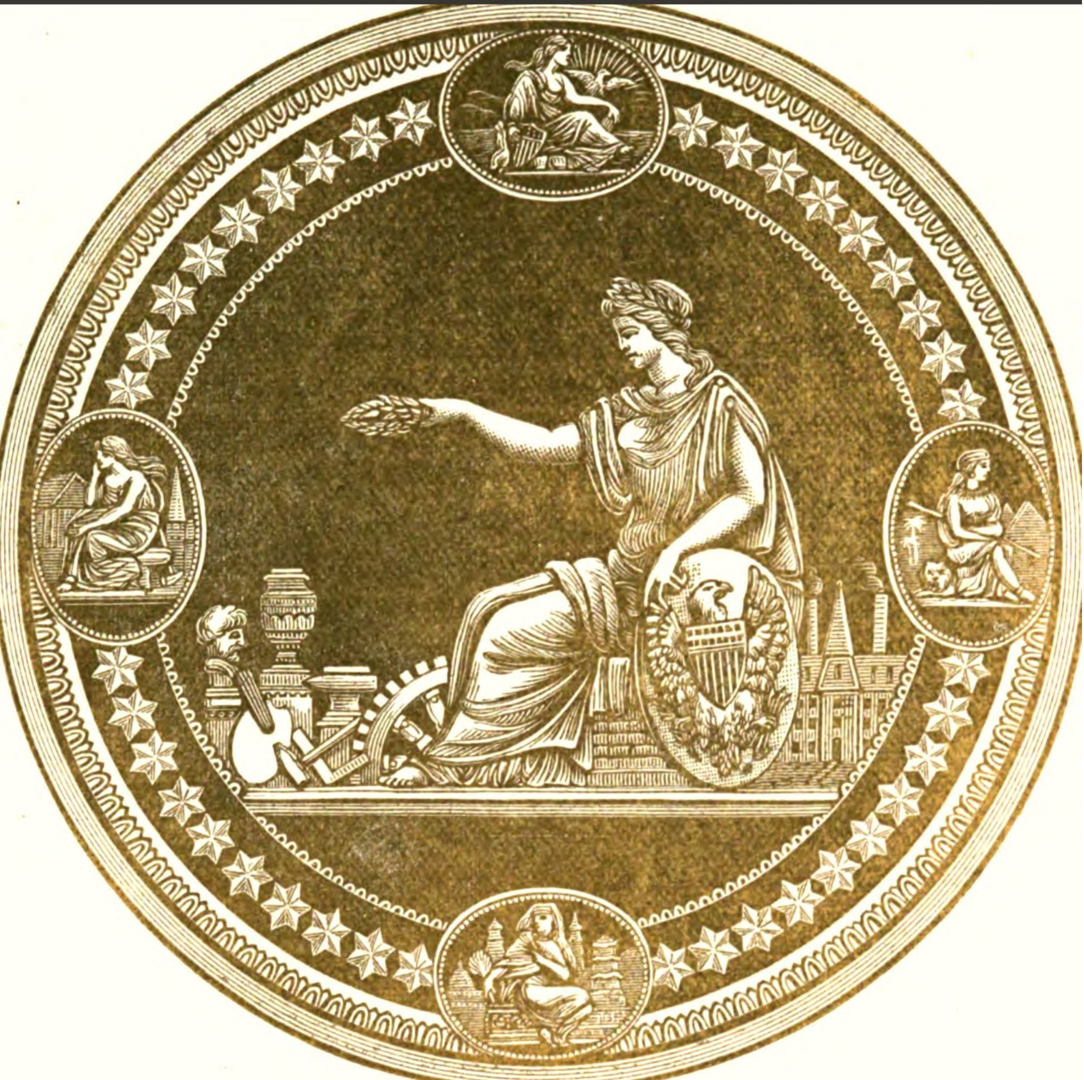


Description and Price-list of First-class Engineering & ...

Geo. N. Saegmuller

ANSWERS TO CORRESPONDENTS.

This Catalogue and price-list supersedes all former editions.

The prices in this Catalogue are net cash.

We do not sell instruments on the installment plan.

We do not exchange instruments, nor do we keep second-hand instruments on hand.

Packing boxes are charged at cost price.

While we take the greatest care in packing, our responsibility ceases when instruments leave the factory. In case of damage, the express companies must be held liable.

Parties ordering goods to be sent C. O. D. must accompany their order with a deposit sufficient to pay expressage both ways.

C. O. D. packages will be sent with the privilege of examination, but we do not send instruments out on trial.

While the engravings in this Catalogue give a good idea of the instruments as we make them now, it must be borne in mind that our constant aim is to improve them by making them more accurate and simple, and unless it is especially requested we will always send the improved instruments.

DESCRIPTION AND PRICE-LIST

OF

FIRST-CLASS

Engineering & Astronomical Instruments

MANUFACTURED BY

GEO. N. SAEGMULLER,

SUCCESSOR TO

FAUTH & CO.

Second Street and Maryland Avenue S.W.

WASHINGTON, D. C.

This List Supersedes all former editions.

WASHINGTON:
GIBSON BROS., PRINTERS AND BOOKBINDERS.
1892.

We deem it unnecessary to print testimonials, but can refer those who are not acquainted with our work to parties using the various instruments described herein.

ALUMINUM.

The cost of production of this metal has of late been so much reduced that efforts have been made to use it in the manufacture of instruments on account of its great lightness.

"This metal in color is white, and next in lustre to silver. It has been found in a pure state, but is known to exist in nearly two hundred different minerals; all common clays and granites are rich ores of this metal. The specific gravity of Aluminum is but 2.6 that of water, being only 1-3 the weight of iron and 1-4 the weight of silver; it is as malleable as gold, and nearly as tenacious as iron. Thus it is capable of the widest variety of uses, being soft, ductile, and tenacious. It melts at 1300 degrees (Fahrenheit), and neither oxidizes in the atmosphere nor tarnishes in contact with gases."

Aluminum in its pure state is entirely too soft, but an alloy is now made which, while scarcely any heavier than the pure metal, has the tensile strength and stiffness of the best red metal or brass, as is demonstrated by the following table:

Aluminum Casting fro[illegible]

Mark.	Dimensions. Inches.	Area Inches.	[illegible]	[illegible]	[illegible]
36	.417 x [illegible]	.[illegible]	[illegible]	[illegible]	[illegible]

For cent[illegible]
use the old [illegible]
many par[illegible]
metal, an[illegible]
Engineer[illegible]
weight.

It is [illegible]
as a red[illegible]
greater [illegible]


CINCINNATI INDUSTRIAL
EXPOSITION.
18 82.


BOARD OF TRADE ★ CHAMBER OF COMMERCE ★
OHIO MECHANICS INSTITUTE
AWARDED
TO
Fauth & Co.
FOR
Display of Astronomical &
Engineering Apparatus
1882.

INTRODUCTION.

Since the appearance of our last Catalogue a change in the firm has taken place, Mr. Fauth having withdrawn on account of ill health.

The aim of the undersigned in continuing the business will be not only to maintain the high reputation of the old firm, but also to keep fully abreast with the progress of the age.

The idea of combining the high degree of accuracy characteristic of European instruments with the lightness and compactness so much desired in this country will always be kept in view.

The best workmanship in the essential parts of instruments will be guaranteed, but money will not be thrown away for useless polishing, which only affects the apearance without adding anything to the quality.

A glance at the engravings in this Catalogue will show that nearly every instrument has been reconstructed to meet the increased requirements which progress in the sciences and engineering have made necessary. We do not build cheap instruments, and we seek that class of purchasers who wish them first-class in every detail and from the best materials, and who are also willing to pay whatever reasonable amount may be necessary to obtain such articles.

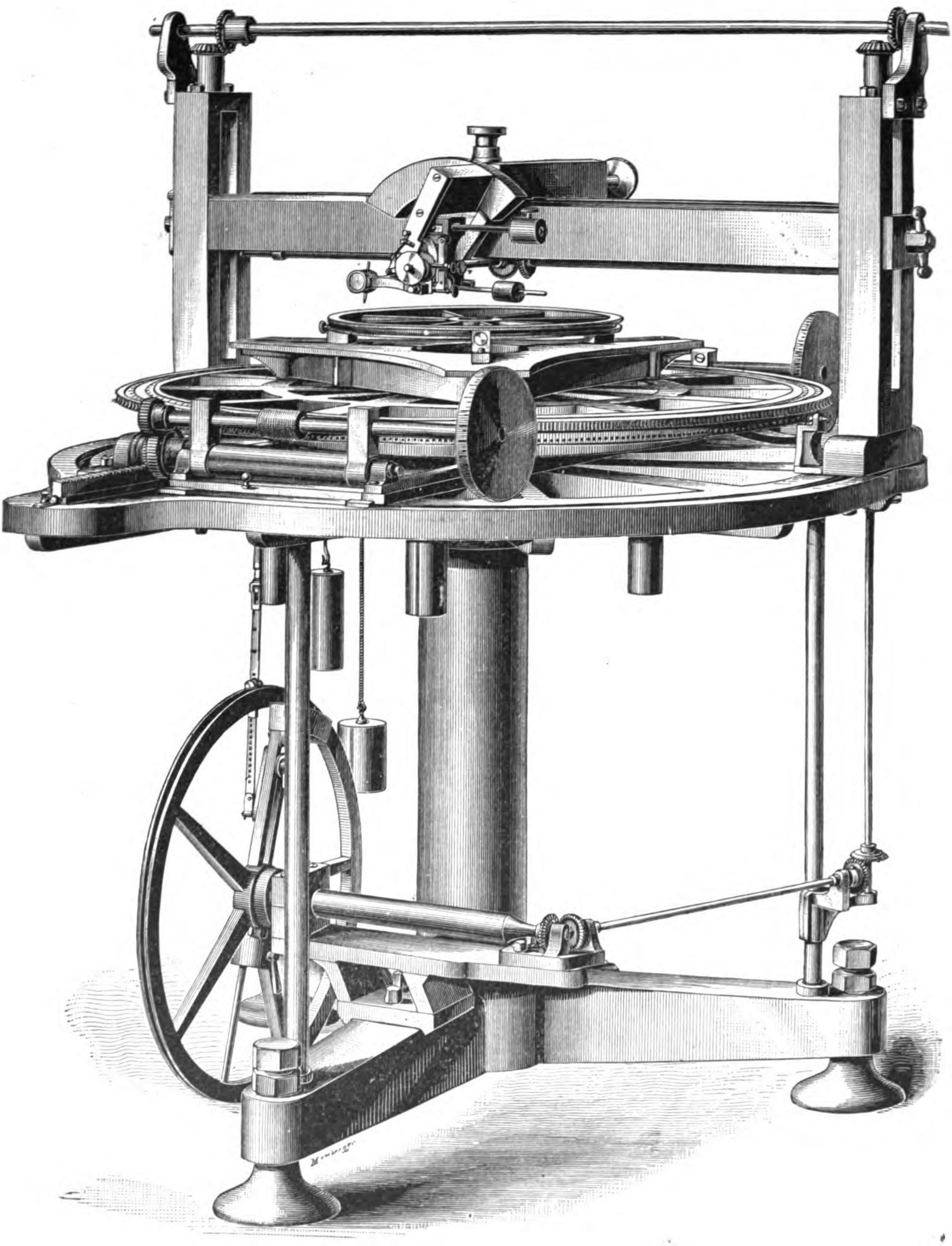
For this reason we give no anxious thought as to whether this or that can be made a little cheaper, but we try to have the material and the workmanship just as thoroughly good as possible, the only criterion being that the article shall be best adapted for its work and as durable as possible. We do not care to sell any instrument that is not as good in every respect as though the purchaser himself had selected the materials and personally supervised its construction in our factory.

The constantly increasing demand for our instruments has made it necessary to greatly enlarge our works. New buildings have been erected, equipped with the most approved tools and appliances, which will enable us to execute all orders promptly.

We take this occasion to thank our patrons for past favors and to solicit a continuance of their patronage.

We desire especially to express our thanks to Dr. T. C. Mendenhall, Superintendent Coast and Geodetic Survey, for his kind permission to insert the tables for the conversion of customary and metric weights and measures, which we believe will form a useful addition to this Catalogue.

GEO. N. SAEGMULLER,
Successor to Fauth & Co.



Large Automatic Dividing Engine.

GRADUATIONS.

The cut on preceding page represents our large Dividing Engine, which we venture to say is one of the best engines ever constructed. We do not claim that it is perfect and we do not believe that a really perfect circle has ever been made. We have often heard the statement that this or that machine graduates with no error greater than one second. Such statements are ridiculous, and we think we have reached the possibilities when we can make an automatic graduation correct to within 2 or 3 seconds of arc. That we have reached this result will be seen by the following:

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY, GEOGRAPHIC BRANCH,
WASHINGTON, D. C., *January* 18, 1892.

Mr. G. N. SAEGMULLER,
108 2*d Street S. W., City*.

MY DEAR SIR: In response to your request of recent date, I take pleasure in sending you herewith a copy of the record of certain examinations of theodolites made by you for this Office.

Concerning 8-inch theodolites, Nos. 300, 362, and 438, the results of the examination of the graduations are given in full.

Concerning six of the seven theodolites which you made for us, I send you an abstract showing for each instrument the greatest plus and the greatest minus errors of subdivision.

Sincerely yours,

HENRY GANNETT,
Chief Topographer.

8-inch Fauth & Co. Theodolite No. 300.

Trial Standard Space 2° 30′ 2° 40′.				Error of Space Divs.	Trial Standard Space 2° 30′ 2° 40′.				Error of Space Divs.
2°	30′	2°	40′	+0.59	182°	30′	12°	40′	—0.54
12	30	12	40	+1.58	192				—1.26
22				+0.26	202				+0.14
32				+0.32	212				—0.14
42				+0.44	222				+0.06
52				+0.18	232				—0.42
62				+0.80	242				+0.54
72				—0.86	252				—0.14
82				+0.28	262				+0.06
92				—0.44	272				+0.04
102				—1.00	282				+0.12
112				—0.42	292				+0.40
122				—0.36	302				+0.68
132				—0.46	312				—0.08
142				—0.46	322				+0.34
152				—0.50	332				+0.36
162				—0.60	342				+0.02
172				—0.30	352				+0.62

8-inch Fauth & Co. Theodolite.

No. 438. **No. 362.**

Standard Space 6° to 6° 10′.			Error of Space Div.	Standard Space 359° 50′ — 360° 00′.			Error of Space Div.
6° 00′	— 6°	10′	+ .10	359°	50′	— 00° 00′	— .02
16	— 16	10	— .08	9	50	10	— .03
26	— 26	10	— .90	19	50	20	+ .11
36	— 36	10	+ .34	29	50	30	— .07
46	— 46	10	— .02	39	50	40	+ .13
56	56	10	+ .08	49	50	50	+ .15
66	66	10	— .80	59	50	60	— .39
76	76	10	+ .08	69	50	70	— .11
86	86	10	— .10	79	50	80	+ .27
96	96	10	— .46	89	50	90	+ .03
106	106	10	— .98	99	50	100	+ .03
116	116	10	— .08	109	50	110	+ .03
126	126	10	+ .14	119	50	120	— .37
136	136	10	— .12	129	50	130	— .45
146	146	10	— .52	139	50	140	+ .03
156	156	10	— .52	149	50	150	— .27
166	166	10	— .64	159	50	160	+ .31
176	176	10	— .50	169	50	170	+ .33
186	186	10	— .70	179	50	180	— .17
196	196	10	— 1.24	189	50	190	— .45
206	206	10	— 0.82	199	50	200	+ .55
216	216	10	— .46	209	50	210	— .33
226	226	10	— .72	219	50	220	+ .23
236	236	10	— .52	229	50	230	+ .13
246	246	10	— .50	239	50	240	+ .23
256	256	10	0.50	249	50	250	— .27
266	266	10	— 0.24	259	50	260	+ .05
276	276	10	+ 0.60	269	50	270	— .19
286	286	10	+ .08	279	50	280	+ .23
296	296	10	— .72	289	50	290	— .29
306	306	10	+ .14	299	50	300	— .01
316	316	10	— .60	309	50	310	+ .47
326	326	10	+ .08	319	50	320	+ .07
336	336	10	— .38	329	50	330	— .05
346	346	10	— .38	339	50	340	+ .17
356	356	10	— .36	349	50	— 350	— .07

8-inch Fauth & Co. Theodolites.

Summary of Space Errors.

	Error of 10′ Space.	
	Largest.	Smallest.
8″ Theod. No. 300.......	+ 1″.58	— 1″.26
362.......	+ 0 .55	— 0 .45
434.......	+ 0 .62	— 0 .76
435.......	+ 0 .69	— 0 .59
436.......	+ 1 .17	— 0 .89
438.......	+ 0 .60	— 1 .24

The wonder is that machines attaining such a degree of accuracy can be made, and not that they are not any more perfect. A second of arc appears large on paper, but in fact is scarcely perceptible in a microscope.

For nearly all practical purposes such extreme accuracy in graduations is not at all required. Whether the instrument is used as a repeater or by shifting position, it is clear that the small errors in the graduations will entirely disappear in the final result.

But for such circles as are used on Meridian instruments we are not satisfied with the degree of precision that our automatic machine gives. Recourse must be had to corrections, and this we accomplish by using the machine automatically only for small arcs, having previously divided the circle into larger spaces, which can quickly be done by copying before changes in temperature have affected a change in the relation of the engine and the circle which is to be divided.

Our engine is made entirely of cast-iron and steel, the moving parts being hardened steel, and a novel arrangement has been introduced for turning two opposite screws, which insures a perfect equality in their motions. As stated before, the errors in automatically divided circles are between 2 and 3 seconds.

Of course so small an error is not perceptible in any vernier reading instrument. The graduations of the latter may be considered perfect.

A silver surface is the most satisfactory for a good Graduation. We use it exclusively for the better class of instruments. The circles for our larger instruments are divided into 2-minute or 5-minute spaces; these are read to single seconds by means of micrometer-microscopes, which are now being extensively used with circles of small radius. To attempt to read a fine graduation by means of a vernier to single seconds, even on a moderately large circle, is very trying to the eye, besides involving two operations at the same time—the seeking for the coincidence and the counting from the zero. With a reading-microscope these two operations are separate—first, a bisection is made by turning the micrometer-screw, and then the divided head is read off as the second part of the operation. It is as easy to read to single seconds by means of micrometer-microscopes as it is to read minutes by means of the vernier. The vernier, however is so simple, and the accuracy with which readings can be taken is so surprisingly great, that it will always hold its place for circles of smaller radius.

Our engineers' transits are graduated either into $\frac{1}{2}$ degrees, reading to single minutes by the vernier having 29 circle parts divided into 30; or the circle is graduated into $\frac{1}{3}$-degree spaces, reading to half minutes by the vernier having 39 circle parts divided into 40. Or the circle is graduated into $\frac{1}{4}$ degrees and the vernier reading to 20 seconds by having 44 circle parts divided into 45. Or the circle is divided into $\frac{1}{6}$ degrees and the vernier reading to 10 seconds by having 59 parts divided into 60.

We take it for granted that any one likely to read this pamphlet knows how to read a vernier.

In order to eliminate any eccentricity of limb or vernier-plate, there should be two verniers 180 degrees apart, as the mean of both readings will completely correct it.

The verniers should always have reflecting shades attached to them, as they throw an even light on the graduation; and it is also of great importance that graduations reading 20″ and less should have the reading-glasses permamently attached in such a manner that they can be moved radially along the entire length of vernier.

THE MICROMETER-MICROSCOPE.

We are often asked to explain the reading-microscrope by parties who have never used them; we think the following description will make its construction and use quite plain:

This instrument consists of a microscope having a set of movable threads in the focal plane of the object-glass. The threads are attached to a diaphragm, which is moved parallel to itself in the micrometer box or frame by a screw of small pitch. The revolutions of this screw and consequent motion of the threads are counted by means of a notched or comb scale, which corresponds exactly to the pitch of the screw and is visible through the eye piece along with the threads. The parts of a revolution are counted by means of a drum or micrometer head, divided into equal parts, attached to and turning with the screw.

The objective of the microscope gives an inverted image in the plane of the cross-threads of any object viewed through the microscope. The eye-piece shows this image and the cross-threads without further inversion; that is, the eye-piece shows an inverted image of the object and an erect image of the cross-threads and comb scale.

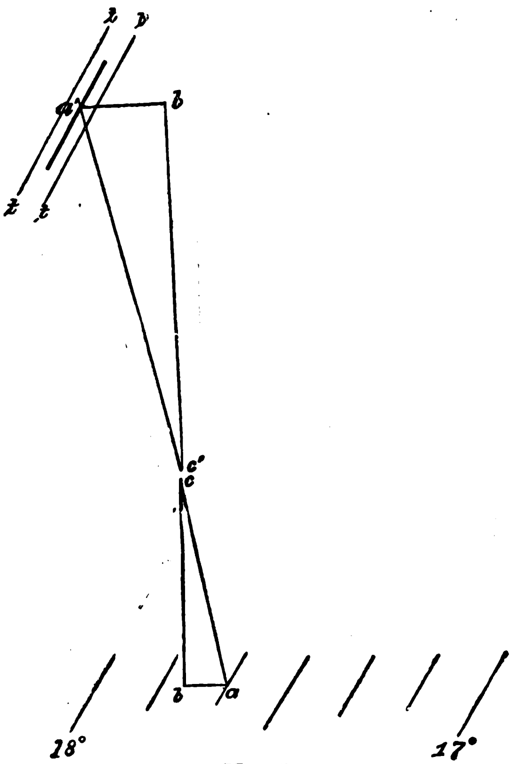
Where the micrometer-microscope is used to read circles it is convenient to have the pitch of the screw and the focal distances of the objective so related that an even number of turns of the screw will correspond to the smallest space on the circle. Thus, if the circle is divided into 10′ spaces it is convenient to have one such space equivalent to five or ten revolutions of the screw; so, that one revolution will be equivalent to 2′ or 1′ as the case may be. Similarly, the micrometer head may be divided to suit our convenience. If, for example, one revolution is equivalent to 1′, the micrometer head may be divided into sixty equal parts, giving thus 1″ per division. If, on the other hand, one revolution is equivalent to 2′, the heads of the micrometers (if there are two of them) should be divided into sixty equal parts and numbered from 0 to 30 twice. The reason for this is that in general the mean of the two microscope readings is desired; and since in this relation the value of one division is 2″, the mean value sought, *in seconds*, is simply the sum of the two micrometer-head readings.

Adjustments.—The following adjustments are to be observed with the micrometer-microscope:

1. To secure distinct vision of the cross-threads, the eye-piece must be moved out or in until the threads are clearly and sharply defined. This adjustment is independent of all others; it differs for different persons, and is the first one to be attended to in using the microscope.

2. To make an even number of turns of the screw equivalent to a given space, measure the image of the space with the screw. If the image is too small the objective must be brought nearer to the object and the cross-threads moved further from the objective; and opposite motions of the parts must be made if the image is too large. The tubes carrying the objective and micrometer box permit such motions. A few trials will make this adjustment sufficiently close.

In making this adjustment care must be taken to avoid parallax, which occurs when the cross-threads and image of the object viewed are not in the same plane. It is detected by moving the eye to and fro sidewise while looking through the eye-piece. If the threads and image show any relative motion there is parallax. It may be removed (supposing the first adjustment made) by moving the whole microscope nearer to or further from the object.



No. 2.

3. To bring the zero of the comb scale into coincidence with the cross-threads when the micrometer head reads zero, move the comb scale by means of the adjusting screw at the end of the micrometer box. This adjustment need not be very close, since the only office of the scale is to count whole revolutions. It may be also accomplished by moving the micrometer head on the screw shaft, since the head is usually held fast by means of a lock nut on the shaft.

4. To place two opposite microscopes 180° apart closely, set one of them at zero and bring a graduation line to bisect the thread interval. Then the other microscope may be brought to bisection on the opposite line, and by moving the drum on the screw shaft and adjusting the comb scale to suit, it may be made to read within a few divisions of the first microscope. Close agreement is not essential, but it is convenient to have both microscopes read the same to the nearest minute.

Method of reading Micrometer-Microscopes.—This may be best understood by considering a special case. Thus, suppose it is required to read the two opposite micrometer-microscopes of a theodolite whose circle is divided into 10′ spaces. Let five revolutions of the screw be equivalent to one of these spaces. Then one revolution is equivalent to 2′, and the micrometer heads will be assumed to be divided into sixty equal parts and numbered from 0 to 30 twice. The relations to be considered are illustrated in the diagram on page 9, which shows a degree of the circle, the positions of the principal points of the microscope objective, the position of the micrometer threads, *t t*, etc. In this diagram the line *b c*, *b′ c′* is the line defined by the micrometer threads (or the point midway between them) when the micrometer reads zero revolutions and zero divisions. This line falls between the 40′ and 50′ lines of the circle, and the reading of the circle is 17° 40′ *plus* the distance *a b* expressed in angular measure. But the image and equivalent of *a b* is *a′ b′*, and this is measured by moving the micrometer threads until the space between them is bisected by the image of the 40′ line *a*, or by *a′* Suppose the distance *a′ b′* is three revolutions (counted by three notches of the comb scale) and 8.3 divisions of the head. Then the complete reading is 17° 46′ 16″.6.

If the opposite micrometer reads 197° 46′ 11″.9 divisions, the mean reading of the circle is (using the degrees from the first microscope) 17° 46′ 20″.2, since $\frac{1}{2}$ (8.3 + 11.9) 2″= 20″.2.

It should be observed that the micrometer-head readings properly increase as the screw is turned backwards, but in bringing the threads to bisection the screw should always be turned positively, or so as to pull the diaphragm against the springs which hold the micrometer screw in its bearings.

TELESCOPES.

While we do not attempt to give the theory of the Telescope, which is found in every book on optics, we add a few remarks concerning objectives and different kinds of eye-pieces.

It is well known that a good objective consists of at least two lenses, one of them being of crown, the other of flint glass. By this combination of glasses, which have different refractive powers, it is possible to correct the chromatic and spherical aberration. The latter correction is best shown by the permanence of the focus, whether the image be formed by the centre or outer portion of the objective; and by partly covering the objective so as to use only certain portions it is easily found how nearly this error has been eliminated.

The achromatic correction of the glass is proved by the absence of the more brilliant colors of the spectrum. It is impossible, with any known combination of glasses, to perfectly overcome the chromatic aberration, as all the colors cannot be united in one point. There will always remain what is called the secondary spectrum.

A glass, however, is well corrected if, on focussing a bright object and then pushing the eye-piece nearer to the objective, a ring of purple surrounds the image, and a ring of green appears if the eye-piece is moved away from the objective.

Small scratches and bubbles in the objective have no injurious effect, as they only take up a very small portion of light. Veins and striæ in a glass, however, are very injurious. They can readily be detected by viewing a bright object, like the moon, or a flame, without the eye-piece. If the glass is evenly illuminated it shows that there are no such veins and that it is homogeneous.

EYE-PIECES.

The performance of a good Telescope depends much more upon the eye-piece than is commonly supposed. And as it is as desirable for the manufacturer as it is for the purchaser that the latter should have easy means of ascertaining what kind of eye-piece will be most suitable, we give a plain description of the different kinds of eye-pieces most in use and the method of determining the power required.

And here we wish to remark that for all practical purposes we consider the Ramsden and Huyghen eye-piece equal to any. For very high powers the solid eye-pieces may be better on account of the absence of the "ghost," but the gain in achromatism and flatness of field in the various so-called achromatic combinations is so small that only an expert can detect it.

It frequently occurs that eye-pieces are ordered without considering the diameter of the adapter or draw-tube to which they have to be attached; and we are frequently compelled to cut down the diameter of the lenses, and consequently the field, much to our own dissatisfaction and that of our customers.

The word "equivalent," in connection with eye-pieces, simply means a comparison of the magnifying power of the compound eye-piece with that of a single lens of a certain focus; thus, a compound eye-piece which is mentioned as the equivalent of *one inch* magnifies as much as a single lens of 1-*inch* focus, and, since the magnifying power of a telescope is found by dividing the focus of its object-glass by that of the eye-piece, it follows that, in order to find the "equivalent" of the eye-piece needed for obtaining a certain magnifying power, the focus of the object-glass has to be divided by the power required, the quotient being the "equivalent" of the eye-piece. Accordingly, if a power of 60 is required with an objective of 30 inches focus, an eye-piece of $\frac{1}{2}$-inch focus has to be used, since $\frac{30}{60} = \frac{1}{2}$.

The following cuts represent the lenses, their distances from each other and their diameters, of the "equivalent" of *one inch* of the different kinds of eye-pieces, from which higher or lower powers may readily be computed.

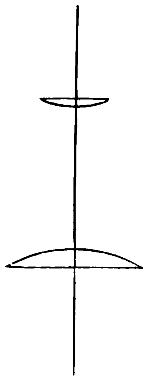


FIG. 1.

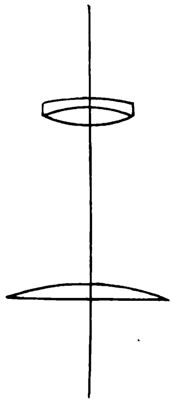


FIG. 2.

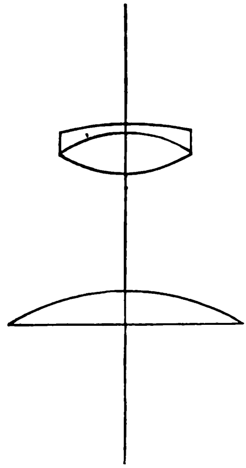


FIG. 3.

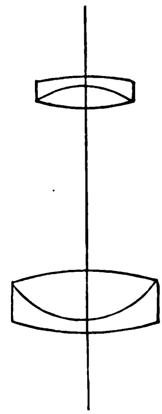


FIG. 4.

It should be kept in mind that for micrometer or cross-hair observations only positive eye-pieces are used, as the focus of the objective is formed in front of the combination; while in the negative eye-piece it falls between the two lenses.

Of positive eye-pieces we have three kinds: the "Ramsden" (Fig. 1), the "Kellner" (Figs. 2 and 3), and the "Steinheil" (Fig. 4). The "Kellner" and "Steinheil" are achromatic combinations, and preferable on account of the absence of color and the greater flatness of the field which they give.

The "Ramsden" has for a long time been the only compound positive eye-piece in use, and does good service. It consists of two plano-convex lenses of equal focus, the plane surfaces being turned outward; the focus of each lens is equal to $1\frac{1}{3}$ of the "equivalent" of the eye-piece, the distance between them being equal to $\frac{2}{3}$ the focus of either lens, and the aperture may be taken as $\frac{1}{2}$ the focal length of either lens.

The "Kellner" consists of a plano-convex, or sometimes a crossed field-lens and an achromatic eye-lens. We give two sketches of it (Figs. 2 and 3). Fig. 3 has the field-lens cut down to secure the greatest possible flatness of field; Fig. 2 is used in cases where the extremest angle of field is required.

The "Steinheil" (Fig. 4) consists of two achromatic lenses. It gives a beautiful field of moderate size, but absolute flatness.

Of negative eye-pieces we have two kinds, the "Huyghens" and the "Airy" (Figs. 5 and 6), the latter being an improvement of the former. They are both achromatic on account of their peculiar construction; the "Huyghens" giving a large but somewhat curved field, while the "Airy" has a perfectly flat and large field. The proportion of foci of eye-lens and field-lens is as 1 to 3, and the distance between the lenses is equal to $\frac{1}{2}$ of their compound foci. The diameter of the field-lens is equal to the "equivalent" of the eye-piece. Thus, the field-lens of a 1-inch eye-piece has a diameter of 1 inch.

All the eye-pieces above mentioned show the objects inverted. As this seems

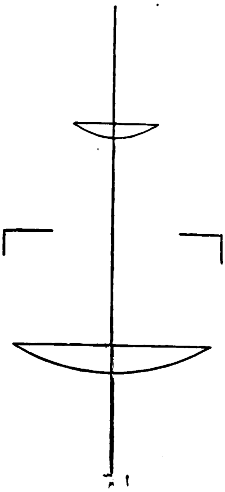


FIG. 5.

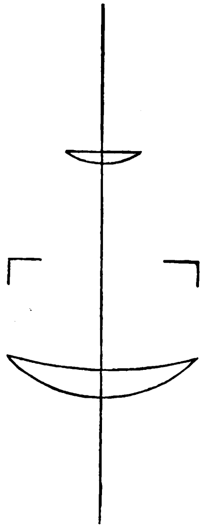


FIG. 6.

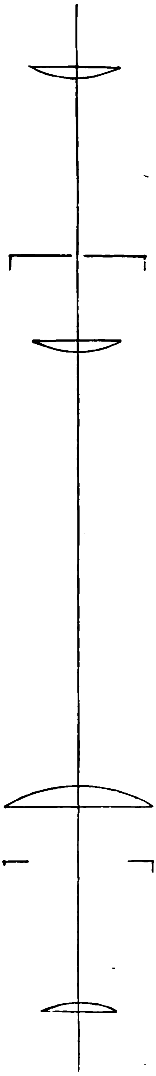


FIG. 7.

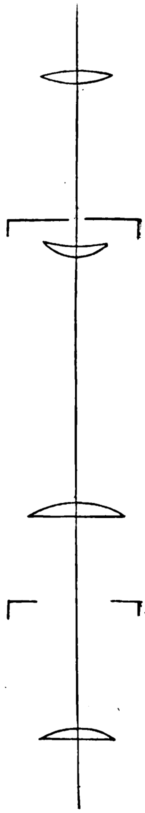


FIG. 8.

to be troublesome to the engineer, "erecting" or "terrestrial" eye-pieces are mostly used on engineering instruments.

As both light and power in the telescope are gained by using inverting eye-pieces, and as it only requires very little practice to get accustomed to them, we strongly recommend the use of inverting or astronomical eye-pieces.

So far, however, engineers seem to prefer Telescopes showing erect. To effect this, four lenses are required, arranged as shown above, and forming the "terrestrial" eye-piece. We make two kinds of these: the "Fraunhofer" (Fig. 7), and the "Airy" (Fig. 8). The latter is mostly used on our levels and transits, as it gives a very flat field and defines well.

The terrestrial eye-piece is often made with a total reflecting prism between the anterior and posterior combinations. They are then called "diagonal" or "elbow" eye-pieces, and are very convenient when observing near the zenith.

As before stated, the magnifying power of a Telescope is found by dividing the focal length of the objective by that of the eye-piece; but a more simple and practical method is the following: Focus the Telescope to any distant object; then withdraw the eye to a distance at which a near object is distinctly seen, when a small disc of light will appear in the centre of the eye-piece. This is the image of the objective. If measured by means of a finely-divided scale and divided into the diameter of the objective, the quotient will be the magnifying power. Thus, supposing a Telescope to have a clear aperture of 2 inches, the diameter of the image being $\frac{1}{16}$ of an inch, then the magnifying power of such a telescope would be 2 inches divided by $\frac{1}{16} = 32$ diam.

By means of a dynameter this image can be measured very accurately, but the above-described method is good enough for all practical purposes.

The power of a Telescope can be increased by substituting an eye-piece of shorter focus; but this increase brings with it a corresponding loss in size and brightness of field. As a general rule it is better to use lower than higher powers.

In Telescopes for engineers' transits and levels, the aperture of the objective and the corresponding magnifying power are carefully determined. The least motion of the level-bubble must be visible by the displacement of the cross-wires. It is therefore important that the magnifying power of a telescope and the sensitiveness of a level are proportionate to each other.

Take the case of a Telescope for a precise level, for instance; one division of the graduated level-bubble equals 5 seconds of arc. Each division being 2mm., a displacement of one-tenth can readily be observed, which means that the instrument was raised or depressed just $\frac{1}{2}$ second of arc. The Telescope, in order to make this small change visible on the rod, must have a magnifying power of about 25 diameters, for it has been observed that the accuracy of pointing is nearly proportional to the magnifying power, unless the latter is out of all proportion to the aperture. As the naked eye can readily point with ordinary sights to within 10 to 15 seconds of arc, or say $12\frac{1}{2}$ seconds, it follows that, in order to point within $\frac{1}{2}$ second, we must have a power of $\frac{12\frac{1}{2}}{\frac{1}{2}} = 25$.

The lenses of a Telescope should not be cleaned too often. Too frequent wipings will scratch the glass and injure the polish, which is more injurious than a little speck of dirt. When it becomes necessary to clean the glass, take a soft dry piece of chamois skin or old piece of linen which by repeated washing has become soft. If the glass is very dirty, use a little alcohol.

Dirt on the eye-piece, especially on the field-lens, is far more objectionable than on the objective; hence they require to be more frequently cleaned.

LEVELS.

The Spirit-Levels form a most important part of an instrument, and, no matter how small they are, they should always be ground to a regular curve. At one time Levels were made by merely filling tubes with alcohol and then hermetically sealing them. By testing these tubes, one side of them was frequently found to be so nearly uniform in curvature as to form quite a good Level. The majority of Levels thus made are, however, very inferior. All the better Levels are now ground to a curve, and it is obvious that the greater the curve the more sensitive is the Level. The sensibility, as well as the uniform run of the bubble, is easily determined by the use of an instrument called the "Level Trier," which is a grooved bar of metal having two-foot screws at one end, and one carefully-made micrometer-screw with a divided head at the other end. Knowing the length of this bar and the pitch of the screw, it is easy to find the value "in arc" corresponding to one division of the divided head. By placing the Level to be tested on the grooved bar, the turning of the screw will show whether equal quantities of elevation will produce equal spaces of run in the bubble, and at the same time show how many inches on the scale are equal to one minute of arc. This value being known, the radius of the curve to which the interior face of the Level has been ground is easily determined. Let r denote the radius of the curve, 21,600 being the number of minutes contained in the circumference of a circle, d the distance in inches and parts run over by the bubble in one minute of elevation, and $2\pi = 6.2832$ being the measure of the circumference to the radius 1, then: $r = \frac{21600\, d}{6.2832}$

For instance, take a Level in which we find $d = 2$ inches, then the radius of curvature will be $\frac{21600 \times 2}{6.2832} = 6878.6$ inches $= 573.2$ feet.

It is to be observed, however, that owing to the adhesion and friction of the fluid the values of the curvature thus found are always a little smaller than they are in reality.

A first-class Level should not only have the curve regular, but it should be perfectly symmetrical—that is, one end of it should have the same width as the other.

If this is not the case, the length of the bubble, in changes of temperature, will change unequally at both ends.

We grind our Levels by a machine which not only shapes them to a perfect curve of any desired radius, but at the same time grinds the entire interior surface, thus making them perfectly symmetrical and not liable to any of the above-mentioned defects.

Sensitive Levels are frequently injured by not being properly fastened in their tubes; the common way of fastening them in with plaster of Paris is entirely inadmissible for any Level of accuracy, as glass and brass will not expand or contract alike. We have lately improved the method of mounting fine Levels by securing them in a **Y** placed in each end of the brass tube. By means of a spring just strong enough to insure a firm bearing the Level-tube is retained in position without undue strain. All our Sensitive Levels are provided with chambers for altering the length of the bubble; they are also covered with a glass tube, to guard against sudden changes of temperature.

THE SAEGMULLER SOLAR ATTACHMENT.

Patented May 3, 1881.

This attachment to the regular Engineer's Transit, by means of which the astronomical meridian may be obtained in a few minutes with an accuracy scarcely thought to be possible, has met with such success that it bids fair to supersede all other methods for the determination of the meridian by means of engineering instruments.

The transit has come to be the universal instrument for the engineer, and will be for the surveyor sooner or later, and the attachment of the solar apparatus to the transit has thus become a necessity.

Since its first introduction this attachment has been greatly improved, and, as now made, is well nigh perfect.

Attached to any transit which possesses a telescope, level and a vertical circle, it will give the meridian within the nearest minute. By using instruments which have a finer graduated vertical circle and better levels than are usually found on transits, the meridian can be determined with greater accuracy still.

Advantages of the "Saegmuller Solar Attachment" over the old form.

First. It is more accurate.

Second. It is simpler and easier of adjustment.

Third. It can be used when the sun is partly obscured by clouds, when the ordinary "solar" fails altogether.

Fourth. It can be used where the sun is quite close to the meridian.

Fifth. The time can be obtained with it reliable to within a few seconds with perfect ease.

Sixth. It can be used as a vertical sighting telescope.

It is as superior to all forms hitherto used as the transit is to the ordinary compass, or as a telescope is to common sights.

The sights of an ordinary solar compass consist merely of a small lens and a piece of silver with lines ruled on it placed in its focus. This is simply a *very primitive* telescope, since the exact coincidence of the sun's image with the lines has to be determined by the unaided eye, or at best with a simple magnifying glass.

That far greater precision can be attained by means of a suitable telescope is obvious; in fact, the *power* of the solar telescope is in keeping with the transit telescope, as it should be.

A glance at the cut will show that the "Saegmuller Solar Attachment" is far simpler than the ordinary form. By raising or depressing, it can be set to north or south declination. To effect this with the ordinary solar compass *two* sets of *primitive telescopes*—one answering for north, the other for south declination—are required, which are difficult to adjust.

The addition of the level on the solar telescope dispenses with the declination arc altogether, the arc or circle on the transit also serving for that purpose in conjunction with it.

The "Saegmuller Solar Attachment" is in fact the only one which should be used in connection with a transit instrument. *It solves the solar problem*, as has been attested by leading astronomers and engineers who have and used it.

Prof. J. B. Johnson, of Washington University, St. Louis, Mo., has given it a thorough test, and writes as follows:

"In order to determine just what accuracy was possible with a Saegmuller Solar Attachment, I spent two days in making observations on a line whose azimuth had been determined by observations on two nights on Polaris at elongation, the instrument being reversed to eliminate errors of adjustment. Forty-five observations were made with the solar attachment on Oct. 24, 1885, from 9 to 10 A. M., and from 1.30 to 4 P. M., and on Nov. 7, forty-two observations between the same hours.

"On the first day's work the latitude used was that obtained by an observation on the sun at its meridian passage, being 38° 39′, and the mean azimuth was 20 seconds in error. On the second day, the instrument having been more carefully adjusted, the latitude used was 38° 37′, which was supposed to be about the true latitude of the point of observation, which was the corner of Park and Jefferson avenues in this city. It was afterwards found this latitude was 38° 37′ 15″, as referred to Washington University Observatory, so that when the mean azimuth of the line was corrected for this 15″ error in latitude it agreed exactly with the stellar azimuth of the line, which might have been 10″ or 15″ in error. On the first day all the readings were taken without a reading glass, there being four circle readings to each result. On the second day a glass was used.

"On the first day the maximum error was 4 minutes, the average error was 0.8 minute, and the 'probable error of a single observation' was also 0.8 minute. On the second day the maximum error was 2.7 minutes, the average error was 1 minute, and the 'probable error of a single observation' was 0.86 minute. The time required for a single observation is from three to five minutes.

"I believe this accuracy is attainable in actual practice, as no greater care was taken in the adjustment or handling of the instrument than should be exercised in the field.

"The transit has come to be the universal instrument for the engineer, and should be for the surveyor, so it is more desirable to have the solar apparatus attached to the transit than to have a separate instrument. The principal advantages of this attachment are:

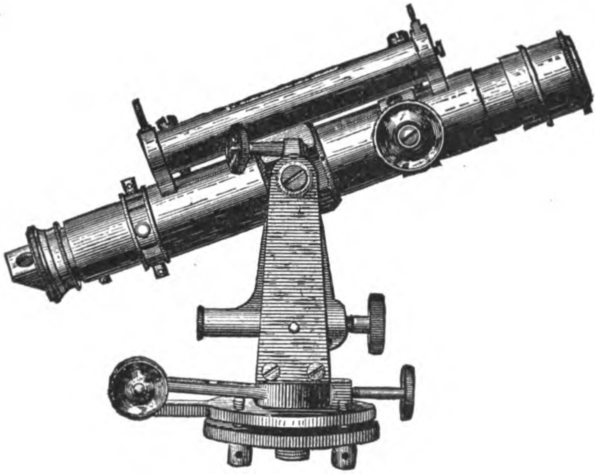
"1. Its simplicity.

"2. Its accuracy of pointing, being furnished with a telescope which is accurately set on the sun's disk.

"3. In its providing that all angles be set off on the vertical and horizontal limbs of the transit, thus eliminating the eccentricity and other inaccuracies usually found in attachment circles or arcs.

"4. Its small cost.

"It is also readily removed and replaced without affecting its adjustments, and is out of the way in handling and reversing the telescope. It may be attached to any transit."



Saegmuller Solar Attachment.

The above cut represents the improved "Saegmuller Solar Attachment" as now made. It consists essentially of a small telescope and level, the telescope being mounted in standards, in which it can be elevated or depressed. The standard revolves around an axis, called the polar axis, which is fastened to the telescope axis of the transit instrument. The telescope called the "Solar Telescope" can thus be moved in altitude and azimuth. Two pointers attached to the telescope to approximately set the instrument are so adjusted that when the shadow of the one is thrown on the other the sun will appear in the field of view.

Adjustment of the Apparatus.

1. The Transit must be in perfect adjustment, especially the levels on the telescope and the plates; the cross axis of the telescope should be exactly horizontal, and the index error of the vertical circle carefully determined.

2. **The Polar axis must be at right angles to the line of collimation and horizontal axis of main telescope.**

To effect this, level the instrument carefully and bring the bubble of each telescope level to the middle of its scale. Revolve the Solar around its polar axis, and if the bubble remains central the adjustment is complete. If not, correct half the movement by the adjusting screws at the base of the polar axis, and the other half by moving the solar telescope on its horizontal axis.

3. **The line of collimation of the solar telescope and the axis of its level must be parallel.**

To effect this bring both telescopes in the same vertical plane and both bubbles to the middle of their scales. Observe a mark through the transit telescope, and note whether the solar telescope points to a mark above this, equal to the distance between the horizontal axes of the two telescopes. If it does not bisect this mark, move the cross wires by means of the screws until it does. Generally the small level has no adjustments and the parallelism is effected only by moving the cross hairs.

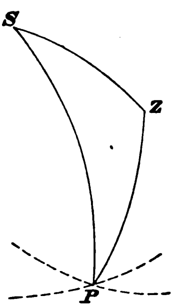
The adjustments of the Transit and the Solar should be *frequently* examined, and kept as nearly perfect as possible.

Directions for using the Attachment.

First. Take the declination of the sun as given in the Nautical Almanac for the given day, and correct it for refraction and hourly change. Incline the *transit telescope* until this amount is indicated by its vertical arc. If the declination of the sun is north, depress it; if south, elevate it. Without disturbing the position of the transit telescope, bring the solar telescope into the vertical plane of the large telescope and to a horizontal position by means of its level. The two telescopes will then form an angle which equals the amount of the declination, and the inclination of the solar telescope to its polar axis will be equal to the polar distance of the sun.

Second. Without disturbing the *relative* positions of the two telescopes, incline them and set the vernier to the co-latitude of the place.

By moving the transit and the "Solar Attachment" around their respective *vertical* axes, the image of the sun will be brought into the field of the solar telescope, and after accurately bisecting it the *transit telescope must be in the meridian, and the compass-needle indicates its deviation at that place.*



The vertical axis of the "Solar Attachment" will then point to the pole, the apparatus being in fact, a small equatorial.

Time and azimuth are calculated from an observed altitude of the sun by solving the spherical triangle formed by the sun, the pole, and the zenith of the place. The three sides, S P, P Z, Z S, complements respectively of the declination, latitude, and altitude, are given, and we hence deduce S P Z, the hour angle, from apparent noon, and P Z S the azimuth of the sun.

The "Solar Attachment" solves the same spherical triangle by construction, for the second process brings the vertical axis of the solar telescope to the required distance, Z P, from the zenith, while the first brings it to the required distance, S P, from the sun.

Observation for Time.

If the two telescopes, both being in position—one in the meridian, and the other pointing to the sun—are now turned on their *horizontal* axes, the vertical remaining undisturbed, until each is level, the angle between their directions (found by sighting on a distant object) is S P Z, the time from apparent noon.

This gives an easy observation for correction of time-piece, reliable to within a few seconds.

To obtain the Latitude with the "Saegmuller Solar Attachment."

Level the Transit carefully and point the telescope toward the south and elevate or depress the object end, according as the declination of the sun is south or north, an amount equal to the declination.

Bring the solar telescope into the vertical plane of the main telescope, level it carefully and clamp it. With the solar telescope observe the sun a few minutes before its culmination; bring its image between the two horizontal wires by moving the transit telescope in altitude and azimuth, and keep it so by the slow motion screws until the sun ceases to rise. Then take the reading of the vertical arc, correct for refraction due to altitude by the table below. Subtract the result from 90°, and the remainder is the latitude sought.

Mean Refraction.

Barometer 30 inches, Fahrenheit thermometer 50°.

Altitude.	Refraction.	Altitude.	Refraction.
10°	5′ 19″	20°	2′ 39″
11	4 51	25	2 04
12	4 27	30	1 41
13	4 07	35	1 23
14	3 49	40	1 09
15	3 34	45	58
16	3 20	50	49
17	3 08	60	34
18	2 57	70	21
19	2 48	80	10

The following table, computed by Prof. Johnson, C. E., Washington University, St. Louis, will be found of considerable value in solar compass work:

"This table is valuable in indicating the errors to which the work is liable at different hours of the day and for different latitudes, as well as serving to correct the observed bearings of lines when it afterwards appears that a wrong latitude or declination has been used. Thus on the first day's observations I used a latitude in the forenoon of 38° 37′, but when I came to make the meridian observation for latitude I found the instrument gave 38° 39′. This was the latitude that should have been used, so I corrected the morning's observations for two minutes error in latitude by this table.

"It is evident that if the instrument is out of adjustment the latitude found by a meridian observation will be in error; but *if this observed latitude be used* in setting off the co-latitude the instrumental error is eliminated. Therefore always use for the co-latitude that given by the instrument itself in a meridian observation."

Errors in Azimuth (by Solar Compass) for 1 Min. Error in Declination or Latitude.

Hour.	For 1 Min. Error in Declination.			For 1 Min. Error in Latitude.		
	Lat. 30°.	Lat. 40°.	Lat. 50°.	Lat. 30°.	Lat. 40°.	Lat. 50°.
	Min.	*Min.*	*Min.*	*Min.*	*Min.*	*Min.*
11.30 A. M. / 12.30 P. M.	8.85	10.00	12.90	8.77	9.92	11.80
11 A. M / 1 P. M.	4.46	5.05	6.01	4.33	4.87	5.80
10 A. M / 2 P. M	2.31	2.61	3.11	2.00	2.26	2.70
9 A. M / 3 P. M.	1.63	1.85	2.20	1.15	1.30	1.56
8 A. M / 4 P. M.	1.34	1.51	1.80	0.67	0.75	0.90
7 A. M / 5 P. M.	1.20	1.35	1.61	0.31	0.35	0.37
6 A. M / 6 P. M.	1.15	1.30	1.56	0.00	0.00	0.00

NOTE.—Azimuths observed with erroneous declination or co-latitude may be corrected by means of this table by observing that for the line of collimation set *too high* the azimuth of any line *from the south point* in the direction S. W. N. E. is found *too small* in the *forenoon* and *too large* in the *afternoon* by the tabular amounts for each minute of error in the altitude of the line of sight. The reverse is true for the line set too low.

Correction for Refraction.

This correction is applied to the declination of the sun, and is equal to the refraction-correction of the sun's observed altitude multiplied by the cosine of the angle which the sun makes between the declination-circle and the vertical.

In order to reduce the refraction correction to the simplest possible form, we have added a separate column to the ephemeris containing them, which we publish every year. They are thus brought in immediate juxtaposition with the declination angle, and we think the arrangement will be appreciated by those who use the Solar Attachment.

Latitude Coefficients.

Lat.	Coeff.	Lat.	Coeff.	Lat.	Coeff.	Lat.	Coeff.
15°	.30	27°	.56	39°	.96	51°	1.47
16	.32	28	.59	40	1.00	52	1.53
17	.34	29	.62	41	1.04	53	1.58
18	.36	30	.65	42	1.08	54	1.64
19	.38	31	.68	43	1.12	55	1.70
20	.40	32	.71	44	1.16	56	1.76
21	.42	33	.75	45	1.20	57	1.82
22	.44	34	.78	46	1.24	58	1.88
23	.46	35	.82	47	1.29	59	1.94
24	.48	36	.85	48	1.33	60	2.00
25	.50	37	.89	49	1.38		
26	.53	38	.92	50	1.42		

Refraction Correction Lat. 40°.

January.	′ ″
1	1h.1 58
2	2 2 16
	3 3 04
3	4 6 23
4	1 1 54
5	2 2 11
6	
7	3 2 59
8	4 6 01
9	1 1 51
10	2 2 07
11	
12	3 2 51
13	4 5 40
14	1 1 46
15	2 2 01
16	
17	3 2 40
18	4 5 00
19	1 1 42
20	2 1 56
21	
22	3 2 31
23	4 4 35
24	1 1 37
25	2 1 58
26	
27	3 2 22
28	4 4 07
29	1 1 32
	2 1 44
30	3 2 13
31	4h.3 41

February.	′ ″
1	
2	
3	1h.1 26
4	2 1 37
5	
6	3 2 04
7	4 3 21
8	1 1 21
9	2 1 31
10	
11	3 1 56
12	4 3 04
13	1 1 16
14	2 1 25
15	3 1 48
16	4 2 47
17	5 8 39
18	1 1 12
19	2 1 20
20	3 1 40
21	4 2 31
22	5 6 49
23	1 1 07
24	2 1 15
25	3 1 33
26	4 2 18
27	5h.5 28
28	

March.	′ ″
1	1h.1 03
2	2 1 10
	3 1 27
3	4 2 06
4	5 4 39
5	1 0 59
6	2 1 06
7	3 1 21
8	4 1 56
9	5 4 04
10	1 0 55
11	2 1 02
12	3 1 15
13	4 1 47
14	5 3 34
15	1 0 52
16	2 0 58
17	3 1 10
18	4 1 39
19	5 3 08
20	1 0 48
21	2 0 54
22	3 1 05
23	4 1 32
24	5 2 51
25	1 0 45
26	2 0 50
27	3 1 01
28	4 1 25
29	5 2 34
30	1 0 42
31	2h.0 47

April.	′ ″
1	3h.0 57
2	4 1 19
3	5 2 18
4	1 0 39
5	2 0 44
6	3 0 54
7	4 1 14
8	5 2 03
9	1 0 36
10	2 0 41
11	3 0 51
12	4 1 10
13	5 1 58
14	1 0 34
15	2 0 38
16	3 0 48
17	4 1 06
18	5 1 49
19	1 0 32
20	2 0 36
21	3 0 45
22	4 1 02
23	5 1 42
24	1 0 30
25	2 0 34
26	3 0 42
27	4 0 58
28	5 1 36
29	1 0 28
30	2h.0 32

May.	′ ″
1	1h.0 28
	2 0 32
2	3 0 39
	4 0 55
3	5 1 30
4	1 0 26
5	2 0 30
6	3 0 37
7	4 0 53
8	5 1 26
9	1 0 25
10	2 0 29
11	3 0 36
12	4 0 51
13	5 1 22
14	1 0 23
15	2 0 27
16	3 0 34
17	4 0 49
18	5 1 18
19	1 0 22
20	2 0 26
21	3 0 33
22	4 0 47
23	5 1 15
24	1 0 21
25	2 0 25
26	3 0 32
27	4 0 46
28	5 1 13
29	1 0 20
	2 0 24
30	3 0 31
	4 0 44
31	5h.1 11

June.	′ ″
1	5h.1 11
2	
3	1 0 19
4	2 0 23
5	3 0 30
6	4 0 43
7	5 1 10
8	1 0 18
9	2 0 22
10	3 0 29
11	4 0 43
12	5 1 09
13	1 0 18
14	2 0 22
15	3 0 29
16	4 0 42
17	5 1 08
18	1 0 18
19	2 0 22
20	3 0 28
21	4 0 42
22	5 1 08
23	1 0 18
24	2 0 22
25	3 0 29
26	4 0 42
27	5 1 08
28	1 0 18
29	2 0 22
	3 0 29
30	4h.0 43

July.	′ ″
1	5h.1 09
2	
3	1 0 19
4	2 0 23
5	3 0 30
6	4 0 43
7	5 1 10
8	1 0 20
9	2 0 24
10	3 0 31
11	4 0 44
12	5 1 11
13	1 0 21
14	2 0 25
15	3 0 32
16	4 0 46
17	5 1 13
18	1 0 22
19	2 0 26
20	3 0 33
21	4 0 47
22	5 1 15
23	1 0 23
24	2 0 27
25	3 0 34
26	4 0 49
27	5 1 18
28	1 0 25
29	2 0 29
	3 0 36
30	4 0 51
31	5h.1 22

August.	′ ″
1	
2	1h.0 26
3	2 0 30
4	3 0 37
5	4 0 53
6	5 1 26
7	1 0 28
8	2 0 32
9	3 0 39
10	4 0 55
11	5 1 30
12	1 0 30
13	2 0 34
14	3 0 42
15	4 0 58
16	5 1 36
17	1 0 32
18	2 0 36
19	3 0 45
20	4 1 02
21	5 1 42
22	1 0 34
23	2 0 38
24	3 0 48
25	4 1 06
26	5 1 49
27	1 0 36
28	2 0 41
29	3 0 51
30	4 1 10
31	5h.1 58

September.	′ ″
1	1h.0 39
2	2 0 44
3	3 0 54
4	4 1 14
5	5 2 08
6	1 0 42
7	2 0 47
8	3 0 57
9	4 1 19
10	5 2 18
11	1 0 45
12	2 0 50
13	3 1 01
14	4 1 25
15	5 2 34
16	1 0 48
17	2 0 54
18	3 1 05
19	4 1 32
20	5 2 51
21	1 0 52
22	2 0 58
23	3 1 10
24	4 1 39
25	5 3 08
26	1 0 55
27	2 1 02
28	3 1 15
29	4 1 47
30	5h.3 34

October.	′ ″
1	1h.0 59
2	2 1 06
3	3 1 21
4	4 1 56
5	5 4 04
6	1 1 03
7	2 1 10
8	3 1 27
9	4 2 06
10	5 4 39
11	1 1 07
12	2 1 15
13	3 1 33
14	4 2 18
15	5 5 39
16	1 1 12
17	2 1 20
18	3 1 40
19	4 2 31
20	5 6 29
21	1 1 16
22	2 1 25
23	3 1 48
24	4 2 47
25	5 8 39
26	1 1 21
27	2 1 31
28	3 1 56
29	4 3 04
30	5 11 01
	1h.1 26
31	1 37
	2 04

November.	′ ″
1	2h.3 21
2	3 13 57
3	4
4	5
5	1 1 32
6	2 1 44
7	3 2 13
8	4 3 41
9	5
10	1 1 37
11	2 1 50
12	3 2 22
13	4 4 07
14	5
15	1 1 42
16	2 1 56
17	3 2 31
18	4 4 35
19	5
20	1 1 46
21	2 2 01
22	3 2 40
23	4 4 59
24	5
25	1 1 50
26	2 2 06
27	3 2 49
28	4 5 33
29	5h.
30	

December.	′ ″
1	1h.1 54
2	2 2 11
	3 2 59
3	4 6 01
4	5
5	1 1 58
6	2 2 16
7	3 3 04
8	4 6 23
9	5
10	1 2 00
11	2 2 19
12	3 3 09
13	4 6 38
14	5
15	1 2 01
16	2 2 20
17	3 3 11
18	4 6 47
19	5
20	1 2 01
21	2 2 20
22	3 3 11
23	4 6 49
24	5
25	1 2 00
26	2 2 19
27	3 3 09
28	4 6 43
29	5h.
30	
31	

The Preparation of the Declination Settings for a Day's Work.

The Solar Ephemeris gives the declination of the sun for the given day, for Greenwich mean noon. Since all points in America are west of Greenwich, by 5, 6, 7, or 8 hours, the declination found in the ephemeris is the declination at the given place at 7, 6, 5, or 4 o'clock A. M., of the same date, according as the place lies in the "Eastern," "Central," "Mountain," or "Western Time" belts respectively.

The column headed "Refraction Correction" gives the correction to be made to the declination, for refraction, for any point whose latitude is 40°. If the latitude is more or less than 40° these corrections are to be multiplied by the corresponding coefficients given in the table of "Latitude Coefficients," p. 21. Thus the refraction corrections in latitude 30° are 65 hundredths, and those of 50° 142 hundredths of the corresponding ones in latitude 40°. There is a slight error in the use of these latitude coefficients, but the maximum error will not amount to over 15″, except when the sun is very near the horizon, and then any refraction becomes very uncertain. All refraction tables are made out for the mean, or average, refraction, whereas the actual refraction at any particular time and place may be not more than one-half, or as much as twice the mean refraction, with small altitudes. The errors made in the use of these latitude coefficients are, therefore, very small as compared with the errors resulting from the use of the mean, rather than unknown actual refraction which affects any given observation.

Example I.

Let it be required to prepare a table of declinations for a point whose latitude is 38° 30′, and which lies in the "Central Time" belt, for April 5, 1890.

Since the time is 6 hours earlier than that at Greenwich, the declination given in the ephemeris is the declination here at 6 A. M. of same date. This is found to be + 6° 9′ 57″. To this must be added the hourly change, which is also plus, and equal to 56″.83. The latitude coefficient is 0.94. The following table may now be made out:

Declination Settings for Apr. 5, 1890, *Lat.* 38° 30′ *Central Time.*

Hour.	Declination.	Ref. Cor.	Setting.	Hour.	Declination.	Ref. Cor.	Setting.
7	+ 6° 10′ 54″	+ 2′ 00″	6° 12′ 54″	1	6° 16′ 35″	+ 37″	6° 17′ 12″
8	6 11 51	+ 1 10	6 13 01	2	6 17 31	+ 41	6 18 12
9	6 12 47	+ 51	6 13 38	3	6 18 28	+ 51	6 19 19
10	6 13 44	+ 41	6 14 25	4	6 19 25	+ 1 10	6 20 35
11	6 14 41	+ 37	6 15 18	5	6 20 22	+ 2 00	6 22 22

Example II.

Let it be required to prepare a declination table for a point in lat. 45°, in the "Eastern Time" belt, for Oct. 10, 1890.

The time now is 5 hours earlier than that of Greenwich, hence the declination given in the ephemeris for Greenwich mean noon is the declination at our point at 7 A. M. The declination found is — 6° 43′ 56″, and the hourly change is — 56′.87. The latitude coefficient is 1.20.

The table then becomes:

Declination Settings for Oct. 10, 1890, *Lat.* 45° *Eastern Time.*

Hour.	Declination.	Ref. Cor.	Settings.	Hour.	Declination.	Ref. Cor.	Settings.
7	— 6° 43′ 56″	+ 5′ 35″	—6°38′21″	1	— 6° 49′ 37″	+ 1′ 16″	—6°48′21″
8	— 6 44 53	+ 2 31	—6 42 22	2	— 6 50 34	+ 1 24	—6 49 10
9	— 6 45 50	+ 1 44	—6 44 06	3	— 6 51 31	+ 1 44	—6 49 47
10	— 6 46 47	+ 1 24	—6 45 23	4	— 6 52 28	+ 2 31	—6 49 57
11	— 6 47 44	+ 1 16	—6 46 28	5	— 6 53 25	+ 5 35	—6 47 50

If the date be between June 20 and Sept. 20 the declination is positive and the hourly change negative, while if it be between Dec. 20 and March 20 the declination is negative and the hourly change positive. The refraction correction is always positive; that is, it always increases numerically the north declinations and diminishes numerically the south declinations. The hourly refraction corrections given in the ephemeris are exact for the middle day of the five-day period corresponding to that set of hourly corrections. For the extreme days of any such period an interpolation can be made between the adjacent hourly corrections, if desired.

By using standard time instead of local time a slight error is made, but the maximum value of this error is found at those points where the standard time differs from the local time by one-half hour, and in the spring and fall when the declination is changing rapidly. The greatest error, then, is less than 30″, and this is smaller than can be set off on the vertical circle or declination arc. Even this error can be avoided by using the true difference of time from Greenwich in place of the standard meridian time.

Transit, with Solar Attachment in position for vertical sighting.

The Saegmuller Solar Attachment when used as a Vertical Sighting Telescope.

Although this attachment is familiar to every engineer, it is only quite recently that it has been recognized as the best Vertical Sighting Telescope which can easily be attached to the ordinary Transit and which will give accurate results.

It is readily seen that the construction of the Attachment allows the small Telescope to be placed in a vertical position, and when so placed, as represented in the preceding cut, it fulfils every requirement of an instrument designed for vertical as well as oblique sighting in mining work.

In order to use the Solar for this purpose proceed as follows:

See that the transit is in perfect adjustment. Point both telescopes horizontal and see that the Solar points as much above the Transit Telescope as equals the distance between their axes. When this is the case the lines of collimation of both telescopes are parallel. Now turn the Transit Telescope 90°, as shown by the vertical circle, taking care not to disturb the relative position of the Solar telescope and that of the Transit, and both will point vertically downwards.

As the standards of the Solar are high enough to allow the small telescope to clear the plates, it is evident that the Solar telescope now points accurately to the Nadir.

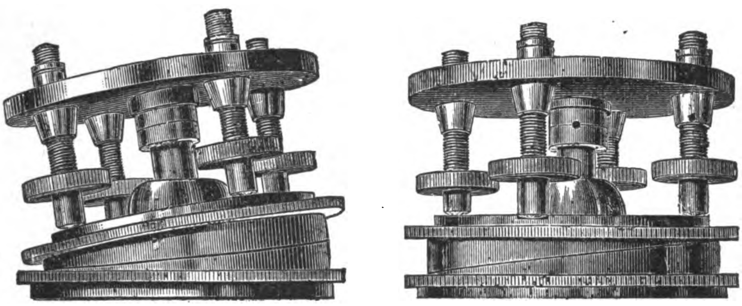
The same *modus operandi* holds good when it is desired to obtain an oblique sight, as it is only necessary to set off the desired slope on the vertical circle, after having both telescopes parallel.

For very accurate work it is desirable to make the observations in two positions by reversal. By taking the mean of the two sets of observations instrumental errors are eliminated.

In order to make the Saegmuller Solar Attachment as efficient as possible for the above purpose, the size of the telescope has been increased, giving it ample power to locate a point with great precision.

New Quick-Levelling Tripod-Head with Shifting-Plate.

PATENTED BY G. N. SAEGMULLER, WASHINGTON, D. C., FEBRUARY 18, 1879.



These engravings represent a new form of Quick-Levelling Tripod, which is the simplest and most convenient yet devised. It consists of two circular discs, which are wedge-shaped; that is, thicker on one side than the other. They are interposed between the levelling-screws and tripod-head proper. By turning one or the other of them around their common centre the instrument can gradually be brought to a vertical position. The final levelling touches are given by means of the usual levelling-screws, which at the same time clamp the instrument firmly. *The great advantage of this Quick-Levelling Tripod over other forms is that the instrument will not fall over even if it is not clamped, and no accident on this account can occur.*

It can be attached to any transit or levelling instrument.

Conversion of Mean Solar into an Equivalent of Sidereal Time, or the Reverse.

If tables for such conversion are not at hand it may be made by the following formula.

Let T represent an interval of time expressed in mean time.

Let S represent a sidereal time interval.

The sidereal year = 366.25636 sidereal days;
= 365.25636 mean solar days;

$$\text{hence, } \frac{S}{T} = \frac{366.25636}{365.25636} = 1.0027379.$$

$$\text{Therefore, } \ldots \quad S = 1.0027379\ T = T + .0027379\ T \ (1).$$

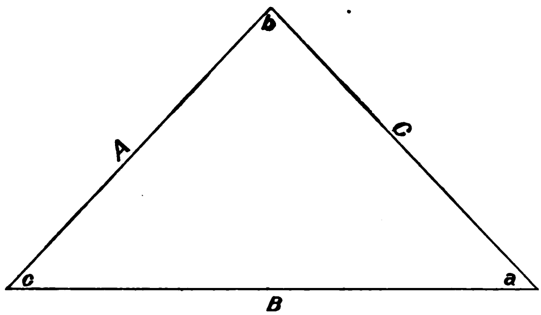
$$T = 0.9972696\ S = S - .0027304\ S \ (2).$$

If in (1) $T = 24^{h.} \therefore S = 24^{h.}\ 3^{m.}\ 56^{s.}.5553$, or in a *mean solar* day sidereal time *gains* on mean time $3^{m.}\ 56^{s.}.5553$. In $1^{h.}$ of mean time the gain is $9^{s.}.8565$. If in (2) $S = 24^{h.} \therefore T = 24^{h.} - 3^{m.}\ 55^{s.}.9094$, or in a *sidereal* day mean time *loses* on sidereal time $3^{m.}\ 55^{s.}.9094$. In $1^{h.}$ of sidereal time the loss is $9^{s.}.8296$. If in (1) and (2) T and S in the last terms be expressed in hours and decimal parts of an hour, then

$$S = T + 9.8565\ T;$$
$$T = S - 9.8296\ S,$$

by which the reduction may be made.

PROPERTIES OF TRIANGLES.



In right angled triangles =

$$\text{hypoth}^2 = \text{base}^2 + \text{perpend}^2$$
$$\text{base}^2 = (\text{hyp} + \text{perp}) \times (\text{hyp} - \text{per})$$
$$\text{perp}^2 = (\text{hy} + \text{ba}) \times (\text{hy} - \text{ba})$$

Value of any Side A.

$$A = \frac{B.\ \sin.\ a.}{\text{Sin}.\ b.} \qquad A = \frac{C.\ \sin.\ a.}{\text{Sin}.\ c.}$$

$$A = \sqrt{B^2 + C^2 - 2\ B\ C \cos.\ a.}$$

$$A = \frac{B}{\text{Cos}.\ c. + \text{Sin}.\ c.\ \text{Cot}.\ a.}$$

$$A = \frac{C}{\text{Cos}.\ b. + \text{Sin}.\ b.\ \text{Cot}.\ a.}$$

$$A = B.\ \cos.\ c. + B.\ \sin.\ c.\ \text{Cot}.\ b.$$

Value of any Angle.

$$\text{Sin. } b. = \frac{\text{B. sin. } a.}{\text{A}} \qquad \text{Sin. } b. = \frac{\text{B. sin. } a.}{\text{C}}$$

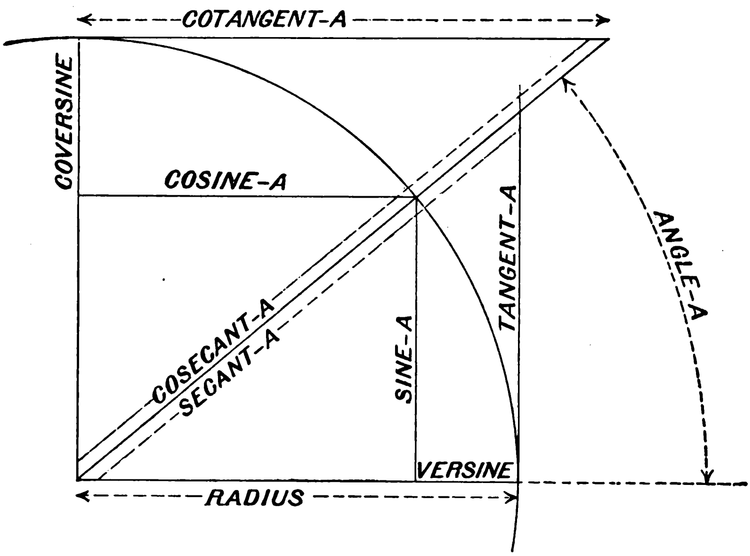
$$\text{Cos. } b. = \frac{A^2 + C^2 - B^2}{2\,A\,C}$$

$$\text{Sin. } b. = \text{Sin. } (c. + a.)$$

$$\text{Sin. } b. = \text{Sin. } c. \text{ Cos. } a. + \text{cos. } c. \text{ sin. } a.$$

TRIGONOMETRICAL EXPRESSIONS.

The diagram shows the different trigonometrical expressions in terms of the angle A.



Complement of an angle = its difference from 90°
Supplement........... = its difference from 180°

TRIGONOMETRICAL EQUIVALENTS.

$\sqrt{(1 - \text{Sin}^2)}$ = Cosin
Sin ÷ Tan = Cosin
Sin × Cotan = Cosin
Sine ÷ Cos = Tangent
Cos ÷ Sine = Cotang
$\text{Sin}^2 + \text{Cos}^2 = \text{Rad}^2$
$\text{Rad}^2 + \text{Tan}^2 = \text{Secant}^2$
1 ÷ Tan = Cotang

$\sqrt{(1 - \text{Cosin}^2)}$ = Sine
Cosin ÷ Cotan = Sine
1 ÷ Cotan = Tangent
1 ÷ Sin = Cosecant
1 ÷ Cosin = Secant
1 ÷ Cosecant = Sine
1 ÷ Secant = Cosin
Rad—Cosin = Versin
Rad — Sin = Coversin

U. S. COAST AND GEODETIC SURVEY.

OFFICE OF STANDARD WEIGHTS AND MEASURES

TABLES FOR CONVERTING U. S. WEIGHTS AND MEASURES.

Metric to Customary.

LINEAR.

	Metres to inches.	Metres to feet.	Metres to yards.	Kilometres to miles.
1 =	39·3700	3·28083	1·093611	0·62137
2 =	78·7400	6·56167	2·187222	1·24274
3 =	118·1100	9·84250	3·280833	1·86411
4 =	157·4800	13·12333	4·374444	2·48548
5 =	196·8500	16·40417	5·468056	3·10685
6 =	236·2200	19·68500	6·561667	3·72822
7 =	275·5900	22·96583	7·655278	4·34959
8 =	314·9600	26·24667	8·748889	4·97096
9 =	354·3300	29·52750	9·842500	5·59233

CAPACITY.

	Millilitres or cubic centimetres to fluid drams.	Centilitres to fluid ounces.	Litres to quarts.	Decalitres to gallons.	Hectolitres to bushels.
1 =	0·27	0·338	1·0567	2·6417	2·8377
2 =	0·54	0·676	2·1134	5·2834	5·6755
3 =	0·81	1·014	3·1700	7·9251	8·5132
4 =	1·08	1·353	4·2267	10·5668	11·3510
5 =	1·35	1·691	5·2834	13·2085	14·1887
6 =	1·62	2·029	6·3401	15·8502	17·0265
7 =	1·89	2·367	7·3968	18·4919	19·8642
8 =	2·16	2·705	8·4535	21·1336	22·7019
9 =	2·43	3·043	9·5101	23·7753	25·5397

SQUARE.

	Square centimetres to square inches.	Square metres to square feet.	Square metres to square yards.	Hectares to acres.
1 =	0·1550	10·764	1·196	2·471
2 =	0·3100	21·528	2·392	4·942
3 =	0·4650	32·292	3·588	7·413
4 =	0·6200	43·055	4·784	9·884
5 =	0·7750	53·819	5·980	12·355
6 =	0·9300	64·583	7·176	14·826
7 =	1·0850	75·347	8·372	17·297
8 =	1·2400	86·111	9·568	19·768
9 =	1·3950	96·875	10·764	22·239

WEIGHT.

	Milligrammes to grains.	Kilogrammes to grains.	Hectogrammes to ounces avoirdupois.	Kilogrammes to pounds avoirdupois.
1 =	0·01543	15432·36	3·5274	2·20462
2 =	0·03086	30864·71	7·0548	4·40924
3 =	0·04630	46297·07	10·5822	6·61387
4 =	0·06173	61729·43	14·1096	8·81849
5 =	0·07716	77161·78	17·6370	11·02311
6 =	0·09259	92594·14	21·1644	13·22773
7 =	0·10803	108026·49	24·6918	15·43236
8 =	0·12346	123458·85	28·2192	17·63698
9 =	0·13889	138891·21	31·7466	19·84160

CUBIC.

	Cubic centimetres to cubic inches	Cubic decimetres to cubic inches.	Cubic metres to cubic feet.	Cubic metres to cubic yards.
1 =	0·0610	61·023	35·314	1·308
2 =	0·1220	122·047	70·629	2·616
3 =	0·1831	183·070	105·943	3·924
4 =	0·2441	244·094	141·258	5·232
5 =	0·3051	305·117	176·572	6·540
6 =	0·3661	366·140	211·887	7·848
7 =	0·4272	427·164	247·201	9·156
8 =	0·4882	488·187	282·516	10·464
9 =	0·5492	549·210	317·830	11·771

WEIGHT—(CONTINUED).

	Quintals to pounds av.	Milliers or tonnes to pounds av.	Kilogrammes to ounces Troy.
1 =	220·46	2204·6	32·1507
2 =	440 92	4409·2	64·3015
3 =	661·39	6613·9	96·4522
4 =	881·85	8818·5	128·6030
5 =	1102·31	11023·1	160·7537
6 =	1322·77	13227·7	192·9044
7 =	1543·24	15432·4	225·0552
8 =	1763·70	17637·0	257·2059
9 =	1984·16	19841·6	289·3567

By the concurrent action of the principal governments of the world an International Bureau of Weights and Measures has been established near Paris. Under the direction of the International Committee, two ingots were cast of pure platinum-iridium in the proportion of 9 parts of the former to 1 of the latter metal. From one of these a certain number of kilogrammes were prepared, from the other a definite number of metre bars. These standards of weight and length were intercompared, without preference, and certain ones were selected as International prototype standards. The others were distributed by lot, in September, 1889, to the different governments and are called National Prototype Standards. Those apportioned to the United States were received in 1890 and are in the keeping of this office.

The metric system was legalized in the United States in 1866.

The International Standard Metre is derived from Mètre des Archives, and its length is defined by the distance between two lines at 0° Centigrade on a platinum-iridium bar deposited at the International Bureau of Weights and Measures.

The International Standard Kilogramme is a mass of platinum-iridium deposited at the same place, and its weight in vacuo is the same as that of the Kilogramme des Archives.

The litre is equal to a cubic decimetre, and it is measured by the quantity of distilled water which, at its maximum density, will counterpoise the standard kilogramme in a vacuum, the volume of such a quantity of water being, as nearly as has been ascertained, equal to a cubic decimetre.

Tables for Converting U. S. Weights and Measures.

Customary to Metric.

LINEAR.

	Inches to millimetres.	Feet to metres.	Yard to metres.	Miles to kilometres.
1 =	25·4001	0·304801	0·914402	1·60935
2 =	50·8001	0·609601	1·828804	3·21869
3 =	76·2002	0·914402	2·743205	4·82804
4 =	101·6002	1·219202	3·657607	6·43739
5 =	127·0003	1·524003	4·572009	8·04674
6 =	152·4003	1·828804	5·486411	9·65608
7 =	177·8004	2·133604	6·400813	11·26543
8 =	203·2004	2·438405	7·315215	12·87478
9 =	228·6005	2·743205	8·229616	14·48412

CAPACITY.

	Fluid drams to millilitres or cubic centimetres.	Fluid ounces to millilitres.	Quarts to litres.	Gallons to litres.
1 =	3·70	29·57	0·94636	3·78543
2 =	7·39	59·15	1·89272	7·57087
3 =	11·09	88·72	2·83908	11·35630
4 =	14·79	118·29	3·78543	15·14174
5 =	18·48	147·87	4·73179	18·92717
6 =	22·18	177·44	5·67815	22·71261
7 =	25·88	207·02	6·62451	26·49804
8 =	29·57	236·59	7·57087	30·28348
9 =	33·27	266·16	8·51723	34·06891

SQUARE.

	Square inches to square centimetres.	Square feet to square decimetres.	Square yards to square metres.	Acres to hectares.
1 =	6·452	9·290	0·836	0·4047
2 =	12·903	18·581	1·672	0·8094
3 =	19·355	27·871	2·508	1·2141
4 =	25·807	37·161	3·344	1·6187
5 =	32·258	46·452	4·181	2·0234
6 =	38·710	55·742	5·017	2·4281
7 =	45·161	65·032	5·853	2·8328
8 =	51·613	74·323	6·689	3·2375
9 =	58·065	83·613	7·525	3·6422

WEIGHT.

	Grains to milligrammes.	Avoirdupois ounces to grammes.	Avoirdupois pounds to kilogrammes.	Troy ounces to grammes.
1 =	64·7989	28·3495	0·45359	31·10348
2 =	129·5978	56·6991	0·90719	62·20696
3 =	194·3968	85·0486	1·36078	93·31044
4 =	259·1957	113·3981	1·81437	124·41392
5 =	323·9946	141·7476	2·26796	155·51740
6 =	388·7935	170·0972	2·72156	186·62088
7 =	453·5924	198·4467	3·17515	217·72437
8 =	518·3914	226·7962	3·62874	248·82785
9 =	583·1903	255·1457	4·08233	279·93133

CUBIC.

	Cubic inches to cubic centimetres.	Cubic feet to cubic metres.	Cubic yards to cubic metres.	Bushels to hectolitres.
1 =	16·387	0·02832	0·765	0·35239
2 =	32·774	0·05663	1·529	0·70479
3 =	49·161	0·08495	2·294	1·05718
4 =	65·549	0·11327	3·058	1·40957
5 =	81·936	0·14158	3·823	1·76196
6 =	98·323	0·16990	4·587	2·11436
7 =	114·710	0·19822	5·352	2·46675
8 =	131·097	0·22654	6·116	2·81914
9 =	147·484	0·25485	6·881	3.17154

1 Gunter's chain	=	20·1168	metres.
1 sq. statute mile	=	259·000	hectares.
1 fathom	=	1·829	metres.
1 nautical mile	=	1853·25	metres.
1 foot = 0.304801 metre,		9·4840158	log.
1 avoir. pound	=	453·5924277	gram.
15432·35639 grains	=	1	kilogramme.

The only authorized material standard of customary length is the Troughton scale belonging to this office, whose length at 59°.62 Fahr. conforms to the British standard. The yard in use in the United States is therefore equal to the British yard.

The only authorized material standard of customary weight is the Troy pound of the Mint. It is of brass of unknown density, and therefore not suitable for a standard of mass. It was derived from the British standard Troy pound of 1758 by direct comparison. The British Avoirdupois pound was also derived from the latter, and contains 7,000 grains Troy.

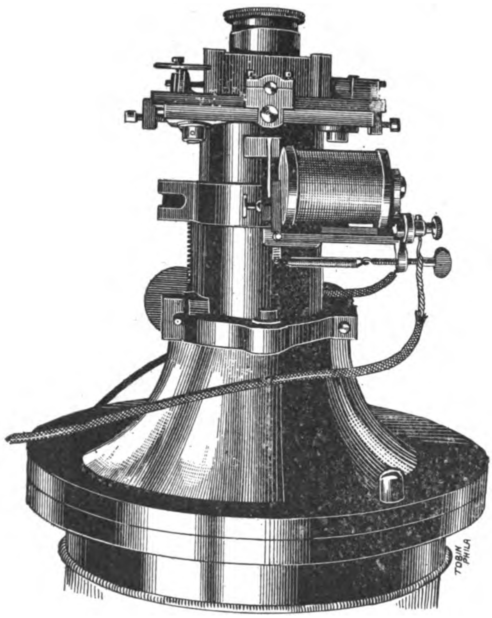
The grain Troy is therefore the same as the grain Avoirdupois, and the pound Avoirdupois in use in the United States is equal to the British pound Avoirdupois.

The British gallon = 4.54346 litres.

The British bushel = 36.3477 litres.

The length of the nautical mile given above and adopted by the U. S. Coast and Geodetic Survey many years ago, is defined as that of a minute of arc of a great circle of a sphere whose surface equals that of the earth (Clarke's Spheroid of 1866).

PHOTO-CHRONOGRAPH.



The Georgetown College Photo-Chronograph,
as designed by Prof. Geo. A. Fargis, S. J.

By means of this attachment the time of the transit of a star is actually registered on the plate, as the name very aptly suggests.

It consists of two parts: a plate holder and an electro-magnet, and is so arranged that sensitive plates can be inserted close against the glass reticle into the photographic focus of the object-glass. To facilitate the insertion the eye-piece slide is hinged, allowing it to be moved out of the way.

A brass collar fits closely around the sliding tube, just behind the micrometer box, and to this collar is attached the electro-magnet, which consists of only one coil in order to diminish weight. The end of the core is cushioned with a thin ring of cork to destroy the force of the armature stroke. The usual adjusting and connecting screws are conveniently placed. A thin, narrow strip of steel, called the occulting bar, is fastened to the armature at right angles to its line of motion and protrudes through a hole in the box across the field. The coil, armature, and occulting bar are so fixed to the collar that, when at rest, the lower edge of the shutter is parallel to the horizontal diameter of the reticle.

Suppose, then, that connection be made with the sidereal clock-relay, and that a star begins its transit. When the current is turned on, the shutter falls with the armature and rises again as the current is broken by the clock.

Hence the negative shows a simple line of dots, each representing a break in the clock current.

The clock contact is arranged that certain seconds do not break the current in order to be able to identify any second, and an arbitrary mark on the glass reticle (which of course is photographed on the negative) indicates which is the east and west side.

Nothing remains to be done now but to photograph the reticle on the plate. To do this the current is switched directly into the apparatus. This holds the shutter down, right across the path just made by the star, *completely protecting the photographic record*, and the wires can now be photographed by holding any kind of light for a few seconds in front of the object-glass. The wires do not cross the star trail on the negative as the occulting bar hides it, but they are shown above and below the trail, and allow the measuring of the distance between dots and wires with the utmost accuracy. These measures can be made at any time, and an ordinary micrometer-microscope is all that is necessary.

This apparatus has been in constant use at the Georgetown College Observatory for several years, and the results show that it is as superior to the chronograph method as this is to the eye and ear method of observation.

The practical importance of this method consists in the entire absence of personal equation.

As an example, we need only mention longitude determinations. The usual exchange of the observers, so expensive in time and money, is, by the photographic method, rendered unnecessary and even useless. If the photo-chronographs at the two stations are worked by the same clock at either station, or at an intermediate one, the sensitive plates will record the difference of the two meridians without the interference of the observers.

Although the objective of the Georgetown transit is only 4½ inches aperture and is not corrected for photographic rays, stars of the fourth magnitude and even below this have been photographed and the plates measured.

For a detailed description of the apparatus, the manner of working it and measuring the plates, and an exhaustive discussion of the results, we would refer to the publications of the Georgetown College Observatory.*

This apparatus can be applied to old instruments, and can easily be removed for visual observation. For price, see page 81.

* The Photo-chronograph and its application to Star Transits, Georgetown College Observatory.

Cheap Astronomical Outfit for Amateurs and Students, consisting of Equatorial, Transit, Clock, and Chronograph.

Numerous inquiries for small mounted telescopes and transit instruments, suitable for the use of the student or amateur, having been received by us, and appreciating the desire, now so popular, of many to acquire a knowledge of astronomy, we have manufactured a cheap, yet effective, instrumental outfit, consisting of an equatorial, an astronomical transit, a sidereal clock, and an electric chronograph.

The equatorial, we feel assured, meets the requirements of the student or the amateur. It possesses a telescope of 4 inches aperture, with finder; has clock-work attached, clamp and tangent movements in R. A. and Decl.; graduated circles for R. A. and Decl.; the whole mounted on either an iron pillar or tripod stand as may be preferred.

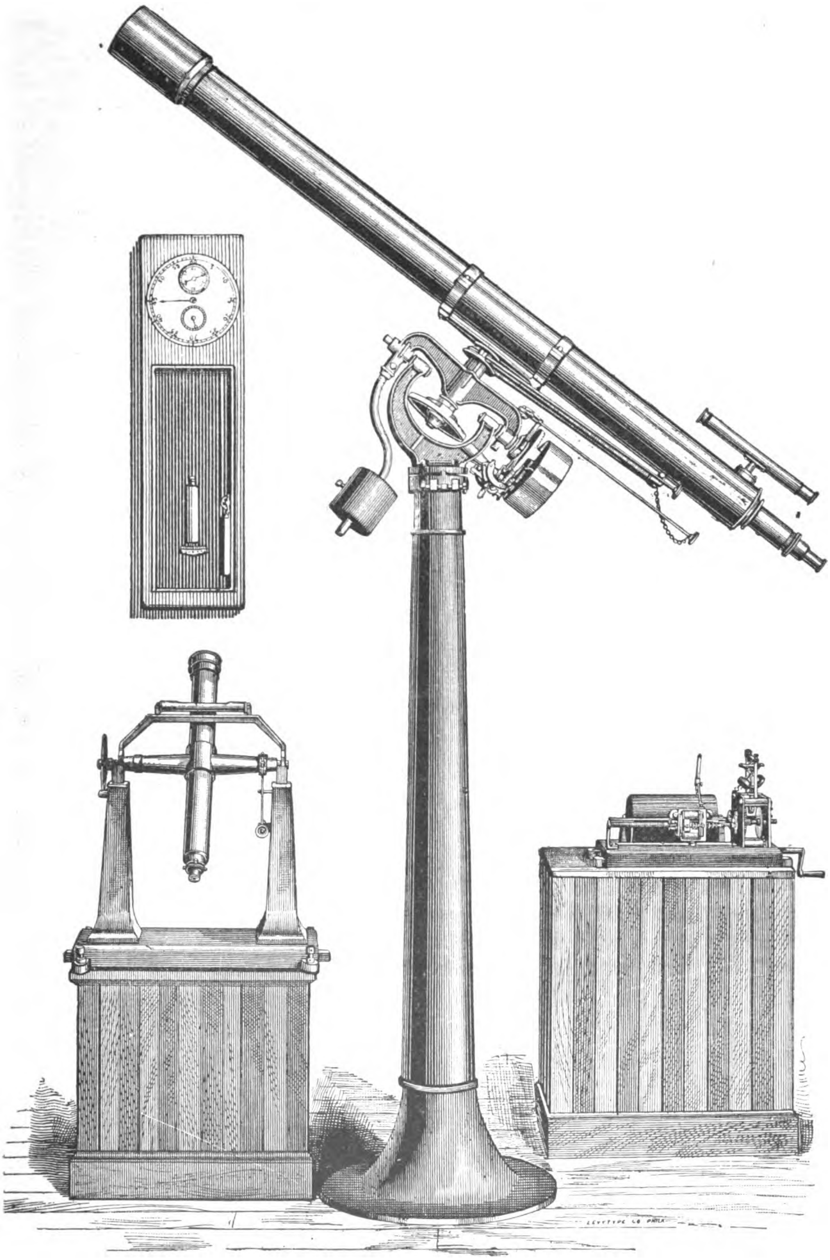
The transit instrument has a 2-in. telescope; massive iron stand, with adjustments in altitude and azimuth, sensitive striding level, declination circle, clamp and tangent, glass micrometer, sun-shade, means for illumination, and prism to fit the eye-piece.

The sidereal clock has the Graham dead-beat escapement, compensated pendulum, break circuit arrangement, and is made throughout with the utmost care. It has 9-in. silvered dial, with extra second and hour dial.

The electric chronograph is in all respects similar to our large ones, excepting that it is smaller. The clock runs for one hour, and governs the motion so regularly that the second marks form a perfect straight line; the barrel is 4 inches in diameter, and tenths of seconds can easily be read off.

Although especially designed for the amateur, these outfits can be advantageously used by the professional astronomer, as they are veritable instruments of precision.

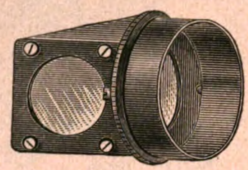
For prices of above, separately, see pages 74, 78, 81, 89.



Cheap Astronomical Outfit,

Consisting of 4-inch Equatorial, with Clock, Circles, Clamps, and Tangents; 2-inch Astronomical Transit; Astronomical Clock, with break circuit attachment; Electric Chronograph. Price for the complete outfit, $850.00.

SAEGMULLER'S OBJECT-PRISM.



PATENTED SEPTEMBER 29, 1885.

A novel attachment to telescopes of surveying instruments, consisting of a rectangular prism, mounted in metal, which can be attached before the object glass like a sun-shade. It brings into the range of the Telescope objects situated in any plane at true right angles to it. It is especially useful for vertical up or down sightings in mining, and supersedes the old practice of attaching an extra telescope to the transit axis for this purpose. The Object-Prism can be furnished to fit the telescope of any level or transit if the sun-shade of the instrument for which it is wanted is sent with the order.

Price, each...$30 00

NOTE.—We draw attention to the fact that these prisms can only be depended upon when the object-glass is fixed to the tube; the least shake in the draw tube (in instruments where the object-glass is moved for focussing) produces great errors. For this reason we consider the "Solar" Telescope preferable to the prism for vertical sighting.

DESCRIPTION AND PRICE-LIST

—OF—

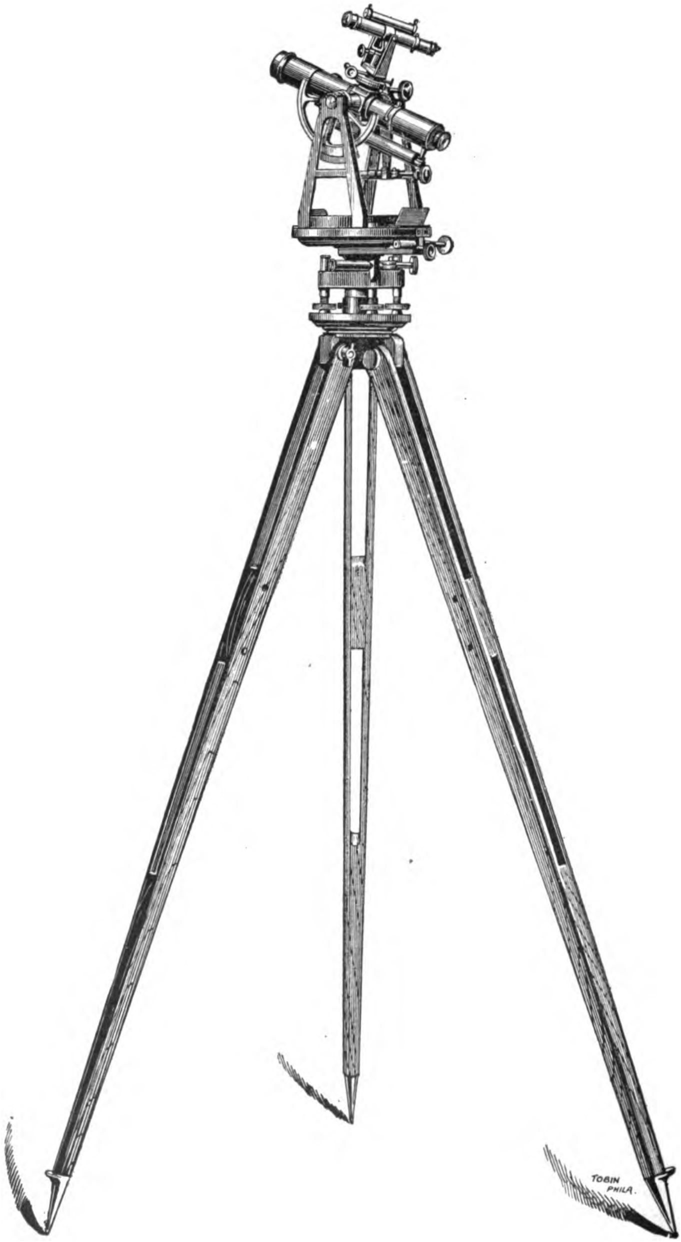
FIRST-CLASS

Engineering and Astronomical Instruments

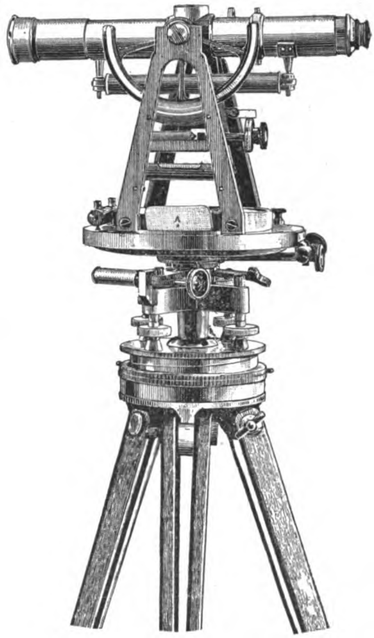
MANUFACTURED BY

G. N. SAEGMULLER,

Successor to FAUTH & CO.



Light Mountain and Mining Transit, with Saegmuller Solar Attachment.



No. 0.—Light Mountain and Mining Transit.

Designed especially for use in rough country and mine work, and differs from our regular Engineer's Transits merely in size and weight. In the cut the verniers are placed at right angles to the telescope, which was necessary in order to accommodate the plate levels. But since we have placed these levels inside the compass-box (see cut No. 1) we are enabled to locate the verniers direct under the telescope, which is a great convenience. This instrument will do most accurate work, and in order not to sacrifice the optical power we make the telescope of the inverting kind, which gives us nearly the same power we get with the ordinary Engineer's telescope possessing the erecting telescope.

The telescope is 9 inches long and magnifies about 20 diameters; 5-inch circle and arc graduated on solid silver reading to minutes; compass-needle $3\frac{3}{4}$ inches long; long sensitive level to telescope; dust-guard to object-slide. The telescope axis is arranged so that the Saegmuller solar can be added to it at any time. Weight about 9 pounds. Packed in box complete with usual accessories, with extension tripod.

Price $260

Note.—By adding the *Saegmuller Solar Attachment* (price $50) this instrument becomes a regular Mining Transit, as the Solar makes an exceedingly accurate *Vertical Sighting Telescope*.

PLAIN TRANSIT, No. 1.

Cut No. 1 represents one of our improved Plain Transits. The circle is 6¾ inches diameter, reading by opposite verniers to 30 seconds; long centres of hard metal; telescope is balanced in axis; has an objective of 1¼ in. diameter, well corrected for spherical and chromatic aberration, magnifying about 24 diameters, and showing objects erect; dust-guard over object slide; compass-needle 4½ inches long, swinging on jewelled centre; levels ground and graduated; action of the clamp entirely on the centre; tangent-screws work smoothly, and are entirely free of play; compass-ring reaches over and forms a cover for the graduation; verniers covered with ground glass; four leveling-screws with shifting tripod. By the use of hard metal and judicious ribbing and bracing great lightness and strength is obtained.

We have lately improved our Transit very much by placing the plate levels inside the compass-box; they are thus out of the way, less liable to get broken, and stay better in adjustment. The adjustment of these levels is effected by means of two screws placed close to compass-box. Being out of the way there is no objection in placing the verniers direct under the telescope. In all other Transits where the plate levels are secured to standard and vernier plate, one level will always be in the way of placing vernier under telescope.

Weight of instrument about 13 pounds.

Weight of tripod about 7 pounds.

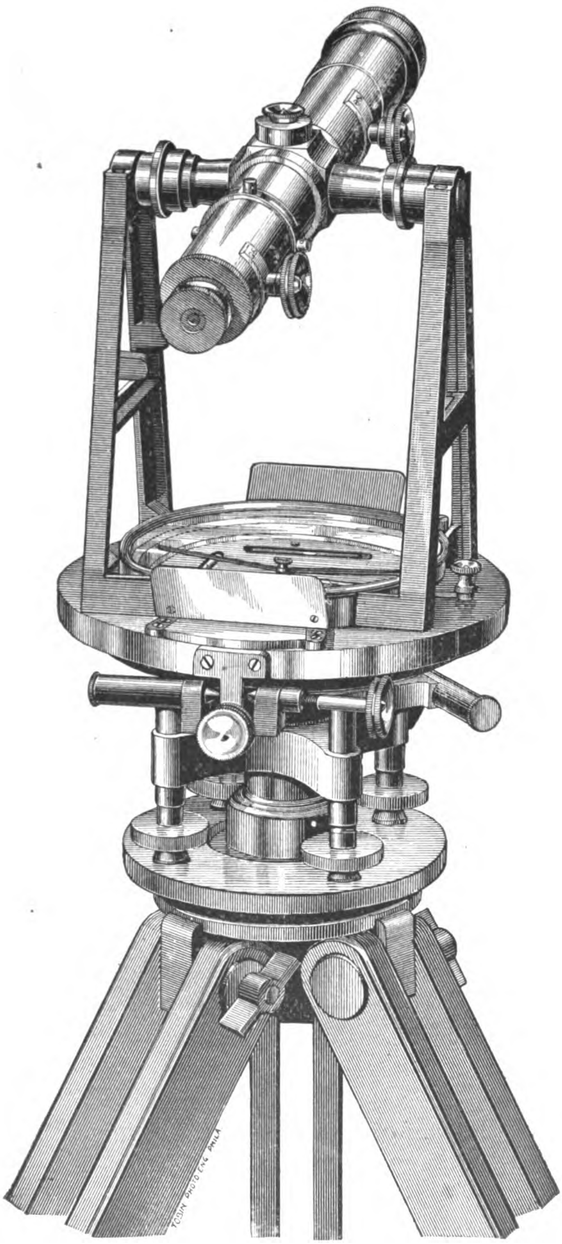
The instrument is securely packed in a neat case, provided with leather strap, and contains, also, a sun-shade, screw-driver, plumb-bob, magnifier, and a couple of adjusting pins.

Price...$185 00

Extras to No. 1.

Graduations on solid silver	$10 00
Focussing rack for eye-piece (in place of screw arrangement)	5 00
Vernier shades	3 00
Fixed stadia wires	3 00
Right angle off-setting arrangement	5 00
Variation plate	20 00
Quick-levelling head (see page 27)	10 00
Gossamer cover	1 00
Extension tripod (in place of ordinary)	5 00

Transit made partly of aluminum, reducing the weight to less than 10 pounds, $25.00 additional.



No. 1.—Plain Transit, showing position of the plate levels inside of compass box.

Unless specially ordered, we make this Transit only with solid silver graduation and vernier shades, and also provide the rack and pinion movement to focus cross-hairs. This makes the price of the above Transit, just as shown in cut, $200.00.

ENGINEER'S TRANSIT, No. 2,

Is exactly like No. 1, with the addition of a vertical arc, level, clamp, and tangent to telescope.

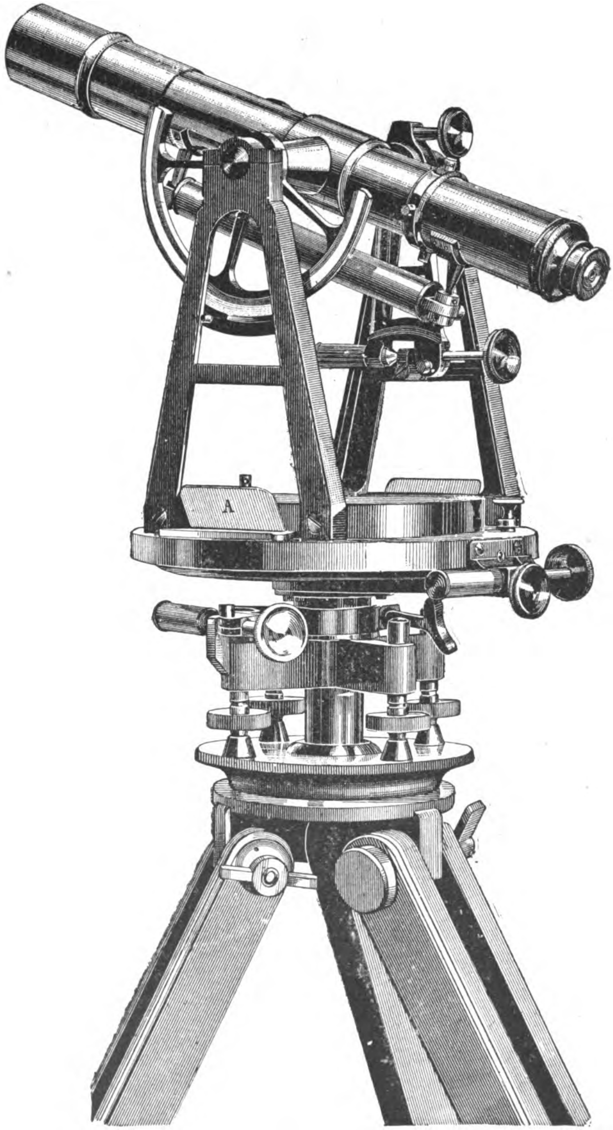
Weight of instrument about 13½ pounds.

Weight of tripod about 7 pounds.

Price..$230 00

Extras to No. 2.

Graduation of horizontal circle on solid silver........................	$10 00
" " vertical arc " " "	5 00
Gradientor attachment...	5 00
Vernier shades..	3 00
Fixed stadia wires..	3 00
Right angle off-setting arrangement.........	5 00
Variation plate...	20 00
Quick-levelling head (see page 27)..................................	10 00
Gossamer cover..	1 00
"Saegmuller's" patent solar attachment....	50 00
Eye-piece prism and extra sun-shade for Transit Telescope...........	10 00
Latitude level..	15 00
Extension tripod (in place of ordinary).............................	10 00



No. 2.—Engineer's Transit No. 2.

Unless specially ordered, we make this Transit only with solid silver graduation and vernier shades, and also provide the rack and pinion movement to focus cross-hairs. This makes the price of the above Transit, just as shown in cut, $250.00.

COMPLETE ENGINEER'S TRANSIT, No. 3,

Is exactly like No. 1, with the addition of Saegmuller's Patent Solar Attachment, Vertical Circle, Level, Clamp, Tangent to telescope, and Quick-levelling Head, and differs from No. 2 only in having a full vertical circle in place of the arc, and the addition of solar attachment. The full vertical circle does no good unless two *opposing* verniers are used, and as it is somewhat in the way of the solar, we recommend the arc instead. It is then our Transit No. 2, with the Solar Attachment.

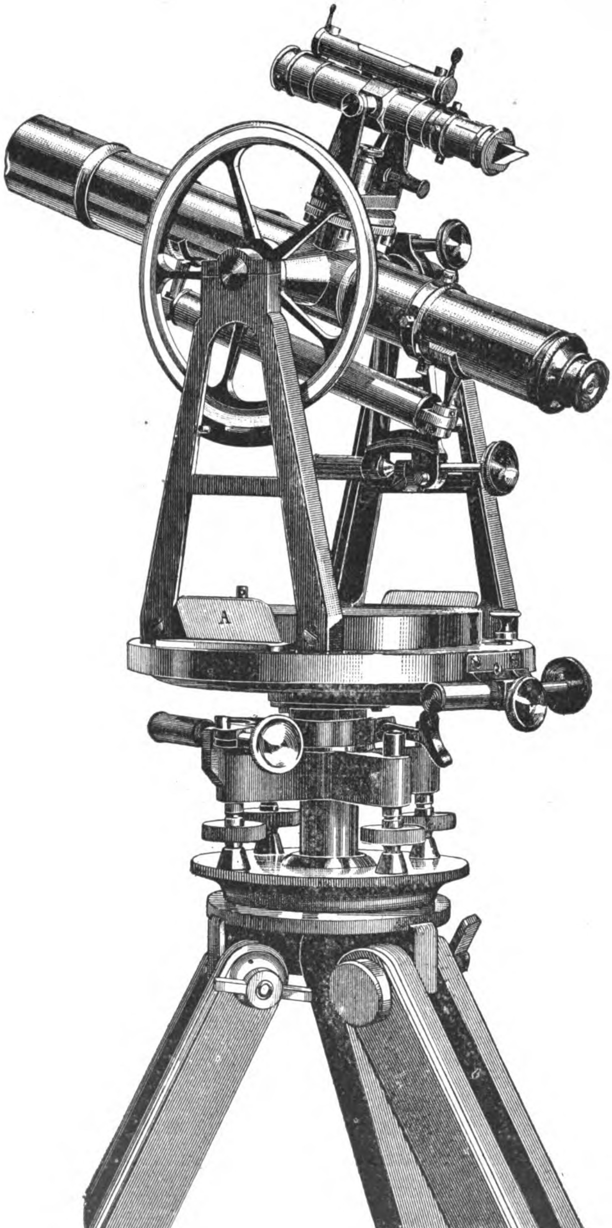
Weight of instrument about 14 pounds.

Weight of tripod about 7 pounds.

Price $300 00

Extras to No. 3.

Graduation of horizontal circle on solid silver	$10 00
" " vertical " " " "	5 00
Gradientor	5 00
Vernier shades	3 00
Fixed stadias	3 00
Right angle off-setting arrangement	5 00
Variation plate	20 00
Latitude level	15 00
Extension tripod (in place of ordinary)	10 00
Two opposite verniers to vertical circle	20 00



No. 3.—Complete Engineer's Transit, with Saegmuller Patent Solar Attachment and Quick-levelling Head.

Unless specially ordered, we make this Transit only with solid silver graduation and vernier shades, and also provide the rack and pinion movement to focus cross-hairs. This makes the price of the above Transit, just as shown in cut, $320.00.

HIGH-GRADE ENGINEERING TRANSIT, NO. 4, OR TRANSIT-THEODOLITE.

This instrument has been designed for the highest class of engineering work, and is used extensively in city surveying and for secondary triangulation. It has no compass permanently attached, but is usually supplied with a box-compass having a 5-inch needle which can be fastened to the top of the telescope and parallel to it. The magnetic bearing of any line can thus be as accurately established as by instruments having a fixed compass.

The great advantage which this instrument possesses over the previously-described forms consists in the great strength of the telescope standard, which is cast in one piece, which, on account of its peculiar shape, is very light and strong. The telescope axis terminates in cylinders, and is held in the standards by caps. This arrangement assures the most accurate movement of the telescope in the vertical plane.

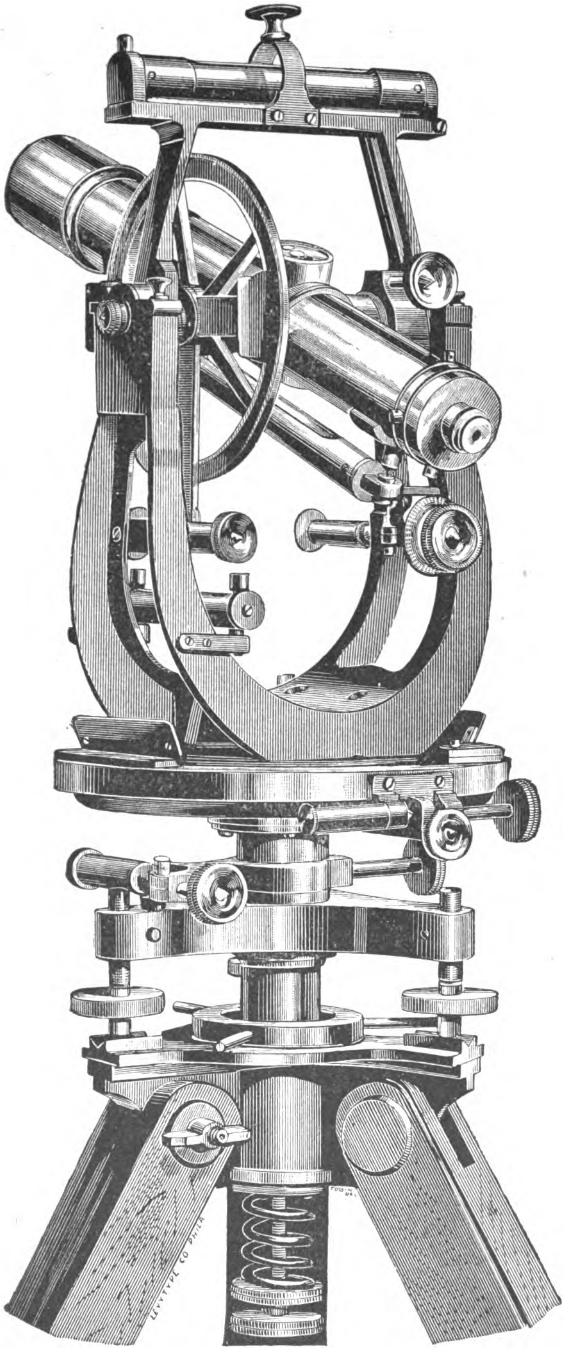
Horizontal circle 6¼ inches diameter, graduated on *solid silver*, and reading by opposite verniers to 30 minutes; powerful telescope of 1⅝ inches aperture and magnifying about 25 diameters; dust-guard over object-slide; extra sensitive levels, improved clamps, and tangents; graduation covered; three leveling screws, &c.

This instrument is usually made with inverting telescope and 3 levelling screws. Horizontal circle 6½ inches diameter, graduated on solid silver, reading to 30 seconds; powerful telescope magnifying about 25 diameters; the levels are very sensitive and the whole instrument is first-class.

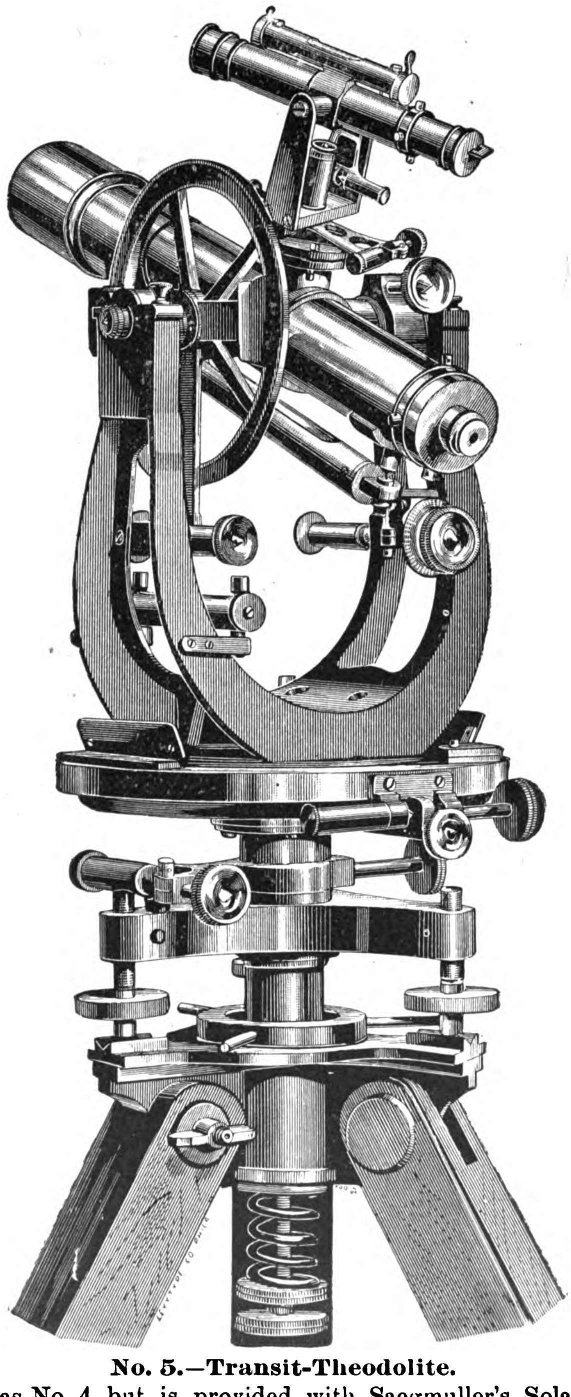
Price as shown in cut	$300 00
Without striding level	275 00
The same instrument plain, *i. e.*, without vertical circle, clamp, or tangent and level to telescope	240 00

Extras to Above Instrument.

Saegmuller's Solar Attachment	50 00
Illumination through axis, with lamp and lamp stand	15 00
Gradientor	5 00
Stadia	3 00
Sensitive striding level, to rest on the cylindrical ends of telescope axis	25 00
Box-compass, with variation plate to attach to telescope. Needle 4 inches long, with 12-degree arc	25 00
Field illumination through axis of telescope	8 00
Diagonal eye-piece (4-lens system, and 1 prism)	16 00
Eye-piece prism	7 50
Shifting head to tripod	6 00
Attached reading-glasses	15 00



No. 4.—Complete Transit-Theodolite.

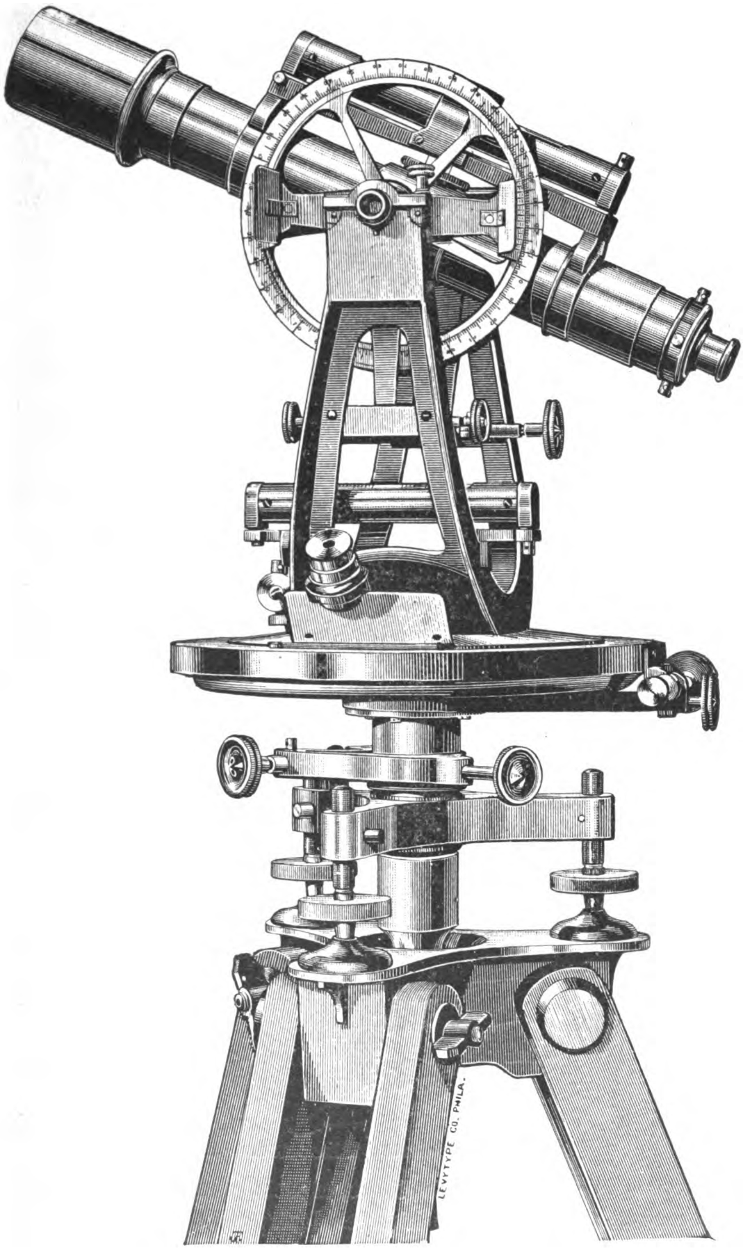


No. 5.—Transit-Theodolite.

Is the same as No. 4, but is provided with Saegmuller's Solar Attachment.

Price....... ....$350 00

For extras see page 46.

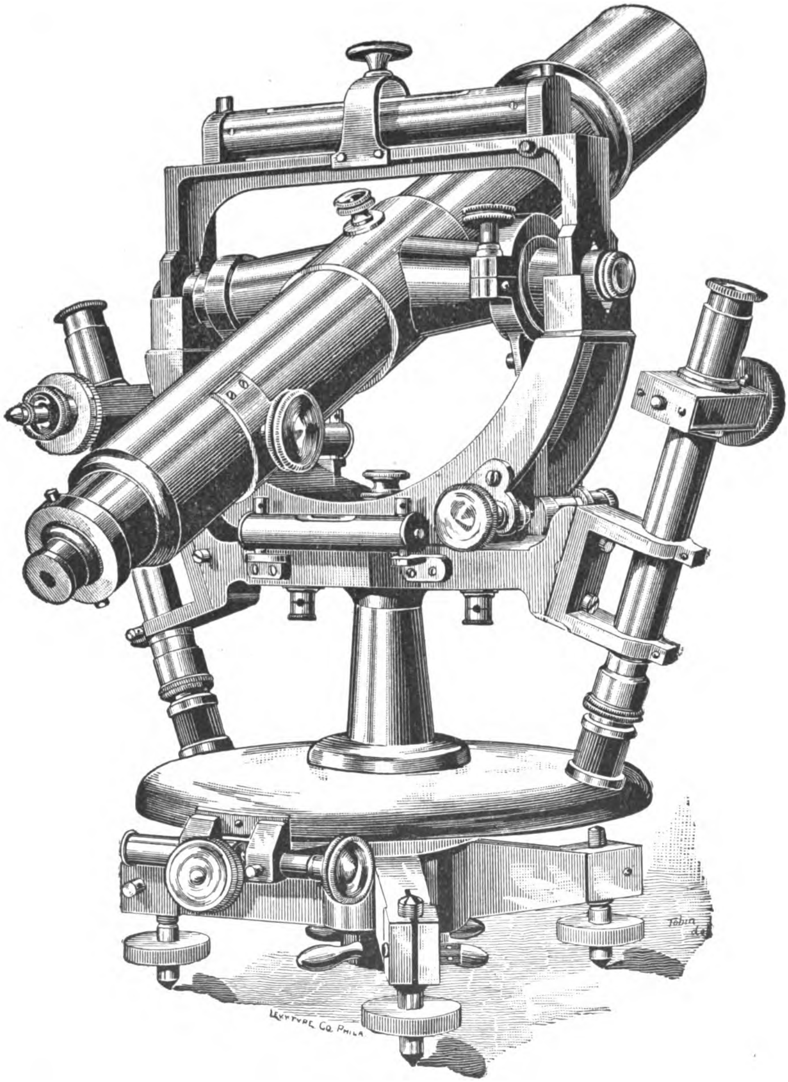


No. 6.—8-inch Transit-Theodolite.

This instrument is of the highest class and especially adapted for triangulation and astronomical work.

It is provided with sensitive striding-level like No. 4 (in place of the telescope level shown in cut), illumination with lamp and lamp stand, circles divided on silver, reading to 10″ and 30″ respectively.

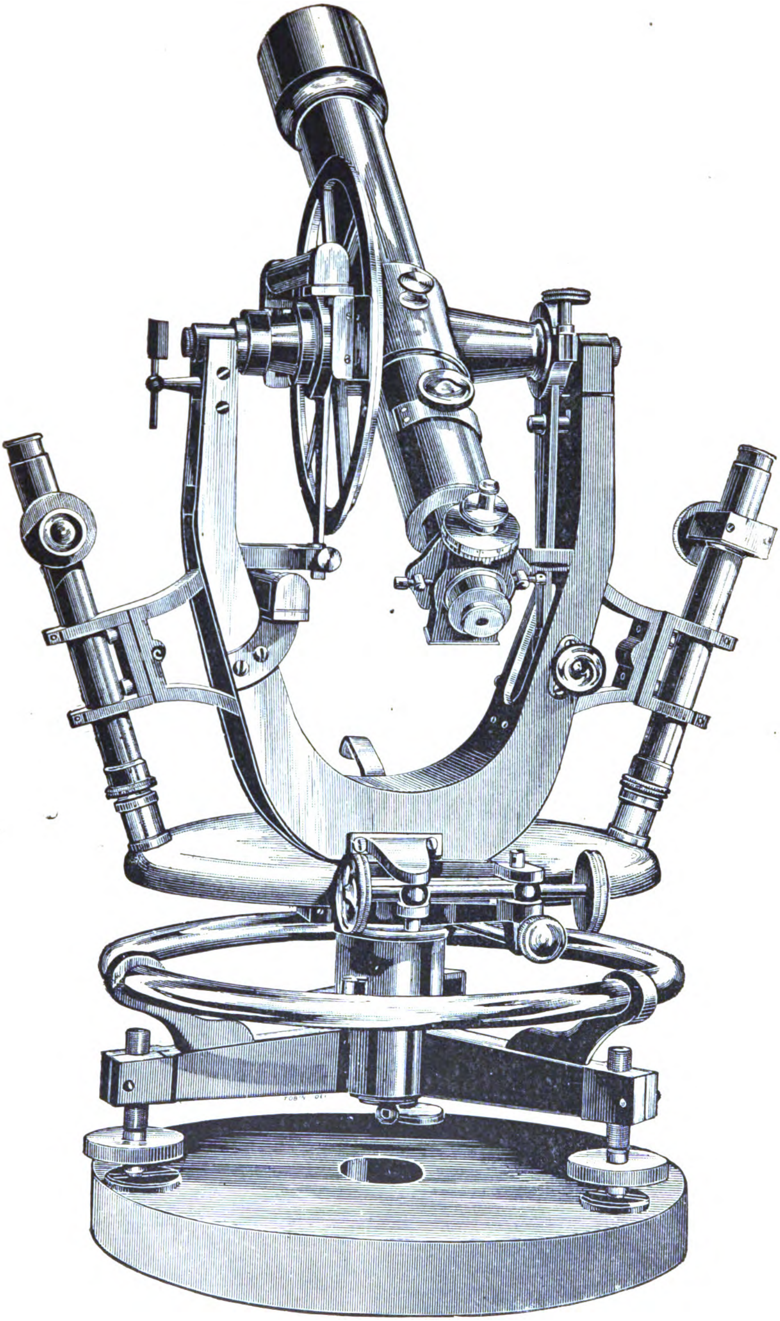
Price..**$400 00**



No. 7.—8-inch Theodolite.

Above cut represents an 8-inch Theodolite, especially adapted for triangulation, and is a non-repeater. This is the kind of instrument to which reference is made under head of "Graduation." It reads to seconds by opposite micrometer-microscopes, and every degree is numbered with minute numbers, nearly 1,000 figures, visible only in the microscope, being engraved on the circle. Telescope $1\frac{3}{4}$ inches aperture, about 18″ focus; improved clamp, sensitive striding-level and field illumination, with stand.

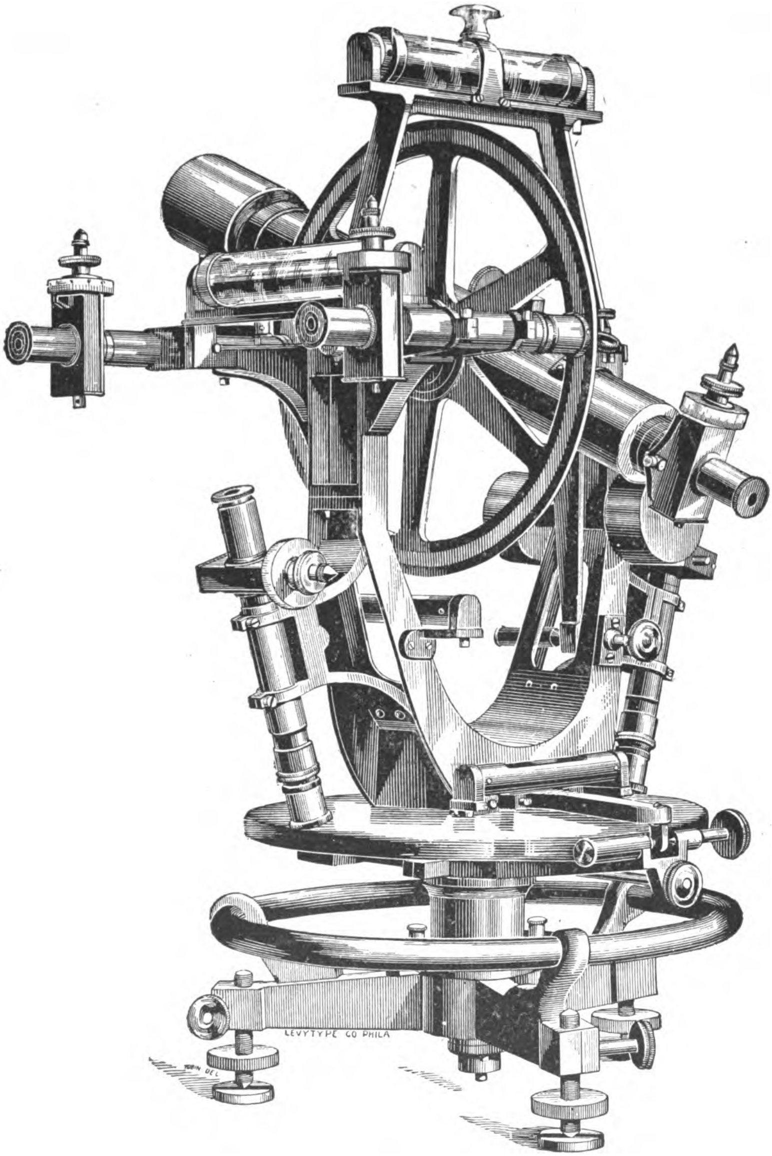
Price..$450 00



No. 8.—10-inch Altitude-Azimuth.

For triangulation and astronomical work. Horizontal circle reads to seconds by two micrometer-microscopes, every degree numbered; vertical circle to 20 seconds by vernier, sensitive striding-level, telescope $1\frac{3}{4}$-inch aperture, field illumination with lamp and lamp stand, direct and diagonal eye-piece; packed in two boxes, with stand.

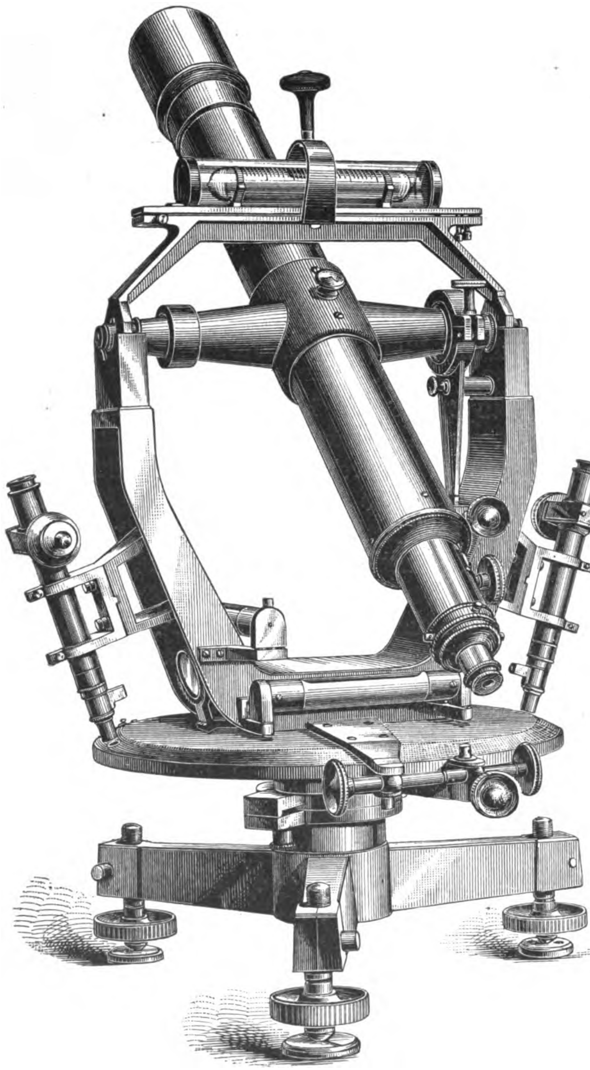
Price..$850 00



No. 9.—10-inch Altitude-Azimuth.

Same as the preceding, but also having a 10-inch vertical circle reading to seconds by micrometer-microscopes. Complete in two boxes, with stand.

Price.. **$1,000 00**



No. 10.—12-inch Theodolite.

The above cut, No. 10, represents a 12-inch Theodolite, intended for primary triangulation. Circle, of 12 inches diameter, reads by 2 opposite micrometer-microscopes to single seconds; every degree numbered; telescope $2\frac{1}{2}$-inch aperture, 24-inch focus; power 30 and 60 diameters; chambered striding-level, with improved mounting, circle free of clamps, and provided with cover; field illumination. Packed complete $800 00

The same, with vertical circle of 8-inch diameter, reading to 10 seconds, with fine level for double zenith distances.. .... 1,000 00

18-INCH ENGINEER'S Y LEVEL.

The telescope has an aperture of $1\frac{3}{8}$ inches and magnifies 35 diameters. Erecting eye-piece with perfectly flat field. Improved arrangement to bring the cross-wire into exact focus. Protection to the object slide. Hard bell-metal rings and centres. Long sensitive level, graduated on the glass. Clamp and tangent attached to the levelling-bar under the eye-piece. The telescope is balanced when focussed for mean distance. Abutting stops to set the wires horizontal and perpendicular.

The instrument does not detach from the levelling-head; it packs into the case erect. The case contains sun-shade, screw-driver, and adjusting pins.

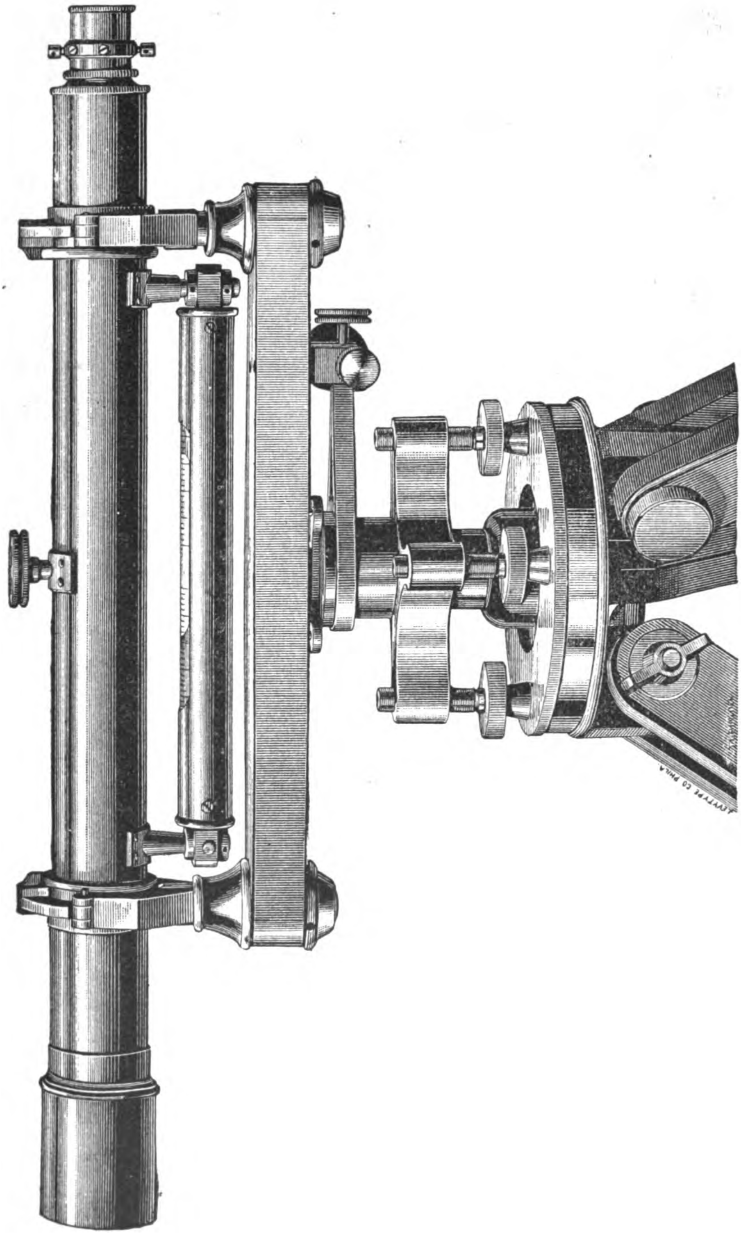
Weight of instrument about 11 pounds.

Weight of tripod about 7 pounds.

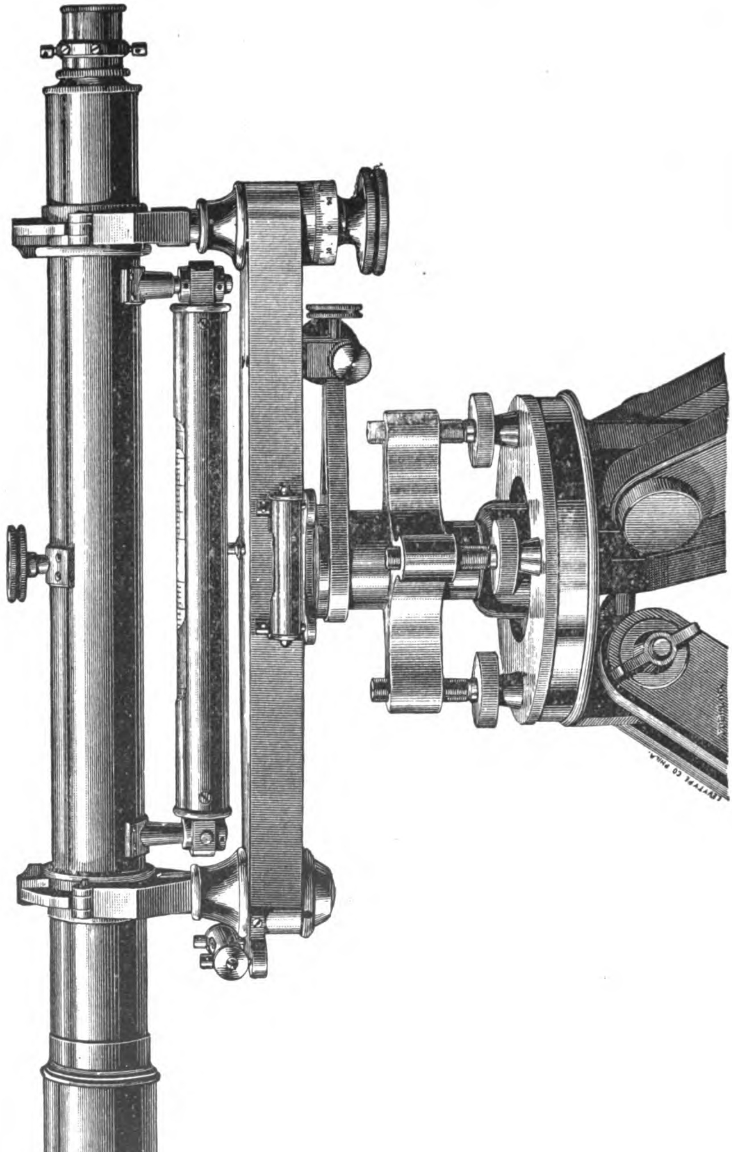
Price..$145 00

Extras to **Y** *Level.*

Attachable mirror, to read the level from the eye-end..................$10 00
Hardened steel centre.. 10 00
Fixed stadias (1 in 100).. 3 00
Gossamer cover... 1 00



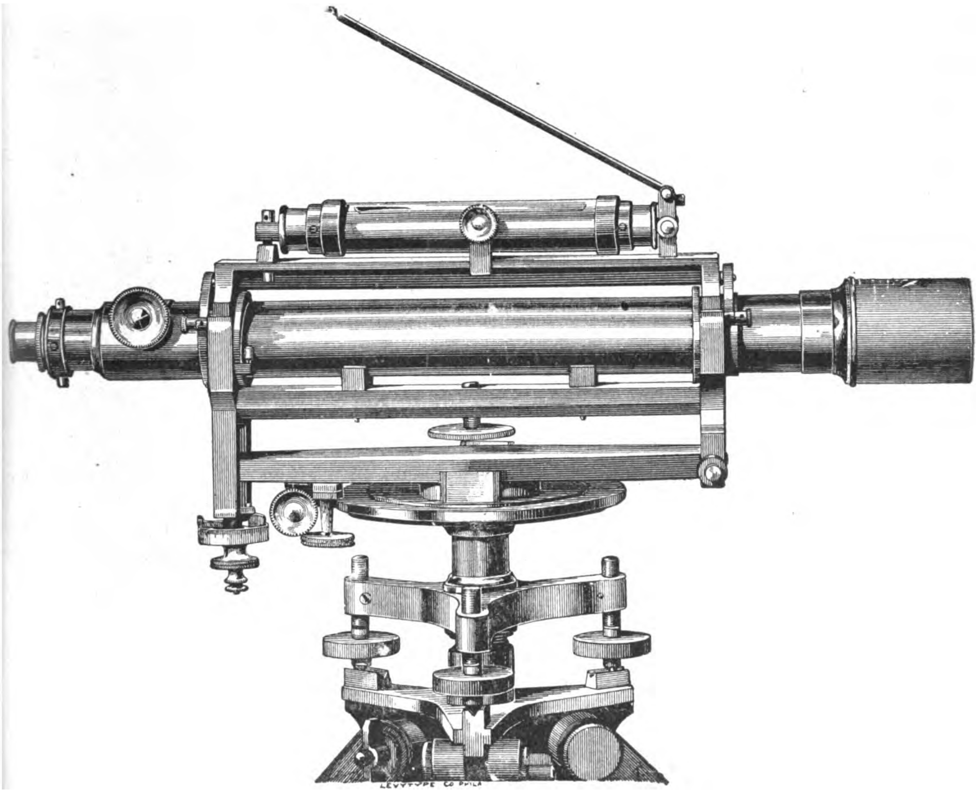
No. 11.—18-Inch Engineer's Y Level.



No. 12.—Precision Y Level.

Same as the preceding, but with one of the **Y**'s movable by means of a graduated micrometer-screw. It is intended for very accurate work.

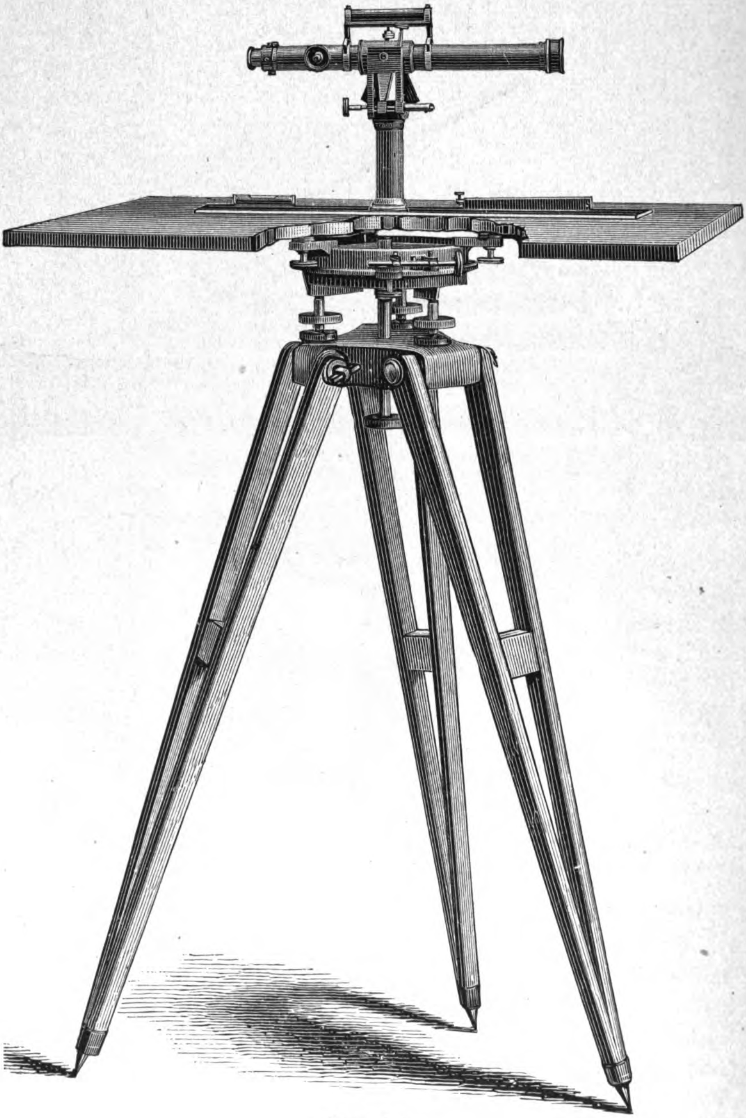
Price...$185 00



No. 13.—Level of Precision.

Level of Precision for the most exact work can also be used as a gradientor, the micrometer-screw for raising or depressing the telescope being made with the utmost exactness, and provided with a graduated head. The telescope has an aperture of 1½ inches, 16 inches focus, with two astronomical eye-pieces, magnifying 40 and 60 times, respectively. The striding-level is chambered, and one division equals 3 seconds of arc. The horizontal circle, of five inches diameter, divided on silver, reads to 30 seconds; the centre is of steel; clamp and spring tangent motion. Completely packed, with tripod. $325 00

PLANE-TABLE.



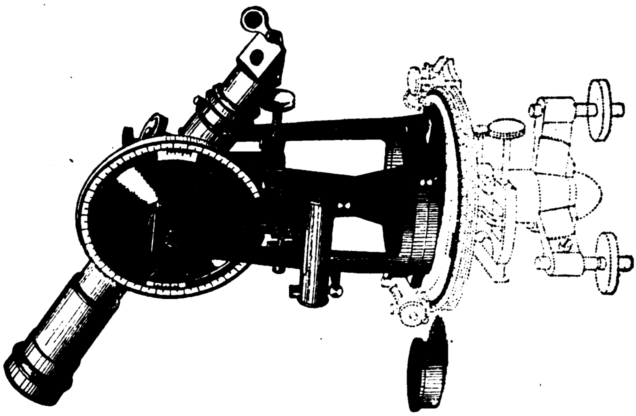
No. 14.

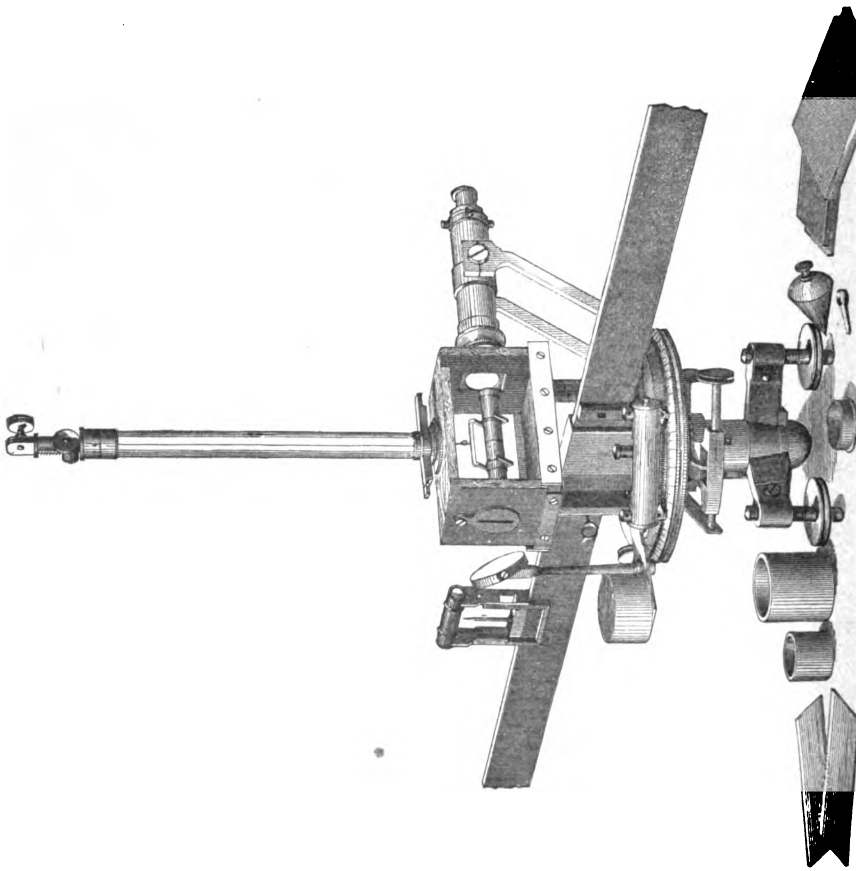
No. 14.—The above cut represents one of our Plane-Tables with a portion of the board cut out to show the motion-work. It is the most simple and effective form of Plane-Table made. The bearing surface of the motion-work being 8 inches in diameter, the table, when clamped, is perfectly firm. The alidade rule is 20 inches in length, and carries a powerful telescope of 1¼ inches aperture and 15 inches focus. For easier adjustment of collimation the telescope can be turned in its axis 180°. The compass-box is detachable; needle 5 inches long; striding-level reading to minutes. Stadia lines for measuring distances, besides the ordinary cross-line, are ruled on glass diaphragm. The vertical arc reads to minutes. The board is 24 by 30 inches and is packed in an extra box. The alidade is in a box with a number of paper clamps, besides the usual accessories; the motion-work also in a separate box.

Price, complete, with firm tripod stand $300 00

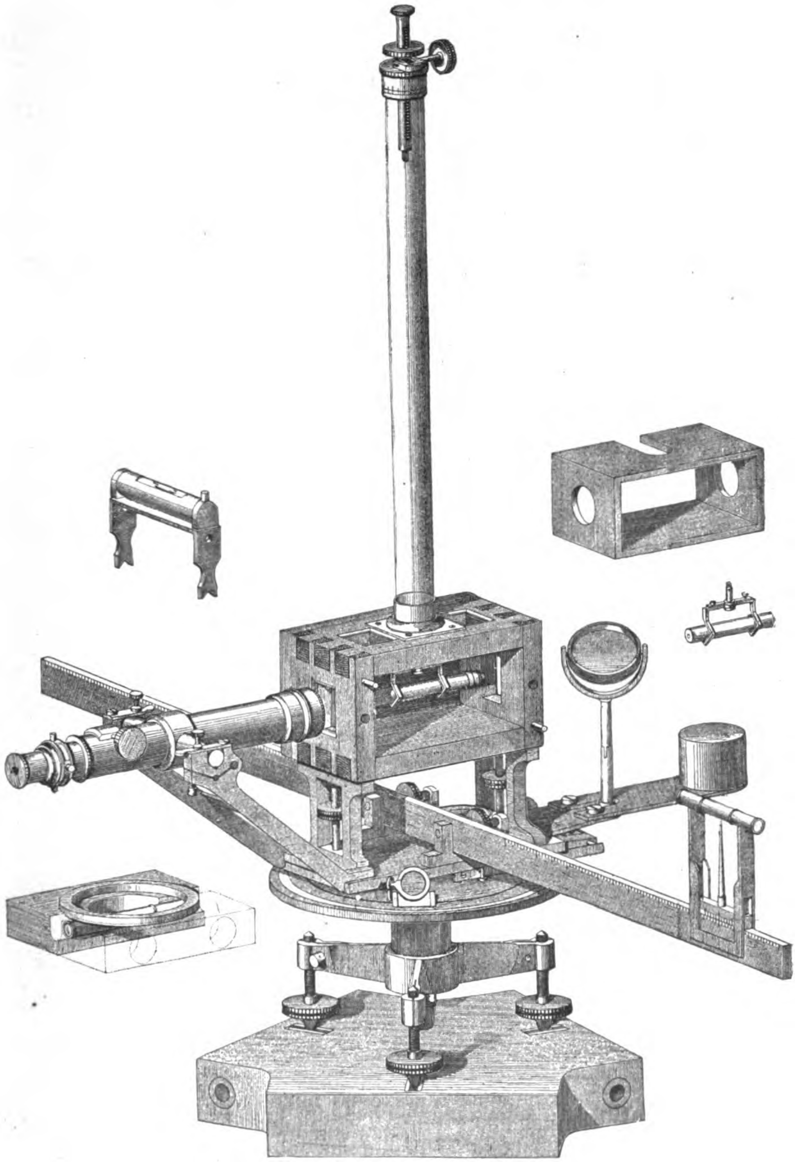
MAGNETOMETER.

No. 15.—Magnetometer, as made by us for the United States Coast and Geodetic Survey. The magnet-box and small telescope, by which the scale of the intensity-magnet is read off, is detachable from the vernier-plate, and the standards, with the telescope of ⅛-inch aperture and 7 inches focus, can be substituted; it then forms a complete small Alt-Azimuth, large enough to obtain, with sufficient accuracy in magnetic work, time, azimuth, and latitude. The circles are five inches in diameter, divided on silver, and read by two opposing verniers to minutes. The telescope has prismatic eye-piece and sun-shade. The deflecting bar is of wood, four feet in length, in two pieces, for convenient carrying. It is divided to tenths of inches. The intensity-magnets have at one end a finely-divided scale (one division being equal to 5 minutes), and at the other a collimating lens; the scale is viewed through a small telescope; tenths of divisions can easily be estimated. Rack and pinion movement to raise and lower the stirrup carrying the magnet. A riding piece fits on the deflecting bar, upon which the deflecting magnet is placed; inertia-ring, twist-piece, together with the usual accessories, accompany the instrument. Price, complete, as shown on cut, packed in box, with tripod.............$500 00



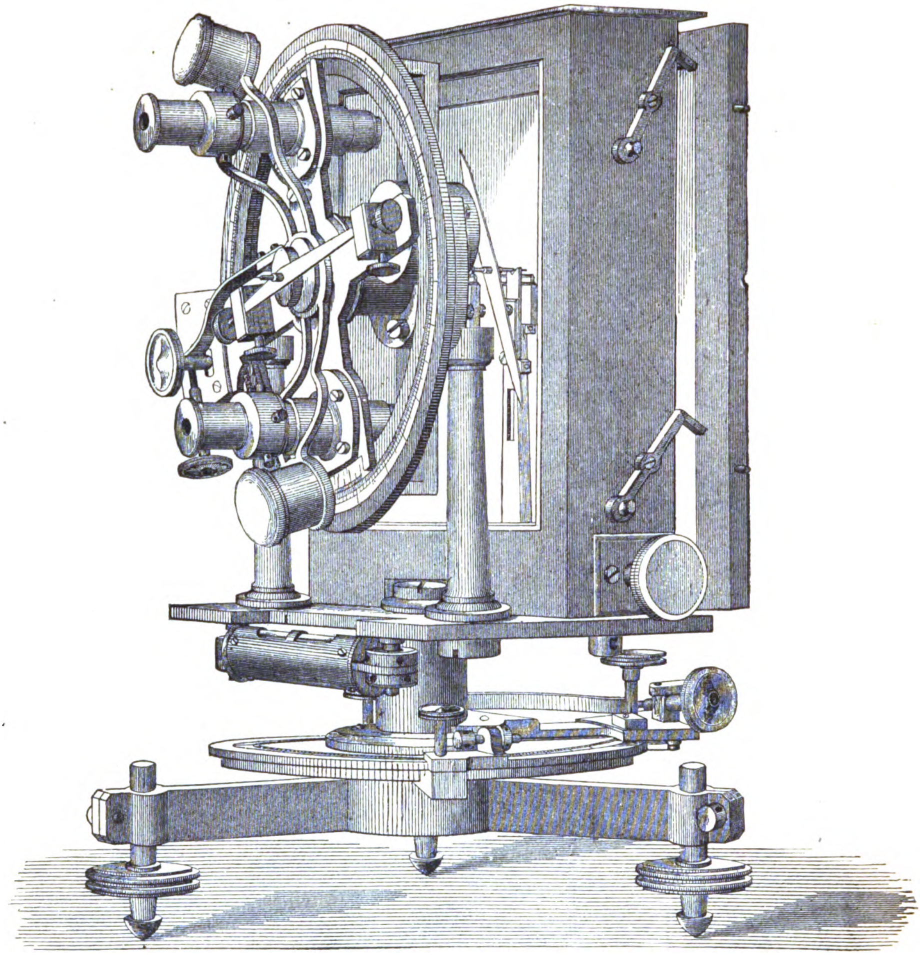


No. 15.—Magnetometer.



No. 16.—Magnetometer.

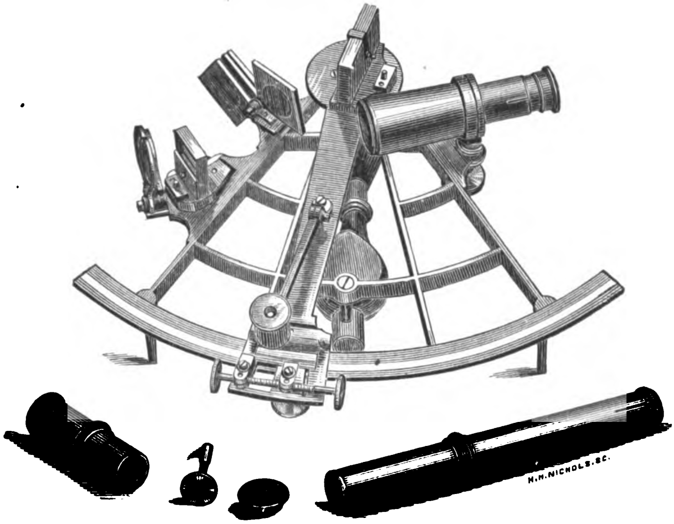
No. 16.—Magnetometer, as made by us for U. S. Corps of Engineers, with only one telescope, used both for determining the magnetic and astronomical meridian. The magnet-box is detachable from the vernier-plate, and telescope can then be used to observe for time or azimuth. Two collimating magnets, deflecting bar, and accessories. Price, completely packed, with tripod............................$300 00



No. 17.—Dip Circle.

No. 17.—Dip Circle, with two $3\frac{1}{2}$-inch needles, swinging on agate and enclosed in glass case. Vertical circle, 6 inches diameter, divided on silver, reading by two opposing verniers to minutes. Attached to the vernier arms are two microscopes to read off the magnets. The lower horizontal circle is also 6 inches in diameter, and reads to minutes. Packed complete in one box, with two large steel magnets and needle-holder for convenience in magnetizing the needles, with usual accessories.. $300 00

SEXTANT.



No. 18.

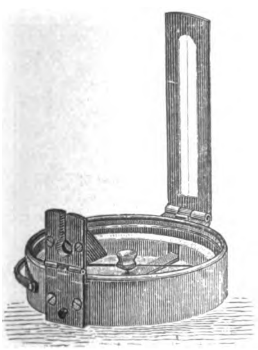
The above cut represents our style of Sextant, which, although very light, is an exceedingly accurate instrument.

No. 18.—Sextant of 7½ inches radius, divided on silver, and reading to ten seconds. The cut shows all accessories. In box complete..... $150 00

ARTIFICIAL HORIZON.

No. 19.—Artificial Horizon, with mercury bottle and trough, rectangular plate-glass cover, packed in mahogany box.......................... $30 00

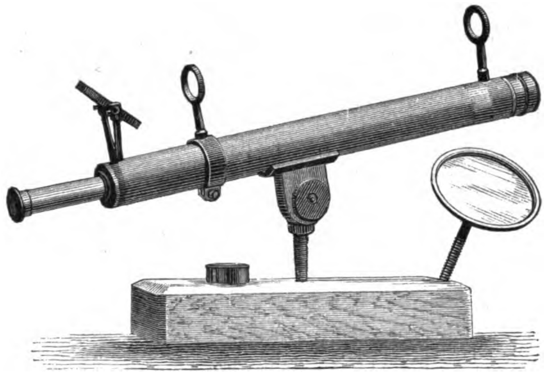
POCKET COMPASS.



No. 20.

No. 20.—Prismatic Compass, 3 inches diameter, with divided ring on needle and folding sights; packed in neat case, very convenient for reconnoissance $35 00

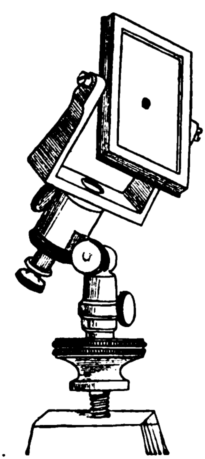
HELIOTROPES.



No. 21.

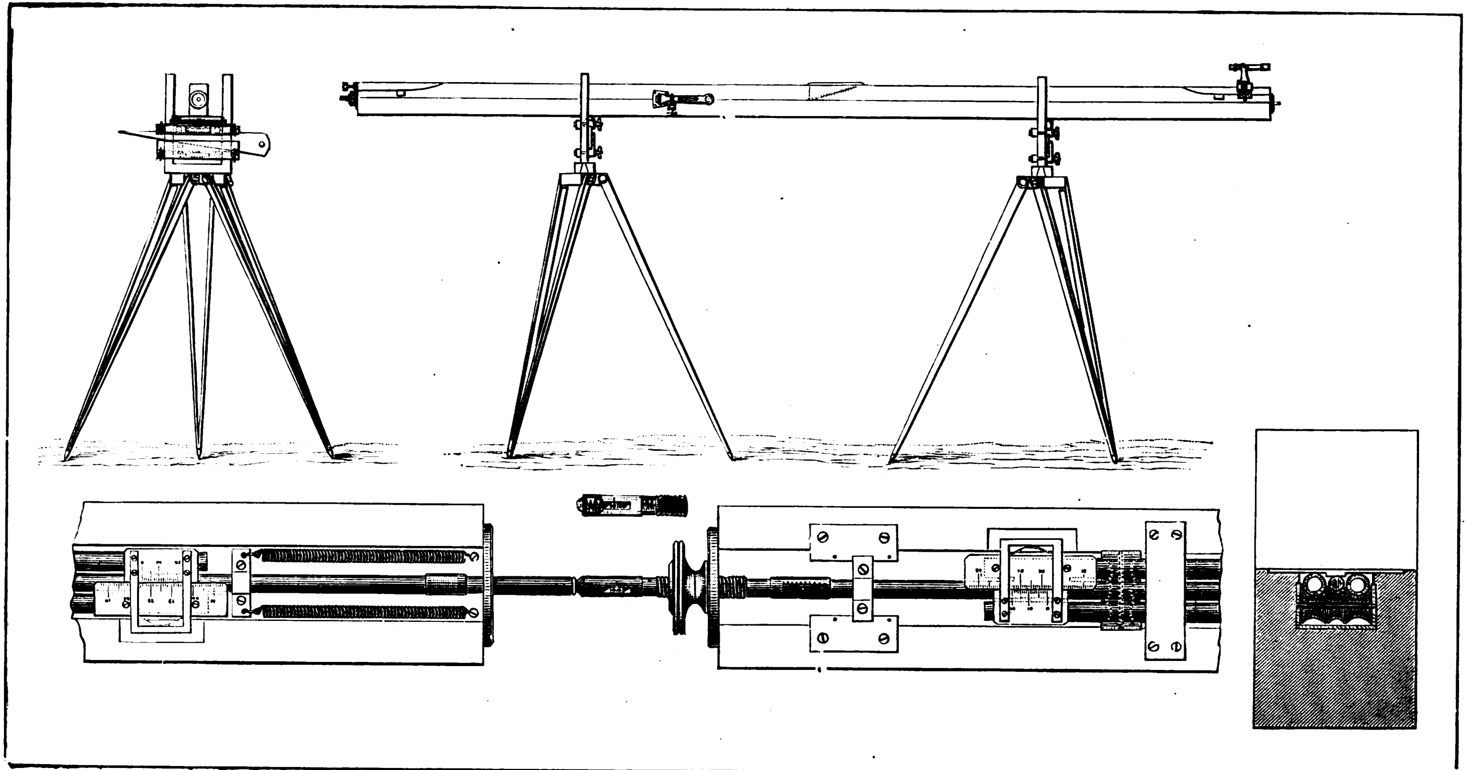
No. 21.—As made by us for the United States Coast and Geodetic Survey. The telescope body is an iron tube; in the middle is a wood screw with joint for attaching the instrument to a tree or post. Mirrors of plate-glass. Price, in box........................... $30 00

No. 22.—Heliotrope, on tripod, with horizontal and vertical axis; a graduated circle for reading angles. Price, boxed............... 75 00



No. 23.

No. 23.—Pocket Heliotrope, Steinheil's; a beautiful instrument that requires no adjustment. In case... .... $35 00



No. 24.—Base Apparatus.

Cut No. 24 represents a perfected form of the Contact-Slide Base Apparatus, as made by us for the U. S. Coast and Geodetic Survey.

The apparatus consists of two measuring bars 4 meters long, exactly alike, supported on trestles. The measurement is made by bringing these bars successively in contact, which is effected by means of a screw motion and defined by the coincidence of lines on the rod and contact-slide. Each bar consists of two pieces of wood about 8×14 cm. square and a little less that 4 meters long, firmly screwed together. Between the pieces of wood is a brass frame carrying three rollers, on the central one of which rests a steel rod about 8 mm. in diameter. On each side there is a zinc tube 9 mm. diameter. The rod and tubes are supported throughout their length on similar systems of rollers. The zinc tubes form with the steel rod a metallic differential thermometer, and are so arranged that one tube is secured to one end of the rod, being free to expand in the other direction, the other tube being in a like manner fastened to the other end of the rod. The zinc tubes, therefore, with any change of temperature, expand or contract in opposing directions, and the amount by which the expansion of the zinc exceeds that of the steel is measured by a fine scale attached to the rod, while the zinc tube carries a corresponding vernier. The cut shows this arrangement, which is identical on both ends of the bars; a perforation in the wood of the bar allows this scale to be read. In addition to these metallic thermometers a mercurial thermometer is attached to the bar about midway of its length.

The rods and tubes thus forming a united whole are lengthwise movable on the rollers by means of a milled nut working in threads cut on the steel rod, which passes through a circular opening in the brass plate screwed to the wooden bar, and against which the nut presses. Two strong spiral springs pull the rods back, and the nut is always pressed against the plate.

One end of the rod is defined by a plain agate securely fastened to it; the other end carries the contact-slide, having an agate with a horizontal knife edge. This slide is a short tube, fitting over the end of the rod and pushed outward by a spiral spring. A slot in the tube shows an index-plate, with a ruled line fastened to the rod.

To align the bars properly a small telescope is placed on each bar, and can be adjusted to bring the line of collimation over the axis of the rod. The trestle, shown in the upper left-hand corner of the illustration, consists of a strong tripod stand, carrying a frame with two upright guides for two cross-slides, which are separated by a movable wedge. These cross-slides can be clamped in any position. By moving the wedge, the bar resting between the uprights is either elevated or depressed. To obtain smooth movements, friction rollers are provided. To move the bars sideways, a coarse screw takes hold of a projection on the lower side of the bar, by turning which the bar can be moved laterally.

There are three pairs of trestles, alike in construction, with the exception that the upper slide of the trestle intended for the forward end of the bar carries a roller on which the bar rests, while the other has a fixed semi-cylindrical surface for the support of the bar. In making the measurement, the bars being four meters in length, the stands are set up at a distance of two meters, each bar being supported at one-fourth its length from the ends, as indicated by painted black bands.

Each bar has a sector with level alidade attached to one side, by which its inclination can be read off to single minutes.

All base bars constructed by us are compared with U. S. standards.

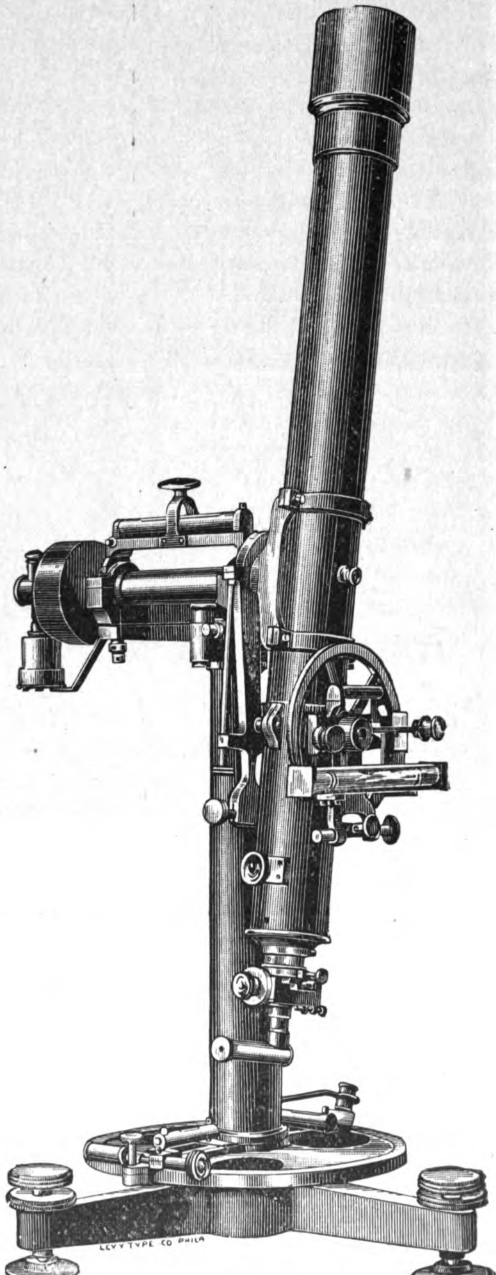
Price of the whole apparatus, including two bars and six trestles......$550 00
Price of simple 4-meter Standard Bar............................ 90 00
Price of Abutting Piece and Level Comparator to test bars.......... 125 00

NOTE.—Bars of the same construction, in feet instead of meters, can be furnished.

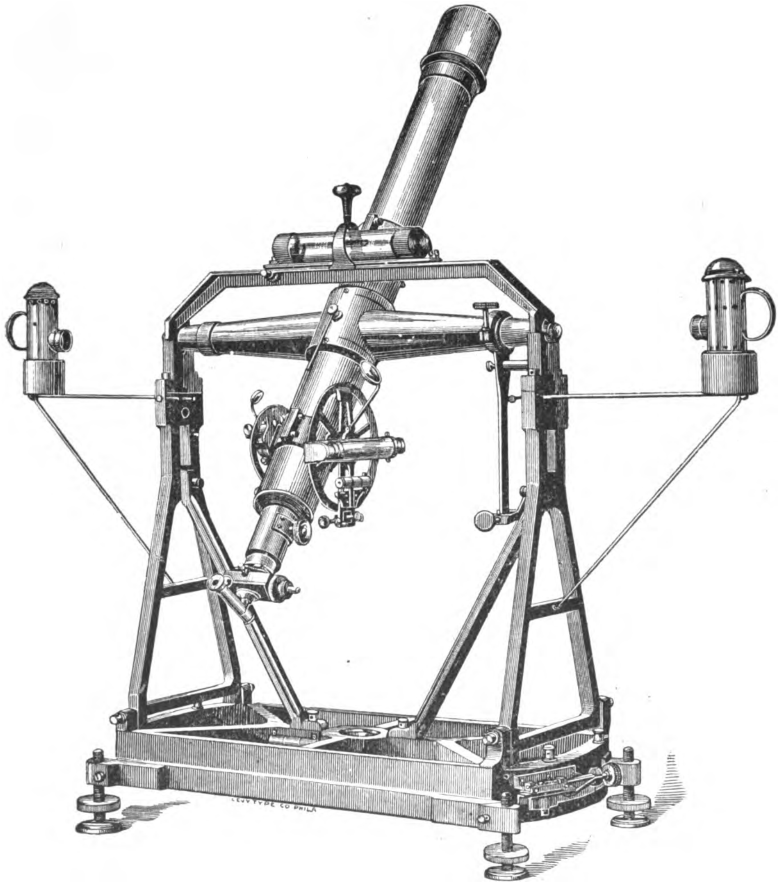
ZENITH INSTRUMENTS.

No. 25.—Following cut represents the most improved form of Zenith Telescopes. The telescope swings on a horizontal axis, which is fastened to a vertical axis, and can therefore be moved into any position. It is especially adapted for the determination of differences of zenith distances. Graduated horizontal circle with clamp and tangent. The telescope, of 3-in. aperture, carries a circle with the fine latitude level, and is provided with a micrometer eye-piece.

Price...$1,000 00



No. 25.—Zenith Instrument.



No. 26.—Combined Transit and Zenith Instrument,
as devised by Prof. G. Davidson, U. S. Coast and Geodetic Survey.

No. 26.—The frame of this instrument consists of two parts, the upper part with the uprights revolving upon the lower, to which it can be firmly clamped if used as a Transit. When used as a Zenith instrument, the clamp-screws are removed; stops and tangent-screw motion for turning it exactly 180° are provided. Two verniers and scale are attached to the upper and lower base. The telescope has a clear aperture of 2½ inches, and is about 28 inches focal length. It is provided with micrometric eye-piece; two setting circles, divided on silver, and reading to minutes, attached to the telescope-tube near the eye-end; one of these carries the delicate zenith level, which reads to single seconds and is chambered; also, an ordinary finding level. The clamp is the latest improved pattern, and need not be carried around with the telescope when reversing. The pivots are of hard steel, and finished with the utmost care; bearings are agate. The illumination is effected through the pivots; the striding-level is chambered, and reads to single seconds. A Ramsden eye-piece, diagonal eye-piece, two illuminating and one reading lamp, are provided. The stand folds, and is packed in box with the telescope.

Price, complete...$1,000 00

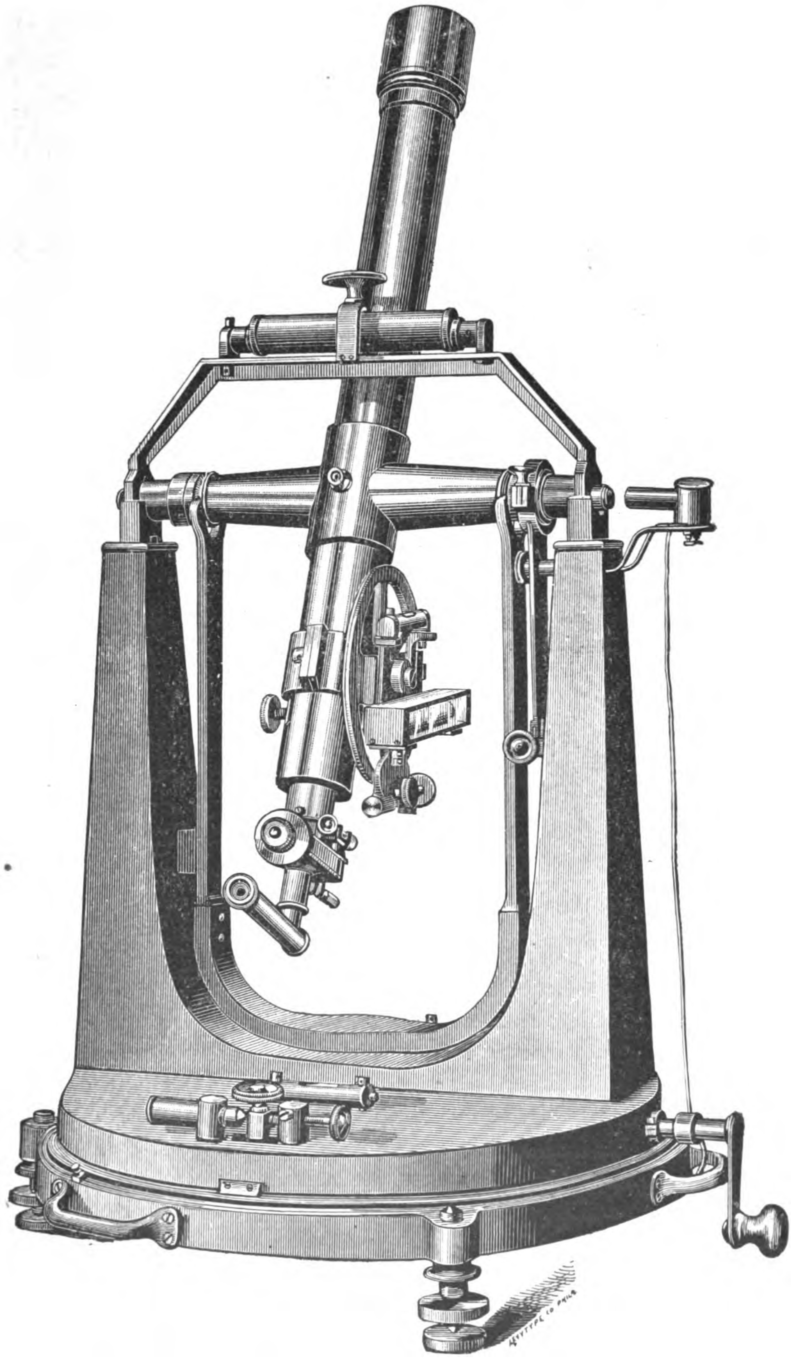
No. 27.—Same, with telescope of 3 inches aperture, the whole instrument being correspondingly larger................................ 1,200 00

NEW COMBINATION TRANSIT AND ZENITH TELESCOPE.

No. 28.—This instrument possesses several advantages over the preceding form. The base is circular, and the upper part moves smoothly upon the lower without disturbing the azimuth; this latter is provided with a graduation.

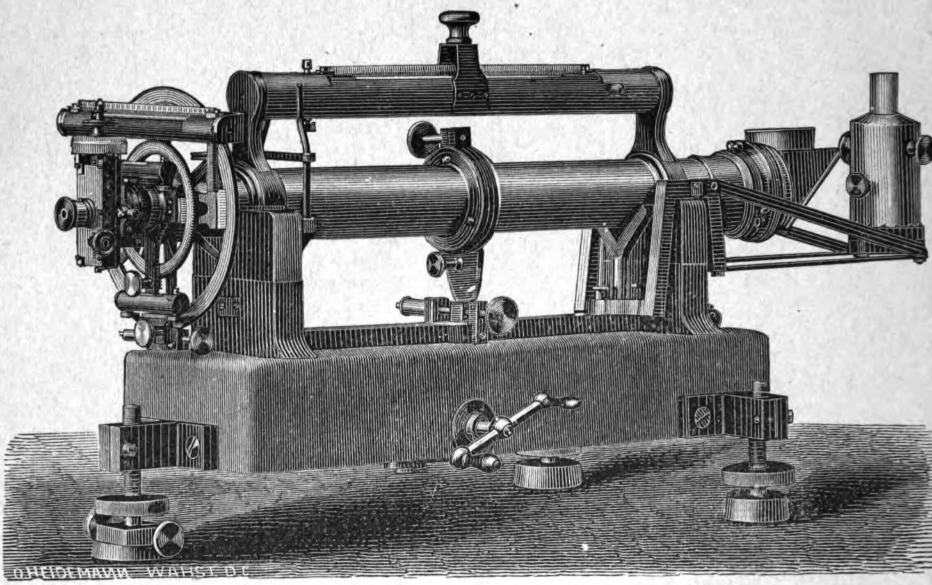
The instrument is provided with a reversing apparatus, and can be manipulated with the greatest ease. It is very rigidly built, although the entire instrument weighs less than 100 pounds. Telescope 3 inches aperture, striding and latitude levels reading to single seconds, eye-piece micrometer, with diagonal eye-piece and swivel adapter, packed in two boxes.

Price..$1,200 00



No. 28.—New Combination Transit and Zenith Telescope.

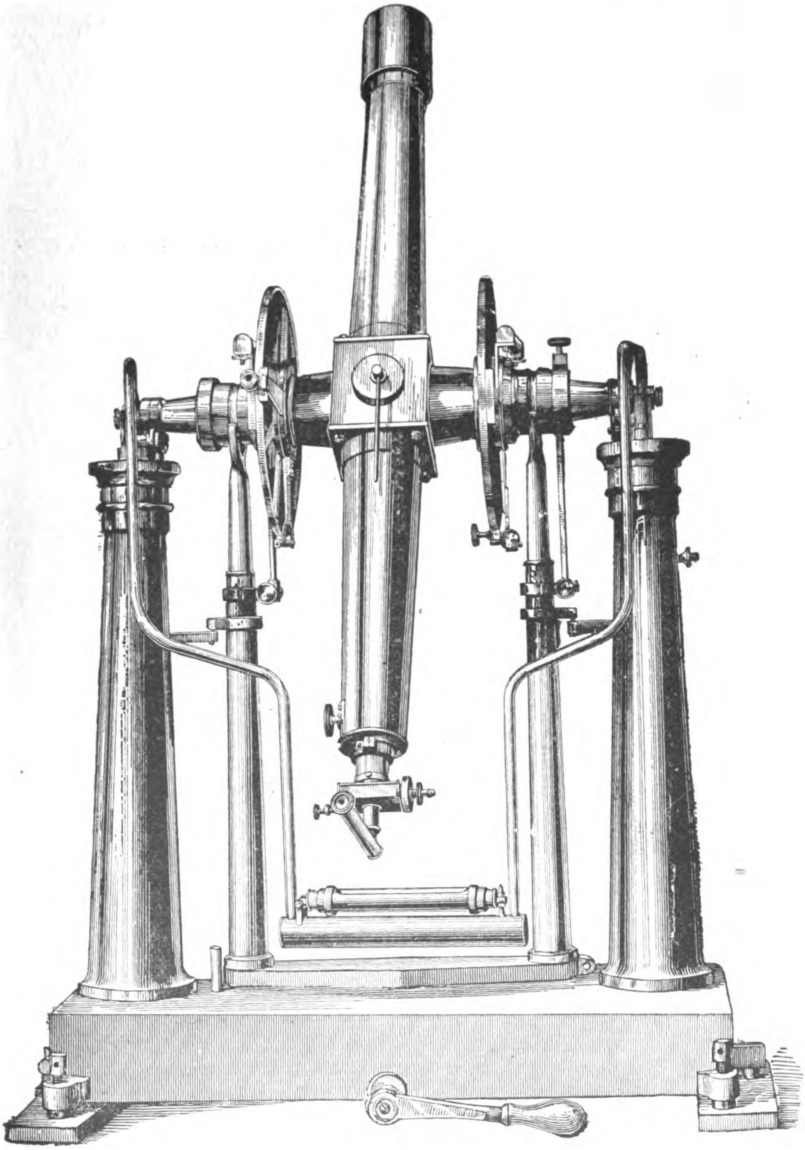
TRANSIT INSTRUMENTS.



No. 29.—The Coast Survey Prismatic Transit.

This form of Transit, suggested by Steinheil, designed by G. N. Saegmuller, was made by us for the United States Coast Survey. It is intended to be set up in the prime vertical, the telescope pointing east and west. By the use of a prismatic objective, any star passing the meridian will be reflected and seen in the field when the instrument is set up correctly; by turning it in its bearings it will sweep the meridian. The pivot-rings are of phosphor bronze, and, to avoid flexure as much as possible, these rings are again connected by a tube, so that the telescope body is really double. By one of the three setting-screws the instrument is moved in azimuth. It is provided with a reversing apparatus, which also carries the illuminating lamp. The fine level over the telescope is held by a projection from the reversing apparatus, which secures the great advantage that the level need not be taken off on reversing the instrument; it remains on whether observing in the zenith or horizon. The setting-circle is attached behind the micrometric eye-piece with level alidade, divided on silver, and reading to minutes. It also carries the latitude level, which is chambered, and reads to single seconds. This instrument, being very simple and portable, is especially adapted for work in a rough or mountainous country.

No. 29.—Telescope of 2½-inch clear aperture, packed complete in box, with two eye-pieces, illuminating and reading lamp, and all accessories...$850 00



No. 30.—3-inch Transit.

No. 30.—Transit Instrument, of 3 inches aperture, about 3½ feet focus. The axis carries two 12-inch circles, one reading to 10 seconds, the other to minutes, both divided on the edge. The fine circle carries the latitude level. We make this transit with striding or hanging level, the latter of same construction as shown in cut No. 34; the counterpoises hang on the inside of the pillars. The iron stand has the necessary adjustments for altitude and azimuth. Reversing apparatus, mercurial basin, diagonal, direct, and collimating eye-pieces, lamps, etc. Price $1,000 00

No. 31.—The same, with 6-inch setting circle, and level alidade on axis; delicate striding-level; glass micrometer instead of spider-lines; direct and diagonal eye-piece, improved clamp. One of the Y's can be moved in azimuth, the other in altitude, and there be firmly clamped. Reversing apparatus, lamps, etc 790 00

No. 32.—The same, with 2-inch telescope, without reversing apparatus 500 00

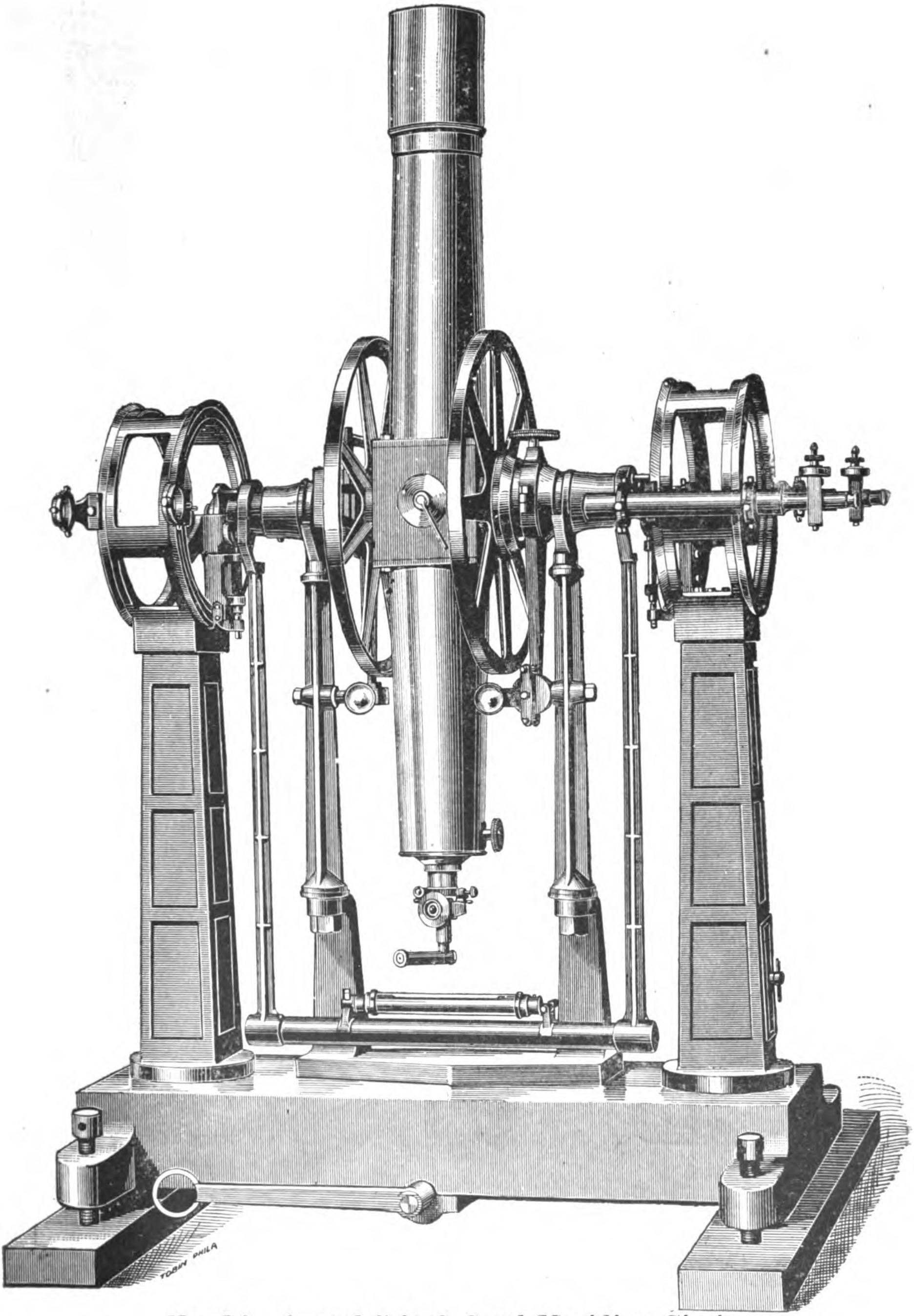
No. 33.—"Outfit" Transit. This is the cheapest Transit we make; it has a telescope of nearly 2-inch aperture with a good objective (not of the first quality), bell-metal pivots; 1 division of striding level equals about 3 seconds; small silvered finding circle, glass reticle, and prism. There is no diagonal eye-piece, and the whole instrument is made as simple as possible in order to keep the price low. Nevertheless it is a very good instrument for time observation.

Price $175 00

NEW STEEL MERIDIAN CIRCLE.

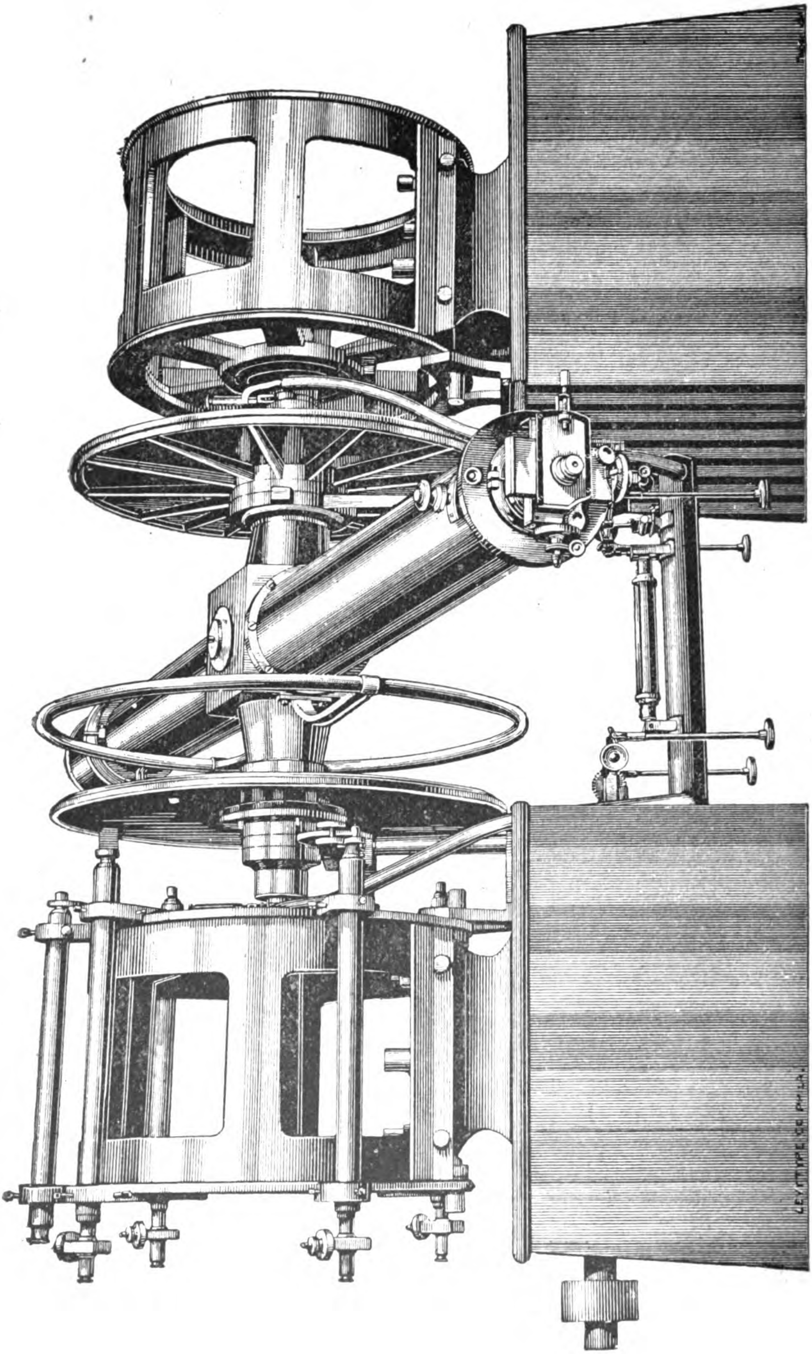
No. 34.—This instrument takes the place of our old 3-inch Meridian Circle. It is built entirely of cast-iron and steel, greatly improved in design, as a glance at the cut will show, and is in fact a new instrument. As the graduations which we are enabled to produce now are of such excellence we had to use a larger telescope in order to make its pointing power equal to the accuracy of the graduation. With a clear aperture of 4½ inches we claim that fundamental work can be done with this instrument, although it is of the semi-portable kind, being complete in itself and ready to be set up on a pier. By placing the circles near the telescope we are enabled to lift it by merely giving the handle at the base one half turn; the telescope can then be turned end for end, and a reverse turn of the handle brings it down into its bearings; it takes less than a quarter of a minute to reverse the telescope. The microscope-holders are circular, allowing the microscope to be placed into any position; the counterpoise weights hang on the inside of the pillars. One of the circles is divided on silver into 5-minute spaces, every degree being numbered, and the other has a coarse graduation for finding purposes at the edge. The level hangs entirely free, and is more convenient and more certain in its action than a striding-level would be. The iron stand is provided with the necessary adjusting screws for movement in altitude and azimuth.

Price of instrument, with 4-inch telescope, 16½-inch circles, sensitive striding-level, diagonal, direct and collimating eye-piece, mercury basin, 2 lamps $1,850 00



No. 34.—4- and 5-inch Steel Meridian Circle.

FIXED MERIDIAN CIRCLES.



No. 35.—Cincinnati Meridian Circle.

Cut No. 35 represents a Meridian Circle of the first class of the old type. While fully equal to other Circles of same size and doing first-class work, it cannot compare with our latest form as far as accuracy and simplicity of manipulation are concerned.

In our latest form of Meridian Circles and large Transits, one being about completed for the new Naval Observatory, the counterpoising and reversing apparatus is concealed below the floor and is fixed there. The piers are thus relieved of all load, excepting the few pounds with which the telescope is resting in the Y's, and as the counterpoise is arranged exactly like a scale-beam resting on hardened knife-edges, its action is at once decisive and delicate, and insures the certainty that both pivots rest with the same weight on each Y. During reversal the counterpoises take care of themselves, and the piers remain absolutely undisturbed, as there is no weight taken off.

In order to reverse the instrument end for end it is only necessary to turn the handle at the west pier until it comes to a dead stop. The instrument has then been lifted, turned 180°, and been lowered again into its bearings. Less than half a minute is required for this operation.

Any one who has worked with the old style reversing wagons will appreciate our improvement. There is absolutely no danger of injury to the instrument during reversal. The operation can be performed in the dark, and it takes but very little time to do it. By an ingenious arrangement, devised by Prof. Wm. Harkness, U. S. N., the Level can be read by means of a small telescope in a very comfortable position.

Wherever it was possible we have simplified the instrument, and have constructed it with a view to the use of steel throughout. The instrument is lighter, stronger than if made of brass, and there is but little polish about it.

CHRONOGRAPHS.

Cut No. 36 represents our style of Chronograph, which, for compactness and regularity of action, cannot be surpassed. It is noiseless, and the governor regulates the speed so perfectly that the second marks form an accurate straight line. The cylinder is 14 inches long, 7½ inches diameter, so that one second is exactly 10 mm. long. An ordinary meter scale will answer to read the sheets with.

The clock-work is provided with maintaining power, which permits winding up without retarding motion; it is strong enough to drive several cylinders, which can readily be attached. The speed of the cylinder can be doubled so as to turn once in 30 seconds, which is especially convenient in exchanging clock signals in longitude work.

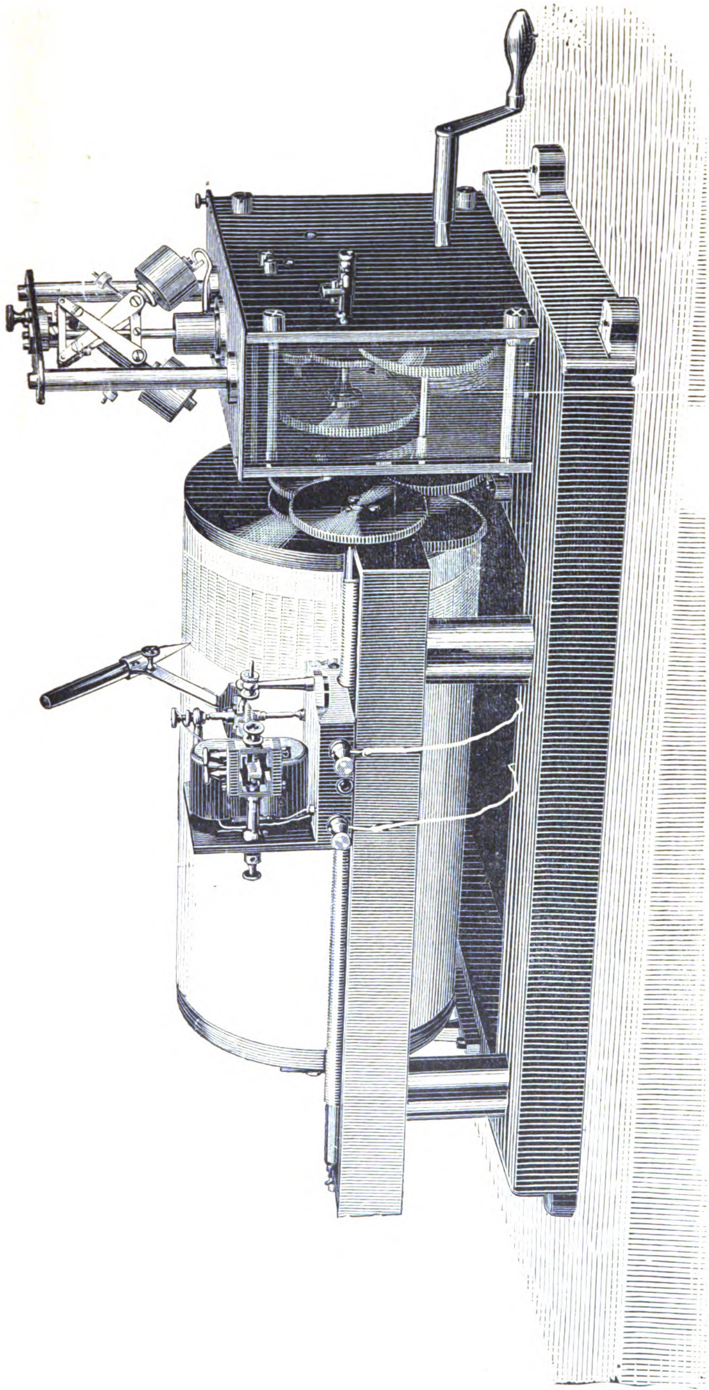
Price, with fountain pen and 100 sheets of paper and reading scale....$355 00

NOTE.—Our Chronographs are not provided with electric control. It is not only entirely unnecessary, but its use absolutely wrong in connection with a Chronograph. The case is entirely different with driving-clocks for equatorials.

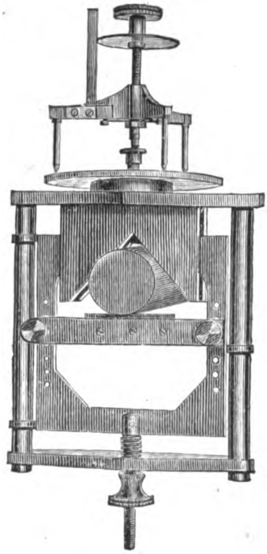
No. 37.—"Outfit" Chronograph, barrel 7 inches long, 4 inches diameter; one second is thus a little more than 5 mm. A nice little instrument, plenty good enough for ordinary time observation.

Price $150 00

NOTE—This price includes nothing but the Chronograph, with the weights.



No. 36.—Chronograph.



No. 38.—Spherometer,
as devised by Prof. Wm. Harkness, U. S. N.

A beautiful and exceedingly accurate instrument for measuring the inequality of pivots; much more reliable and expeditious than the contact level. As made by us, it will measure pivots from 2½ inches down to the smallest size. The glass disc on which the three legs rest is perfectly flat; the screw is made with the utmost exactness, bearing on a jewelled centre, and the nut is so constructed that there can be no dead motion. Price, as shown in cut, in box.................. $60 00

MERIDIAN MARKS (MIRES),

As made by us for the new Naval Observatory. They are operated from the observing room, the switch being located on the side of one of the piers. By turning this to the right the door of the Mark opens, and at the same time closes a circuit and lights the small incandescent lamp which is located inside the Mark, and which serves as the artificial star. The size of the hole through which this light is visible can be changed at will. By turning the switch to the left, the door is closed again and the lamp extinguished.

These Marks, in shape like a little house, measure 12 inches square at the base, and are about 18 inches high. They are firmly bolted to solid stone piers, located due north and south from the instrument, and as far away from it as practicable. When it is necessary to place them close to the instrument a collimating lens is introduced between the telescope and the Mark to prevent the necessity of changing the focus.

COLLIMATORS.

All sizes, horizontal and vertical, with telescopes from 2 to 6 inches aperture.

ASTRONOMICAL CLOCKS.

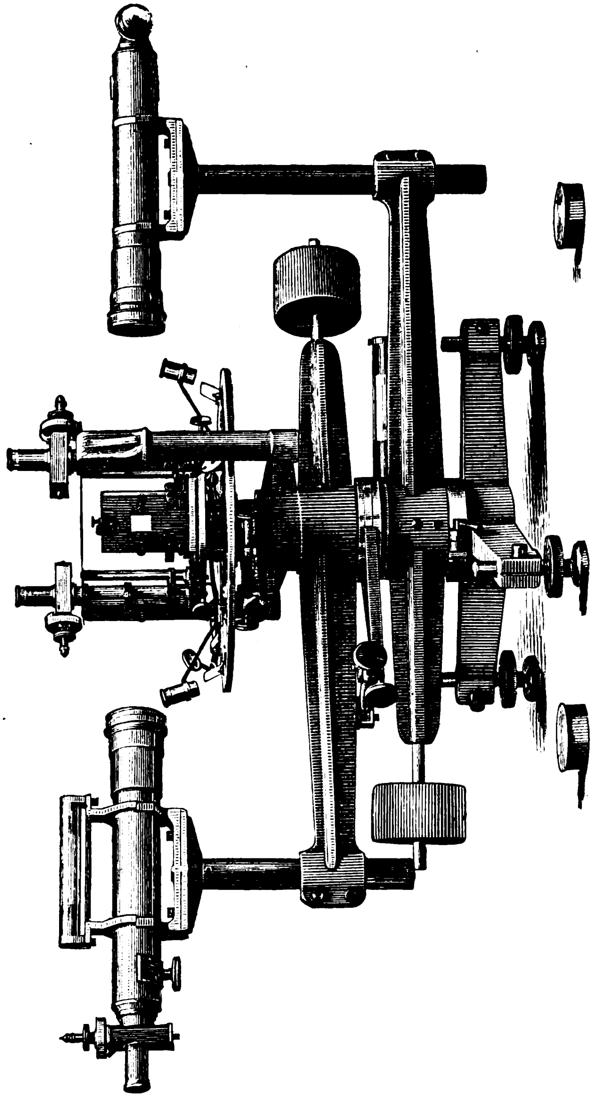
No. 39.—We make two kinds of clocks. No. 1, the cheaper kind, is the one which we supply with our cheap outfit. It is a well-made Clock, having dead-beat escapement, mercurial pendulum, and break-circuit attachment. In this Clock this is done by the pendulum. 9-inch full minute dial, extra second and hour dial ....Price, $160 00

NOTE.—Owing to the difficulty of transporting mercury, we do not furnish it with Clocks. The pendulum jar is marked up to where it has to be filled with mercury.

No. 40.—**Standard Astronomical Clock** is made with the greatest care—gravity escapement, break-circuit attachment on scape-wheel arbor, zinc and steel pendulum, 13-inch full minute dial, extra second and hour dial. Case has iron back, upper parts removable to be able to get at the works..................................Price, $500 00

NOTE.—Gravity escapements require a well-cut train, but it need not be fine as long as the teeth are of the correct shape and are spaced accurately. By adjusting the pallets properly the escapement error may be made to counteract the circular error of the pendulum; hence clocks with gravity escapements have scarcely any barometric error. We find that a zinc and steel pendulum with a heavy lead bob (about 50 lbs.) is superior to the mercurial.

Photo-Chronograph (see pages 32–33) $100 00



No. 41.—Spectrometer.

Cut No. 41 represents a very complete Spectrometer, made according to the plan of Prof. C. A. Young.

We have made several sizes of this instrument, with circles from 12 to 18 inches in diameter, and telescopes from 2 to 2½ inches aperture. The circle is graduated into 5-minute spaces and read by means of two micrometer-microscopes to single seconds; these microscopes are attached to the arm carrying the observing telescope. The collimating telescope can be turned on a separate axis by itself, and the whole instrument can be rotated on another axis. The grating-table, which is provided with all the necessary adjustments, turns on a centre of its own and has attached to itself two verniers reading to 5 seconds on the graduation of the circle. Both telescopes turn in adjustable **Y**'s, for which purpose a sensitive striding-level is provided.

The price of these instruments varies according to size.

EQUATORIALS.

The great interest which has been taken in late years in celestial photography and spectral analysis has of necessity brought forth great improvements in equatorial mountings.

Rigidity in the whole apparatus and the utmost regularity in the action of the driving-clock are especially necessary. By the extensive use of steel and by judicious ribbing and bracing of parts we gain lightness without sacrificing strength. This is especially desirable in the parts which move and have to be driven by the clock.

The fixed parts, such as the pier and head-stock, may be made heavy; there is no harm in any excess of weight, as it tends to increase the stability. There is, however, no use in putting more there than is necessary, and for this reason the shape of those parts should be so chosen as to give them the utmost stiffness with a given amount of material.

The best possible cross section for a pillar is the round one, and we have adopted it for this reason, and because it requires less space than any other shape. We forego the advantage of a closet, which the square pier affords, for the sake of greater beauty and strength.

Experience has fully demonstrated the superiority of the round pillar.

The Driving-Clock is of special importance. We have calculated for different telescopes the required sizes of the clock and the number of foot-pounds they should control per hour. We arrived at these conclusions by ascertaining what weight was actually required to drive existing telescopes of different sizes.

The Regulator or Governor is the most important part of the clock. We experimented with a great many, and found the friction regulator, as suggested by Prof. Young, to be the best. This governor is so constructed that any increase in speed produces increased friction, thus retarding it again. By carefully calculating its dimensions we get it as astatic as possible, and secure a high degree of power and sensitiveness. By selecting materials with the required coefficients of friction we can make it more or less powerful. The angle which the arms make with the vertical driving-shaft must be carefully determined, and for this reason we effect the regulation for speed by moving the balls up or down in the direction of the arm.

The *Electric Control* is now universally applied to all telescopes of considerable size, as it corrects the small irregularities due to a varying load and keeps the driving-clock in unison with the standard clock. The simplest and most effective electric control we consider to be the one contrived by Prof. J. E. Keeler, which consists of a soft-iron sector clamped to the vertical axis of the governor, rotating in a horizontal plane. The sector passes very close to the poles of an electromagnet, mounted on a slightly elastic standard of steel. At every second a strong current is sent through the coils of this magnet by means of a standard clock, the circuit being closed. The driving-clock is set so as to run a little too fast, and when the governor is started the sector continually gains until it reaches the magnet of the control, when the friction produced by the attraction of the latter prevents any further acceleration. With this control no shock is communicated to the telescope. By making the magnet movable about the axis of the governor, it can at once be set to the proper position after the governor has attained its maximum speed, and then be clamped. If the governor rotates faster than once in a second, the sector can be applied to the train below the governor. Whether the polar axis will rotate with a correspondingly uniform motion depends upon the perfection of the gear-cutting in the intermediate parts of the train, and especially in the accuracy with which the worm-wheel has been spaced.

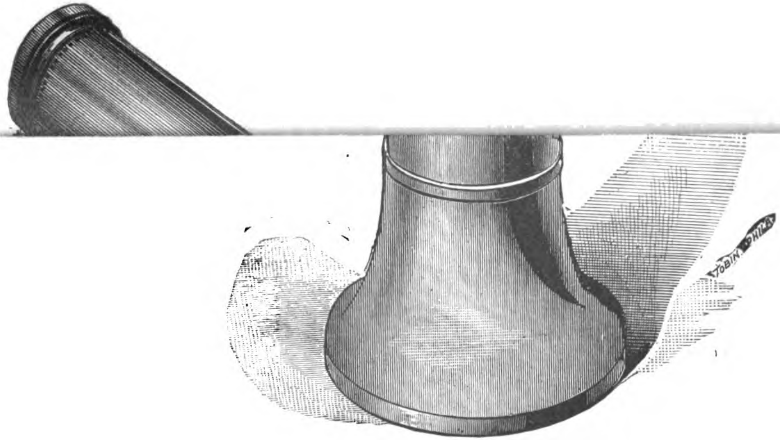
The best control is one applied to the driving-worm, as it corrects all the errors of the clock and intermediate train, it is, however, expensive, and requires a most accurately cut worm-wheel.

The *Worm-Wheels* in our Equatorials of the larger size are spaced on our dividing engine and then cut on a specially constructed apparatus; the teeth are not only spaced accurately but are cut with the correct pitch, as the cutting tooth moves forward while cutting an amount equal to the pitch.

We employ two worm-wheels; the large one is loose on the polar axis and is driven by the worm connected with the clock. A smaller worm-wheel fits loose on the large one, to which it may be clamped from the eye end of the telescope. The declination sleeve carries the worm gearing into the smaller wheel, and this worm can also be operated from the eye end. It will thus be seen that by clamping from the eye end the clock will drive the main worm-wheel and the telescope. By turning the worm which gears in the smaller wheel from the eye end, the telescope can be moved *with* or *against* the clock without checking or retarding it, and the motion is continuous, being only limited by the clamp.

It is certainly a great convenience to be able to move the telescope from the eye end both in R. A. and Declination, but it will not do to use these motions to correct by hand for long exposure in photography, as it would cause the telescope to tremble. Hand correction is necessary, especially in large telescopes, as no electric control or the most accurate gear cutting will remove the errors caused by change of refraction and flexure. This hand correction we effect by giving the clock-worm an independent motion by means of epicycloidal gearing.

Anti-friction devices are a necessity in large telescopes, especially for the



No. 42.—12-INCH EQUATORIAL.

As made by us for the Ladd Observatory, Providence, R. I.; the Georgetown College Observatory; and (with slight modifications) for the New Naval Observatory, Washington, D. C.

polar axis. The simplest and the most elegant is the one devised by the Repsolds, to whom nearly all improvements in equatorials are due since the immortal Fraunhofer devised the now universally adopted German plan of mounting.

Near the upper end of the polar axis, just below the worm-wheels, is a steel collar turned to such an angle that its lower surface is horizontal. Against this collar a vertical friction roller is forced up with a pressure equal to the weight of the moving parts of the telescope, and these moving parts rest thus on the roller in unstable equilibrium. The relief of pressure is precisely proportional to the pressure on the bearings.

We have modified this arrangement by using a number of rollers which turn loose on a spindle. As the collar is part of a cone, the roller pressing on the larger part will revolve faster than the one pressing against the smaller part, and there will be a little differential movement between the rollers. By using a number of rollers—the number depending on the size of the telescope—the weight to be relieved is proportionately divided among them all, each one bearing its part. The contact between roller and collar can thus be made very small, as theoretically it should be a point. But a point will not sustain much weight, and in order to overcome the grinding friction which would result from a broad contact between a conical and a cylindrical roller we divide up the weight among a number of rollers. Each one is slightly rounded and touches the collar only in the middle.

Excepting for very large telescopes there is no use to relieve the friction of the Declination axis.

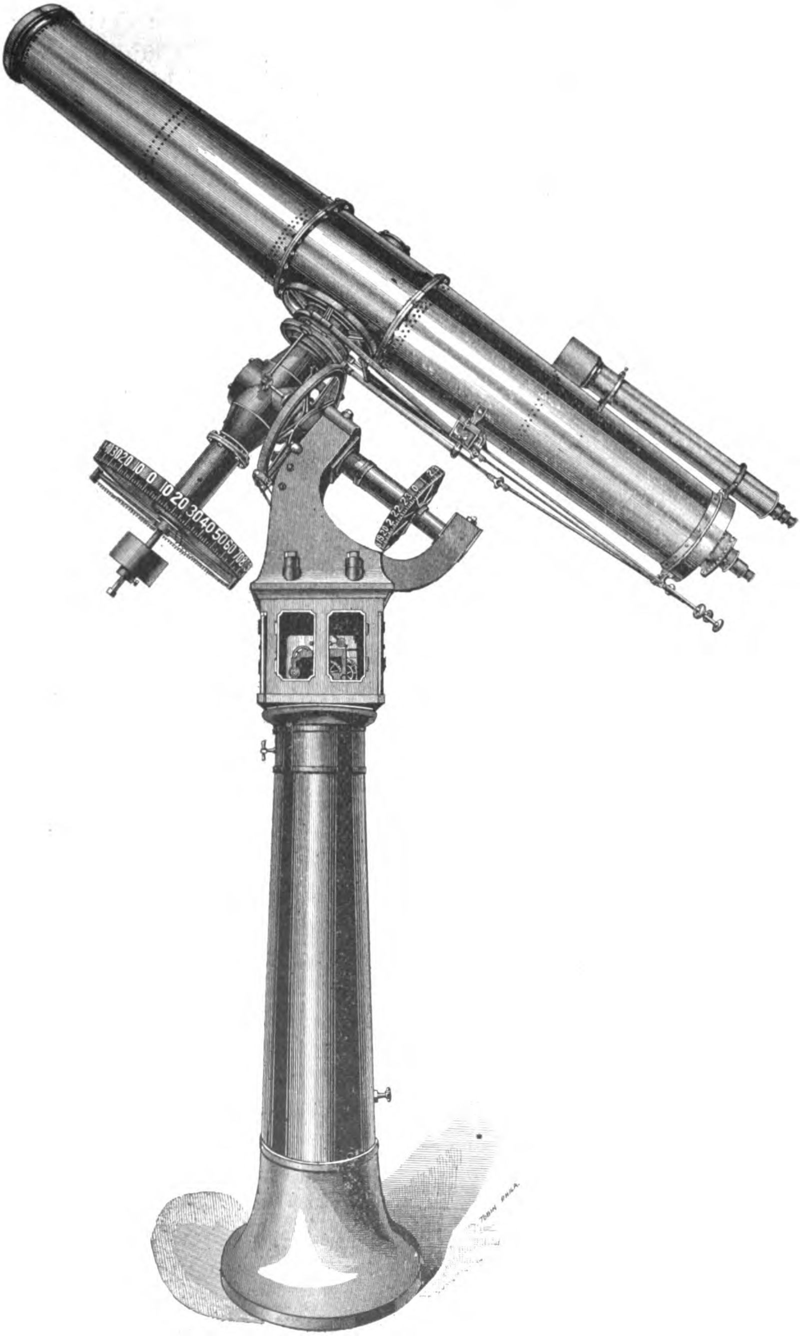
Hand-wheels, by means of which the telescope can be turned in R. A. and Decl. from the floor, are a great convenience in large instruments. We place them on the south side of the pier, where they are out of the way.

Finding Circles.—In order to see where the telescope points to when operating these hand-wheels, we have introduced, for larger instruments, finding circles with pointers, which indicate, with sufficient accuracy for finding purposes, the R. A. and Decl. to which the telescope is pointing. In order to prevent the Declination Circle from turning when moving the telescope in R. A. an epicycloidal train is introduced. By the use of a clock, driving a pointer, the instrument can at once be set in R. A. without calculating the hour angle.

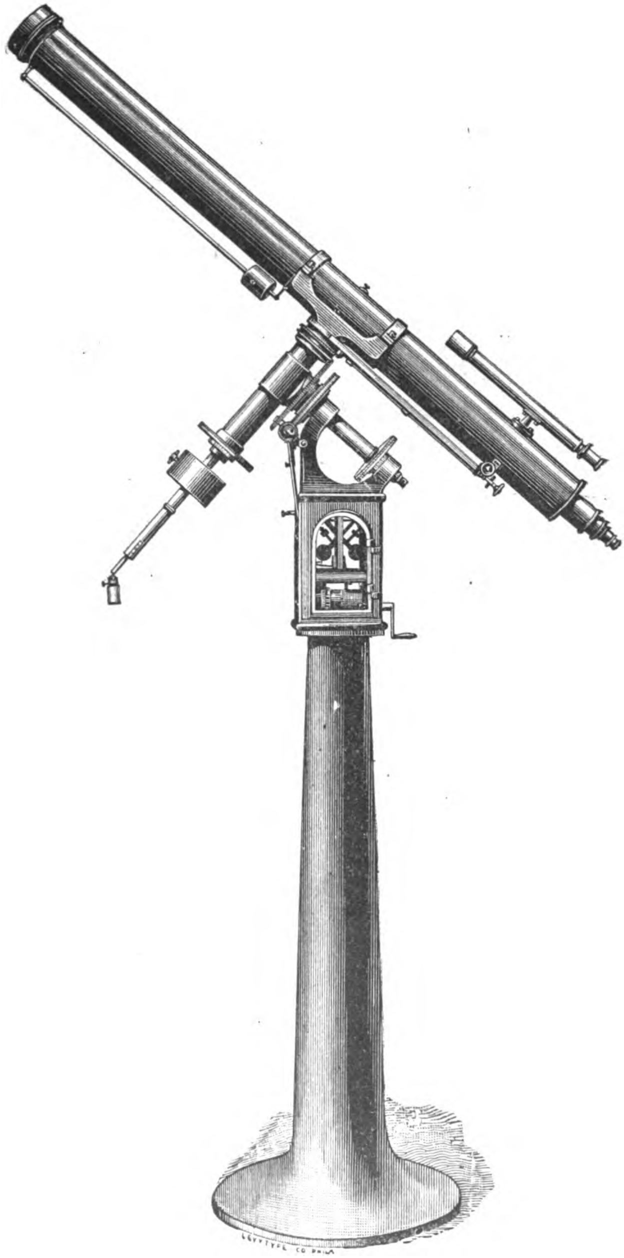
To attach the finding circle to the eye end of telescopes is only feasible in large instruments. In smaller ones the gears have to be made so small that they are difficult to secure to the rods, and the back-lash in a small gear is much more than in a large one.

For most purposes it is good enough to set by large circles which are provided with bold graduations and numbers, visible from the floor.

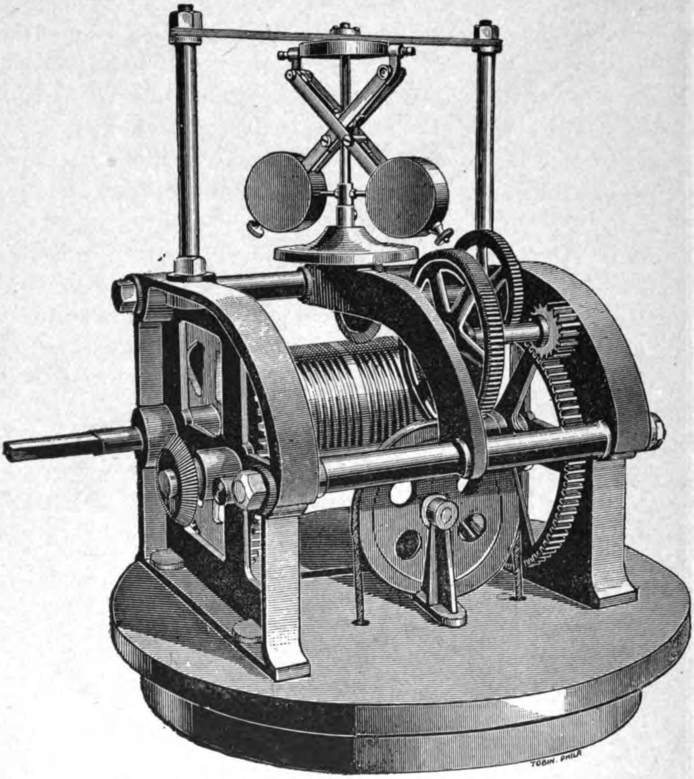
It must be borne in mind that the simpler the construction, the less work the clock has to do.



No. 43.—9-inch Equatorial,
as made for the Catholic University of America.



No. 44.—6-inch Equatorial.



No. 45.—Equatorial Driving-Clock.

The above cut represents our style of driving-clock suitable for a 12-inch Equatorial. It is very compactly built, provided with maintaining power, and the weight is hung in such a manner that it descends centrally without moving in a lateral direction.

The governor is a rotating pendulum suspended in such a manner that the pendulum itself is absolutely free, while the arm on which it hangs exerts more friction as the amplitude of the pendulum increases.

With a friction coefficient of .34, this clock controls about 4500 inch-pounds per hour.

Price List of Equatorials.

The cheapest equatorial mounting we make is the one we supply with the "Cheap Outfit." We do not believe that there is a better mounting in the market for that amount of money, and although we sell it so low we can conscientiously recommend it as a very good instrument. As we make them now they differ somewhat from the one shown in cut, as we have substituted for the original spring driving-clock one of our own make with friction governor, which is more powerful and regular. This clock stands on a bracket cast on the south side of the pillar.

As the prices of Equatorials depend largely on the amount of refinement and detail expended on them, we have divided them into two classes. Class No. I are our Standard Equatorials, and they are made with the utmost accuracy. The clamp and slow motions are brought to the eye-end and located close to the clamp and slow motion in declination. This is a very convenient arrangement, but expensive, as it involves the use of a number of gears.

The Circles are divided on solid silver, and throughout the instruments are elaborate and perfect in construction.

Class No. II are cheaper; the R. A. movements are not carried to the eye-end, but are effected by means of rods and handles; the circles are silvered and not graduated as fine as those of the Standard instruments.

The workmanship of both, as far as it goes, is equally perfect.

Price of 3-inch "Outfit" Equatorial with 2 eye-pieces	$400
Price of 4-inch "Outfit" Equatorial with 2 eye-pieces	500
Price of 5-inch "Outfit" Equatorial with 3 eye-pieces	750

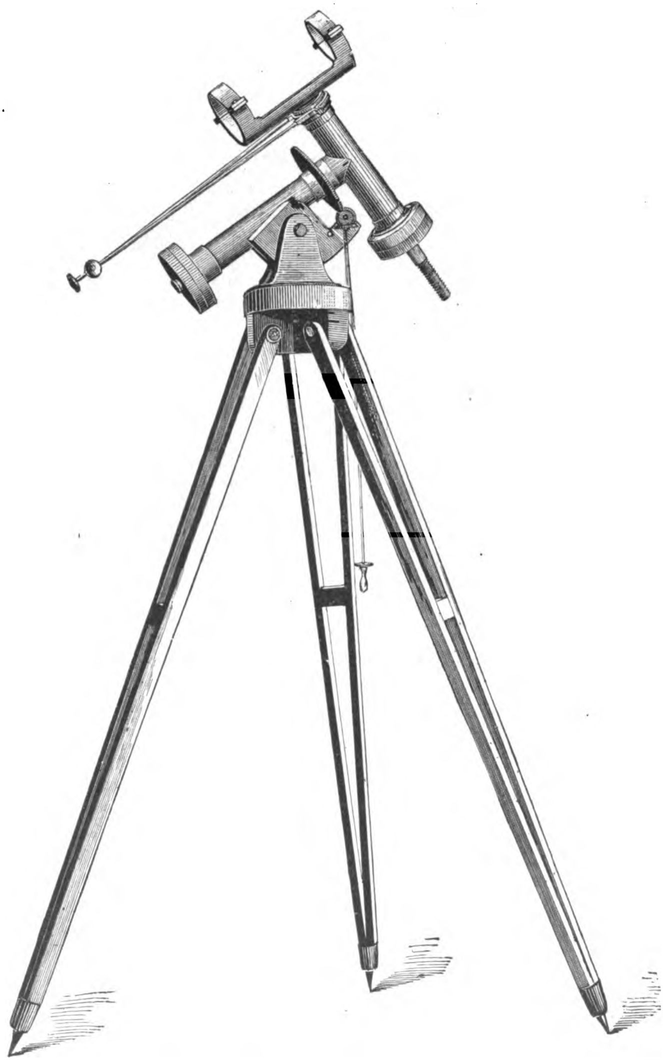
Prices of Standard Equatorials:

5-inch	Equatorial with	4	eye-pieces	and prism	$1,250 00
6 "	"		"	"	1,650 00
7 "	"		"	"	1,950 00
8 "	"	6	"	"	2,400 00
9 "	"		"	"	3,250 00

Prices for Equatorials No. II:

5-inch	Equatorial with	4	eye-pieces and prism	$900 00
6 "	"		"	1,200 00
7 "	"		"	1,500 00
8 "	"	6	"	2,000 00
9 "	"		"	2,800 00

The prices of larger instruments may be had on application.

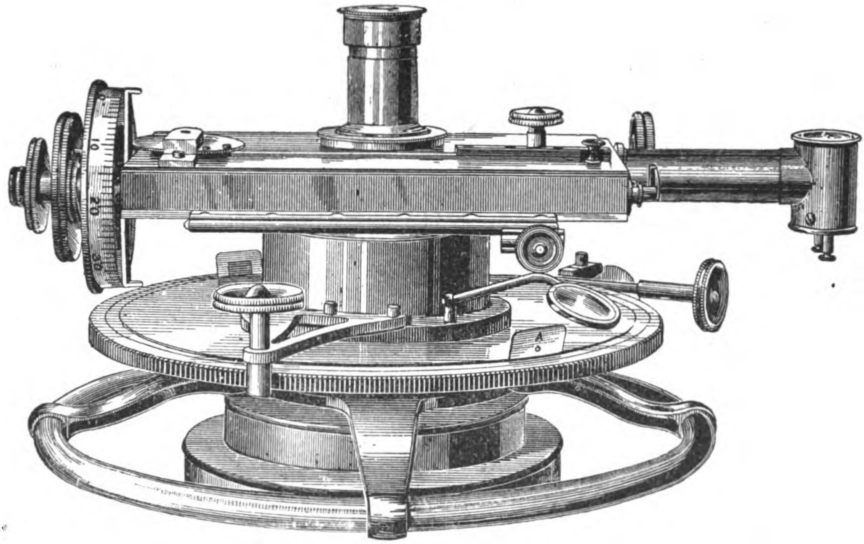


No. 46.—Portable Equatorial Mounting.

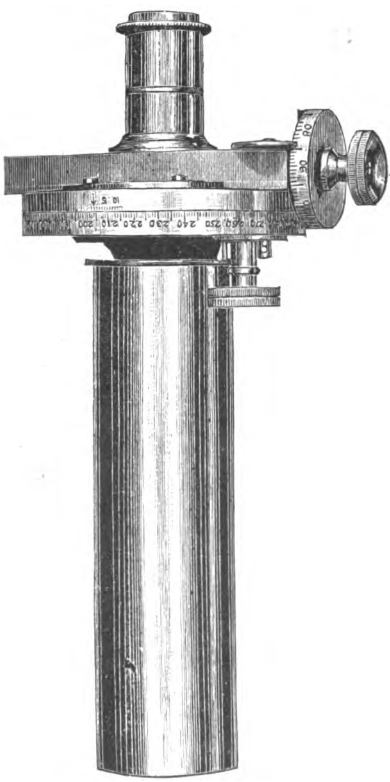
Above cut represents a Portable Equatorial Mounting, suitable for telescopes from 3 to 5 inches aperture. As shown in the cut, it has clamp and tangent movements, silvered circles reading to single minutes and 5 seconds of time, respectively.

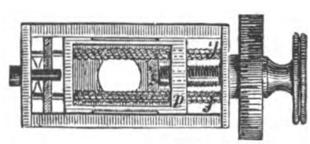
Equatorial Mounting, as above.................................$150 00

MICROMETERS.



No. 47.—Position Micrometer, as made by us for the Lick Telescope.





No. 49.—Reading Micrometer.

No. 48.—Small Position Micrometer.

Cut 48 represents a simple form of Position Micrometer; screw 100 to the inch; head divided into hundredths; full revolution index, 4-inch position circle. Price..$150 00

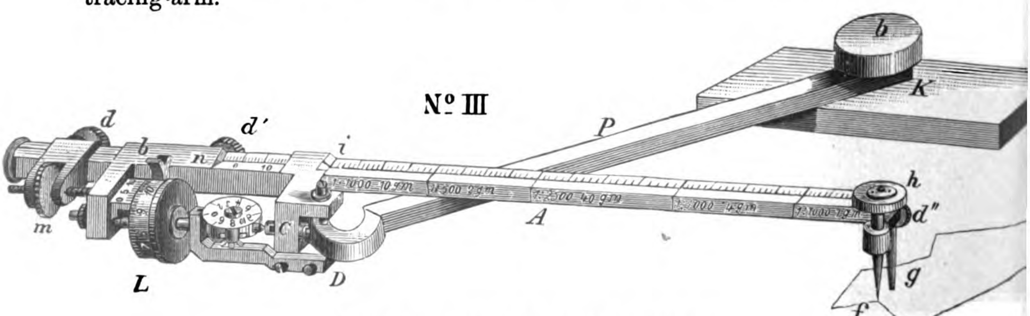
No. 47 represents the large Micrometer we máde for the Lick telescope; it weighs about 50 pounds, and is the largest micrometer in use. We make this class of micrometers in 3 sizes.

5-inch Micrometers	$250 00
8 " "	600 00
12 " "	900 00

The sizes refer to the diameter of the circle. The micrometers are made with the utmost exactness and with all the latest improvements. The illumination is electric and arranged for either bright or dark field.

PRECISION PLANIMETERS.

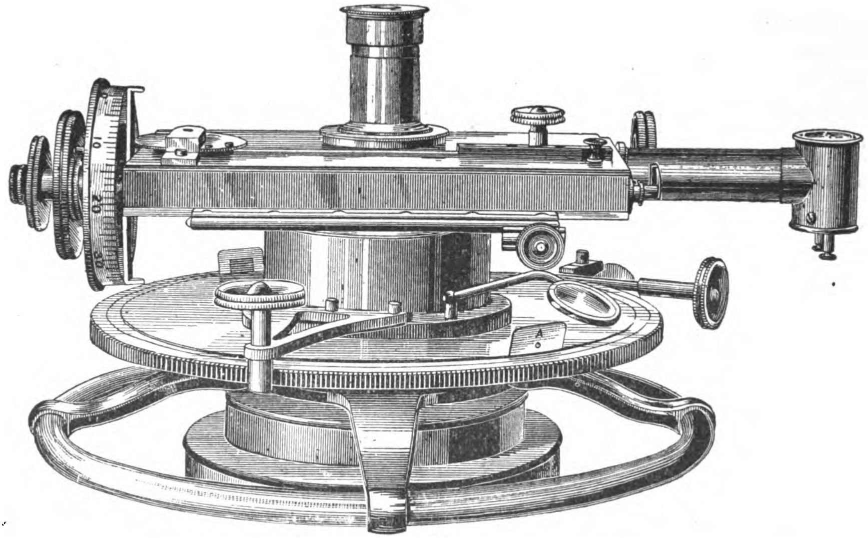
These instruments have been very much perfected of late, and we draw especial attention to the "Roller" and "Suspended" Planimeters as the most accurate ones now in use. *They are ten to twenty times more exact than all other similar instruments.* The roller does not run directly on the paper, but on a perfectly flat disc, and, consequently, the results of the instrument are in nowise affected by the nature of the paper. The rotation of the roller is ten to twenty times smaller than that of the Amsler Planimeter with equal length of tracing-arm.



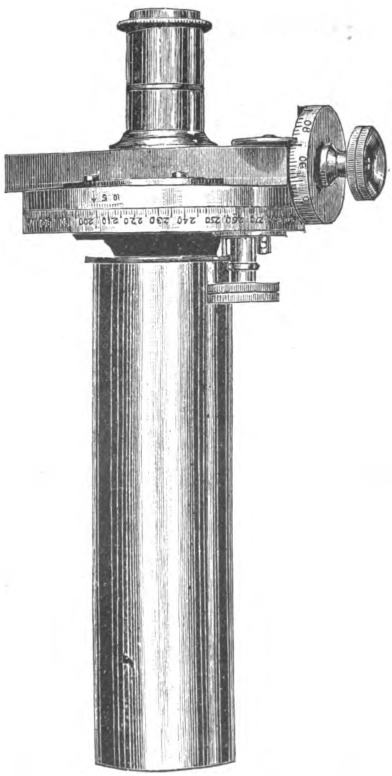
No. 50.—Precision Planimeter.

No. 50.—Simple Precision Planimeter, in case..............................$40 00

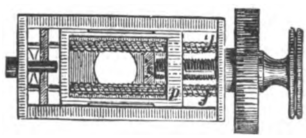
MICROMETERS.



No. 47.—Position Micrometer, as made by us for the Lick Telescope.



No. 48.—Small Position Micrometer.



No. 49.—Reading Micrometer.

PROTRACTORS.

No. —. Three-arm Protractor, 6-inch circle, divided on silver, extension arms 30 inches long.......................................$110 00

TIDE-GAUGES.

No. —. Three-roller Tide-gauges, with strong clock-work, having adjusted lever balance, metal frame and metal wheel, on strong stand.$350 00

EYE-PIECES.

Positive Eye-Pieces.

Ramsden—¼-inch to ¾-inch equivalent, each........................... $5 50
1 " 1½ " " " 6 00
1¾ " 2¼ " " " 7 00
Kellner (achromatic)—⅛-inch to ¾-inch equiv., each.................... 7 50
1 " " " " 8 00
1¼ " " " " 9 50
1½ " " " " 12 00
Steinheil (achromatic)—⅛-inch to ¾-inch equiv., each.................. 10 00
1 " " " " 12 50

Negative Eye-Pieces.

Huyghens—¼-inch to 1-inch equiv., each.............................. $5 50
1¼ " 1½ " " " 6 00
Airy (giving a large and perfectly flat field), ¼-inch to ½-inch equiv., each. 7 00
¾-inch equiv., each.. 8 00
1 " " " 9 50
1¼ " " " 10 50
1½ " " " 12 50
2 " " " 17 00

Terrestrial or Inverting Eye-Pieces for Direct Vision.

Fraunhofer—¼-inch to ½-inch equivalent, each......................... $9 50
¾ " " " " 10 00
1 " " " " 12 00
1½ " to 2 inches " " 18 00

Diagonal Terrestrial Eye-Pieces.

½ inch to ¾ inch equiv., each..$18 00
1 " 1½ " " " 20 00
Swivel adapters for the above.. 3 00

REFLECTING PRISMS.

First surface-reflecting prism (solar)..$15 00
⅜-inch square, mounted with sun-shade.. 10 50
½ " " " " " 12 00
¾ " " " " " 15 00
1 " " " " " 20 00

Helioscopic eye-piece, Merz, according to size, from $50 up.

Compensation slides, of neutral tint glass, according to size, from $5 up.

Revolving sun-shades with 6 sun-glasses..$7 50

LEVEL TRIERS.

24-inch iron base with fine micrometer screw, 1 div. = 1″.0 ....$30 00

LEVEL VIALS,

Of all sizes and grades of sensitiveness, from $0.75 to $1.00 per inch. Chambered levels, reading to seconds, from $3 to $8 per inch.

Note.—Persons who do not know what patience and labor is required to produce a really good Level, having a value of one or two seconds for one millimeter space, express astonishment at the prices we ask for such a level. If we were not obliged to have these Levels for our instruments we would not make them at all; and we would rather keep a good Level vial than sell it, even at a seemingly high price.

LEVELLING RODS.

New York Rod..$16 00
Philadelphia Rod.. 18 00
Boston Rod.. 15 00
Ranging Poles, painted red and white alternately, made of wood with steel shoes, 6 to 8 feet long.. 3 50

HAND LEVELS.

Locke's Hand-Level, nickel-plated..$11 00
Abney Level and Clinometer.. 15 00

STEEL TAPES.

Excelsior Steel Tapes in leather case:

100 feet long, divided in tenths	$15 00
66 " " "	10 50
50 " " "	8 00

Chesterman's Steel Tapes in leather case:

100 feet long, divided in tenths	12 50
66 " " " "	11 00
50 " " " "	7 00

LIGHT, NARROW STEEL TAPES.

Fine Steel Tape, 50 feet long, $\frac{3}{32}$ inch wide, with spring balance, spirit level, thermometer, and brass handles, on reel, for very accurate measurement, each	$20 00
Narrow Steel Tape, $\frac{3}{32}$ or $\frac{1}{8}$ inch wide, 100 feet long, with two brass handles, graduated at every 50 feet, on reel	6 50
Each additional 100 feet, graduated the same	5 00

SURVEYORS' CHAINS.

Made of No. 12 steel, brazed links and rings:

Land Chain, 50 feet long	$6 00
" " 100 "	11 00
" " 33 "	5 50
" " 66 "	10 00
Meter chains, 10 meters long	5 50
" " 15 "	7 50
" " 20 "	10 00

ARROWS.

Steel Arrows, No. 11 wire, bright, 11 in set, 14 inches long—set	$1 25

READING-GLASSES.

Pocket Reading-Glasses, oval pattern, mounted in rubber:

1 lens, $1\frac{1}{2}$ inch diameter	$0 60
2 lenses " "	1 50
Coddington lenses, brass frame and handle, nickel-plated, $\frac{3}{4}$-inch	1 50
" " " " " $1\frac{1}{8}$ "	2 00

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