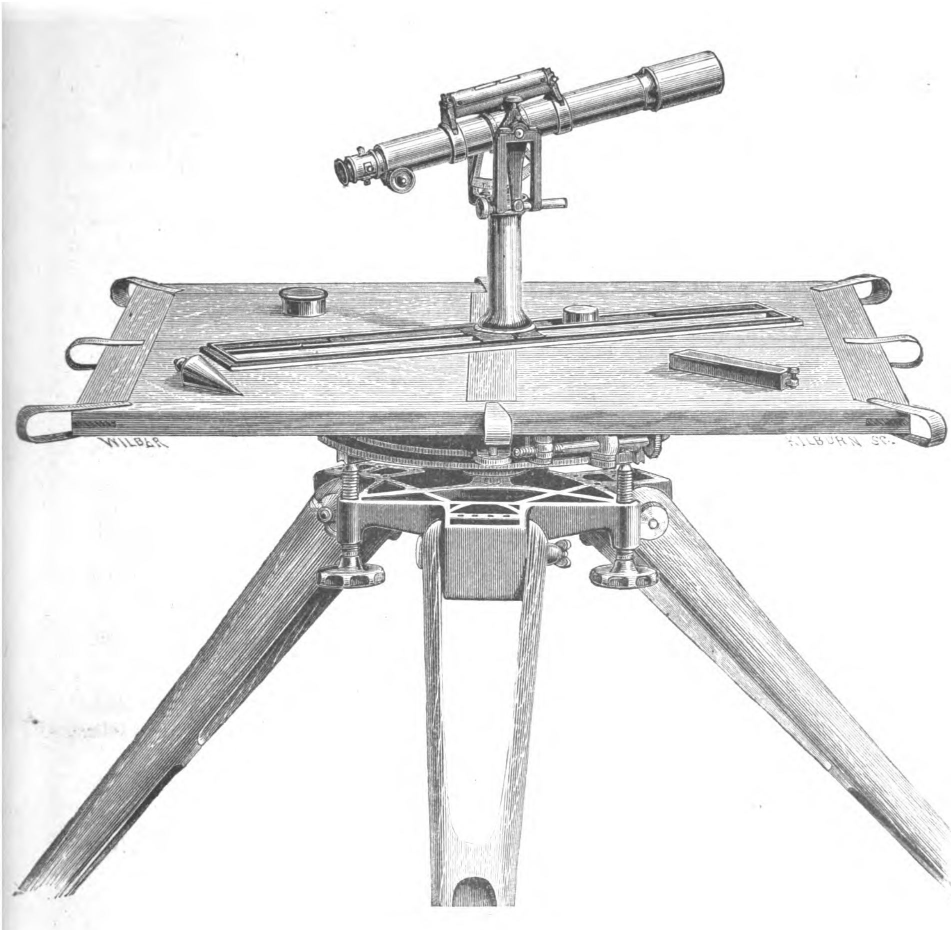
## Plane Table.

The instrument, of which an excellent engraving is shown on the opposite page, is made by us in two sizes.

Size 1 has a larger base for the table to rest on than is usual in plane tables, and therefore is particularly adapted for the more accurate work in topographical surveying. For work of a general character, where greater portability is required, we make this base of the ordinary size like those used in the U.S. Coast Survey, but with all the improvements of the larger base. One tangent screw is attached to the lower part, and this, as well as the alidade, is built on the skeleton plan, so as to make them light and stiff. The alidade is provided with a powerful telescope, striding level, vertical arc, small round level and stadia wires, and is so arranged that lines can be ruled to coincide with the line of collimation of the telescope.

Price of Plane Table No. 1, including table, detached compass, 2 cases, screw drivers, clamps, etc., . . . . . . . . . . . . **$300.00.**

Price of Plane Table, No. 2. . . . . . . . . . . . **280.00.**




**Plane Table.**

**As made by Buff & Berger.**

# Current Meters.

*For description see manual.*

**Price complete,** in mahogany case, as in Fig. **I.** . . . . . . . **$125.**
" " " " " **II.** . . . . . . **150.**
" " in 3 mahogany cases, " " **III.** with electric register and one battery . . . . . . . . . . . . . . . . **185.**

**Nos. I, II, III,** with the addition of the **floating wheel** extra, $15.00.

**Price complete,** as in Figure **IV**, with electric register and one battery etc., packed in 3 cases, . . . . . . . . . . . . . . **$195.**

**Price** of this instrument without electric register and battery . . **135.**

The instruments as represented in Figs. **III** and **IV** are those made by us for the U. S. Engineer Corps. For speed, as well as for accuracy of work, we believe they are not excelled.

The electric current meters are sometimes provided by us with an arrangement for sounding depths, as well as to signal above when the meter touches the bottom of the river. This arrangement is connected with an electric bell, which is attached to the register.

**Price** extra, $15.00.

* * *

# Current Meter No. V.*

*An illustration of this instrument will be found on page* 137.

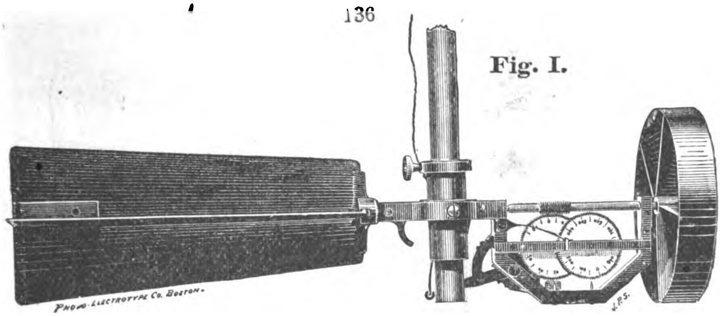
This form of Current Meter is specially adapted for observations upon smaller rivers, streams, conduits, flumes, etc. It is provided with a registering apparatus similar to that described under No. II., page 62 of catalogue. For more extended observation upon rivers, etc., an electric register and battery similar to those used with Nos. III and IV can be supplied with this instrument.

**Price of Current Meter No. V,** supplied only with the ordinary registering apparatus, as shown in the main cut on page 137, and with 12 feet of brass tubing, made in sections of four feet, and graduated in feet and tenths. Complete in two cases, . . . . **$160.00.**

**Price of Current Meter No. VI,** in all respects similar to that above, but in addition to the ordinary registering apparatus this instrument is provided with an electric register, one battery and copper wire, as shown in the smaller cuts on page 137. Complete in four cases, . . . . . . . . . . . . . . . . **$220.00.**

*For further information on this Current Meter read "Description of some experiments on the Flow of Water, made during the Construction of Works for Conveying the Water of Sudbury River to Boston;" by A. Fteley and F. P. Stearns (Transactions of the Society of Civil Engineers, Jan.-March, 1883) Also, "On the Current Meter, together with a Reason why the Maximum Velocity of Water Flowing in Open Channels is Below the Surface;" by F. P. Stearns; a paper read at the Annual Convention of the American Society of Civil Engineers, St. Paul, Minn., June 21st, 1883. (Transactions, etc., Vol. XII., August, 1883.)

Fig. I.



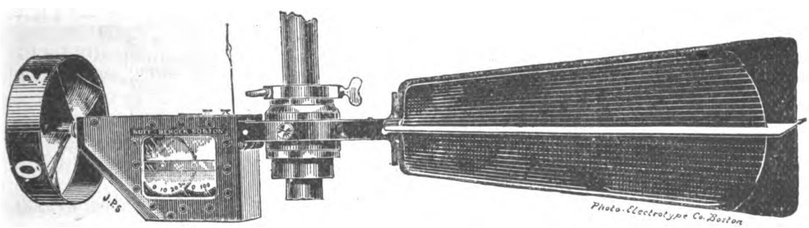




Fig. II.

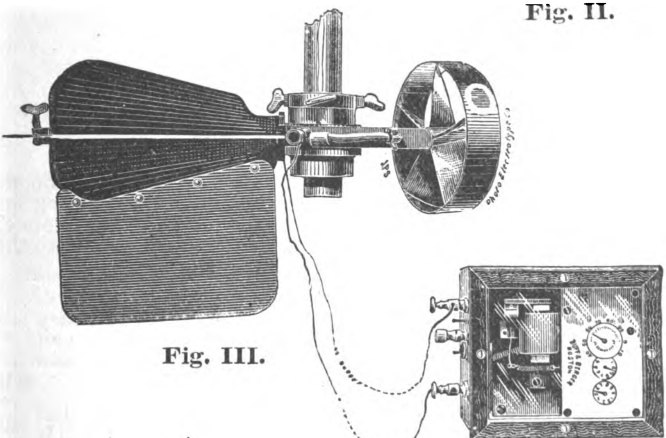


Fig. III.

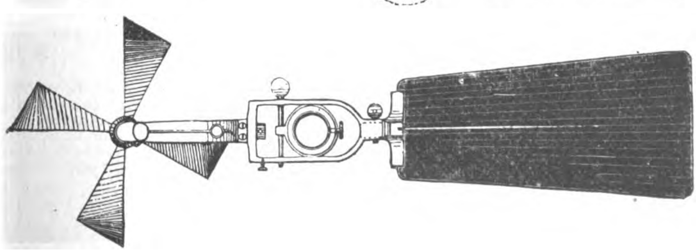
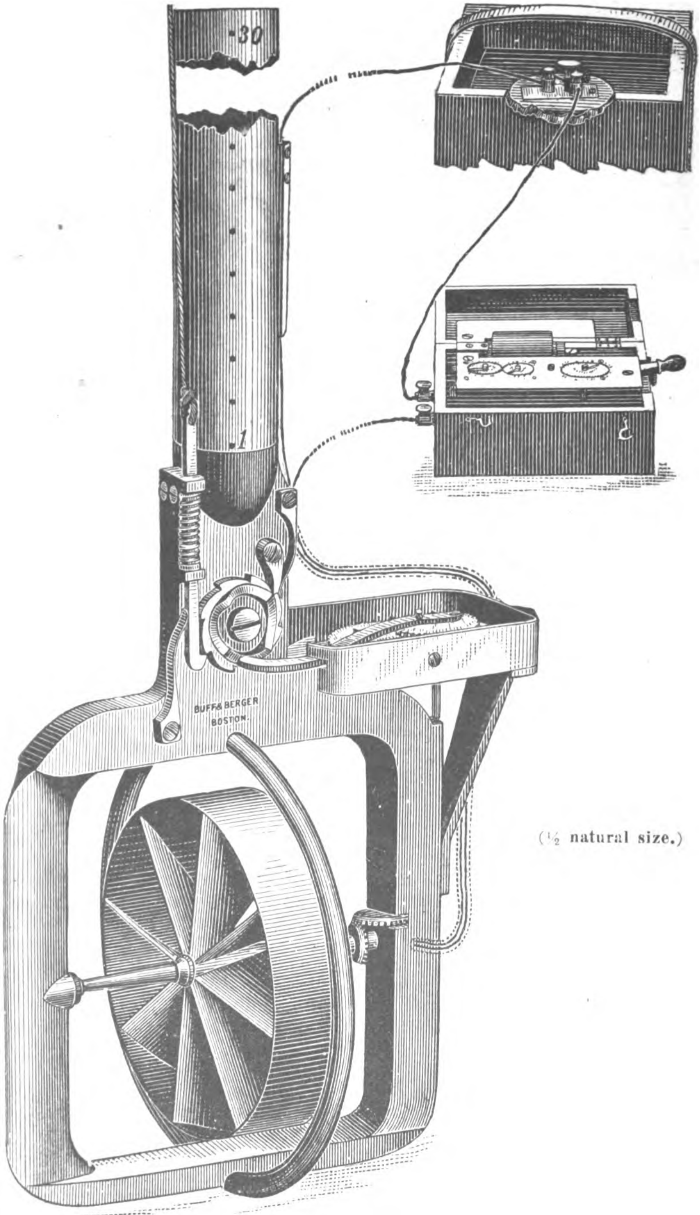


Fig. IV.

**Current Meters.**

**As made by Buff & Berger.**




(½ natural size.)

**Current Meters No. V and VI.**

**As made by Buff & Berger.**

*For price, etc., see page 135.*

**For the convenience of our customers we append a list of miscellaneous articles kept in stock, but most of them are not of our manufacture. Those not made by us are of the best quality obtainable, and the prices quoted are identical with those in the market.**

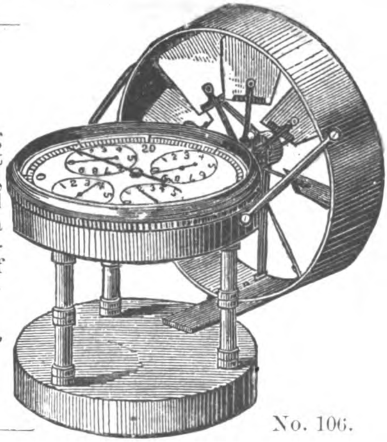
## Gauges.

No. 101. **Hook Gauges, according to size and construction, from . $15 to $60.00**
" 105. Rain Gauge, Smithsonian Institute Pattern, . . . . . . 6.00

## Portable Anemometer.

No.106. An instrument used for measuring the velocity of air currents passing at any point on the surface of the earth, or if used in mines, etc., the velocity of the air can be gauged at any defined point in the cross-section of a shaft. The instrument is capable of registering from 1 foot to 10,000,000 cubic feet of air. Full instructions for its use and regulation accompany each instrument.

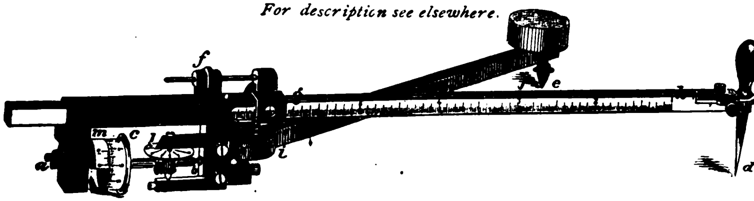
**Price, $30.00.**



No. 106.

## Planimeter.

*For description see elsewhere.*

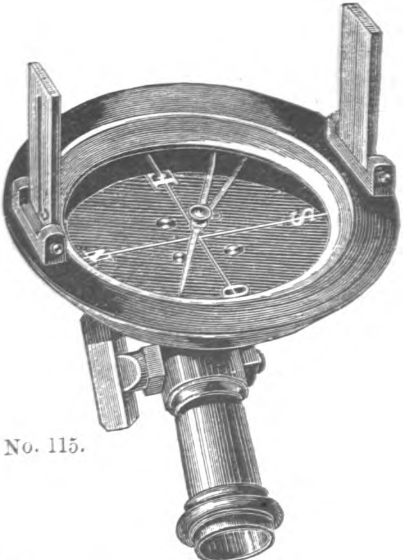



An instrument for measuring the areas of plane surfaces, by passing a pointer around their periphery. It is of great convenience to all classes of engineers, and practically applicable to a great variety of purposes. To measure the areas of figures that are bounded by irregular lines, such as:—drainage areas; lots bounded by rivers or creeks; contour lines of ponds, etc.; to get the true average of observations taken at irregular intervals; to measure indicator and other diagrams, and for many other portions of engineering work. As these instruments will not only give the area of any figure, but also any multiple of such area, and the sum of any number, or series of such multiples, at one operation, they may be used to very great advantage in the calculation of the cubical contents of solids; as in the calculation of earth-work, etc. See on this point an article by Clemens Herschel, Esq., Civil Engineer, of Boston, in the *Journal* of the Franklin Institute for April, 1874, and the directions for use which we furnish with each instrument. Earth-work measurements, made in the manner indicated, do NOT *require the plotting of cross-sections.* The planimeters graduated by us are rated to read square inches of area, square centimeters of area, any multiple of these areas, and so as to give the cubic yards in any cut or fill, if used according to the directions that will accompany each instrument. Two consecutive measurements of the same area need never differ by more than 0.02 of a square inch; and by repeating the measurement in the same manner that angles are repeated with a transit instrument, the error of observation may be reduced to but a small fraction of one hundredth of a square inch of area.

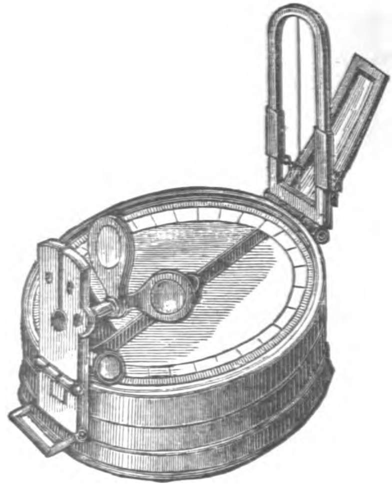
No. 107. **Price** of instrument, when rated as above indicated, . . **32.00.**
" 108. " " not " but with all our improvements, **28.00.**

## Surveyors' Pocket and Marine Compasses.

No. 111. Burt's Solar Compass, with adjusting socket and leveling tripod, $220.00



No. 115.



No. 117.

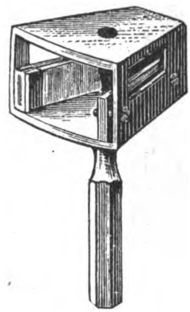
| | | |
|---|---|---|
| No. 112. | Pocket Compass, with folding sights, 2½ inch needle, . . . | $10.00 |
| " 113. | " " 2½ inch needle, Jacob Staff mountings, . . . | 12.00 |
| " 114. | " " 3½ " " " . . | 14.00 |
| " 115. | " " with level, folding sights, 4 inch needle, with ball and socket joint. . . . . . . . . . . . . | 17.00 |
| " 116. | Vernier Pocket Compass, 4½ inch needle, Staff mountings, and 2 levels | 23.00 |
| " 117. | Prismatic Compass, complete, with azimuth glasses, and divided aluminium ring, 3 inch Leather Sling Case. Best kind. . . | 35.00 |
| " 118. | Pocket Compass, watch pattern, brass, 1½ inches in diameter with hinged cover and stop to needle, . . . . . . . . . . | 2.50 |
| " 119. | Pocket Compass, gilt, watch pattern, with stop, enamelled dial and agate centre; 1 or 2 inches in diameter, in morocco case, . | 6.50 |
| " 120. | Ritchie's Patent Liquid Compasses, of all sizes, from $33.00 to $35.00, $45.00 and $55.00. | |

## Miners' Compasses.

No. 125.

| | | |
|---|---|---|
| No. 125. | Miners' Compass, provided with stop and glass covers, for tracing iron ore, 3 inch Norwegian needle, . . . . . . . . | $12.00 |
| " 126. | Miners' Compass, provided with stop and glass covers, 4 in. Norwegian needle, . . . . . . . . . . . | 15.00 |

## Reflecting Instruments.



No. 130.

| | | |
|---|---|---|
| No. 130. | Optical Square, to take right angles, . . . . . . | $6.00 |
| " 134. | Pocket Sextant, best quality, . . . . . . . . . | 50.00 |
| " 135. | Reflecting circle, after Pistor & Martin's, 10 inches diameter, reading to 10″, . . . . . . . . . . . | 170.00 |
| " 136. | Reflecting Circle, same kind, 6 inches diameter, reading to 20″, | 105.00 |

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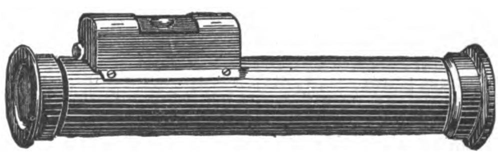
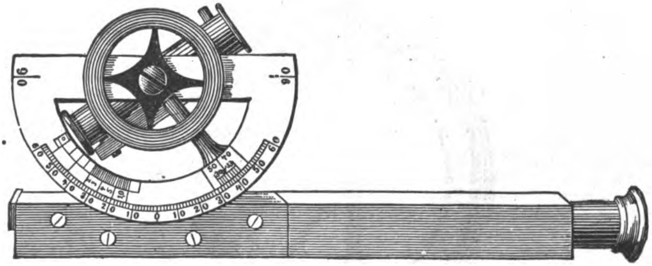
## Hand Levels.

No. 140.



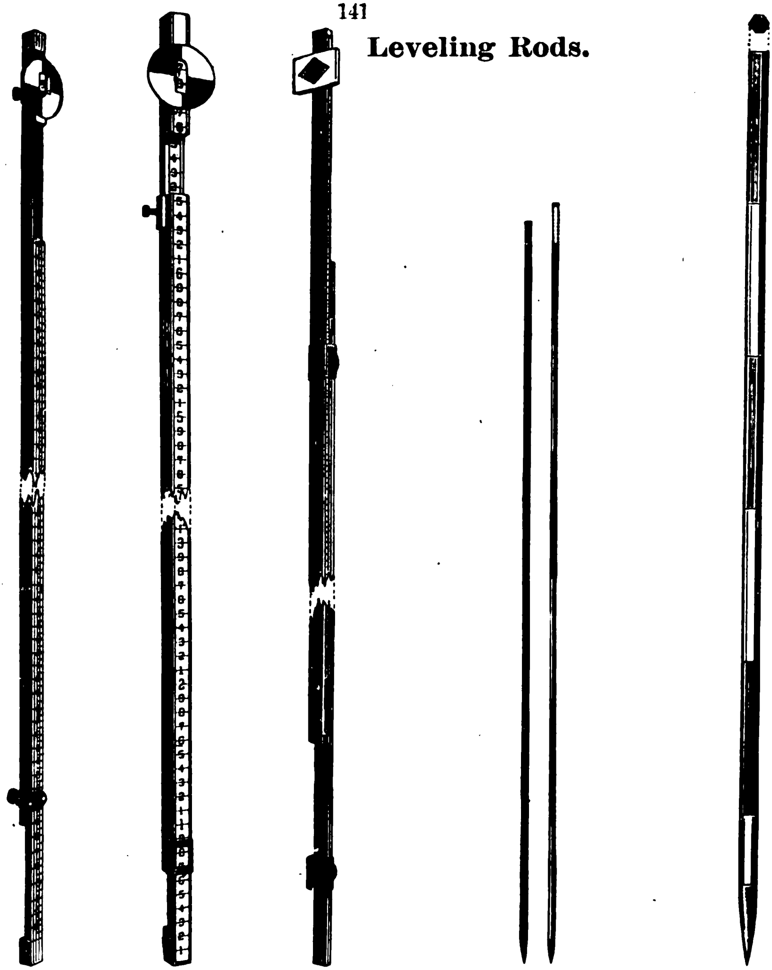
| | | |
|---|---|---|
| No. 140. | Locke's Hand Level, of brass and nickel-plated, . . . . . | $11.00 |
| " 141. | " " " " . . . . . . . . . . . . . | 10.00 |
| " 142. | Universal Pocket Level, complete, . . . . . . . | 22.50 |

No. 143.



| | | |
|---|---|---|
| No. 143. | Abney Level and Clinometer, . . . . . . . . . | $15.00 |

# Leveling Rods.



No. 145. No. 146. No. 147. Nos. 152 & 153. No. 154.

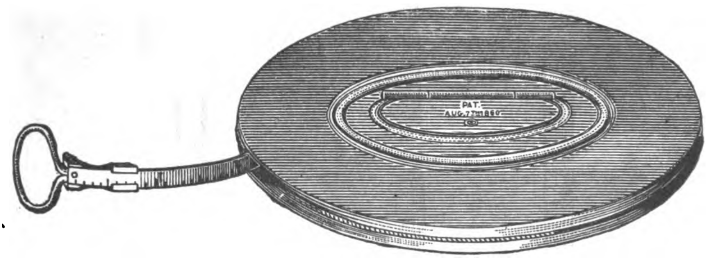
No. 145. New York Rod, with improved mountings. . . . . . . $16.00
Extra Target for New York Rod, for use with gradienter, or stadia measurements, . . . . . . . . . . . . . 5.50
Extra Clamp for New York Rod, . . . . . . . . . . 2.50
" 146. Philadelphia Rod, . . . . . . . . . . . . . . 18.00
Extra Target for Philadelphia Rod. . . . . . . . . . 5.50
" 147. Boston Rod, . . . . . . . . . . . . . . 15.00
" 148. Mining Rod and Target, 5 feet long, Philadelphia pattern. . . . 15.00
" 149. Flexible Self-reading Level Rod, . . . . . . . . . . 4.00
This rod is prepared on canvas and can be rolled up. When used it is fastened upon a board with thumb tacks.
" 150. Metric Level Rod, Philadelphia Pattern. . . . . . . . . 18.00
" 151. " " " New York Pattern, . . . . . . . 18.00

## Ranging Poles.

No. 152. Six feet long, of steel, . . . . . . . . . . . . . $4.00
" 153. Six feet long, of iron tube eleven-sixteenth of an inch in diam,, with steel shoe and divided off in feet, which are painted white and red alternately, . . . . . . . . . . . . 3.50
" 154. Eight feet long, of wood, with steel shoe and divided off in feet, which are painted white and red alternately. . . . . . 3.50

## Paine's Steel Tape Measures.

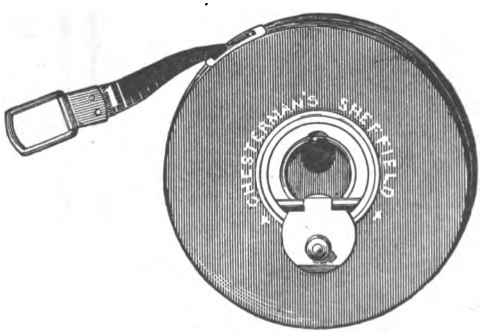
**¼ inch wide. In Leather Cases, with flush handles.**



| | | |
|---|---|---|
| No. 160. | 100 feet Paine's Steel Tape, divided in 10ths. . . . . . | $15.00 |
| " 161. | 50 " " " " " " . . . . . | 8.00 |
| " 162. | 100 " " " " " " on one side, on the other in centimeters, . . . . . . . . . . . . . | 20.00 |

## Chesterman's Steel Tape Measures.

**⅜ inch wide. In Leather Boxes.**



| | | |
|---|---|---|
| No. 163. | 100 feet Chesterman's Steel Tape, divided in 10ths, . . . . | ~~$12.50~~ 14.00 |
| " 164. | 66 " " " " " . . . . . . | 11.00 |
| " 165. | 50 " " " " " . . . . . . | ~~7.00~~ 7.50 |
| " 166. | 33 " " " " " . . . . . . | 6.25 |

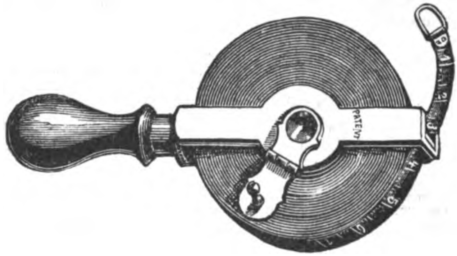
## Chesterman's Pocket Steel Tape Measures.

**In German Silver Cases, with spring and stop.**

| | | |
|---|---|---|
| No. 167. | 3 feet long, divided in 10ths. . . . . . . . . . . . | $1.75 |
| " 168. | 5 " " " " . . . . . . . . . . . | 2.25 |
| " 169. | 5 " " " " on one side, and in centimeters and millimeters on the other side. . . . . . . . . . | 2.50 |

## Excelsior Steel Tape Measures.

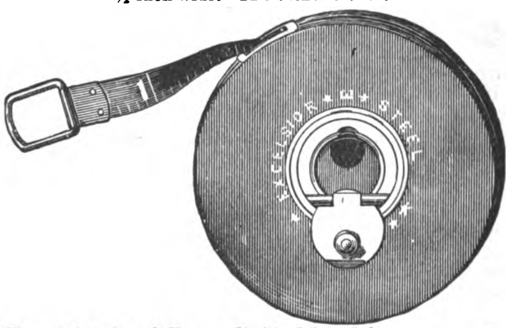
**½ inch wide. Patent Brass Frame with Handle.**




| | | |
|---|---|---|
| No. 170. | 100 feet Excelsior Steel Tape, divided in 10ths, . . . . . | $16.00 |
| " 171. | 50 " " " " " . . . . . | 9.00 |

## Excelsior Steel Tape Measures.

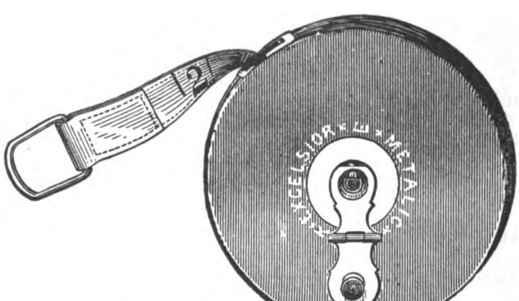
**½ inch wide. In Leather Boxes.**




| | | |
|---|---|---|
| No. 172. | 100 feet Excelsior Steel Tape, divided in 10ths, . . . . | $15.00 |
| " 173. | 66 " " " " " . . . . . . . | 10.50 |
| " 174. | 50 " " " " " . . . . . . | 8.00 |

## Excelsior Metallic Tape Measures.

**In Leather Boxes.**

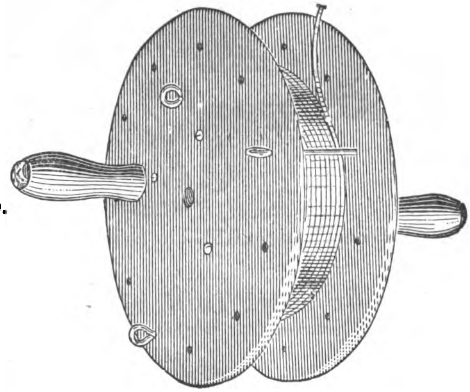



| | | |
|---|---|---|
| No. 175. | 100 feet Metallic Tape Measure, divided in 10ths, . . . . | $5.00 |
| " 176. | 66 " " " " " . . . . . . . | 3.60 |
| " 177. | 50 " " " " " . . . . . . | 3.00 |
| " 178. | 33 " " " " " . . . . . . | 2.40 |

## Standard Steel Tape Measures.

**For city and bridge engineering, in lengths from 100 to 1000 feet.**

No. 180.



These tapes are the exact United States Standard and have no joints. They are generally made in lengths of 300 feet with graduations at every 10 feet, the last 10 feet graduates in single feet, and the last foot into 10ths. For railroad and underground work we frequently furnish them in lengths of 400 and 500 feet. A clamping handle can be furnished to attach to the tape at any desired length, if shorter measures than the whole length are intended to be made. We also can furnish a small brass clamp to fasten on the tape in order to mark lengths that are used repeatedly.

| | |
|---|---|
| **Price** of tape 100 feet, graduated at every 10 feet, the last 10 feet graduated in single feet, the last foot in 10ths, . . . . . . . . . . . | $10.80 |
| **Price** of tape 100 feet, marked only at 50 feet, . . . . . . . | 6.00 |
| **Every additional** 100 feet, marked only every 50 feet, . . . . . | 5.50 |

### Extras to Standard Steel Tape Measures.

| | |
|---|---|
| Each additional graduation and figuring, . . . . . . . . . . . | $0.20 |
| Reel, handle and stop to wind up tape, . . . . . . . . . . . | 4.50 |
| 2 large brass handles to unship, . . . . . . . . . . . . . | 3.00 |
| Clamping handles, each, . . . . . . . . . . . . . . . | 1.80 |
| Small brass clamp to fasten on tape, . . . . . . . . . . . . | .75 |

## Standards of Lengths.

We can supply the U. S. Engineer Corps and others with the standard centimeters and inches made by Prof. William A. Rogers. The centimeter is divided into 100 equal parts, and is guaranteed to be one one-hundredth part of the U. S. Coast Survey meter marked Y and M No. 2. The inch is one thirty-sixth of the U. S. Coast Survey yard, engraved on the same bar. Graduations made on glass, polished tempered steel, silver, &c.

**Price** from $6.00 to $20.00, including a tabular statement of the errors of graduations.

---

## Metric Steel and Metallic Tape Measures.

**In Leather Boxes.**

| | | | | |
|---|---|---|---|---|
| No. 191 | 20 | Meter Steel Tape, divided in meters and centimeters, 9 mm. wide | | $13.00 |
| " 192 | 10 | " " " " " " 9 " | | 7.00 |
| " 193 | 20 | " Metallic Tape, divided in meters and centimeters, 17 mm. wide | | 4.00 |
| " 194 | 10 | " Metallic Tape, divided in meters and centimeters, 17 mm. wide | | 3.00 |

## Chains.

No. 195. Surveyors' Chain, 2 poles, 50 links, No. 12 best steel wire, brazed links and rings, . . . . . . . . . . . . $5.50

" 196. Surveyors' Chain, 4 poles, 100 links, No. 12 best steel wire, brazed links and rings, . . . . . . . . . . . . 10.00

" 197. Engineers' Chain, 50 feet, 50 links, No. 12 best steel wire, brazed links and rings, . . . . . . . . . . . . 6.25

" 198. Engineers' Chain, 100 feet, 100 links, No. 12 best steel wire, brazed links and rings, . . . . . . . . . . . . 11.50

## Metric Chains.

No. 199. 20 Meter Chain, 60 links, No. 12 best steel wire, brazed links and rings, $9.00

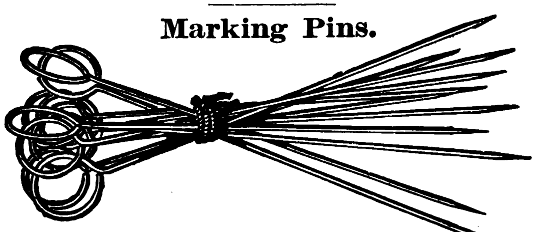
" 200. 10 " " 30 " " " " " " " 6.00

## Extras to Tapes and Chains.

No. 201. Pocket Thermometer, . . . . . . . . . . . . $1.50

" 202. Spring Balance and Level, . . . . . . . . . . 4.00

## Marking Pins.



No. 203. **Set of Marking Pins,** eleven in a set, steel wire, No. 6, . . $2.00

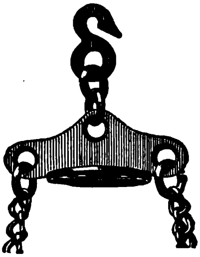
## Odometer.

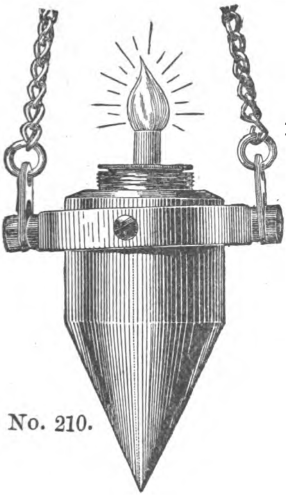
No. 204. An instrument for measuring distances traveled by carriage, . $20.00

## Pedometer.

No. 205. An instrument for measuring distances walked, in german silver case, of the size of a watch, . . . . . . . . . . $5.00

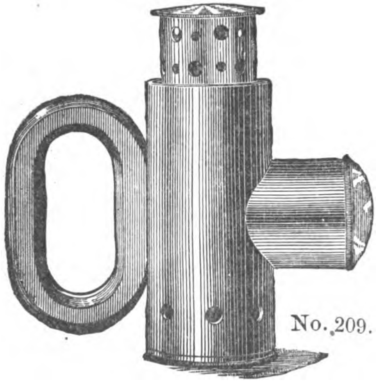
## Plummet Lamp.





No. 210.

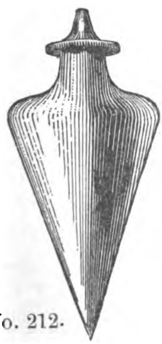
## Lamp for Mining Engineering.



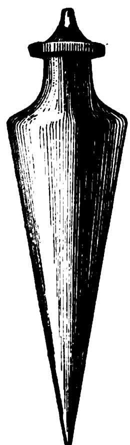
No. 209.

| | | |
|---|---|---|
| No. 209. | Lamp for illuminating graduations, cross wires, etc., for use in underground work, of brass and nickel-plated, with ground lens, . . . . . . . . . | $7.00 |
| " 210. | Small Plummet Lamp, of brass, steel point, 16 oz., . | 8 00 |
| " 211. | Large Plummet Lamp, of brass, steel point, 24 oz., . | 10 00 |
| | Box with shoulder straps, for pair of Plummet Lamps, | 4.00 |

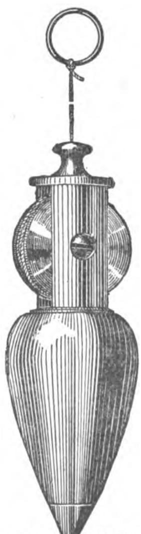
## Plumb Bobs.



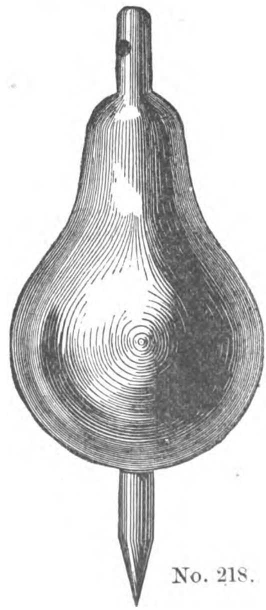
No. 212.



No. 214.



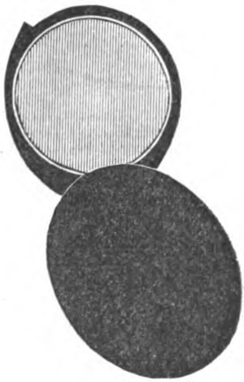
No. 216.



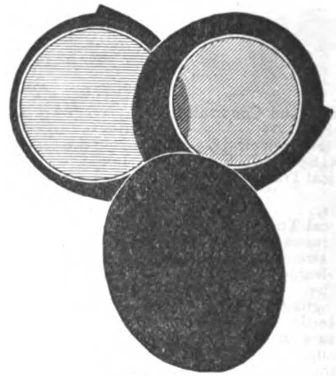
No. 218.

| | | |
|---|---|---|
| No. 212. | Plumb Bob of Brass, steel point, shape as in cut, 8 oz., . . | $2.25 |
| " 213. | " " " " " No. 212, 11 oz., . . | 2.50 |
| " 214. | " " " " " in cut, 6 oz., . . | 2.00 |
| " 215. | " " " " " No. 214, 10 oz., . . | 2.50 |
| " 216. | " " " patent reel adjustment, 8 oz., | 2.50 |
| " 217. | " " " " " " 14 oz., | 2.80 |
| " 218. | " " " for use in shafts, 36 oz., . . | 5.00 |

## Pocket Magnifiers.



No. 221.



No. 224.

| | | |
|---|---|---|
| No. 221. | Rubber Case, as in cut, size of lens 1 inch diameter, . . . . | $0.50 |
| " 222. | " " " 221, " " 1¼ " " . . . . | .75 |
| " 223. | " " " 221, " " 1½ " " . . . . | 1.00 |
| " 224. | " " " cut " of lenses, 1⅛ and 1¼ in diameter, . | 1.25 |
| " 225. | Shell Case, as in 221, size of lens 1¼ inch diameter, . . . . | 1.30 |
| " 226. | " " " 224, " lenses 1⅛ and 1¼ inch diameter. . | 1.80 |

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## Gossamer and Silk Bags.

| | |
|---|---|
| Gossamer Water-proof Bag, to cover Transit or Level in case of rain or dust, | $1.00 |
| Silk Bag, to cover Transit, with solid silver graduations, . . . . . | 1.00 |

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## Lubricants.

| | |
|---|---|
| Bottle of Fine Watch Oil, for lubricating Transit Centers, etc., . . . | $0.30 |
| " " Vaseline for lubricating Level Centers, Leveling and Tangent screws, etc., . . . . . . . . . . . . . . . . . | .30 |

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## Utensils for Cleaning Instruments.

| | |
|---|---|
| Camel's Hair Brush, . . . . . . . . . . . . . . . . | $0.40 |
| Stiff Brush for cleaning screw-threads, . . . . . . . . . . . . | .40 |
| Chamois-skin for cleaning lenses, centers, etc., . . . . . . . . . | .50 |
| Stick for cleaning centers, . . . . . . . . . . . . . . . . | .50 |

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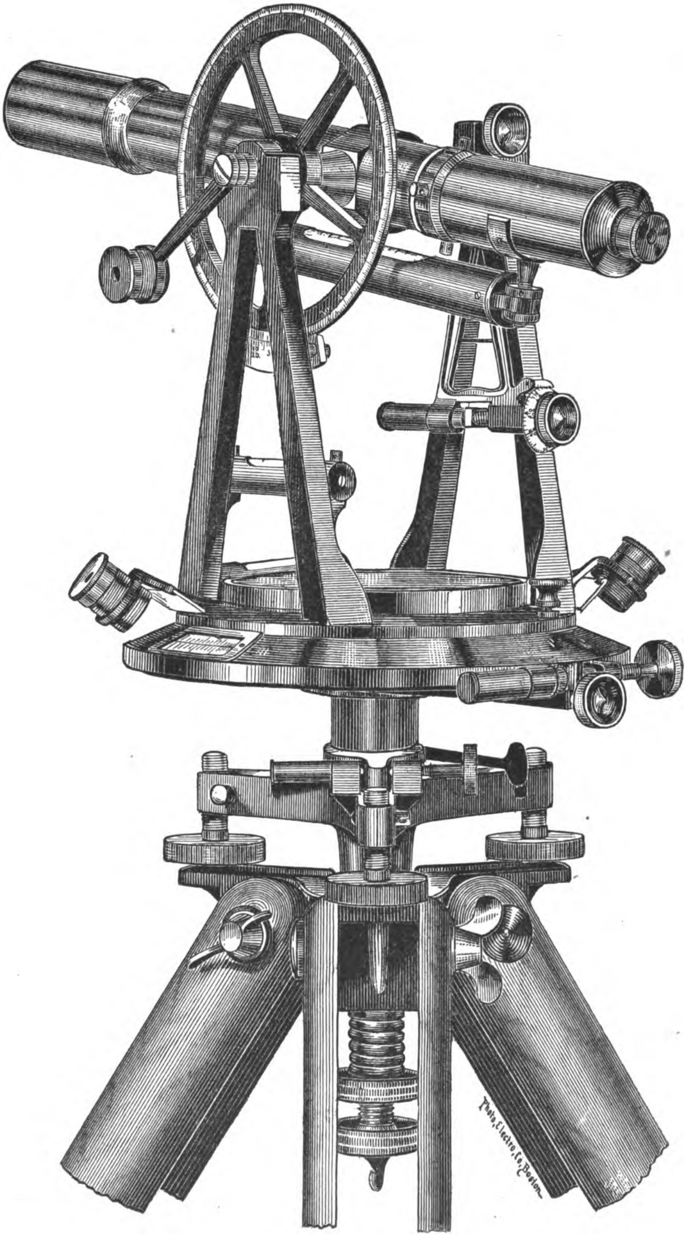
## Spirit Levels.

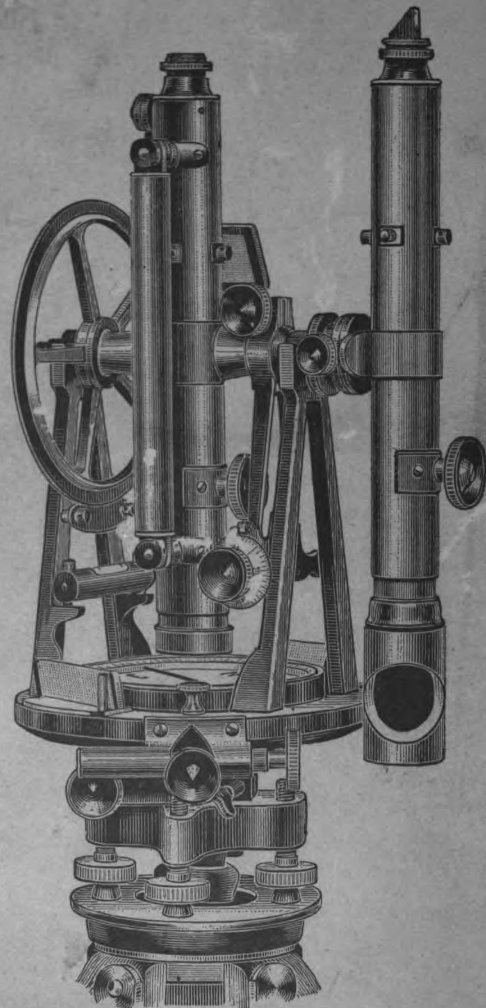
Engineers' Spirit Levels, of all sizes and grades of sensitiveness, accurately ground and tested by us.

Per inch according to length and diameter, . . . . from $0.80 to $1.00

# INDEX.




NOTE.—The above cut represents the 6¾ inch Transits with solid silver bevel limb, as made by us many years ago for city engineering. The high cost of manufacture and consequent high price of this instrument has led us to discontinue entirely its manufacture. We confidently recommend our Transit No. 11 as being of greater range, and as being better adapted to work of this character.



SUPPLEMENTARY CUT TO MINING TRANSITS,

Showing in detail the detachable side telescope, and the reflector for illuminating the cross-wires, &c.