ILLUSTRATED CATALOGUE

ASTRONOMICAL,

ENGINEERING

and SURVEYING

INSTRUMENTS

MANUFACTURED BY

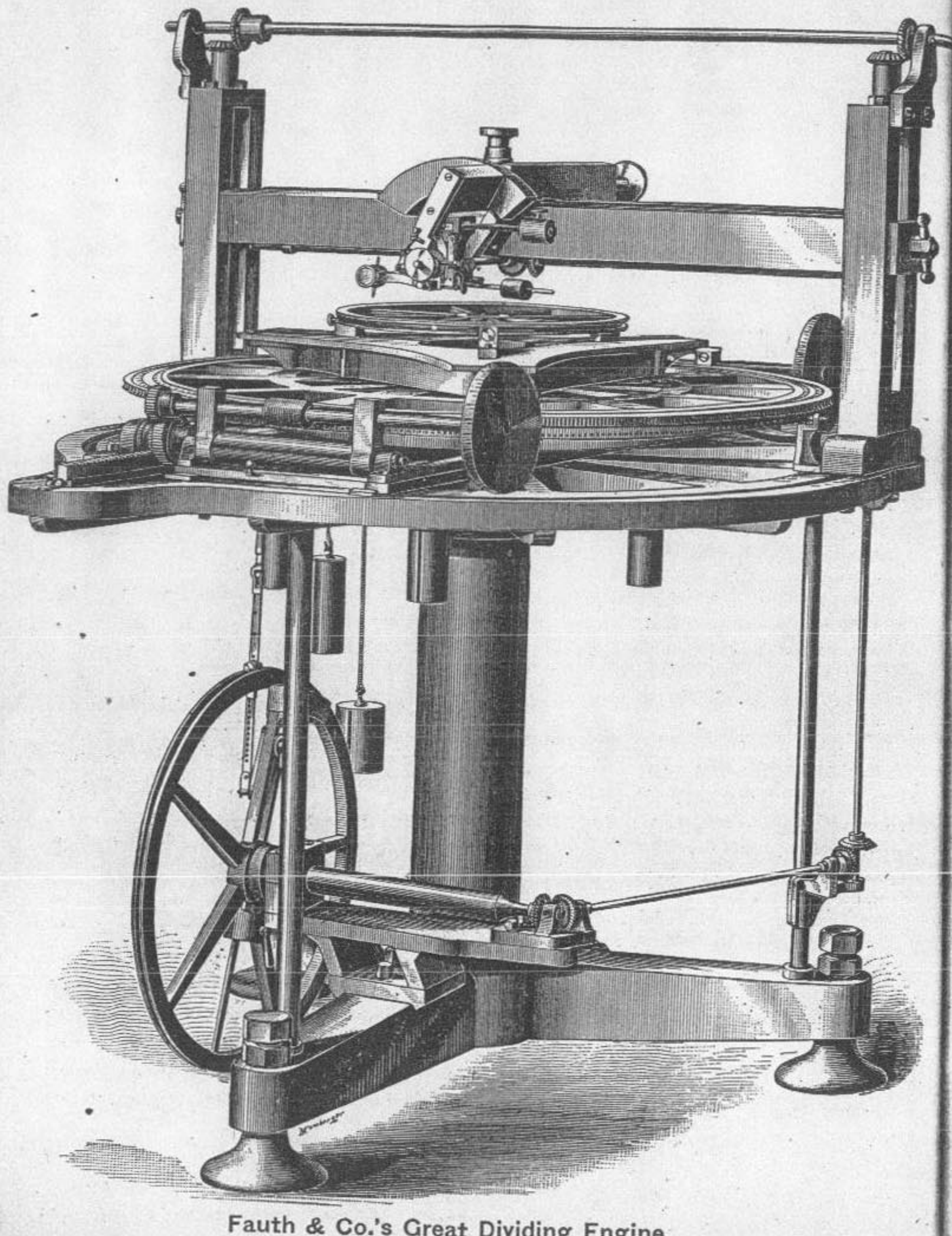
FAUTH & CO.

132, 134 Maryland Avenue S.W.

WASHINGTON, D.C.

1885

PRICE, 50 Cents.



Fauth & Co.'s Great Dividing Engine.

INTRODUCTION.

In presenting this new catalogue and price-list we take occasion to thank
friends for past favors and to solicit a continuance of their patronage.

The increased demand for our instruments has necessitated the enlargement
our works. We have erected a new building and fitted it up with the most
proved tools and appliances. The increased appreciation of our engineering inst
ments has induced us to give this branch of the business particular attenti
These instruments we manufacture now from improved patterns and of the sa
accuracy as our astronomical instruments. The engravings in this catalogue g
a good idea of our instruments as now made. Our constant aim, however, is
improve them, increase their accuracy and simplicity, and make their use pleas
and convenient.

The prices are put as low as good workmanship and the use of the best materi
will allow.

We use only the very best objectives, well corrected for chromatic and spheri
aberration.

Our graduations are made on solid silver, unless otherwise mentioned, and
call special attention to the beauty and correctness of our divisions.

Our level-vials are all ground, and their sensibility is in accordance with the
of the instrument for which they are intended. Our finest levels, which are cha
bered for the regulation of the bubble in changes of temperature, are ground t
radius of from 800 to 1,500 feet and upwards. We have the only machine
which such great curves can be ground to mathematical accuracy.

This machine is wholly automatic, and not only forms a correct curve that
be set at will, but also grinds the entire inside of the tube, making it perfec
symmetrical. The weight of instruments is carefully considered in connect
with their use. Those intended for purely astronomical or the higher grades
geodetic work, while not of excessive weight, are yet so constructed as to insu
perfect stability. Those the use of which necessarily involves much transp
tation by hand are so constructed that, while the weight is materially decreas
the strength required is obtained by a judicious and careful distribution of
metal.

All portable instruments, with their accessories, are packed in neat boxes, firm
and conveniently arranged, so they can be put in and taken out without troubl

While we give the closest attention to careful packing, our responsibility cea when instruments leave the factory; in case of damage, the express companies must be held liable.

Terms net cash.

Deposits will be required on orders from persons not known to us.

DIVIDING ENGINE.

The cut on page 10 represents our large new Dividing Engine recently completed, which we venture to say is one of the best engines ever constructed. We have studied all the best Dividing Engines in Europe and this country, and have endeavored to improve on them, sparing neither trouble nor expense in making it as perfect as a machine can be constructed. The 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. The machine is entirely automatic and corrects its own errors by simple and sure mechanism. It is enclosed in a case not shown in cut, in which the temperature is kept uniform while a circle is being divided. The temperature is regulated automatically.

We have produced excellent graduations with a less perfect machine than this, and with this improved engine we feel justified in promising still better results.

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.

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.

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.

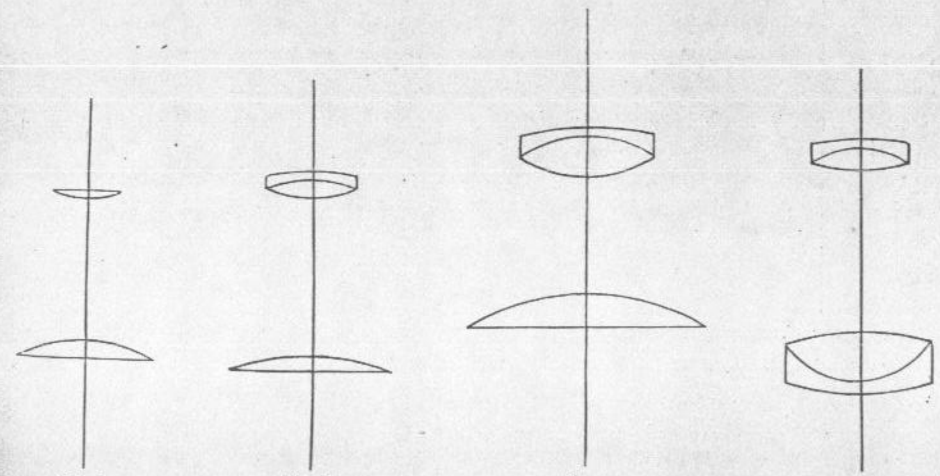


Fig. 1. Fig. 2. Fig. 3. Fig. 4.

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. Even with this large field-lens it will give more satisfaction than the best "Ramsden."

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

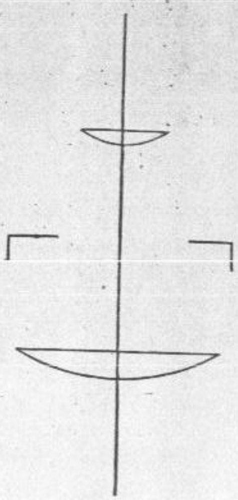


Fig. 5.

Of negative eye-pieces we have two kinds, the "Huygens" 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 "Huygens" 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. For instance, the field-lens of a 1-inch eye-piece has a diameter of 1 inch from which the diameters of higher or lower powers may readily be computed.

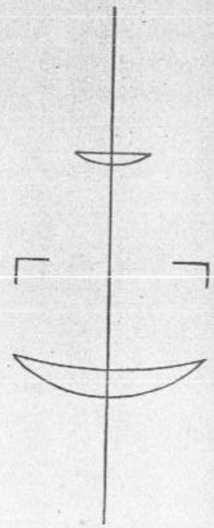


Fig. 6.

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

Fig. 7.

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.

Fig. 8.

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 ½ 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 12½ seconds, it follows that, in order to point within ½ 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.

GRADUATIONS.

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 upon the higher classes of engineering instruments. 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 ½ degrees, reading to single minutes by the vernier having 29 circle parts divided into 30; or the circle is graduated into ⅓-degree spaces, reading to half minutes by the vernier having 39 circle parts divided into 40. Or the circle is graduated into ¼ degrees and the vernier reading to 20 seconds by having 44 circle parts divided into 45. Or the circle is divided into ⅙ 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 permanently attached in such a manner that they can be moved radially along the entire length of vernier. The tube in which these reading-glasses are mounted should also have at the end nearest the graduation a fine pointer which will just reach the end of the lines. This pointer, being in the centre of the field, will serve as a guide in moving the reading-glass just opposite the coinciding line; the centre of the lens is thus used in reading, and parallax is avoided. Every engineer who has not used these before will find them of great service.

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

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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.

VERTICAL SIGHTING ATTACHMENT.

Cut on page 55 represents a simple Attachment to engineer's transits, invented and patented by G. N. Saegmuller, for sighting vertically, upwards or downwards. It consists of a right angle prism placed in front of the objective, and has the effect of reflecting the rays at an angle of 90°. Thus, if the telescope be pointed horizontally, by putting the prism in front of it, so that the upper cathete surface is in a horizontal plane, the line of sight will be directed upwards; by changing the position of this prism 180° the line of sight will be vertically downwards. Turning the transit 180°, and taking the *mean* of the two sightings, the point vertically above or below the centre of the instrument is obtained.

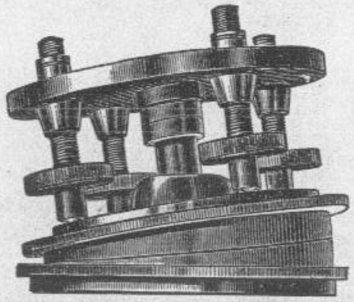
This is the simplest and most exact method of getting a vertical sight. The use of a prism is far more convenient than the clumsy plan of attaching an extra telescope to the axis, which tilts the instrument, and is also very expensive.

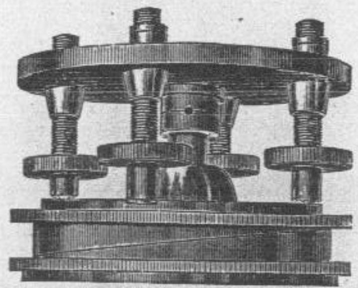
Although a plain mirror can be used for this purpose, it is objectionable on account of the double images caused by the front and back surface, and a prism is therefore preferable. By making the mirror slightly wedge-shaped, so as to throw the faint image out of the field, the annoyance of double images can be overcome. This style of mirror costs nearly as much as a prism, and altogether we find that prisms are the most satisfactory, as there is no silvering, which is liable to deteriorate. The prisms, however, have to be perfectly homogeneous, and must be ground to exact surfaces, as a bad prism would undo the work of a good objective.

It is readily seen that by turning the prism 90° it can also be used to offset at right angles. It can also be used for vertical sighting by attaching it to a level. This Attachment can be fitted to any instrument.

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

PATENTED BY G. N. SAEGMULLER, WASHINGTON, D. C.





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.*

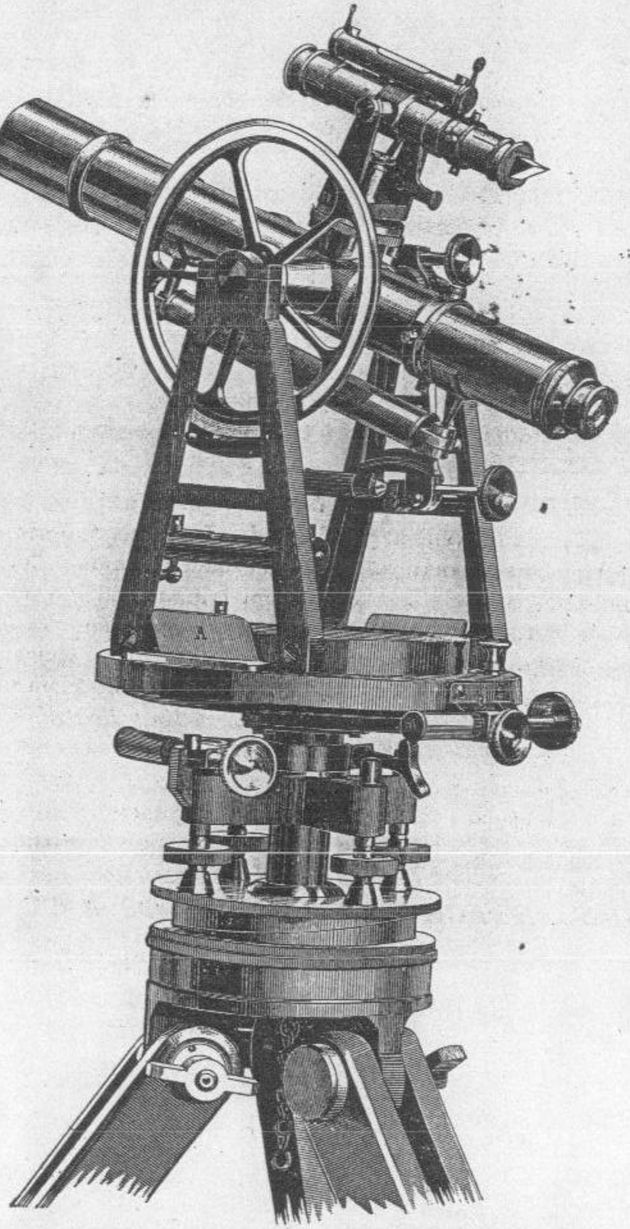
It can be attached to any transit or levelling instrument.

The cut on the following page represents a new form of

SOLAR ATTACHMENT APPLIED TO A TRANSIT,

invented and patented by G. N. Saegmuller, which is the simplest and most accurate ever devised. Attached to any engineer's transit, the true meridian and deviation of the needle can be obtained with far greater accuracy than with any Solar Attachment yet invented.

The cut represents the "Solar Attachment" applied to an engineer's transit. 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. It is provided with shade-glasses to subdue the glare of the sun, as well as a prism to observe with greater ease when the declination is far north. Two pointers attached to the telescope to



Solar Attachment on Engineer's Transit.

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.

This is very simple, and requires even less work than to adjust the common transit.

First. Attach the "polar axis" to the main telescope axis in the centre at right angles to the line of collimation. The base of this axis is provided with three adjusting-screws for this purpose; by means of the level on the solar telescope this condition can be readily and accurately tested.

Second. Point the transit telescope—which instrument we assume to be in adjustment—exactly horizontal and bisect any distant object. The transit level will then be in the middle of the scale. Point the "solar telescope" also horizontally by observing the same object and adjust its level to read Zero, for which purpose the usual adjusting-screws are provided.

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 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.

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, &c., reliable to within a few seconds.

Advantages of the "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 with the sun quite close to the meridian.

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

Sixth. It is much cheaper.

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. For the ordinary surveyor's compass the degree of accuracy of the old attachment will answer, although even on a compass this "Solar Attachment" would be an improvement.

When angles are laid off with a transit, however, it is certainly going back a step to attempt to establish a meridian with a less precise instrument, or one that has less pointing power.

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 apparent; 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 "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.

This "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 the leading astronomers and engineers who have seen and used it.

Mean Refraction.

Barometer, 30 inches. Fahrenheit thermometer, 50°.

Apparent altitude.	Mean refraction.	Apparent altitude.	Mean refraction.	Apparent altitude.	Mean refraction.	Apparent altitude.	Mean refraction.	Apparent altitude.	Mean refraction.
° ′	′ ″	° ′	′ ″	° ′	′ ″	° ′	′ ″	° ′	′
0 0	36 30	12 40	4 14	19 0	2 48	28 0	1 49	41 0	1
1 0	24 54	13 0	4 7	30	2 43	30	1 47	42 0	1
2 0	18 25	20	4 1	20 0	2 39	29 0	1 45	43 0	1
3 0	14 25	40	3 55	30	2 34	30	1 43	44 0	1
4 0	11 44	14 0	3 49	21 0	2 31	30 0	1 41	45 0	0 5
5 0	9 52	20	3 44	30	2 27	30	1 39	46 0	0 5
6 0	8 28	40	3 39	22 0	2 23	31 0	1 37	47 0	0 5
7 0	7 24	15 0	3 34	30	2 20	30	1 35	48 0	0 [illegible]
8 0	6 33	20	3 29	23 0	2 16	32 0	1 33	49 0	0 5
9 0	5 52	40	3 25	30	2 13	30	1 31	50 0	0 4
10 0	5 19	16 0	3 20	24 0	2 10	33 0	1 29	55 0	0 4
20	5 9	20	3 16	30	2 7	34 0	1 26	60 0	0 3
40	5 0	40	3 12	25 0	2 4	35 0	1 23	65 0	0 2
11 0	4 51	17 0	3 8	30	2 2	36 0	1 20	70 0	0 2
20	4 43	20	3 5	26 0	1 59	37 0	1 17	75 0	0 1
40	4 35	40	3 1	30	1 56	38 0	1 14	80 0	0 1
12 0	4 27	18 0	2 57	27 0	1 54	39 0	1 12	85 0	0
20	4 20	30	2 52	30	1 52	40 0	1 9	90 0	0

Correction of the Mean Refraction for the Height of the Barometer.

Barometer, subtract.	Mean Refraction										Barometer, add.
	1′	2′	3′	4′	5′	6′	7′	8′	9′	10′	
	″	″	″	″	″	″	″	″	″	″	
27.50	5	10	15	20	25	30	35	40	45	51	
27.75	4	9	13	18	23	27	32	36	41	46	
28.00	4	8	12	16	20	24	28	32	36	41	
28.25	3	7	10	14	18	21	25	28	32	35	
28.50	3	6	9	12	15	18	21	24	27	30	31.50
28.75	2	5	7	10	13	15	18	20	23	25	31.25
29.00	2	4	6	8	10	12	14	16	18	20	31.00
29.25	1	3	4	6	8	9	11	12	14	15	30.75
29.50	1	2	3	4	5	6	7	8	9	10	30.50
29.75	0	1	1	2	3	3	4	4	5	5	30.25
30.00	0	0	0	0	0	0	0	0	0	0	30.00

Correction of the Mean Refraction for the Height of the Thermometer.

Ther., add.	Mean Refraction.									
	1′	2′	3′	4′	5′	6′	7′	8′	9′	10′
°	″	″	″	″	″	″	″	″	″	″
0	7	13	20	27	34	41	49	57	65	74
10	5	10	15	21	26	32	38	44	51	58
15	4	9	13	18	23	28	33	38	44	50
20	4	8	11	15	19	24	28	33	37	42
25	3	6	9	13	16	19	23	27	31	35
30	2	5	7	10	13	15	18	21	24	28
35	2	4	6	7	9	11	14	16	18	20
40	1	2	4	5	6	8	9	10	12	13
45	1	1	2	2	3	4	4	5	6	7
50	0	0	0	0	0	0	0	0	0	0
Subtract.										
55	1	1	2	2	3	4	4	5	6	6
60	1	2	3	5	6	7	9	10	11	13
65	2	3	5	7	9	11	13	15	17	19
70	2	5	7	9	12	14	17	20	22	25
75	3	6	8	11	14	18	21	24	28	31
80	3	7	10	14	17	21	25	29	33	37
85	4	8	12	16	20	24	29	33	38	43
90	4	9	13	18	23	27	32	38	43	49
95	5	10	15	20	25	30	36	42	48	54
100	5	11	16	22	28	34	40	46	53	60

Correction for Refraction.

This correction is applied to the *declination* of the sun, and is equal to the refraction-correction to the sun's observed altitude multiplied by the cosine of Z S P, the angle at the sun between the declination-circle and the vertical. The value of this cosine to hundredths, or the percentage of the refraction-correction to be applied, is given in the following table. This factor is to be multiplied by the refraction given in the above tables, and by the resulting quantity north declinations are to be *increased* and south declinations to be *diminished* to give the apparent place of the sun.

Tables of this factor, as calculated by Mr. Burt, have already been published. In them, however, the sun has been supposed on the equator, and no account taken of its declination. They give a close approximation to the truth, *in high latitudes*, but their error at times, when used in connection with such a delicate and accurate solar apparatus as that here described, may become quite considerable. In the following table, allowance is made for declination:

Percentage of Refraction in Altitude, to be applied to Sun's Declination, in adjustment of Solar Attachment, etc.

(Enter Time to or from noon at left, and latitude of place at top; percentage for Sun on Equator in body of table, and correction for declination immediately to its right.)

Sun's hour-angle.	Lat. 25° N. Decl. 0°.	Lat. 25° N. Cor. for 1°.	Lat. 30° N. Decl. 0°.	Lat. 30° N. Cor. for 1°.	Lat. 35° N. Decl. 0°.	Lat. 35° N. Cor for 1°.	Lat. 40° N. Decl. 0°.	Lat. 40° N. Cor. for 1°.	Lat. 45° N. Decl. 0°.	Lat. 45° N. Cor. for 1°.	Lat. 50° N. Decl. 0°.	Lat. 50° N. Cor. for 1°.	Lat. 55° N. Decl. 0°.	Lat. 55° N. Cor. for 1°.	Lat. 60° N. Decl. 0°.	Lat. 60° N. Cor. for 1°.
h. m.	*p. c.*	*N. S.*		*N. S.*		*N. S.*		*N. S.*		*N. S.*		*N. S.*		*N. S.*		*N. S.*
0 0	100	.0 .0	100	.0 .0	100	.0 .0	100	.0 .0	100	.0 .0	100	.0 .0	100	.0 .0	100	.0 .0
20	98	— .5 + .1	99	— .2 .0	99	— .1 .0	100	— .1 .0	100	— .1 .0	100	.0 .0	100	.0 .0	100	.0 .0
40	94	— 1.3 + .2	96	— .6 + .1	97	— .3 + .1	98	— .2 + .1	98	— .1 .0	99	— .1 .0	99	.0 .0	100	.0 .0
1 0	88	— 1.8 + .4	91	— 1.0 + .3	94	— .6 + .2	96	— .3 + .1	97	— .2 + .1	98	— .1 .0	98	— .1 .0	99	.0 .0
20	81	— 1.9 + .6	86	— 1.2 + .4	90	— .8 + .3	92	— .4 + .2	95	— .3 + .1	96	— .2 + .1	97	— .1 + .1	98	— .1 .0
40	74	— 1.9 + .7	81	— 1.3 + .5	86	— .9 + .3	89	— .6 + .3	92	— .4 + .1	94	— .2 + .1	96	— .1 + .1	97	— .1 .0
2 0	68	— 1.8 + .8	76	— 1.4 + .5	81	— .9 + .4	86	— .7 + .3	90	— .5 + .1	92	— .3 + .1	94	— .2 + .1	96	— .1 .0
20	63	— 1.7 + .9	71	— 1.3 + .6	77	— .9 + .5	83	— .7 + .3	87	— .5 + .2	90	— .3 + .1	93	— .2 + .1	95	— .1 .0
40	59	— 1.5 + .8	67	— 1.2 + .6	74	— .9 + .5	79	— .7 + .3	84	— .5 + .2	88	— .3 + .1	91	— .2 + .1	94	— .1 .0
3 0	55	— 1.3 + .8	63	— 1.1 + .6	70	— .9 + .5	77	— .7 + .3	82	— .5 + .2	86	— .3 + .1	90	— .2 + .1	93	— .2 .0
20	52	— 1.1 + .7	60	— 1.0 + 6	67	— .8 + .5	74	— .7 + .3	79	— .5 + .2	84	— .3 + .1	88	— .2 + .1	91	— .1 + .1
40	50	— 1.0 + .6	58	— .9 + .5	65	— .7 + .4	72	— .6 + .3	77	— .4 + .3	82	— .3 + .2	87	— .2 + .1	90	— .1 + .1
4 0	47	— .8 + .6	55	— .7 + .5	63	— .6 + .3	70	— .5 + .2	76	— .4 + .2	81	— .4 + .1	86	— .2 + .1	89	— .1 + .1
20	46	— .7 + .5	54	— .6 + .4	61	— .5 + .3	68	— .5 + .2	74	— 4 + .2	80	— .3 + .1	85	— .2 .0	89	— .1 .0
40	44	— .6 + .4	52	— .5 + .3	60	— .5 + .2	67	— .4 + .1	73	— .3 + .1	79	— .3 + .1	84	— .2 .0	88	— .1 .0
5 0	44	— .5 + .2	51	— .4 + .2	59	— .4 + .1	66	— .3 + .1	72	— .3 + .1	78	— .2 .0	83	— .1 .0	88	— .1 .0
20	43	— .3 + .1	51	— .3 + .1	58	— .3 + .1	65	— .3 + .1	71	— .2 + .1	77	— .1 .0	82	— .1 .0	87	— .1 .0
40	42	— .2 + .1	50	— .2 .0	58	— .2 .0	64	— .2 .0	71	— .1 .0	77	— .1 .0	82	— .1 .0	87	— .1 — .1
6 0	42	— .1 — .1	50	— .1 — .1	57	— .1 — .1	64	— .1 — .1	71	— .1 — .1	77	— .1 — .1	82	— .1 — .1	87	— .1 — .1

For example, suppose the latitude of place of observation 39° N., the local time 9.15 A. M., and the sun's declination 9° S. Here the time to noon is 2h. 45m., whence we easily find the tabular numbers for latitude 35° 73%, and for 40° 78½%; for 39°, therefore, 77%. The declination-factor should be found by a similar interpolation, when necessary. Here it is to be taken + .3, which, multiplied by 9°, gives 3%, additive. Correct the declination, therefore, in setting the "Solar Attachment" by 77 + 3, or 80% of the *refraction* in *altitude.*

The accuracy of the table may be judged from the accompanying calculation of an extreme case, in which (as the errors are largest, as a rule, when the declination-factors are largest) the latitude is taken 25° and the hour-angle 2h., and the percentage given by the table compared with the true value as given by calculation for different declinations. The only considerable differences, it will be seen, are for high north declinations; and here the sun is so near the zenith and the total refraction so small as to render them insignificant. The errors of other parts of the table will fall far within these limits.

Decl.	*% by table.*	*True %.*
23½ N.	26	16
20	32	27
15	41	41
10	50	53
5 N.	59	61
0	68	68
5 S.	72	73
10	76	77
15	80	80
20	84	83
23½ S.	87	84

Example I.

Salt Lake City, Utah, *October* 24, 1884.

Find the refraction-correction by means of the above table, which is to be applied to the sun's declination before setting it off on the Solar Attachment.

Observed altitude of sun at 9h. 20m. A. M., 23° 03′. The time-piece is supposed to indicate local civil time, old style. This is found by subtracting from *mean* time of true noon the time of observation corrected for error of time-piece. Equation of time for October 24, —12m. 48.0s. ; hence mean time of true noon 12h. 12m. 48.0s. = 11h. 47m. 12s. Subtracting from this the time of observation, viz., 9h. 20m., we find 2h. 28m. for the hour angle with which to enter our table.

The latitude of place of observation is + 40° 46′.

The percentage found in the table for these two arguments is 82
Correction for sun's declination, which is 12° *south*, is found by taking from table the correction for 1°, which in this case is + 0.3; hence for 12° . + 3.6
Hence total percentage of refraction in altitude, ... 85.6

Tabular mean refraction for altitude of 23° 03′ = 2′ 12″, eighty-five and six-tenths per cent. of which, namely, 2′.2 × .856 = 1′.9, is the correction to be applied to the sun's declination, and which in this case is subtractive, because it is *south*.

Sun's declination at instant of observation, ... 12° 00′.5
Hence declination to be set off on solar instrument, ... 11° 58′.6

Example II.

Washington, D. C., *May* 23, 1885.

Observed altitude of sun at 4h. 55m. P. M., 24° 10′; find the refraction-correction to be applied to the sun's declination. Here hour angle is equal to time of observation plus the equation of time. Equation of time = + 3.5 minutes. Assuming time-piece to indicate true local and not standard time, the sun's hour angle at observation = 4h. 58.5m.

Latitude of place of observation, + 38° 33′.

Percentage by table for these two arguments, ... 65
Sun's declination *north* + 20° 42′. Tabular correction for 1° north declination, — .3; hence correction for declination, 20° 7 + 3 = ... — 6.2
Total percentage of refraction in altitude, ... 58.8

Refraction for observed altitude, 2′ 36″. Then for refraction-correction to be applied to sun's declination, 2.6 + .588 = 1′.5, and which is *additive*, because the sun is north of the equator.

Sun's declination for Washington, mean noon, ... + 20° 42′.3
Correction for hour angle 5 × 28″ = ... + 2′.3
Correction for refraction as found above, ... + 1′.5
Sun's declination to be set off on instrument, ... + 20° 46′.1

It will readily be seen that, unless great precision is sought, the equation of time and the error of the time-piece on *local* time, if not exceeding about 15 minutes, may be disregarded in working out the hour angle of the sun, to be used in finding the percentage of refraction in altitude. But for computing the sun's declination, the hour angle should be known much more accurately, especially during the equinoxial periods, when the hourly change of declination amounts to as much as a minute of arc nearly.

SOLAR EPHEMERIS, 1885.

FOR WASHINGTON MEAN NOON.

Date.	Apparent Declination—Mean Noon.	Hourly Motion—Declination.	Equation of Time for Apparent Noon.	Date.	Apparent Declination—Mean Noon.	Hourly Motion—Declination.	Equation of Time for Apparent Noon.
1885.	° ′ ″	″	m. s.	1885.	° ′ ″	″	m. s.
Jan. 0	—23 2 6.7	+12.06	+ 3 38.10	Jan. 25	—18 47 20.5	+37.62	+12 43.70
1	22 57 3.5	13.20	4 6.31	26	18 31 67.2	38.47	12 56.32
2	22 51 32.9	14.34	4 34.17	27	18 16 33.8	39.30	13 8.11
3	22 45 34.9	15.47	5 1.65	28	18 0 40.8	40.11	13 19.08
4	22 39 9.8	16.60	5 28.74	29	17 44 28.5	40.91	13 29.23
5	22 32 17.9	17.71	5 55.41	30	17 27 57.2	41.69	13 38.55
6	22 24 59.3	18.82	6 21.64	31	17 10 67.3	42.46	13 47.05
7	22 17 14.0	19.92	6 47.40	Feb. 1	16 53 59.3	43.21	13 54.73
8	22 9 2.4	21.02	7 12.66	2	16 36 33.5	43.93	14 1.60
9	22 0 24.8	22.10	7 37.40	3	16 18 50.3	44.65	14 7.66
10	21 51 21.4	23.17	8 1.60	4	16 0 50.2	45.35	14 12.90
11	21 41 52.5	24.23	8 25.22	5	15 42 33.6	46.02	14 17.35
12	21 31 58.3	25.28	8 48.26	6	15 23 60.8	46.69	14 21.02
13	21 21 39.2	26.31	9 10.66	7	15 5 12.2	47.33	14 23.90
14	21 10 55.3	27.33	9 32.42	8	14 45 68.3	47.96	14 26.02
15	20 59 47.1	28.34	9 53.52	9	14 26 49.5	48.58	14 27.37
16	20 48 14.9	29.34	10 13.95	10	14 7 16.2	49.17	14 27.95
17	20 36 19.0	30.32	10 33.66	11	13 47 28.9	49.75	14 27.77
18	20 23 59.7	31.28	10 52.63	12	13 27 27.9	50.31	14 26.83
19	20 11 17.4	32.23	11 10.86	13	13 7 13.8	50.85	14 25.15
20	19 58 12.5	33.17	11 28.32	14	12 46 46.9	51.38	14 22.73
21	19 44 45.2	34.08	11 45.00	15	12 25 67.6	51.88	14 19.58
22	19 30 56.0	34.99	12 0.88	16	12 5 16.5	52.37	14 15.70
23	19 16 45.3	35.88	12 15.96	17	11 44 13.9	52.84	14 11.12
24	—19 2 13.3	+36.76	+12 30.24	18	—11 22 60.2	+53.28	+14 5.84

FOR WASHINGTON MEAN NOON—Continued.

Date.	Apparent Declination—Mean Noon.	Hourly Motion—Declination.	Equation of Time for Apparent Noon.
1885.	° ′ ″	″	m. s.
Feb. 19	−11 1 35.9	+53.72	+13 59.85
20	10 39 61.5	54.15	13 53.20
21	10 18 17.3	54.53	13 45.88
22	9 56 23.7	54.92	13 37.90
23	9 34 21.1	55.29	13 29.27
24	9 11 70.0	55.63	13 20.03
25	8 49 50.7	55.97	13 10.20
26	8 27 23.6	56.28	12 59.78
27	8 4 49.1	56.58	12 48.80
28	7 41 67.6	56.87	12 37.27
Mar. 1	7 19 19.4	57.14	12 25.22
2	6 56 25.0	57.39	12 12.70
3	6 33 24.7	57.63	11 59.70
4	6 10 18.9	57.85	11 46.24
5	5 46 68.0	58.06	11 32.35
6	5 23 52.3	58.25	11 18.07
7	5 0 32.2	58.42	11 3.39
8	4 36 68.1	58.58	10 48.34
9	4 13 40.4	58.72	10 32.95
10	3 49 69.5	58.85	10 17.24
11	3 26 35.7	58.96	10 1.24
12	3 2 59.4	59.06	9 44.94
13	2 39 21.1	59.13	9 28.36
14	2 15 41.1	59.20	9 11.53
15	1 51 59.7	59.25	8 54.48
16	1 28 17.4	59.27	8 37.22
17	1 4 34.6	59.26	8 19.74
18	0 40 51.7	59.28	8 2.07
19	0 17 9.0	59.26	7 44.24
20	+ 0 6 33.1	59.23	7 26.24
21	0 30 14.2	59.19	7 8.12
22	0 53 54.0	59.13	6 49.89
23	1 17 32.0	59.05	6 31.57
24	1 41 8.0	58.96	6 13.17
25	2 4 41.6	58.84	5 54.71
26	2 28 12.4	58.71	5 36.21
27	2 51 40.1	58.58	5 17.70
28	3 15 4.4	58.43	4 59.20
29	3 38 24.8	58.26	4 40.74
30	+4 1 41.1	+58.09	+ 4 22.34

Date.	Apparent Declination—Mean Noon.	Hourly Motion—Declination.	Equation of Time for Apparent Noon.
1885.	° ′ ″	″	m. s.
Mar. 31	+ 4 24 53.0	+ 57.90	+4 4.02
Apr. 1	4 48 0.1	57.69	3 45.81
2	5 11 2.1	57.47	3 27.73
3	5 33 58.6	57.24	3 9.77
4	5 56 49.4	56.98	2 52.00
5	6 19 34.1	56.72	2 34.43
6	6 42 12.3	56.45	2 17.07
7	7 4 43.8	56.16	1 59.94
8	7 27 8.1	55.85	1 43.06
9	7 49 25.0	55.54	1 26.44
10	8 11 34.0	55.21	1 10.14
11	8 33 34.9	54.86	0 54.08
12	8 55 27.3	54.50	0 38.35
13	9 17 10.8	54.13	0 22.94
14	9 38 45.1	53.73	0 7.87
15	10 0 9.9	53.33	−0 6.85
16	10 21 24.8	52.91	0 21.22
17	10 42 29.4	52.47	0 35.22
18	11 5 23.4	52.02	0 48.84
19	11 24 6.4	51.56	1 2.07
20	11 44 38.2	51.08	1 14.89
21	12 4 58.3	50.58	1 27.30
22	12 25 6.4	50.08	1 39.28
23	12 45 2.2	49.57	1 50.81
24	13 4 45.5	49.04	2 1.90
25	13 24 15.8	48.49	2 12.53
26	13 43 32.9	47.93	2 22.69
27	14 2 36.4	47.36	2 32.35
28	14 21 26.0	46.77	2 41.51
29	14 39 61.5	46.18	2 50.15
30	14 58 22.5	45.57	2 58.27
May 1	15 16 28.7	44.95	3 5.85
2	15 34 19.8	44.32	3 12.88
3	15 51 55.5	43.67	3 19.34
4	16 9 15.5	43.01	3 25.23
5	16 26 19.6	42.34	3 30.55
6	16 43 7.3	41.64	3 35.28
7	16 59 38.4	40.95	3 39.43
8	17 15 52.6	40.24	3 42.99
9	+17 31 49.7	+39.51	−3 45.96

FOR WASHINGTON MEAN NOON.—Continued.

Date.	Apparent Declination—Mean Noon.	Hourly Motion—Declination.	Equation of Time for Apparent Noon.
1885.	° ′ ″	″	m. s.
May 10	+17 47 29.2	+38.78	−3 48.34
11	18 2 50.9	38.04	3 50.13
12	18 17 54.5	37.28	3 51.34
13	18 32 39.8	36.50	3 51.96
14	18 47 6.3	35.71	3 52.00
15	19 1 13.8	34.92	3 51.48
16	19 15 2.1	34.11	3 50.40
17	19 28 30.8	33.28	3 48.76
18	19 41 39.7	32.45	3 46.58
19	19 54 28.5	31.61	3 43.87
20	20 6 56.9	30.76	3 40.63
21	20 19 4.7	29.89	3 36.87
22	20 30 51.7	29.02	3 32.59
23	20 42 17.5	28.14	3 27.80
24	20 53 22.0	27.25	3 22.52
25	21 4 5.0	26.34	3 16.76
26	21 14 26.2	25.42	3 10.52
27	21 24 25.3	24.50	3 3.81
28	21 34 2.2	23.57	2 56.64
29	21 43 16.8	22.63	2 49.02
30	21 52 8.8	21.69	2 40.97
31	22 0 38.0	20.74	2 32.47
June 1	22 8 44.2	19.77	2 23.54
2	22 16 27.3	18.80	2 14.21
3	22 23 47.2	17.83	2 4.50
4	22 30 43.6	16.85	1 54.42
5	22 37 16.4	15.87	1 43.98
6	22 43 25.5	14.88	1 33.20
7	22 49 10.7	13.89	1 22.10
8	22 54 31.9	12.89	1 10.69
9	22 59 29.0	11.88	0 59.00
10	23 4 11.9	10.87	0 47.07
11	23 8 10.5	9.85	0 34.92
12	23 11 54.7	8.83	0 22.57
13	23 15 14.4	7.81	0 10.04
14	23 18 9.5	6.78	+0 2.64
15	23 20 39.9	5.75	0 15.43
16	23 22 45.7	4.73	0 28.31
17	23 24 26.8	3.70	0 41.27
18	+23 25 43.1	+2.67	+0 54.28

Date.	Apparent Declination—Mean Noon.	Hourly Motion—Declination.	Equation of Time for Apparent Noon.
1885.	° ′ ″	″	m. s.
June 19	+23 26 34.6	+1.63	+1 7.29
20	23 27 1.3	0.60	1 20.29
21	23 27 3.2	− 0.43	1 33.25
22	23 26 40.3	1.46	1 46.16
23	23 25 52.6	2.50	1 58.99
24	23 24 40.2	3.53	2 11.73
25	23 23 3.0	4.56	2 24.35
26	23 21 1.2	5.59	2 36.83
27	23 18 34.7	6.61	2 49.14
28	23 15 43.7	7.63	3 1.28
29	23 12 28.2	8.65	3 13.24
30	23 8 48.3	9.66	3 24.98
July 1	23 4 44.1	10.67	3 36.49
2	23 0 15.6	11.67	3 47.75
3	22 55 23.1	12.68	3 58.74
4	22 50 6.6	13.68	4 9.44
5	22 44 26.3	14.67	4 19.84
6	22 38 22.2	15.66	4 29.91
7	22 31 54.6	16.64	4 39.63
8	22 25 3.6	17.61	4 48.98
9	22 17 49.3	18.58	4 57.95
10	22 10 12.0	19.53	5 6.51
11	22 2 11.8	20.48	5 14.65
12	21 53 48.8	21.42	5 22.34
13	21 45 3.4	22.35	5 29.55
14	21 35 55.8	23.28	5 36.28
15	21 26 26.1	24.19	5 42.51
16	21 16 34.4	25.10	5 48.22
17	21 6 21.1	26.00	5 53.39
18	20 55 46.4	26.88	5 58.02
19	20 44 50.6	27.76	6 2.09
20	20 33 33.8	28.62	6 5.59
21	20 21 56.4	29.48	6 8.51
22	20 9 58.5	30.33	6 10.84
23	19 57 40.3	31.17	6 12.58
24	19 44 62.2	32.00	6 13.74
25	19 32 4.4	32.81	6 14.30
26	19 18 47.1	33.62	6 14.25
27	19 5 10.6	34.42	6 13.60
28	+18 51 15.2	−35.20	+6 12.36

FOR WASHINGTON MEAN NOON—Continued.

Date.	Apparent Declination—Mean Noon.	Hourly Motion—Declination.	Equation of Time for Apparent Noon.
1885.	° ′ ″	″	m. s.
July 29	+18 36 61.1	—35.97	+6 10.53
30	18 22 28.6	36.73	6 8.11
31	18 7 38.0	37.48	6 5.10
Aug. 1	17 52 29.6	38.22	6 1.49
2	17 36 63.6	38.94	5 57.29
3	17 21 20.3	39.65	5 52.52
4	17 5 20.1	40.36	5 47.17
5	16 48 63.2	41.06	5 41.25
6	16 32 29.9	41.73	5 34.75
7	16 15 40.6	42.40	5 27.66
8	15 58 35.5	43.06	5 19.99
9	15 41 15.0	43.69	5 11.75
10	15 23 39.3	44.30	5 2.95
11	15 5 48.8	44.91	4 53.58
12	14 47 43.9	45.50	4 43.65
13	14 29 24.9	46.08	4 33.17
14	14 10 52.0	46.65	4 22.13
15	13 52 5.6	47.21	4 10.54
16	13 33 6.1	47.75	3 58.42
17	13 13 53.6	48.28	3 45.77
18	12 54 28.6	48.80	3 32.60
19	12 34 51 4	49.30	3 18.91
20	12 14 62.3	49.79	3 4.72
21	11 54 61.5	50.26	2 50.05
22	11 34 49.5	50.73	2 34.92
23	11 14 26.5	51.18	2 19.34
24	10 53 52.8	51.62	2 3.32
25	10 33 8.7	52.05	1 46.88
26	10 12 14.5	52.47	1 30.04
27	9 51 10.6	52.86	1 12.83
28	9 29 57.2	53.25	0 55.27
29	9 8 34.7	53.62	0 37.37
30	8 47 3.4	53.99	0 19.15
31	8 25 23.5	54.33	0 0.62
Sept. 1	8 3 35.4	54.67	—0 18.20
2	7 41 39.4	55.00	0 37.30
3	7 19 35.9	55.30	0 56.63
4	6 57 25.1	55.60	1 16.19
5	6 35 7.4	55.88	1 35.97
6	+6 12 43.1	—56.14	—1 55.96

Date.	Apparent Declination—Mean Noon.	Hourly Motion—Declination.	Equation of Time for Apparent Noon.
1885.	° ′ ″	″	m. s.
Sept. 7	+5 50 12.6	—56.39	—2 16.14
8	5 27 36.3	56.63	2 36.49
9	5 4 54.4	56.85	2 56.99
10	4 42 7.3	57.06	3 17.64
11	4 19 15.4	57.26	3 38.41
12	3 56 19.0	57.44	3 59.29
13	3 33 18.4	57.60	4 20.27
14	3 10 13.9	57.76	4 41.32
15	2 47 6.0	57.90	5 2.44
16	2 23 55.0	58.02	5 23.60
17	2 0 41.2	58.13	5 44.78
18	1 37 24.9	58.23	6 5.97
19	1 14 6.4	58.30	6 27.13
20	0 50 46.2	58.37	6 48.25
21	0 27 24.5	58.43	7 9.30
22	0 4 1.6	58.48	7 30.28
23	—0 19 22.1	58.50	7 51.13
24	0 42 46.2	58.52	8 11.85
25	1 6 10.5	58.52	8 32.40
26	1 29 34.7	58.50	8 52.77
27	1 52 58.4	58.47	9 12.93
28	2 16 21.2	58.43	9 32.86
29	2 39 42.9	58.38	9 52.53
30	3 2 63.1	58.30	10 11.93
Oct. 1	3 26 21.4	58.22	10 31.02
2	3 49 37.5	58.12	10 49.79
3	4 12 51.1	58.00	11 8.22
4	4 35 61.8	57.87	11 26.28
5	4 58 69.1	57.73	11 43.95
6	5 22 12.8	57.56	12 1.25
7	5 45 12.4	57.39	12 18.15
8	6 7 67.6	57.20	12 34.63
9	6 30 57.9	56.99	12 50.66
10	6 53 43.1	56.77	13 6.23
11	7 16 22.7	56.52	13 21.32
12	7 38 56.3	56.26	13 35.91
13	8 1 23.4	55.99	13 50.02
14	8 23 43.8	55.70	14 3.60
15	8 45 57.1	55.39	14 16.66
16	—9 7 62.8	—55.06	—14 29.15

FOR WASHINGTON MEAN NOON—Continued.

Date.	Apparent Declination—Mean Noon.	Hourly Motion—Declination.	Equation of Time for Apparent Noon.
1885.	° ′ ″	″	m. s.
Oct. 17	—9 29 60.5	—54.72	—14 41.08
18	9 51 49.9	54.37	15 52.41
19	10 13 30.6	54.00	15 3.14
20	10 34 62.2	53.62	15 13.25
21	10 56 24.4	53.22	15 22.72
22	11 17 36.7	52.80	15 31.54
23	11 38 38.7	52.36	15 39.69
24	11 59 30.1	51.91	15 47.11
25	12 19 70.5	51.45	15 53.79
26	12 40 39.5	50.96	15 59.76
27	13 0 56.7	50.46	16 4.97
28	13 20 61.8	49.95	16 9.42
29	13 40 54.4	49.43	16 13.09
30	14 0 34.0	48.87	16 15.97
31	14 19 60.1	48.31	16 18.04
Nov. 1	14 38 72.5	47.72	16 19.30
2	14 57 70.8	47.13	16 19.74
3	15 16 54.5	46.51	16 19.35
4	15 35 23.2	45.87	16 18.12
5	15 53 36.5	45.22	16 16.05
6	16 11 33.9	44.55	16 13.14
7	16 29 15.1	43.87	16 9.40
8	16 46 39.6	43.17	16 4.81
9	17 3 46.9	42.44	15 59.38
10	17 20 36.8	41.71	15 53.11
11	17 36 68.8	40.96	15 46.01
12	17 53 22.4	40.18	15 38.07
13	18 9 17.3	39.39	15 29.30
14	18 24 53.0	38.58	15 19.70
15	18 39 69.2	37.75	15 9.28
16	18 54 65.5	36.92	14 58.04
17	19 9 41.5	36.07	14 45.98
18	19 23 56.8	35.20	14 33.12
19	19 37 51.0	34.32	14 19.44
20	19 51 23.8	33.42	14 4.96
21	20 4 34.9	32.50	13 49.68
22	20 17 23.9	31.57	13 33.60
23	—20 29 50.4	—30.63	—13 16.73

Date.	Apparent Declination—Mean Noon.	Hourly Motion—Declination.	Equation of Time for Apparent Noon.
1885.	° ′ ″	″	m. s.
Nov. 24	—20 41 54.1	—29.67	—12 59.09
25	20 53 34.7	28.70	12 40.68
26	21 4 51.9	27.72	12 21.50
27	21 15 45.3	26.73	12 1.60
28	21 26 14.6	25.72	11 40.97
29	21 36 19.6	24.69	11 19.63
30	21 45 59.9	23.66	10 57.60
Dec. 1	21 55 15.2	22.62	10 34.88
2	22 4 5.3	21.56	10 11.52
3	22 12 29.8	20.49	9 47.54
4	22 20 28.6	19.41	9 22.97
5	22 27 61.4	18.32	8 57.84
6	22 35 7.9	17.22	8 32.1
7	22 41 47.8	16.10	8 5.96
8	22 47 61.0	14.99	7 39.30
9	22 53 47.3	13.86	7 12.2
10	22 59 6.5	12.73	6 44.6
11	23 3 58.3	11.59	6 16.8
12	23 8 22.6	10.45	5 48.5
13	23 12 19.4	9.30	5 20.0
14	23 15 48.4	8.13	4 51.2
15	23 18 49.5	6.96	4 22.1
16	23 21 22.6	5.79	3 52.9
17	23 23 27.6	4.62	3 23.4
18	23 25 4.5	3.45	2 53.8
19	23 26 13.2	2.27	2 24.1
20	23 26 53.6	— 1.09	1 54.3
21	23 27 5.7	+ 0.08	1 24.5
22	23 26 49.6	1.26	0 54.6
23	23 26 5.2	2.44	0 24.8
24	23 24 52.5	3.62	+ 0 5.0
25	23 23 11.5	4.80	0 34.8
26	23 21 2.3	5.97	1 4.5
27	23 18 25.0	7.14	1 34.0
28	23 15 19.6	8.30	2 3.4
29	23 11 46.2	9.46	2 32.6
30	23 7 44.9	10.62	3 1.6
31	—23 3 15.9	+11.77	+ 3 30.4

SOLAR EPHEMERIS, 1886.

FOR WASHINGTON MEAN NOON.

Date.	Apparent Declination—Mean Noon.	Hourly Motion—Declination.	Equation of Time for Apparent Noon.	Date.	Apparent Declination—Mean Noon.	Hourly Motion—Declination.	Equation of Time for Apparent Noon.
1886.	° ′ ″	″	m. s.	1886.	° ′ ″	″	m. s.
Jan. 0	−23 3 15.9	+11.79	+ 3 30.41	Feb. 6	−15 28 33.2	+46.54	+14 20.32
1	22 58 19.3	12.93	3 58.84	7	15 9 48.4	47.18	14 23.47
2	22 52 55.2	14.07	4 26.95	8	14 50 48.2	47.81	14 25.81
3	22 47 3.7	15.21	4 54.72	9	14 31 33.1	48.42	14 27.34
4	22 40 45.1	16.34	5 22.09	10	14 11 63.6	49.01	14 28.07
5	22 33 59.6	17.45	5 49.03	11	13 52 20.1	49.59	14 28.01
6	22 26 47.3	18.56	6 15.52	12	13 32 23.0	50.15	14 27.16
7	22 19 8.5	19.66	6 41.52	13	13 12 12.6	50.70	14 25.54
8	22 11 3.4	20.75	7 7.00	14	12 51 49.4	51.23	14 23.16
9	22 2 32.3	21.83	7 31.92	15	12 31 13.8	51.73	14 20.02
10	21 53 35.3	22.90	7 56.27	16	12 10 26.3	52.22	14 16.15
11	21 44 12.8	23.96	8 20.02	17	11 49 27.2	52.69	14 11.57
12	21 34 25.1	25.01	8 43.14	18	11 28 16.9	53.14	14 6.29
13	21 24 12.4	26.04	9 5.61	19	11 6 55.8	53.59	14 0.33
14	21 13 34.9	27.06	9 27.41	20	10 45 24.3	54.01	13 53.70
15	21 2 33.0	28.07	9 48.52	21	10 23 42.8	54.41	13 46.44
16	20 51 7.1	29.07	10 8.94	22	10 1 51.7	54.81	13 38.55
17	20 39 17.4	30.05	10 28.64	23	9 39 51.4	55.19	13 30.05
18	20 26 64.3	31.02	10 47.61	24	9 17 42.3	55.55	13 20.95
19	20 14 28.0	31.98	11 5.83	25	8 55 24.7	55.90	13 11.29
20	20 1 28.9	32.92	11 23.30	26	8 32 59.2	56.22	13 1.08
21	19 48 7.4	33.85	11 40.01	27	8 10 26.0	56.52	12 50.34
22	19 34 23.8	34.77	11 55.96	28	7 47 45.7	56.82	12 39.07
23	19 20 18.4	35.67	12 11.14	Mar. 1	7 24 58.5	57.10	12 27.29
24	19 5 51.7	36.55	12 25.54	2	7 1 64.9	57.35	12 15.03
25	18 50 63.9	37.42	12 39.17	3	6 38 65.3	57.60	12 2.30
26	18 35 55.5	38.27	12 52.02	4	6 15 60.1	57.82	11 49.11
27	18 20 26.8	39.10	13 4.07	5	5 52 49.7	58.03	11 35.48
28	18 4 38.2	39.92	13 15.32	6	5 29 34.6	58.22	11 21.42
29	17 48 30.1	40.72	13 25.77	7	5 6 15.1	58.39	11 6.95
30	17 31 63.0	41.51	13 35.43	8	4 42 51.6	58.55	10 52.09
31	17 15 17.2	42.28	13 44.29	9	4 19 24.5	58.70	10 36.85
Feb. 1	16 58 13.1	43.03	13 52.34	10	3 55 54.2	58.82	10 21.25
2	16 40 51.1	43.77	13 59.57	11	3 32 21.1	58.93	10 5.31
3	16 23 11.7	44.50	14 5.98	12	3 8 45.6	59.02	9 49.04
4	16 5 15.3	45.19	14 11.58	13	2 44 68.1	59.09	9 32.47
5	−15 46 62.3	+45.87	+14 16.36	14	− 2 21 28.9	+59.15	+9 15.61

FOR WASHINGTON MEAN NOON—Continued.

Date.	Apparent Declination—Mean Noon.	Hourly Motion—Declination.	Equation of Time for Apparent Noon.	Date.	Apparent Declination—Mean Noon.	Hourly Motion—Declination.	Equation of Time for Apparent Noon.
1886.	° ′ ″	″	m. s.	1886.	° ′ ″	″	m. s.
Mar. 15	−1 57 48.4	+59.20	+8 58.48	Apr. 24	+12 59 54.1	+49.17	−2 0.15
16	1 33 67.0	59.23	8 41.11	25	13 19 27.7	48.64	2 10.83
17	1 10 25.0	59.25	8 23.53	26	13 38 48.2	48.08	2 21.01
18	0 46 42.8	59.25	8 5.76	27	13 57 55.4	47.52	2 30.68
19	0 22 60.7	59.25	7 47.82	28	14 16 48.9	46.94	2 39.82
20	+0 0 40.9	59.22	7 29.73	29	14 35 28.4	46.35	2 48.43
21	0 24 21.7	59.18	7 11.53	30	14 53 53.5	45.74	2 56.49
22	0 48 1.3	59.13	6 53.22	May 1	15 12 4.0	45.13	3 4.02
23	1 11 39.5	59.05	6 34.84	2	15 29 59.5	44.50	3 11.00
24	1 35 15.8	58.97	6 16.41	3	15 47 39.7	43.85	3 17.43
25	1 58 50.0	58.87	5 57.95	4	16 5 4.3	43.19	3 23.30
26	2 22 21.6	58.75	5 39.48	5	16 22 12.8	42.52	3 28.62
27	2 45 50.3	58.63	5 21.04	6	16 39 5.0	41.83	3 33.38
28	3 9 15.8	58.49	5 2.64	7	16 55 40.6	41.13	3 37.59
29	3 32 37.7	58.33	4 44.29	8	17 11 59 3	40.42	3 41.25
30	3 55 55.7	58.16	4 26.01	9	17 27 60.8	39.70	3 44.35
31	4 19 9.4	57.98	4 7.82	10	17 43 44.7	38.96	3 46.89
Apr. 1	4 42 18.5	57.78	3 49.74	11	17 59 10.8	38.21	3 48.88
2	5 5 22.6	57.56	3 31.79	12	18 14 18.7	37.45	3 50.32
3	5 28 21.3	57.33	3 13.98	13	18 29 8.2	36.67	3 51.20
4	5 51 14.3	57.07	2 56.31	14	18 43 39.0	35.88	3 51.52
5	6 14 1.2	56.81	2 38.82	15	18 57 50.8	35.08	3 51.27
6	6 36 41.6	56.54	2 21.52	16	19 11 43.4	34.28	3 50.47
7	6 59 15.2	56.24	2 4.43	17	19 25 16.5	33.46	3 49.12
8	7 21 41.7	55.94	1 47.55	18	19 38 29.8	32.63	3 47.21
9	7 44 0.6	55.62	1 30.88	19	19 51 23.1	31.79	3 44.75
10	8 6 11.7	55.29	1 14.46	20	20 3 56.1	30.95	3 41.73
11	8 28 14.5	54.94	0 58.31	21	20 16 8.6	30.09	3 38.16
12	8 50 8.8	54.58	0 42.43	22	20 27 60.4	29.23	3 34.05
13	9 11 54.2	54.21	0 26.83	23	20 39 31.3	28.36	3 29.39
14	9 33 30.4	53.81	0 11.55	24	20 50 40.9	27.46	3 24.19
15	9 54 57.1	53.40	−0 3.40	25	21 1 29.0	26.56	3 18.48
16	10 16 13.8	52.99	0 18.00	26	21 11 55.5	25.65	3 12.25
17	10 37 20.3	52.55	0 32.23	27	21 21 60.1	24.74	3 5.53
18	10 58 16.3	52.10	0 46.08	28	21 31 42.7	23.82	2 58.31
19	11 19 1.5	51.64	0 59.53	29	21 41 3.0	22.88	2 50.62
20	11 39 35.6	51.18	1 12.56	30	21 49 60.8	21.94	2 42.47
21	11 59 58.2	50.70	1 25.15	31	21 58 35.8	20.99	2 33.89
22	12 20 9.0	50.20	1 37.29	June 1	22 6 47.9	20.03	2 24.88
23	+12 40 7.7	+49.69	−1 48.96	2	+22 14 37.0	+19.06	−2 15.49

FOR WASHINGTON MEAN NOON—Continued.

Date.	Apparent Declination—Mean Noon.	Hourly Motion—Declination.	Equation of Time for Apparent Noon.	Date.	Apparent Declination—Mean Noon.	Hourly Motion—Declination.	Equation of Time for Apparent Noon.
1886.	° ′ ″	″	m. s.	1886.	° ′ ″	″	m. s.
June 3	+22 22 2.9	+18.09	−2 5.73	July 13	+21 47 11.8	−22.11	+5 29.09
4	22 29 5.3	17.11	1 55.60	14	21 38 9.6	23.04	5 35.77
5	22 35 44.1	16.12	1 45.13	15	21 28 45.3	23.96	5 41.95
6	22 41 59.2	15.13	1 34.36	16	21 18 59.1	24.87	5 47.63
7	22 47 50.4	14.14	1 23.30	17	21 8 51.2	25.77	5 52.80
8	22 53 17.6	13.14	1 11.97	18	20 58 21.7	26.66	5 57.44
9	22 58 20.7	12.13	1 0.40	19	20 47 30.9	27.54	6 1.55
10	23 2 59.5	11.12	0 48.61	20	20 36 19.1	28.41	6 5.13
11	23 7 14.0	10.10	0 36.62	21	20 24 46.5	29.28	6 8.17
12	23 11 4.0	9.08	0 24.44	22	20 12 53.3	30.13	6 10.66
13	23 14 29.5	8.06	0 12.10	23	20 0 39.7	30.98	6 12.60
14	23 17 30.4	7.03	+0 0.38	24	19 48 6.1	31.81	6 13.98
15	23 20 6.7	6.00	0 13.00	25	19 35 12.6	32.63	6 14.79
16	23 22 18.3	4.97	0 25.73	26	19 21 59.6	33.44	6 15.02
17	23 24 5.1	3.94	0 38.54	27	19 8 27.3	34.23	6 14.68
18	23 25 27.2	2.91	0 51.40	28	18 54 36.0	35.02	6 13.75
19	23 26 24.5	1.87	1 4.31	29	18 40 25.9	35.80	6 12.24
20	23 26 57.0	0.84	1 17.24	30	18 25 57.4	36.57	6 10.12
21	23 27 4.7	− 0.20	1 30 19	31	18 11 10.8	37.31	6 7.39
22	23 26 47.6	1.23	1 43.13	Aug. 1	17 56 6.3	38.05	6 4.06
23	23 26 5.6	2.26	1 56.02	2	17 40 44.3	38.78	6 0.13
24	23 24 58.9	3.29	2 8.85	3	17 25 5.0	39.49	5 55.58
25	23 23 27.6	4.32	2 21.62	4	17 9 8.8	40.18	5 50.41
26	23 21 31.6	5.34	2 34.28	5	16 52 55.9	40.87	5 44.63
27	23 19 11.0	6.36	2 46.80	6	16 36 26.6	41.55	5 38.24
28	23 16 25.7	7.38	2 59.16	7	16 19 41.3	42.22	5 31.24
29	23 13 16.0	8.40	3 11.35	8	16 2 40.3	42.86	5 23.63
30	23 9 41.9	9.42	3 23.33	9	15 45 23.8	43.50	5 15.42
July 1	23 5 43.5	10.43	3 35.07	10	15 27 52.2	44.12	5 6.62
2	23 1 20.8	11.44	3 46.55	11	15 10 5.8	44.74	4 57.24
3	22 56 34.1	12.44	3 57.74	12	14 52 4.9	45.33	4 47.28
4	22 51 23.4	13.44	4 8.62	13	14 33 49.7	45.92	4 36.76
5	22 45 48.8	14.43	4 19.18	14	14 15 20.6	46.50	4 25.69
6	22 39 50.5	15.42	4 29.38	15	13 56 37.9	47.05	4 14.08
7	22 33 28.7	16.39	4 39.20	16	13 37 41.9	47.60	4 1.96
8	22 26 43.4	17.36	4 48.61	17	13 18 32.8	48.14	3 49.33
9	22 19 34.9	18.33	4 57.59	18	12 59 11.0	48.67	3 36.20
10	22 12 3.3	19.29	5 6.15	19	12 39 36.8	49.17	3 22.59
11	22 4 8.8	20.24	5 14.27	20	12 19 50.5	49.67	3 8.51
12	+21 55 51.6	−21.18	+5 21.92	21	+11 59 52.4	−50.16	+2 53.98

FOR WASHINGTON MEAN NOON—Continued.

Date.	Apparent Declination—Mean Noon.	Hourly Motion—Declination.	Equation of Time for Apparent Noon.	Date.	Apparent Declination—Mean Noon.	Hourly Motion—Declination.	Equation of Time for Apparent Noon.
1886.	° ′ ″	″	m. s.	1886.	° ′ ″	″	m. s.
Aug. 22	+11 39 42.8	−50.63	+ 2 39.02	Oct. 1	− 3 20 48.6	−58.25	−10 24.93
23	11 19 22.0	51.08	2 23.63	2	3 43 65.6	58.15	10 43.75
24	10 58 50.4	51.53	2 7.83	3	4 7 20.0	58.03	11 2.26
25	10 38 8.3	51.97	1 51.63	4	4 30 31.3	57.90	11 20.45
26	10 17 15.9	52.39	1 35.04	5	4 53 39.3	57.76	11 38.30
27	9 56 13.7	52.79	1 18.08	6	5 16 43.6	57.60	11 55 80
28	9 35 2.0	53.18	1 0.75	7	5 39 43.7	57.43	12 12.91
29	9 13 41.1	53.56	0 43.08	8	6 2 39.4	57.23	12 29.62
30	8 52 11.3	53.91	0 25.07	9	6 25 30.3	57.01	12 45.91
31	8 30 32.9	54.26	0 6.72	10	6 48 16.0	56.79	13 1.75
Sept. 1	8 8 46.4	54.60	−0 11.95	11	7 10 56.1	56.55	13 17.12
2	7 46 52.0	54.93	0 30.92	12	7 33 30.3	56.29	13 32.02
3	7 24 50.1	55.23	0 50.17	13	7 55 58.3	56.03	13 46.40
4	7 2 41.0	55.52	1 9.69	14	8 18 19.7	55.75	14 0.24
5	6 40 25.2	55.80	1 29.47	15	8 40 34.1	55.45	14 13.53
6	6 18 2.8	56.06	1 49.48	16	9 2 41.1	55.14	14 26.24
7	5 55 34.2	56.31	2 9.72	17	9 24 40.4	54.81	14 38.36
8	5 32 59.8	56.55	2 30.15	18	9 46 31.6	54.45	14 49.86
9	5 10 19.8	56.77	2 50.76	19	10 8 14.3	54.09	15 0.72
10	4 47 34.6	56.98	3 11.54	20	10 29 48.2	53.72	15 10.93
11	4 24 44.5	57.18	3 32.45	21	10 50 72.9	53.33	15 20.47
12	4 1 49.9	57.37	3 53.47	22	11 12 27.9	52.92	15 29.33
13	3 38 51.0	57.53	4 14.58	23	11 33 32.9	52.50	15 37.48
14	3 15 48.1	57.69	4 35.76	24	11 54 27.5	52.05	15 44.92
15	2 52 41.6	57.84	4 56.99	25	12 14 71.2	51.59	15 51.65
16	2 29 31.8	57.97	5 18.23	26	12 35 43.7	51.11	15 57.65
17	2 6 19.0	58.08	5 39.47	27	12 55 64.5	50.61	16 2.91
18	1 43 3.5	58.19	6 0.68	28	13 15 73.2	50.10	16 7.41
19	1 19 45.6	58.29	6 21.84	29	13 35 69.4	49.58	16 11.15
20	0 56 25.7	58.36	6 42.94	30	13 55 52.6	49.02	16 14.12
21	0 33 4.1	58.43	7 3.95	31	14 15 22.5	48.46	16 16.34
22	0 9 41.2	58.48	7 24.85	Nov. 1	14 34 38.6	47.88	16 17.78
23	− 0 13 42.8	58.51	7 45.61	2	14 53 40.4	47.27	16 18.42
24	0 36 67.5	58.53	8 6.23	3	15 12 27.6	46.66	16 18.27
25	1 0 32.5	58.54	8 26.68	4	15 30 59.8	46.03	16 17.33
26	1 23 57.4	58.53	8 46.95	5	15 49 16.6	45.37	16 15.59
27	1 47 21.9	58.50	9 7.02	6	16 7 17.5	44.70	16 13.03
28	2 10 45.7	58.46	9 26.86	7	16 24 62.1	44.01	16 9.64
29	2 33 68.3	58.41	9 46.47	8	16 42 30.0	43.31	16 5.43
30	−2 57 29.4	−58.33	−10 5.83	9	−16 59 40.9	−42.60	−16 0.39

FOR WASHINGTON MEAN NOON—Continued.

Date.	Apparent Declination—Mean Noon.	Hourly Motion—Declination.	Equation of Time for Apparent Noon.	Date.	Apparent Declination—Mean Noon.	Hourly Motion—Declination.	Equation of Time for Apparent Noon.
1886.	° ′ ″	″	m. s.	1886.	° ′ ″	″	m. s.
Nov. 10	—17 16 34.4	—41.86	—15 54.51	Dec. 6	— 22 33 28.5	—17.48	—8 37.84
11	17 32 70.1	41.11	15 47.79	7	22 40 14.7	16.37	8 11.96
12	17 49 27.5	40.35	15 40.20	8	22 46 34.1	15.25	7 45.59
13	18 5 26.4	39.56	15 31.75	9	22 52 26.7	14.13	7 18.79
14	18 20 66.3	38.76	15 22.46	10	22 57 52.2	13.00	6 51.57
15	18 36 26.9	37.95	15 12.32	11	23 2 50.4	11.86	6 23.96
16	18 51 27.7	37.12	15 1.31	12	23 7 21.1	10.71	5 55.96
17	19 5 68.4	36.27	14 49.45	13	23 11 24.3	9.56	5 27.62
18	19 20 28.7	35.41	14 36.75	14	23 14 59.8	8.41	4 58.96
19	19 34 28.2	34.54	14 23.20	15	23 18 7.5	7.25	4 30.03
20	19 47 66.4	33.64	14 8.81	16	23 20 47.3	6.07	4 0.84
21	20 1 23.0	32.74	13 53.59	17	23 22 59.0	4.90	3 31.42
22	20 14 17.7	31.82	13 37.56	18	23 24 42.7	3.73	3 1.80
23	20 26 50.1	30.88	13 20.72	19	23 25 58.2	2.56	2 32.02
24	20 38 59.8	29.93	13 3.09	20	23 26 45.5	1.38	2 2.13
25	20 50 46.5	28.97	12 44.69	21	23 27 4.5	0.20	1 32.15
26	21 2 9.9	27.98	12 25.54	22	23 26 55.3	+0.98	1 2.11
27	21 13 9.6	26.99	12 5.68	23	23 26 17.8	2.16	0 32.06
28	21 23 45.2	25.98	11 45.12	24	23 25 12.0	3.33	0 2.03
29	21 33 56.4	24.95	11 23.87	25	23 23 38.0	4.51	+0 27.94
30	21 43 43.0	23.92	11 1.95	26	23 21 35.8	5.68	0 57.82
Dec. 1	21 53 4.6	22.88	10 39.29	27	23 19 5.4	6.85	1 27.55
2	22 1 61.0	21.82	10 16.22	28	23 16 6.9	8.01	1 57.10
3	22 10 31.8	20.75	9 52.45	29	23 12 40.5	9.17	2 26.43
4	22 18 36.8	19.67	9 28.12	30	23 8 46.2	10.33	2 55.51
5	—22 26 15.8	—18.58	— 9 3.23	31	—23 4 24.0	+11.49	+3 24.30

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;

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

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

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

If in (1) $T = 24^{h.}$ ∴ $S = 24^{h.}\ 3^{m.}\ 56^{s.}.5553$, 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) $S = 24^{h.}$ ∴ $T = 24^{h.} - 3^{m.}\ 55^{s.}.9094$, 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.

Tables of English and Metric Weights and Measures.

Long Measure.

Inches.	Feet.	Yards.	Rods.	Furlongs.	Mile.
1 =	0.0833 =	0.02778 =	0.00505 =	0.000126 =	0.000016
12 =	1 =	0.33333 =	0.06061 =	0.001515 =	0.000189
36 =	3 =	1 =	0.18182 =	0.004545 =	0.000568
198 =	16.5 =	5.5 =	1 =	0.025 =	0.003125
7920 =	660 =	220 =	40 =	1 =	0.125
63360 =	5280 =	1760 =	320 =	8 =	1

1 hand = 4 inches.

1 span = 9 inches.

1 fathom = 6 feet.

1 cable's length = 120 fathoms.

1 knot or nautical mile = 6080.27 feet = $\frac{1}{21600}$ of the great circle of a sphere whose surface is equal to the surface of the earth.

1 admiralty knot = 6080 feet = 1.1515 statute miles.

Surveyors' Measure.

Inches.	Links.	Feet.	Chains.	Mile.
1 =	0.126 =	0.0833 =	0.00126 =	0.000016
7.92 =	1 =	0.66 =	0.01 =	0.000125
12 =	1.515 =	1 =	0.01515 =	0.000189
792 =	100 =	66 =	1 =	0.0125
63360 =	8000 =	5280 =	80 =	1

Square Measure.

Inches.	Feet.	Yards.	Rods.	Roods.	Acres.	Mile.
1 =	0.00694 =	0.00077 =	0.0000255 =	0.0000006 =	0.0000002 =	
144 =	1 =	0.11111 =	0.003673 =	0.0000918 =	0.0000230 =	0.000000036
1296 =	9 =	1 =	0.033058 =	0.0008264 =	0.0002066 =	0.000000323
39204 =	272.25 =	30.25 =	1 =	0.025 =	0.00625 =	0.000009766
1568160 =	10890 =	1210 =	40 =	1 =	0.25 =	0.0003906
6272640 =	43560 =	4840 =	160 =	4 =	1 =	0.0015625
	27878400 =	3097600 =	102400 =	2560 =	640 =	1

10 square chains = 1 acre.
6,400 square chains = 1 square mile.
1 chain wide × 1 mile long = 80 square chains = 8 acres.
A section of land is 1 mile square, and contains 640 acres.
A square 208.710 feet on a side contains 1 acre.
A circle 235.504 feet in diameter contains an acre.

Cubic Measure.

Inches.	Feet.	Yard.
1	= 0.0005787	= 0.00002143
1728	= 1	= 0.03703704
46656	= 27	= 1

16 cubic feet = 1 cord foot.
8 cord feet, or 128 cubic feet = 1 cord.
42 cubic feet = 1 ton of shipping.
24.75 cubic feet = 1 perch of masonry.

Capacity Measures.

Dry Measure.

Pints.	Quarts.	Pecks.	Bushel.
1	= 0.5	= 0.0625	= 0.015625
2	= 1	= 0.125	= 0.03125
16	= 8	= 1	= 0.25
64	= 32	= 4	= 1

Liquid Measure.

Minims.	Fl. Drams.	Fl. Ounces.	Gills.	Pints.	Quarts.	Gallon.
1	= 0.01667	= 0.0020833	= 0.0005208	= 0.0001302	= 0.0000651	= 0.0000163
60	= 1	= 0.125	= 0.03125	= 0.0078125	= 0.0039062	= 0.0009766
480	= 8	= 1	= 0.25	= 0.0625	= 0.03125	= 0.0078125
1920	= 32	= 4	= 1	= 0.25	= 0.125	= 0.03125
7680	= 128	= 16	= 4	= 1	= 0.5	= 0.125
15360	= 256	= 32	= 8	= 2	= 1	= 0.25
61440	= 1024	= 128	= 32	= 8	= 4	= 1

1 bushel	contains	2150.42 cub. inches.
1 peck	"	537.605 "
1 quart, dry,	"	67.201 "
1 pint "	"	33.600 "
1 gallon	"	231. "
1 qt., liquid,	"	57.75 "
1 pint "	"	28.875 "
1 gill	"	7.219 "
1 fluid ounce	"	1.805 "

1 cubic foot =	0.80356 bushel.
=	3.21426 pecks.
=	25.71405 quarts.
=	51.4281 pints.
=	7.48052 gallons.
=	29.92208 quarts.
=	59.8442 pints.
=	239.377 gills.
=	957.506 fluid oz.

Avoirdupois Weight.

Grains.	Drams.	Ounces.	Pounds.	Quarters.	Cwt.	Ton.
1	= 0.03657	= 0.0022857	= 0.0001429	= 0.0000057	= 0.0000014	= 0.0000001
27.3438	= 1	= 0.0625	= 0.0039062	= 0.0001563	= 0.0000391	= 0.0000020
437.5	= 16	= 1	= 0.0625	= 0.0025	= 0.000625	= 0.0000312
7000	= 256	= 16	= 1	= 0.04	= 0.01	= 0.0005
175000	= 6400	= 400	= 25	= 1	= 0.25	= 0.0125
700000	= 25600	= 1600	= 100	= 4	= 1	= 0.05
14000000	= 512000	= 32000	= 2000	= 80	= 20	= 1

Troy Weight.

Grains.	Pennyweights.	Ounces.	Pound.
1	= 0.041667	= 0.0020833	= 0.0001736
24	= 1	= 0.05	= 0.0041667
480	= 20	= 1	= 0.0833333
5760	= 240	= 12	= 1

Apothecaries' Weight.

Grains.	Scruples.	Drams.	Ounces.	Pound.
1	= 0.05	= 0.01667	= 0.0020833	= 0.0001736
20	= 1	= 0.33333	= 0.0416667	= 0.0034722
60	= 3	= 1	= 0.125	= 0.0104167
480	= 24	= 8	= 1	= 0.0833333
5760	= 288	= 96	= 12	= 1

Relation of Metric to American Measures.

The following relations were established by the act of Congress of July 28, 1866, as the legal equivalents of the weights and measures of the metric system in the weights and measures now in general use:

Measures of Length.

Myriameter, . . .	10,000 meters	= 6.2137 miles.
Kilometer, . . .	1,000 meters	= 0.62137 mile = 3280 ft. 10 in.
Hectometer, . . .	100 meters	= 328 feet 1 inch.
Dekameter, . . .	10 meters	= 393.7 inches.
Meter, ...	1 meter	= 39.37 inches.
Decimeter, . . .	0.1 meter	= 3.937 inches.
Centimeter, . . .	0.01 meter	= 0.3937 inch.
Millimeter, . . .	0.001 meter	= 0.0394 inch.

[1 micron (μ) = 0.000001 meter = 0.00003937 inch.]

Measures of Surface.

Hectare, ...	10,000 square meters	= 2.471 acres.
Are, ...	100 square meters	= 119.6 square yards.
Centare, ...	1 square meter	= 1550. square inches.

Measures of Capacity.

Names.	Number of liters.	Cubic measure.	Dry measure.	Liquid or wine measure.
Kiloliter or stere	1,000	1 cubic meter	1.308 cubic yards	264.17 gallons.
Hectoliter	100	1-10 of a cubic meter	2 bush. and 3.35 pecks	26.417 gallons.
Dekaliter	10	10 cubic decimeters	9.08 quarts	2.6417 gallons.
Liter	1	1 cubic decimeter	0.908 quart	1.0567 quarts.
Deciliter	0.1	1-10 of a cubic decimeter	6.1022 cubic inches	0.845 gill.
Centiliter	0.01	10 cubic centimeters	0.6102 cubic inch	0.338 fluid ounce.
Milliliter	0.001	1 cubic centimeter	0.061 cubic inch	0.27 fluid dram.

Weights.

Names.	Number of grams.	Weight of what quantity of water at maximum density.	Avoirdupois weight.
Millier or tonneau	1,000,000	1 cubic meter	2204.6 pounds.
Quintal	100,000	1 hectoliter	220.46 pounds.
Myriagram	10,000	10 liters	22.046 pounds.
Kilogram or kilo.	1,000	1 liter	2.2046 pounds.
Hectogram	100	1 deciliter	3.5274 ounces.
Dekagram	10	10 cubic centimeters	0.3527 ounce.
Gram	1	1 cubic centimeter	15.432 grains.
Decigram	0.1	1-10 of a cubic centimeter	1.5432 grains.
Centigram	0.01	10 cubic millimeters	0.1543 grain.
Milligram	0.001	1 cubic millimeter	0.0154 grain.

Relation of English to Metric Measures.

From the ratios established in the above table are obtained the following equivalents:

Mile	= 1609.3	meters.	Pint	= 0.4732	liters.
Chain	= 20.117	"	Fl. ounce	= 0.0296	"
Link	= 0.2012	"	Fl. dram	= 0.0037	"
Yard	= 0.9144	"	Bushel	= 35.242	"
Foot	= 0.3048	"	Peck	= 8.811	"
Inch	= 0.02540	"	Quart	= 1.101	"
Acre	= 4046.9	sq. meters.	Pound	= 453.59	grammes.
Chain	= 404.69	"	Ounce	= 28.35	"
Sq. yard	= 0.8361	"	Dram	= 1.772	"
Sq. foot	= 0.0929	"	Troy pound	= 373.24	"
Gallon	= 3.785	liters.	Troy ounce	= 31.103	"
Quart	= 0.9464	"	Grain	= 0.648	"

Relation of United States to British Standards.

The standard of linear, surface, and cubic measure in America is identical with that in England—the British imperial yard.

The troy pound of the mint at Philadelphia was made by law, in 1828, the standard weight for the United States.

The avoirdupois pound of the United States agrees with the British commercial pound, which is itself derived from the British imperial pound.

The grain which is $\frac{1}{5760}$ part of the mint troy pound and the grain which is $\frac{1}{7000}$ part of the British commercial pound are said to agree within $\frac{1}{8000000}$ part, (App. 12, Report U. S. Coast and Geodetic Survey, 1877,) *i. e.*, are identical.

The U. S. standard bushel = 0.96945 British imperial bushel.

The imperial bushel = 1.0315 U. S. standard bushel.

The U. S. standard gallon = 0.8331 British imperial gallon.

The imperial gallon = 1.2005 U. S. gallon.

The U. S. fluid ounce = $\frac{1}{128}$ U. S. standard gallon = 1.0412 imperial fluid ounce = $\frac{1}{160}$ imperial gallon.

1 imperial fluid ounce = 0.9604 U. S. fluid ounce.

These measures are defined as follows:

"The U. S. gallon is a vessel containing 58372.2 grains (8.3389 pounds avoirdupois) of the standard pound of distilled water at the temperature of maximum density of water, (39.4 Fahr.,) the vessel being weighed in air in which the barometer is 30 inches at 62° Fahr."

"The U. S. bushel is a measure containing 543391.89 standard grains (77.6274 pounds avoirdupois) of distilled water, at the temperature of maximum density of water, and barometer at 30 inches at 62° Fahrenheit." (W. and M. Rep., 1857.)

The imperial gallon contains 10 pounds avoirdupois of distilled water weighed by brass weights in air at the temperature of 62° Fahrenheit, the barometer being at 30 inches.

The imperial bushel contains 8 such gallons.

Relation of Meter to Yard.

The British standard of length is the distance (the bar being at 62° Fahrenheit) between two lines drawn on plugs at the bottom of wells sunk to one-half the depth of the bar, one inch from each end, on a bar of Baily's bronze, known as the imperial standard yard.

The metric standard is the distance (the bar being at a temperature of 0° centigrade) between the ends of a bar of platinum known as the *mètre des Archives.*

The two standards being of so different definition, it is a matter of much difficulty to determine their relation. Hence there is great diversity in the determinations that have been made. The following are some of these determinations. The value given by Clarke in 1866 is that most generally recognized, and, next, that of Kater. Other determinations will be made after the distribution of the new international meters now in process of construction.

Kater, (1821,)	1 meter = 39.37079 inches.
Hassler, (1832,)	1 meter = 39.38103 inches.
Clarke, (1866,)	1 meter = 39.370432 inches.
Rogers, (1884,)	1 meter = 39.37015 inches.
Comstock, (1885,) . . .	1 meter = 39.36985 inches.

Relation of Kilogram to Pound.

The British standard of weight is a cylinder of platinum with a groove around it for convenience of handling. The metric standard is also a cylinder of platinum. The relation between the two is therefore more easily to be determined than that of the standards of length. The value generally accepted is that obtained by Prof. W. H. Miller, of England, (1844,) which is—

1 kilogram = 15432.34874 grains.

The comparison is made in vacuum. For ordinary commercial purposes not the platinum pound, but a pound of gun-metal gilded is used. This pound is equal to the platinum pound in a vacuum.

Theory of the Rolling Planimeter.

BY F. H. REITZ.*

A large number of new planimeters have been introduced of late years, and accounts of these have from time to time appeared in different journals. Among these may be mentioned the various constructions of Amsler's Planimeter, Hohmann Coradi's Precision Planimeter, Günther's Planimeter, Kloth's Planimeter, and lastly Hohmann-Coradi's Suspended Planimeter. To these may now be added the *Rolling Planimeter*, an instrument which may be described as the outcome of an extensive series of protracted experiments made by Herr Coradi, which led him to the peculiar solution of the problem we are now going to explain.

In the new instrument four distinct features are embodied, each of which may be set down as a *sine qua non* of a proper construction of a planimeter. In the first place, the unit of the vernier is so small that surfaces of quite diminutive size may be determined by it with sufficient accuracy, and in this respect the new planimeter seems to have stolen a march on its older rivals. Secondly, the space to be encompassed at one fixing of the apparatus is very large in proportion to the dimensions of the apparatus, more especially in the case of long-stretched diagrams or drawings, which occur very frequently in practice. Thirdly, the results are scarcely ever affected by the nature of the surface of the paper on which the diagram is drawn or printed; and fourthly, the whole arrangement of the instrument is such as to admit of all its parts being kept in good working order for a great length of time.

* Translated from the *Zeitschrift für Vermessungs-Wesen* (The surveyor's Journal.) 1884. No. 20.

Fig. 1 is a perspective view of the instrument taken from a photograph.

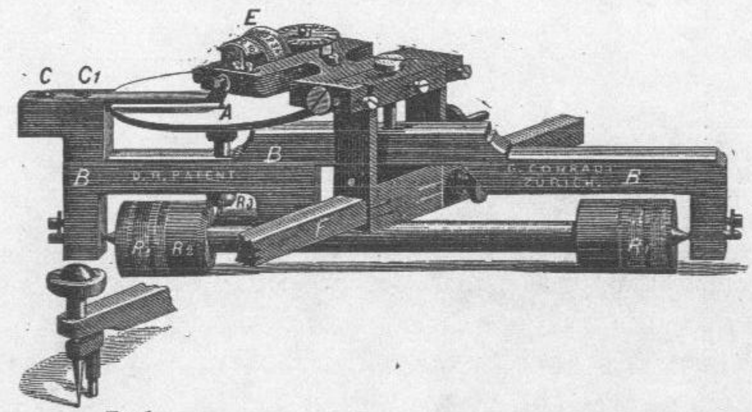


Fig. 1.

The frame B is supported by the shaft of the two rollers R_1, the surfaces of which are fluted in a peculiar way. To the frame B are fitted the disc A and the axis of the tracing-arm F. The whole apparatus moves in a straight line to

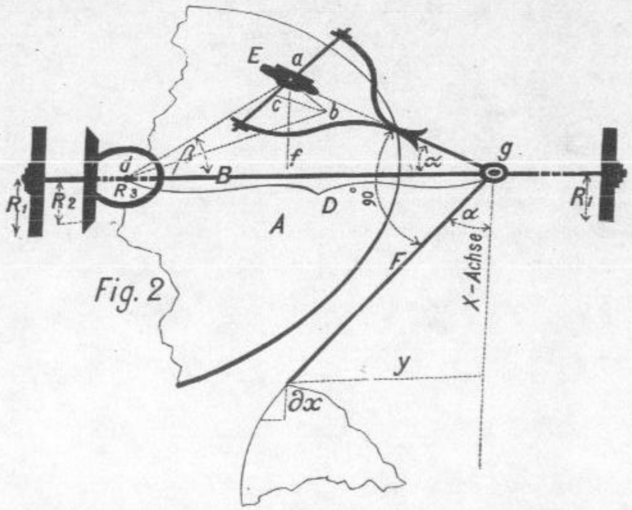


Fig. 2.

any desired length upon the two rollers resting on the paper, while the tracing-point travels around the diagram of which the measurement is required.

Upon the shaft that forms the axis of the two rollers R_1 a minutely divided mitre-wheel, R_2, is fixed, which gears into a pinion, R_3. This pinion, being fixed upon the same spindle as the disc A, causes the disc to revolve and thereby induces the rolling motion of the entire apparatus.

The measuring-roller E, resting upon the disc A, travels thereon to and fro, in sympathy with the motion of the tracing-arm F, this measuring-roller being actuated by another arm fixed at right angles to the tracing-arm and moving freely between pivots. The axis of the measuring-roller is parallel to the tracing-arm F. The top end of the spindle upon which the disc A is fixed pivots on a radial steel bar, CC_1, fixed upon the framing B.

According to the general theory of planimeters furnished with measuring-rollers it is immaterial what line the free end of the tracing-arm travels over; nevertheless there is some practical advantage in the construction of the apparatus to be obtained from causing that end to travel as nearly as possible in a straight line. Still, from the reason given heretofore, it is obvious that a slight deviation from the straight line would not involve any inaccuracy in the result.

Seeing that the fulcrum of the tracing-arm keeps travelling in a straight line, it appears advisable, in evolving the theory of the apparatus, to assume a rectangular system of co-ordinates and fix upon the line along which that fulcrum travels as the axis of abscissæ.

The passage of the tracing-point around the perimeter of a diagram may be looked upon as being made up of two motions, one parallel to the axis of abscissæ and the other at right angles to that axis. Inasmuch as the latter of these two motions, in the direction of the axis of ordinates, is after all but an alternate motion of the tracing-point which takes place in an equal ratio, until the tracing-point has returned to the spot it had started from, no one point of the circumference of the measuring-roller is continuously moved forward in consequence of this motion. Therefore it is only necessary to take the differential motion of the tracing-point in the direction of the axis of abscissæ into consideration.

In Fig. 2 the same letters of reference denote identical parts or organs as in Fig. 1, and the position of parts in Fig. 2 corresponds exactly to that in Fig. 1, the letter D denoting the distance between the fulcrum of the tracing-arm and the axis of the disc A. In connection with Fig. 2 it remains to be determined what must be the quantity representing the motion of a point on the surface of the measuring-roller E while the tracing-point travels to the extent of $d\,x$. If the construction of the planimeter be correct, the quantity referred to must appear as the product of the differential quotient of the surface with reference to rectangular co-ordinates, $(y\ d\ x,)$ multiplied into a constant derived from the dimensions of the instrument.

It is obvious that, as the tracing-point moves to the extent of $d\,x$, a point in the circumference of the rollers of such a radius as R_1 has must also be shifted to the extent of $d\,x$. This being so, any point in the pitch-line of the mitre-wheel R_2 must necessarily move to the extent of $d\,x\,\frac{R_2}{R_1}$. By the same motions, a point

of the disc A is moved at a distance $a\,d$ of the point of contact of the measuring-roller to the extent of $d\,x\,\frac{R_2}{R_1} \times \frac{a\,d}{R_3}$. In Fig. 2 this quantity is denoted by $a\,b$, therefore:

$$a\,b = d\,x\,\frac{R_2}{R_1} \times \frac{a\,d}{R_3} \qquad (1)$$

In consequence of the position of the axis of the measuring-roller, the motion of the disc A to the extent of $a\,b$ produces a further shifting of a point in the circumference of the measuring-roller to the extent of $c\,b$, whilst the measuring-roller itself travels to the extent of $a\,c$. It therefore becomes necessary to find a formula for the value of $c\,b$.

It will be readily perceived that $c\,b = a\,b\ sin\ (\alpha + \beta)$, seeing that $d\,a\,b = 90°$ and $c\,a\,g = 90°$, wherefore $c\,a\,f = \alpha$ and $f\,a\,b = \beta$. Now we have $sin\ (\alpha + \beta) = sin\ \alpha\ cos\ \beta + cos\ \alpha\ sin\ \beta$; again

$$sin\ \alpha = \frac{y}{F},\ cos\ \alpha = \sqrt{1 - \frac{y^2}{F^2}},\ sin\ \beta = \frac{a\,f}{a\,d} = \frac{a\,g\ sin\ \alpha}{a\,d} = \frac{a\,g\,\frac{y}{F}}{a\,d},$$

$$cos\ \beta = \frac{d\,f}{a\,d} = \frac{D - a\,g\sqrt{1 - \frac{y^2}{F^2}}}{a\,d}.$$

If these values be substituted in the equation of $c\,b$, we find

$$c\,b = a\,b\left(\frac{y}{F} \times \frac{D - a\,g\sqrt{1 - \frac{y^2}{F^2}}}{a\,d} + \sqrt{1 - \frac{y^2}{F^2}} \times \frac{a\,g\,\frac{y}{F}}{a\,d}\right) = a\,b\,\frac{y\,D}{F\,a\,d};$$

again, substituting the value of $a\,b$ as per (1), we find

$$c\,b = y\,d\,x\,\frac{D \times R_2}{F \times R_1 \times R_3}; \qquad (2)\quad \text{Q. E. D.}$$

Seeing that the sum of $c\,b$ is equal to the difference in the reading multiplied into the circumference of the measuring-roller, and that $\int y\,d\,x$ is equal to the area of the diagram traced around, we find, by integrating the equation (2) and setting down the circumference of the measuring-roller as U, the area of the diagram as J, and the difference in the reading as N, that

$$J = N \cdot \frac{U\,R_1\,R_3\,F}{R_2\,D} \qquad (3)$$

The formula (3) shows that the distance $a\,g$ of the roller from the fulcrum of the tracing-arm g is immaterial and does not affect the results obtained by the use of the instrument.

How to Use and How to Test the Precision Planimeter.

The Precision Planimeter may, on the whole, be used in the same way as an ordinary Polar Planimeter. The following general rules ought to be observed:

1st. The instrument should be worked at a very slow rate of speed, especially when the measuring-wheel comes close to the edge of the disc S; the measuring-roller must not move too quick for each of the figures marked on its pitch-line being clearly distinguished while the motion is going on.

2d. In making the tracer travel around the perimeter of any figure, the starting-point must always be chosen in such a way that the tracing-arm and the pole-arm, or the tracing-arm and the axis of the fluted rollers, as the case may be, are at right-angles to each other, for in this position alone the error or difference is neutralized, which arises from the fact of the tracer, after having done its work, not returning to its exact starting-point.

3d. It is essential that all the revolving parts of the instrument should spin round easily, but, withal, quite accurately; this applies more especially to the measuring-wheel.

Prior to using the planimeter, it is necessary to satisfy one's self of its being in good working order. Both the fulcrum of the tracing-arm and the fulcrum mm of the frame M of the measuring wheel must turn easily, but without leaving the least margin between their points. It is necessary that the disc S should readily spin round, yet without there being any margin or wavering of its spindle. Whether this spindle be accurately fitted or not can be readily ascertained by laying hold of the edge of the disc and trying to move it up and down; if it does not stir, then the fitting is all right. The axis of the measuring-wheel must work with the utmost ease, at the same time there must not be the slightest rocking or wabbling; this again can be tested by laying hold of the frame M with one hand and trying to shift the measuring-wheel along its axis. The pitch-line of the measuring-wheel ought to be as close as possible to the vernier, without, however, touching it. The counting-wheel must work smoothly and must in no way interfere with the motion of the measuring-wheel.

The whole of the spindles that pivot on points work in steel-bolts which may be brought closer to the spindles by means of screws. The bolts are kept in the required position by means of binding-screws. These screws are first eased and then tightened, after the bolt has been properly fitted in the required position, so as to admit of no inaccuracy. In the case of the Rolling Planimeter, the points of the spindle of the disc S work in two steel plates, of which the upper may be raised and lowered by means of the two screws $c c^1$, for the purpose of making the spindle of the disc work accurately. When the motion of this spindle is too easy, showing that it does not fit quite accurately, the screw c must be eased and the screw c^1 made tighter; if, after this, the spindle seems too tight, then c must first be made a little tighter, and if that is not enough, c^1 be slightly eased again.

In the Rolling Planimeters the supporting-wheel cc^1 ought also to work very smoothly, but without wabbling, and the gearing of the conic wheel connected

therewith into the conic pinion fixed upon the spindle of the disc S ought also to take place smoothly, but without being too easy. Should the gearing take place with undue ease, the supporting-wheel, along with the mitre-wheel connected with it, should be brought a little nearer the spindle of the disc by means of the bolts dd^1, and after the gearing and the working of the supporting-wheel have been duly adjusted the binding-screws which had previously been eased are to be made a little tighter again.

The various working parts or organs of the planimeter having thus been properly adjusted, the operator may try to move the instrument to and fro on the paper by laying hold of the knob of the tracing-point and observing at the same time the working of the various parts, so as to make himself more familiar with it. The apparatus ought to work quite smoothly, and in quickly changing the direction in which it moves, no wabbling of any kind ought to be perceptible.

In order to test the accurate working of the instrument, it is necessary to ascertain—

1st. Whether the readings as they appear on the measuring-wheel are the same when the perimeter of one and the same figure is travelled over with the instrument occupying various positions, so that at one time the measuring-wheel turns only on the front half of the disc S, and another time only on the back half of that disc.

2d. Whether the position of the vernier on the tracing-arm, as tabulated, be correct.

First test.—As regards in the first place the readings on the measuring-wheel, they are to be tested by means of the check-rule that is supplied along with the instrument. This rule is a small band of German silver upon which divisions are marked at distances of either 1 centimeter or 1 inch from each other. At the commencement of the divisions the rule is perforated, and through the hole, at right-angles to the rule, a fine needle-point is inserted, which is kept in its position by means of a screw. The other end of the rule is beveled and has an index line marked on it, which is fixed upon the point of the perimeter from which the tracer starts in travelling over the perimeter, that point being marked by a thin stroke on the paper. If the point of the needle of the check-rule be stuck into the paper and the tracer be put down in one of the points of the perimeter, circles of a specified radius may be travelled round by the tracer. Great care must be taken, however, that while the tracer passes round no lateral pressure be brought to bear on the tracer, but that the pressure take place only in the direction of the circle itself. The way in which the check-rule is to be used is illustrated in Figs. 3, 4, 5, and 6.

The instrument having been "anchored" in the manner shown in Figs. 3 and 4, so that the circumference of the circle K to be travelled over, which has a radius of from 4 to 5 cm. = 1.6 to 2 in., lies to the *left* of the tracing-arm A, which is placed at a right-angle to B, the starting-point is marked on the right extremity of the check-rule L, and the reading on the pitch-line of the measuring-wheel and the counting-wheel having been ascertained, is taken down. The tracer is now moved carefully over the circumference in the direction of the arrow, until the index of the check-rule covers the starting-point once more; another reading is taken and the first reading deducted from the second. By this means the real

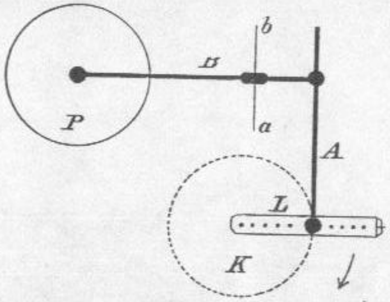


FIG. 3.

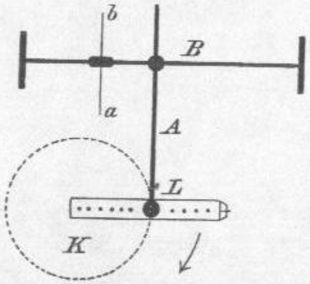


FIG. 4.

number of units of the vernier is obtained by which the measuring-wheel has moved forward. The passage of the tracer over the circumference may be repeated several times and the average of the readings taken.

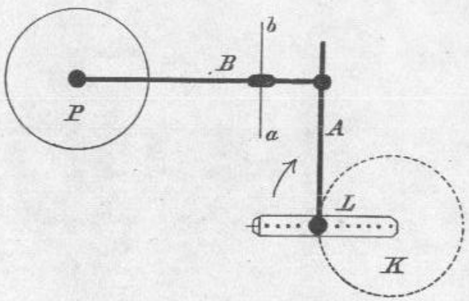


FIG. 5.

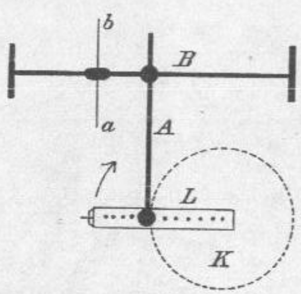


FIG. 6.

The instrument is now placed in the position shown in Figs. 5 and 6, when the circle K appears on the *right*-hand side of the tracing-arm A, and the passage of the tracer takes place in exactly the same way.

If the results obtained right and left of the tracing-arm be equal to one another, it is clear that the axis $a\,b$ of the measuring-wheel is parallel to the tracing-arm, and, this being so, the second test may now be applied. But if the result be *greater* in the first case, that is to say, when the circle lies to the left of the tracing-arm, the extremity a of the axis of the measuring-wheel must be further removed from the tracing-arm; if it be *less*, that extremity must be brought nearer to the tracing-arm.

Second test.—The tracing-arm is adjusted, by means of the vernier on the guide and by means of the micrometer-screw, in accordance with the table of adjustments for different areas; it then is fixed within the guide by means of the binding-screw. The circumference of circles of various sizes are then travelled over with the check-rule, and the results thus obtained are multiplied into the unit of

the vernier corresponding to the area given for that particular adjustment in the table. The figures thus obtained ought to be equal to the calculated area of the circles of which the circumferences have been travelled over. If the results obtained with the planimeter fall short of the calculated areas to the extent of $\frac{1}{n}$ of those areas, the length of the tracing-arm, that is to say the distance between the tracer and the fulcrum of the tracing-arm, must be reduced to the extent of $\frac{1}{n}$ of that length; in the opposite case it must be increased in the same proportion. The vernier on the guide-piece of the tracing-arm shows the length thus defined with sufficient accuracy, in half millimeters or about fiftieths of an inch, on the gauged portion of the arm.

In order to test the accuracy of the readings according to the two methods just described, some prefer the use of a check-plate in lieu of the check-rule. The check-plate is a circular brass disc of 17 centimeters = 6.69 in. in diameter, upon which are engraved circles having a radius of 80, 60, 30, and 10 mm., or about 3.2, 2.4, 1.2, and .4 in. The tracer may be made to travel upon these circumferences. It is advisable to apply the second test also to a large diagram drawn on paper and having a known area.

The instrument having been found correct throughout, may now be used. The operation takes place as follows: The drawing of which the figures are to be measured, is laid down as flat as possible on a drawing-board or table. Assuming the plan to be drawn to the scale 1 : 500, the tracing-arm is adjusted to or set at the length corresponding to the scale of 1-500th in the table for the *adjustment of the vernier on the tracing-arm*. The instrument is now brought close to the figure, and the operator satisfies himself that there is no "hitch" anywhere. He then sets the tracing-arm at a right-angle to the polar-arm or to the axis of the supporting-wheel, and, having placed the tracer upon the nearest point of the figure which can be easily marked, he takes the reading on the counting-wheel, the measuring-roller and its vernier. Assuming the reading on the counting-wheel to be between 3 and 4, the zero of the vernier to be between the 5th and 6th line following after the figure 6, and assuming the 5th line of the vernier to coincide with a division mark on the pitch-line of the measuring-roller, the first reading will be 3655. After the perimeter of the figure has been travelled over, let the reading on the counting-wheel be between 16 and 17, let the zero of the vernier lie between the 7th and 8th line following after 7, and let the 8th division of the vernier coincide with a stroke on the pitch-line of the measuring-wheel,

then the second reading will be . . 16778
Subtracting from this . . . . . 3655, being first reading,
we obtain the result, ... 13123. Multiplying this into the area corresponding to the unit of the vernier, as we find it in the table opposite 1-500th, say .2 sq. meter or square yard, we shall obtain 13123 × .2 = 2624.6 sq. meters or square yards as the area of the figure the perimeter of which has been travelled over.

If, during the passage of the tracer over the perimeter, the zero of the counting-wheel passes its index, the second reading must have 10000, 20000, or 40000 added to it, according as to whether that wheel counts up to 10, 20, or 40.

Inasmuch as the counting-wheel must have a certain amount of scope or margin, so as not to interfere with the proper working of the measuring-wheel, the divisions of the counting-wheel do not always coincide exactly with the zero of the pitch-line of the measuring-wheel; but this does not produce an error of 1000 units of the vernier, if the following rule be observed: If the reading of the vernier on the measuring-wheel be a little *below* zero, say 80 or 90, the *previous* line of the counting-wheel holds good. If, on the contrary, the vernier stand at a little above 0, say 10 or 20, the line upon which the index of the counting-wheel falls stands for the first figure in the reading.

If the paper has shrunk, ascertain the proportion of the shrinkage, and if in consequence of this the area of the plan should have been reduced to the extent of $\frac{1}{n}$, reduce the length of the tracing-arm also by $\frac{1}{n}$. In that event, the planimeter returns the area of the figure, as though the paper had not shrunk.

To keep the instrument in good condition, great care must, as a matter of course, be taken that no portion of it should ever be damaged by a knock or a fall. The edge of the measuring-wheel must be scrupulously guarded from corrosion, and whenever it has been touched by any one's fingers it should be rubbed with a soft piece of rag. In all places in which the axes are subjected to friction some fine watchmaker's oil is to be applied from time to time as a lubricant. Whenever the paper of the disc *S* has got soiled or too smooth, it may be cleaned by rubbing it with tissue-paper, and in the end another may be substituted for it and fixed with isinglass. To this effect the disc, together with its spindle, is taken out of the bearings, and the spindle is screwed off the disc by inserting a pin in the central hole of the spindle. While this is going on, the frame of the measuring-wheel is kept in its position with a cardboard wedge, so as to prevent the measuring-wheel from being damaged.

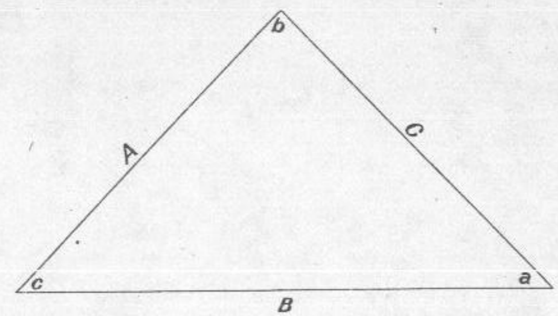
A Table showing the Accuracy of Different Descriptions of Planimeters compared with others.

The following tabulated statement, showing the maximum of errors in the readings of various descriptions of planimeters, has been drawn up in connection with the extensive experiments made by Professor Lorber, of the Imperial and Royal Mining Academy of Loeben, in Austria, which experiments agree with those

made by several other authorities. The table shows the great superiority of the Hohmann-Coradi planimeters as compared with others:

Area in—		The error in one passage of the tracer amounts on an average to the following fraction of the area measured by—				
		The ordinary Polar Planimeter unit of vernier: 10 sq. mm. = .015 sq. in.	Stark's Linear Planimeter unit of vernier: 1 sq. mm. = .001 sq. in.	Suspended Planimeter unit of vernier: 1 sq. mm. = .001 sq. in.	Rolling Planimeter— Unit of vernier: 1 sq. mm. = .001 sq. in.	Rolling Planimeter— Unit of vernier: 1 sq. mm. = .001 sq. in.
Square cm.	Square inches.					
10	1.55	$\frac{1}{75}$	$\frac{1}{588}$	$\frac{1}{625}$	$\frac{1}{625}$	$\frac{1}{1000}$
20	3.10	$\frac{1}{148}$	$\frac{1}{1000}$	$\frac{1}{1111}$	$\frac{1}{1000}$	$\frac{1}{2000}$
50	7.75	$\frac{1}{355}$	$\frac{1}{1852}$	$\frac{1}{2500}$	$\frac{1}{2000}$	$\frac{1}{3000}$
100	15.50	$\frac{1}{682}$	$\frac{1}{2857}$	$\frac{1}{4167}$	$\frac{1}{333}$	$\frac{1}{5000}$
200	31.00	$\frac{1}{1274}$	$\frac{1}{4255}$	$\frac{1}{7143}$	$\frac{1}{5128}$	$\frac{1}{7693}$
300	46.50	....	....	$\frac{1}{9375}$	$\frac{1}{8000}$	$\frac{1}{10000}$

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.

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

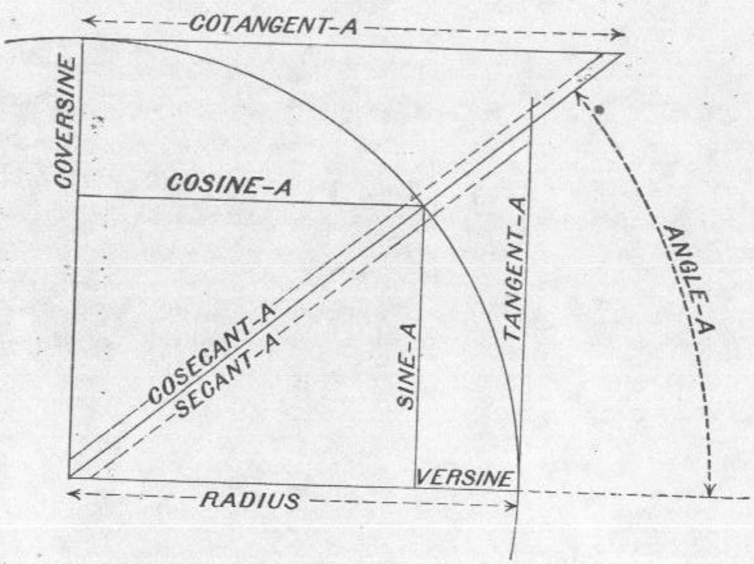
$$\text{Cos. } b. = \frac{\text{A}^2 + \text{C}^2 - \text{B}^2}{2\text{ A C}}$$

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

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

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

DESCRIPTION AND PRICE-LIST

OF

FIRST-CLASS

ENGINEERING AND ASTRONOMICAL INSTRUMENTS

MANUFACTURED BY

FAUTH & CO.

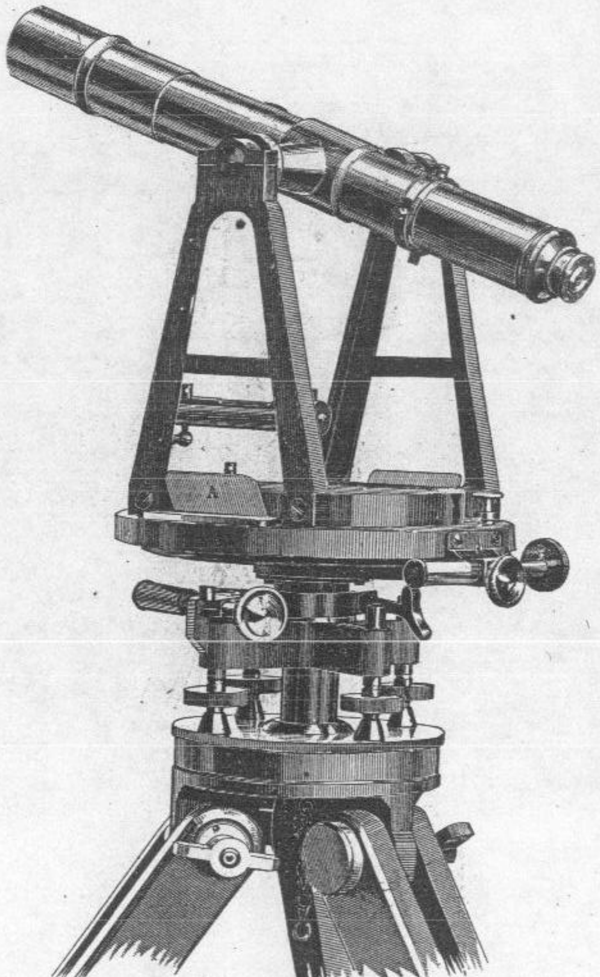
Corner Second Street and Maryland Avenue,

WASHINGTON, D. C.

This List supersedes all former editions.

PLAIN TRANSIT.

Cut No. 2 represents one of our improved Engineering Transits. The circle is $6\frac{3}{4}$ inches diameter, reading by opposite verniers to 30 seconds; long centres of hard metal; telescope is balanced in axis; has an objective of $1\frac{1}{8}$ in. diameter, well corrected for spherical and chromatic aberration, magnifying about 22 diameters, and showing objects erect; dust-guard over object-slide; separate focussing rack for eye-piece; compass-needle $4\frac{1}{2}$ inches long, swing-

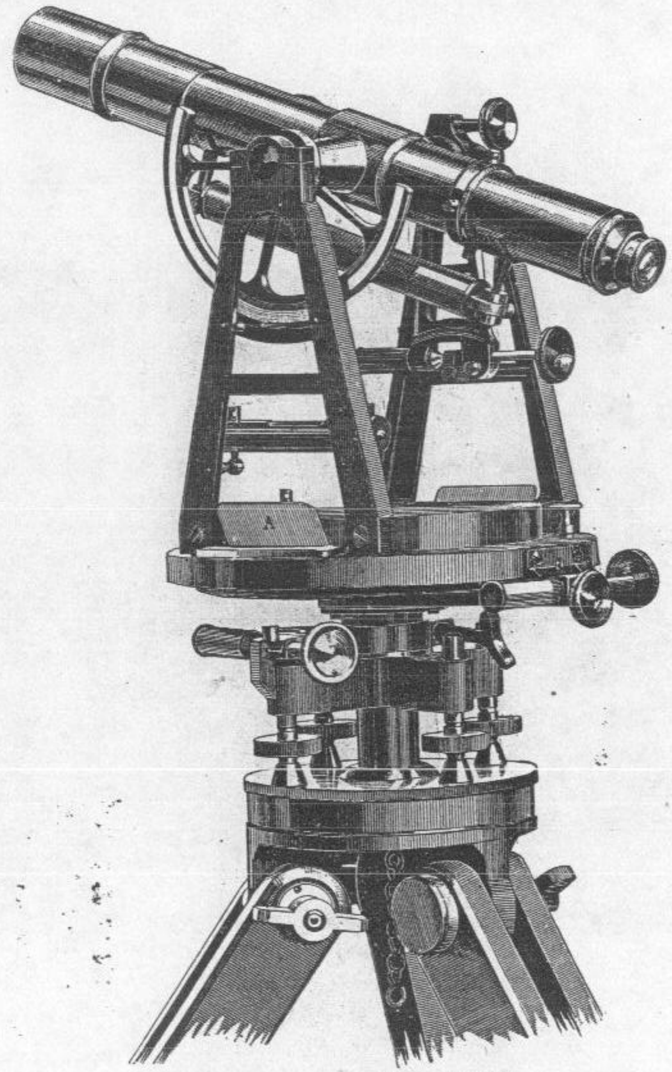


No. 2.—PLAIN TRANSIT.

ing 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 levelling-screws with shifting tripod. By the use of hard metal and judicious ribbing and bracing great lightness and strength is obtained.

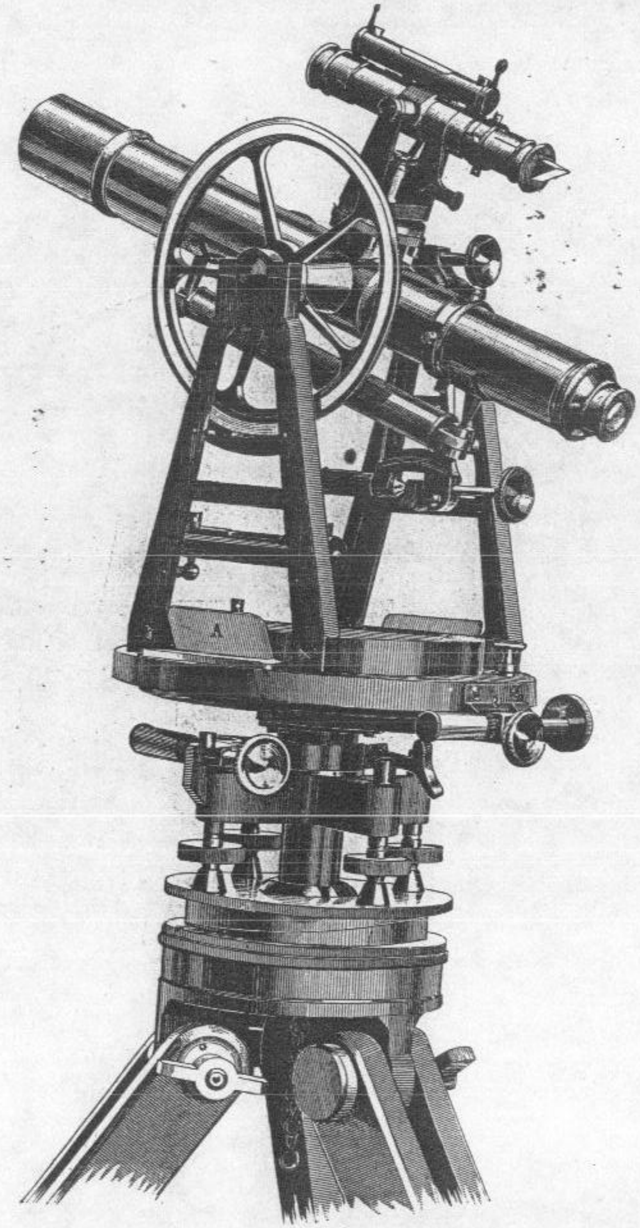
Weight of instrument....13 pounds. | Price $180 00



No. 3.—ENGINEER'S TRANSIT.

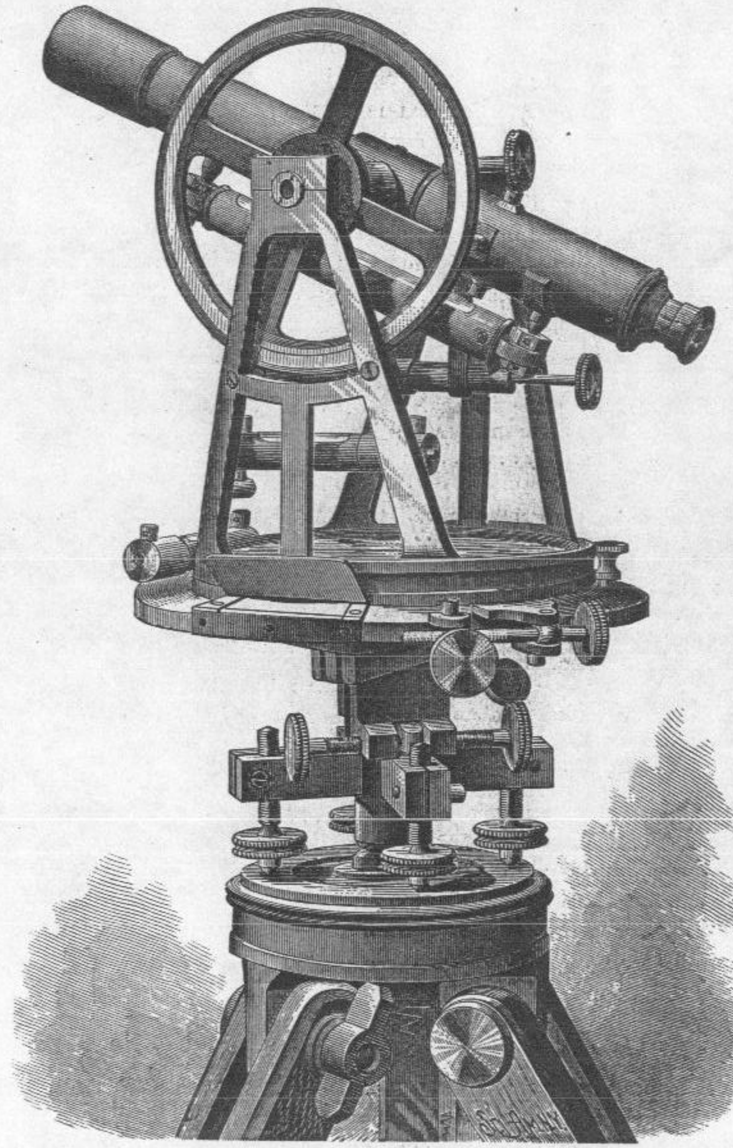
No. 3 is like the preceding, No. 2, with the following additions: Vertical ar sensitive level, clamp and tangent screws to telescope.

Price.. $225



No. 4.—COMPLETE ENGINEER'S TRANSIT.

With vertical circle, level, clamp, and tangent to telescope, solar attachment, quick-levelling and shifting tripod.................... $285 00



No. 5.—HIGH-GRADE ENGINEER'S TRANSIT.

Cut No. 5 represents one of our complete high-grade Engineer's Transits, intended for fine city and mine work. It differs from those of the ordinary construction in its great lightness and strength, its judicious ribbing and bracing, and the use of hard metal. The standards are not of the common construction, but are cast in one piece, fitting tightly around the compass-ring. Each Y is supported by 3 standards, the two outer ones being curved so as to stand well in towards the centre of the plate, while the middle one is directly under the bearing. By thus casting a great many parts in one, which are usually made in pieces and screwed together, the instrument is lighter and stronger and also remains better in adjustment. The centres are long and of hard metal; the graduation is on solid silver, reading by opposite verniers to 10 seconds; powerful telescope, magnifying 25 diameters, showing erect or inverting; vertical circle 5 inches diameter, reading by opposite verniers to 30 seconds; the striding-level over axis and the long level attached to telescope are chambered and graduated; illumination through axis, 3 or 4 levelling-screws.

Weight, 16 lbs.; tripod, $7\frac{1}{2}$ lbs.; price.......... $350 00

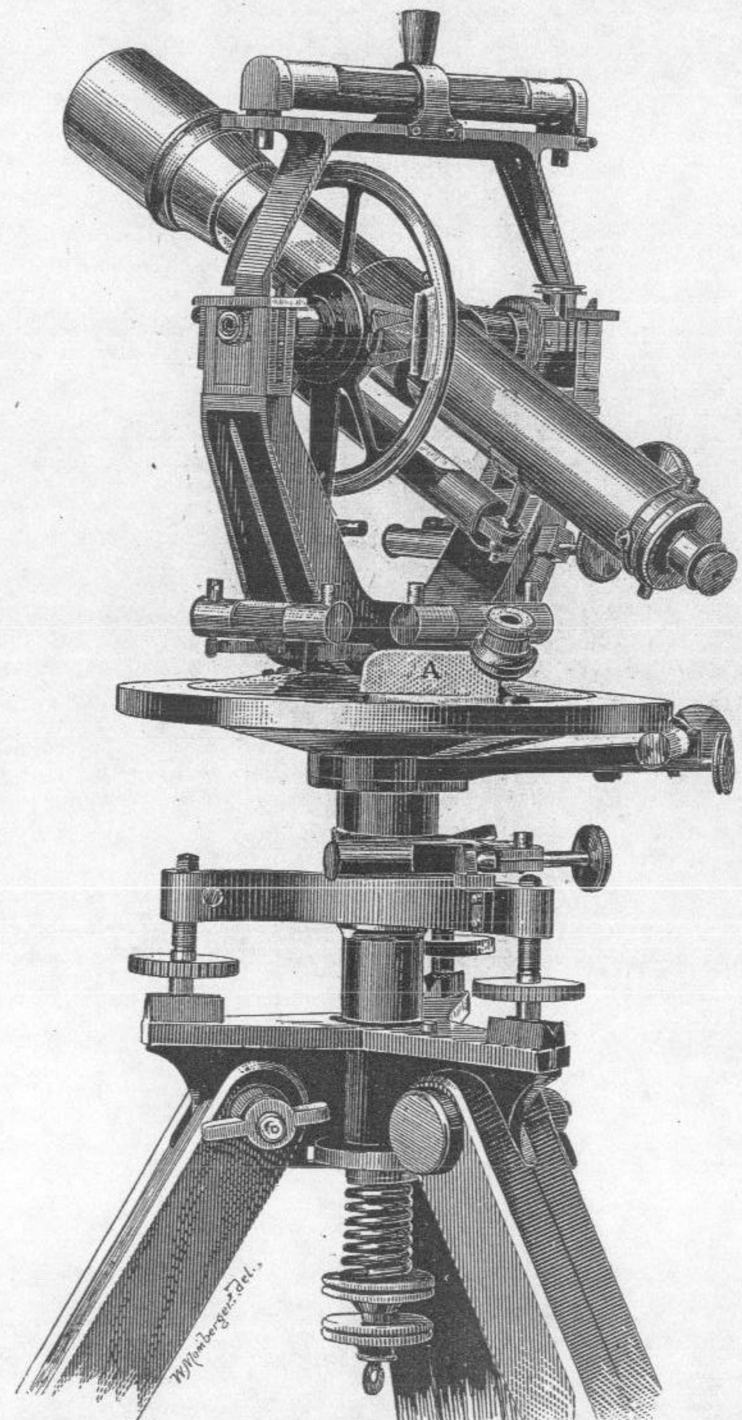
EXTRAS TO TRANSITS.

5-inch vertical arc, reading to minutes..........	$15 00
" " solid silver graduation..........	20 00
" circle, double verniers..........	20 00
" " graduation on solid silver..........	25 00
Level on telescope with clamp and tangent movement..........	30 00
Gradientor attachment..........	30 00
Vernier shades..........	5 00
Fixed stadia wires..........	3 00
Variation plate..........	3 00
Graduations on horizontal circle on solid silver..........	10 00
Graduation to read 30 seconds..........	10 00
" " 20 "	10 00
Solar attachment, improved pattern..........	20 00
Prism and sun-shade for same..........	50 00
Vertical sighting attachment..........	10 00
Quick-levelling..........	30 00
Extension tripod..........	10 00
	15 00

Cut No. 6 represents a Transit Theodolite of very superior construction, as made by us for U. S. Government surveys. The standards in which the telescope rests are cast in one piece, which, on account of its peculiar shape, is very light and strong. The telescope is provided with illumination, can be reversed in Y's, has an aperture of $1\frac{1}{2}$ inches, and is provided with achromatic Kellner eye-piece. The vertical circle of 5 inches diameter reads to single minutes by two opposite verniers. The circle is graduated on solid silver, and reads by means of two opposite double verniers to 10 seconds. Sensitive level to telescope. Chambered striding-level over axis of telescope. The instrument is made only with 3 levelling-screws, and has no compass. These instruments we also make with telescope to swing through, or with only enough vertical movement to allow the observation of polaris.

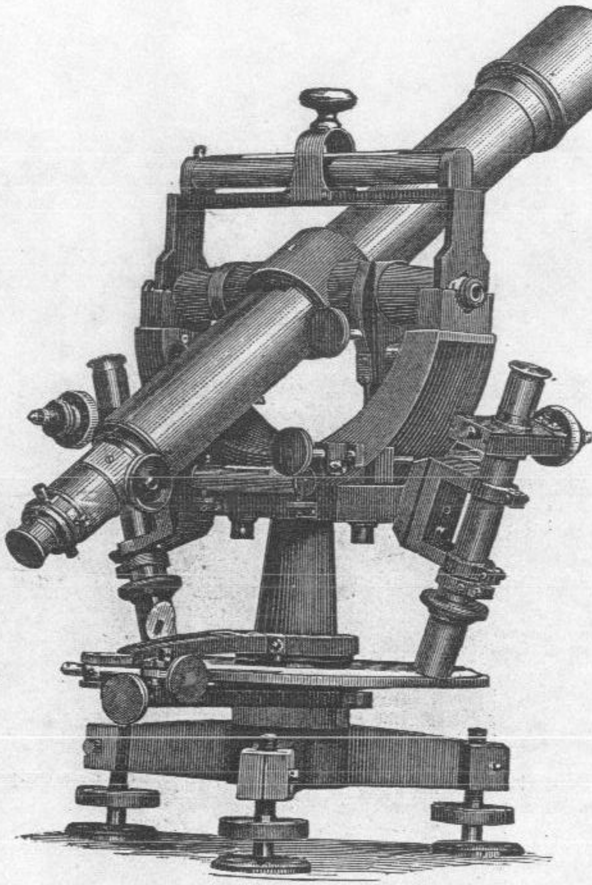
Price as shown in cut.......... $350 00

No. 7, same instrument, with circles of 8 inches diameter; telescope, $1\frac{3}{4}$ inches diameter; 18-inch focus.......... 450 00



No. 6.—TRANSIT THEODOLITE.

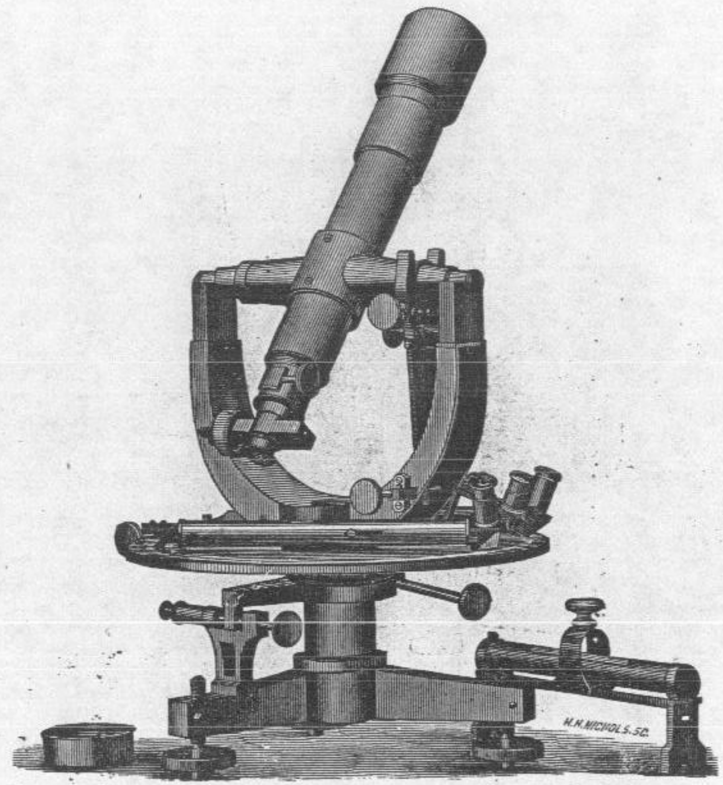
THEODOLITES.



No. 8.—8-INCH THEODOLITE.

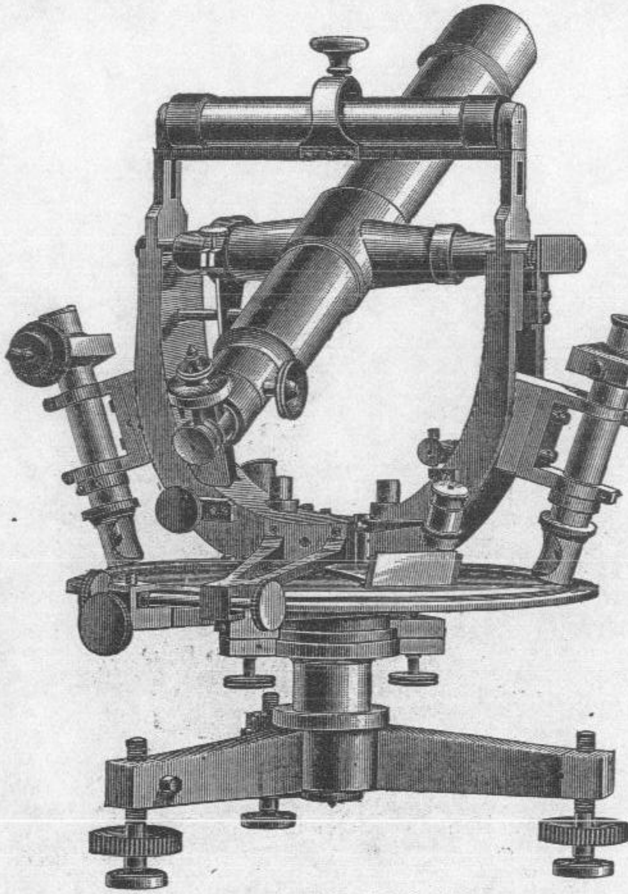
No. 8 represents an 8-inch Theodolite, of which quite a number have been made by us for the U. S. Coast and Geodetic Survey. The circle, which shifts for position, is 8 inches diameter, divided into 10-minute spaces, and is read by means of two micrometer-microscopes to seconds. The telescope has an aperture of $1\frac{3}{4}$ inches and is about 18 inches focus. Improved clamp, sensitive striding-level, and field illumination. Price, with stand..$425 00

No. 9.—This cut represents a 10-inch Repeating Theodolite, as made by us for the U. S. Coast and Geodetic Survey. Circle is 10 inches diameter, reading by two verniers and microscopes to 5 or 10 seconds. The telescope is of $1\frac{3}{4}$ inches aperture and about 16 inches focus; improved clamps and tangent-screws; sensitive level over telescope, and field illumination for azimuth observations. Packed complete........$550 00



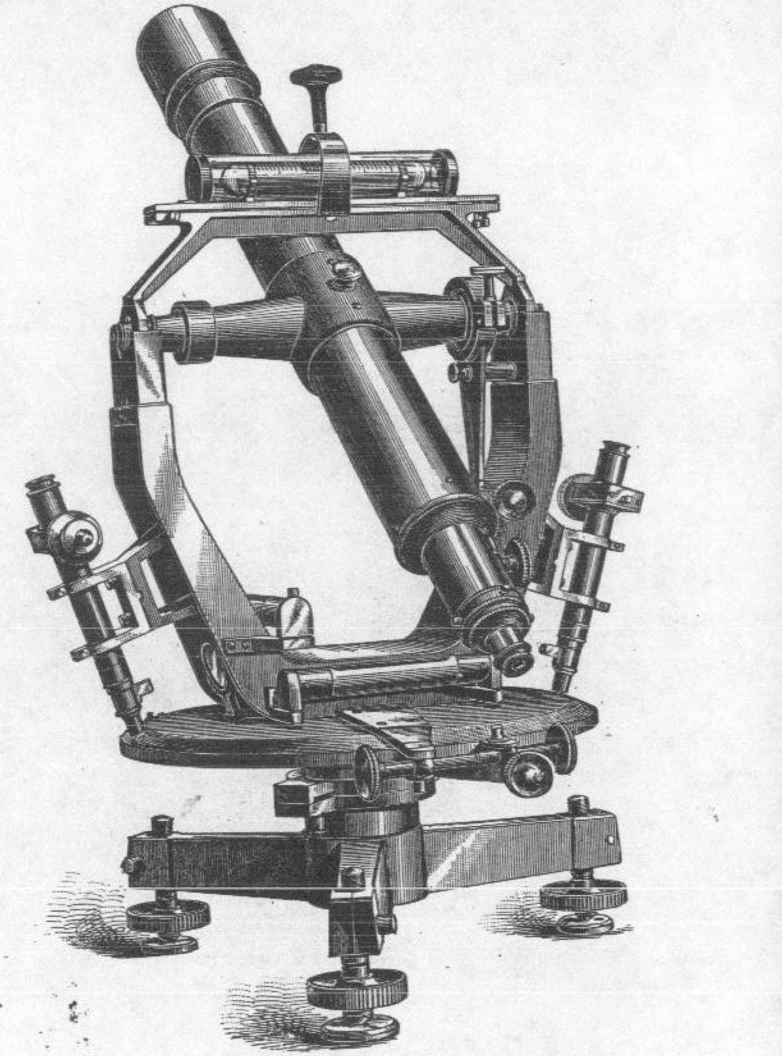
No. 9.—10-INCH REPEATING THEODOLITE.

In above cut the verniers are read off by means of a prismatic arrangement, the instrument having been designed for a particular purpose. The above price does not include this nor the eye-piece micrometer.



No. 10.—10-INCH THEODOLITE.

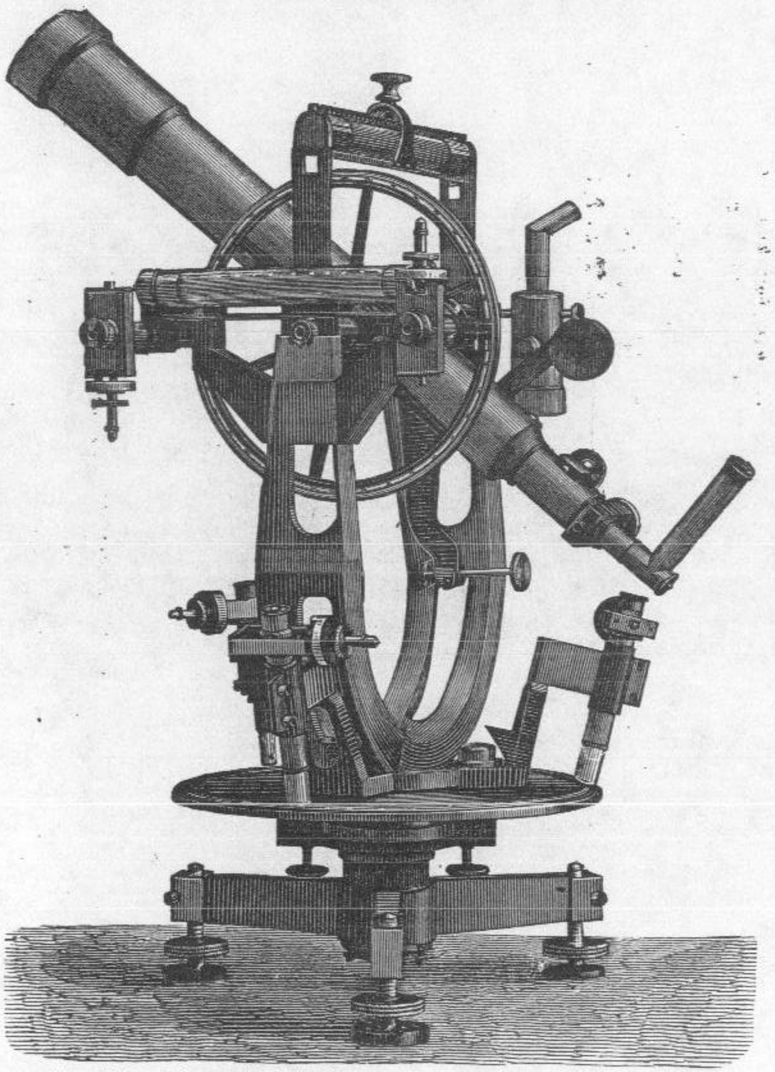
Cut No. 10 represents a Theodolite of which we have made a great number. It is especially adapted for purposes of instruction, and is in every respect a first-class instrument. The circle, which shifts for position, is read by two micrometer-microscopes, and also two verniers; the telescope has an aperture of $1\frac{3}{4}$ inches, and is about 16 inches focus; improved clamp, sensitive striding-level, and field illumination for azimuth observations. Packed complete........................... $550 00



No. 11—12-INCH THEODOLITE.

The above cut, No. 11, represents a 12-inch Theodolite as made by us for U. S. Coast Survey for primary triangulation. Circle, of 12 inches diameter, reads by 2 opposite micrometer-microscopes to single seconds; 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 0

ALTITUDE AND AZIMUTH INSTRUMENTS.



From Gebbie & Barrie's "Masterpieces of the U. S. International Exhibition, 1876."

No. 12.—ALTITUDE AND AZIMUTH INSTRUMENT.

Cut No. 12 represents one of our instruments, which was on exhibition in the International Exhibition at Philadelphia, for which we received an award.

It is of superior construction, and differs from other instruments of this class in many important particulars. Not being a "repeating instrument," strictly speaking, and, therefore, not liable to the defects inherent to repeaters, yet both

the horizontal and vertical circles can be shifted for position, so as to bring a different part of the graduation under the microscopes. The circles are divided on silver into 5-minute spaces, reading by micrometer-microscopes to single seconds. The standards radiate out from the centre, and are high enough to let the telescope swing through. The pivots of the telescope axis rest on agate, and are made of phosphor bronze; a delicate striding-level, reading to seconds, over the pivots, is provided; illumination through pivots; the horizontality of the microscopes for vertical circle is controlled by a chambered level, reading to seconds.

Both circles are entirely free of clamps and tangent-screws, these being attached to a collar, so as not to produce any strain.

No. 12.—Altitude-Azimuth, as described above; horizontal circle eighteen, vertical circle twelve inches in diameter; former reading by three, and latter by two microscopes; telescope 3-inch clear aperture, 28 inches focal length, with micrometric eye-piece; levels are chambered, and read to seconds; packed complete in two boxes, with positive and diagonal eye-piece, two lamps, and all accessories...... $2,000 00

No. 13.—Same, without vertical circle, and standards only high enough for observation of polaris...... 1,200 00

No. 14.—Same as No. 12, and exactly like cut; horizontal circle twelve, vertical circle ten inches in diameter; former reading by three, latter by two microscopes. Telescope 2½-inch clear aperture, 24-inch focus; packed complete...... 1,300 00

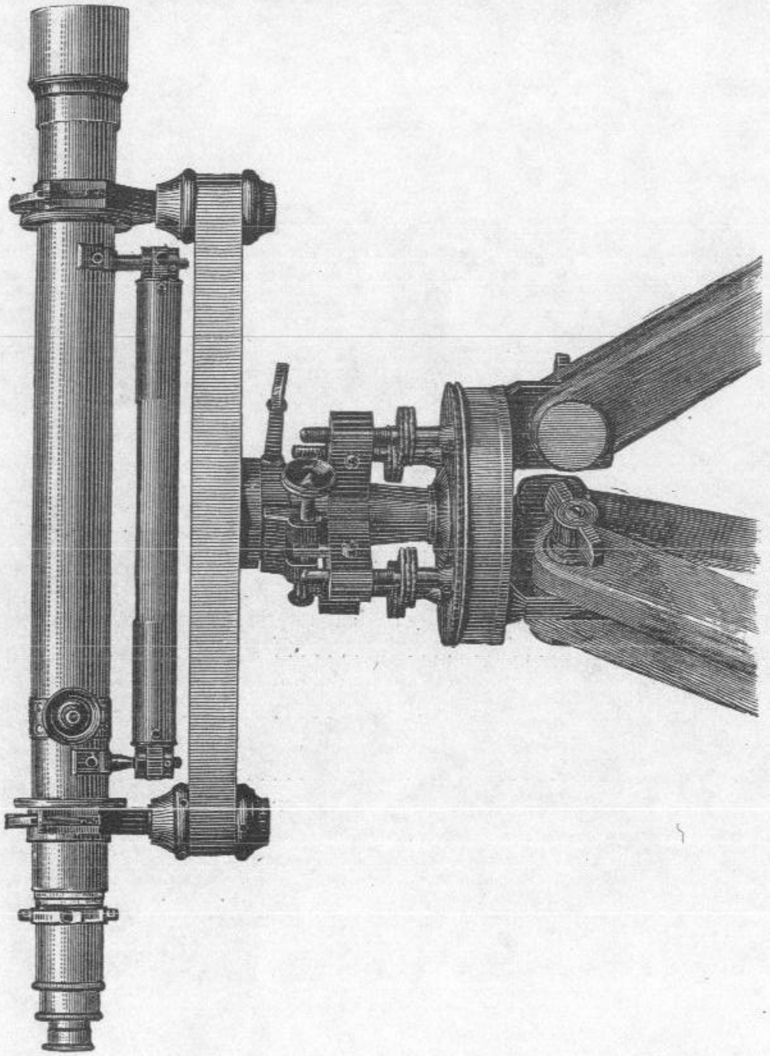
No. 15.—Same, without vertical circle; standards as in No. 13; telescope 2-inch aperture; packed complete...... 800 00

No. 16.—Same as No. 15; circle reading by two instead of three microscopes...... 700 00

No. 17.—Same as No. 12, and shown on cut; horizontal circle ten, vertical circle seven inches in diameter; former reading by two microscopes to seconds, the latter, by means of level alidade, to ten seconds. Telescope swinging through 2 inches aperture, about 18 inches focal length; packed complete...... 850 00

No. 18.—Same, but without the vertical circle; telescope not swinging through; packed complete...... 650 00

LEVELLING INSTRUMENTS.

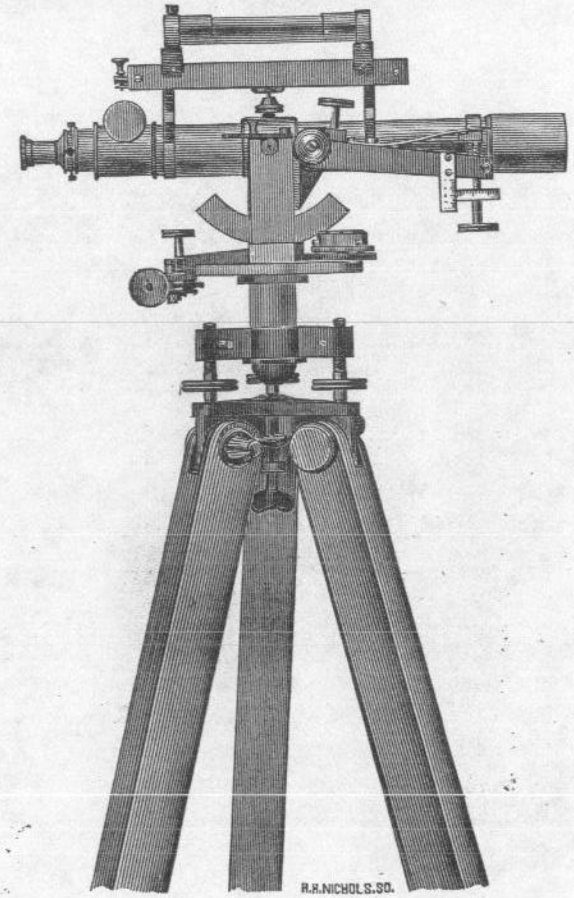


No. 19.—ENGINEER'S Y LEVEL.

The above cut represents a **Y** Level of the most approved form. The telescope has an aperture of $1\frac{1}{4}$ inches, and is about 16 inches long. It rests in the **Y**'s on hard bell-metal rings; the level-bubble is very sensitive; centre long and compound; four levelling-screws.

Price, packed complete $140 00

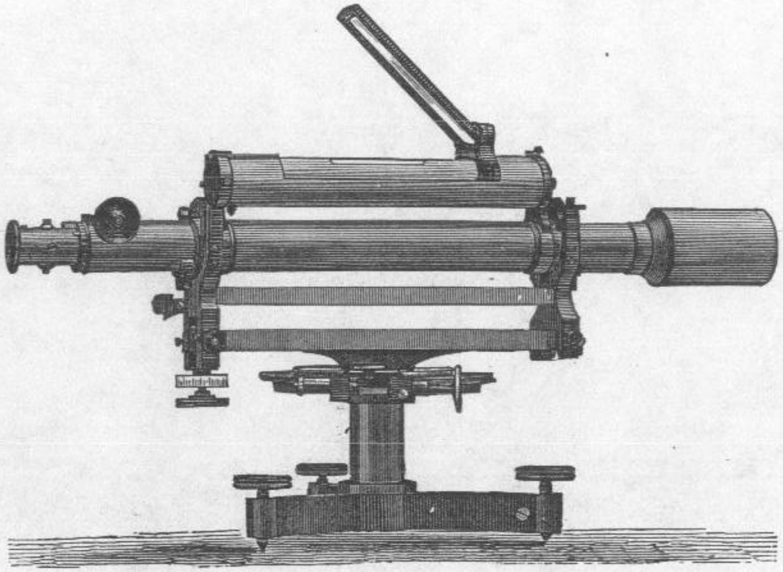
LEVELLING INSTRUMENT AND GRADIENTOR.



No. 20.

No. 20.—Telescope $1\frac{1}{4}$-inch aperture, 10 inches focal length; 4-inch horizontal circle, vertical arc, both divided on silver and reading to minutes. By means of the gradientor attachment distances can be taken and angles of depression or elevation measured with great précision. The compass-needle is 5 inches long, in oblong box under the striding-level; this latter is ground and is very sensitive. Packed complete in box, with all accessories, tripod stand $225

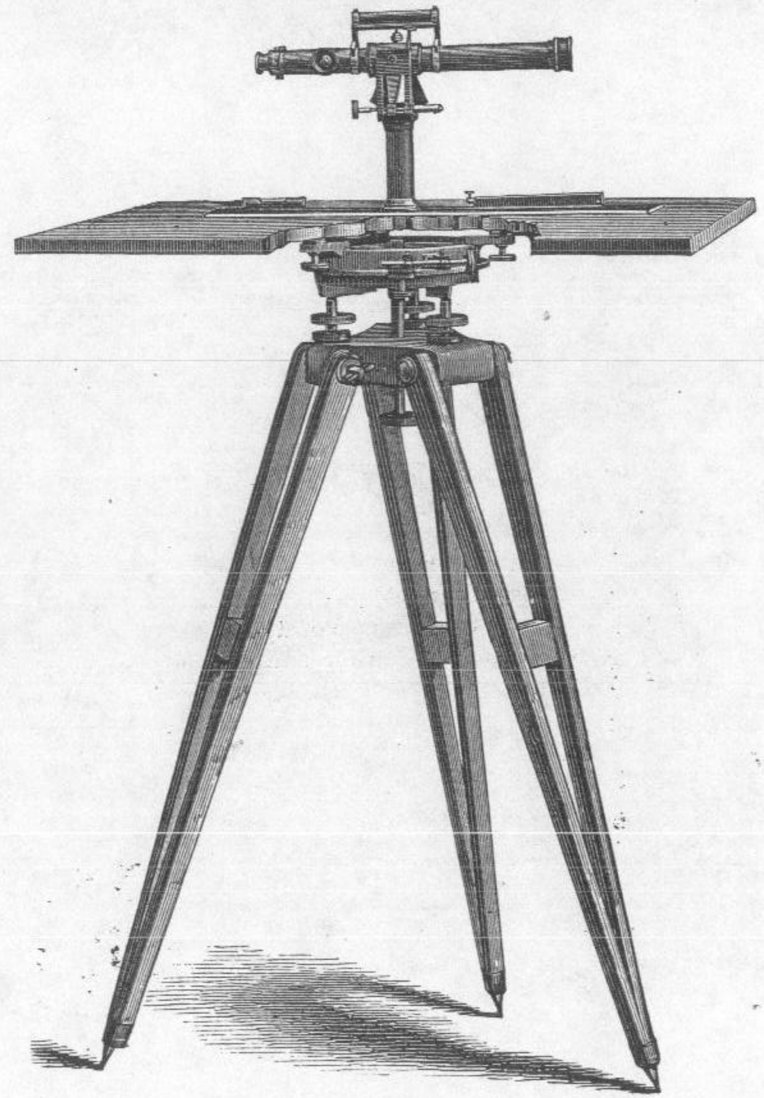
LEVEL OF PRECISION.



No. 21.

No. 21.—Level of Precision, as made by us for U. S. C. & G. Survey, 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 pivot-rings are of phosphor bronze, and rest on agate. 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.

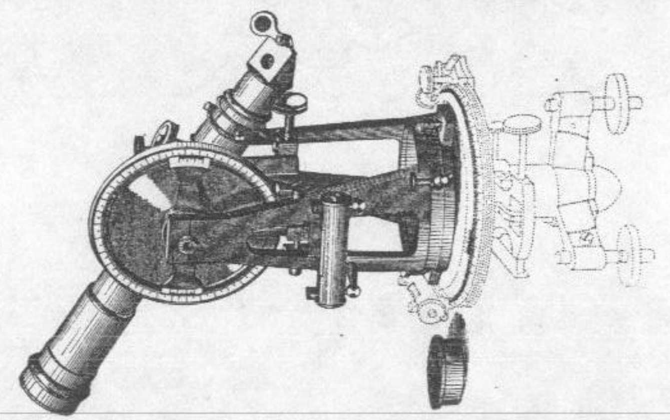


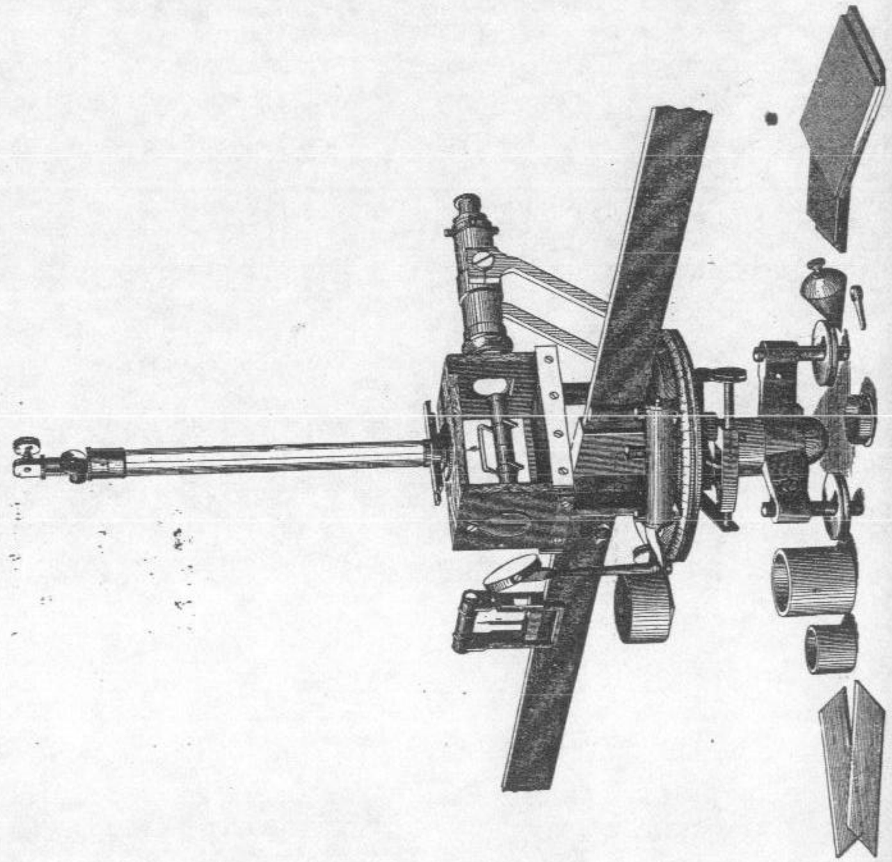
No. 22.

No. 22.—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 $1\frac{1}{4}$ 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, beside 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, beside the usual accessories; the motion-work also in a separate box. Price, complete, with firm tripod stand, $300 00

MAGNETOMETER.

No. 23.—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 $1\frac{1}{8}$-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





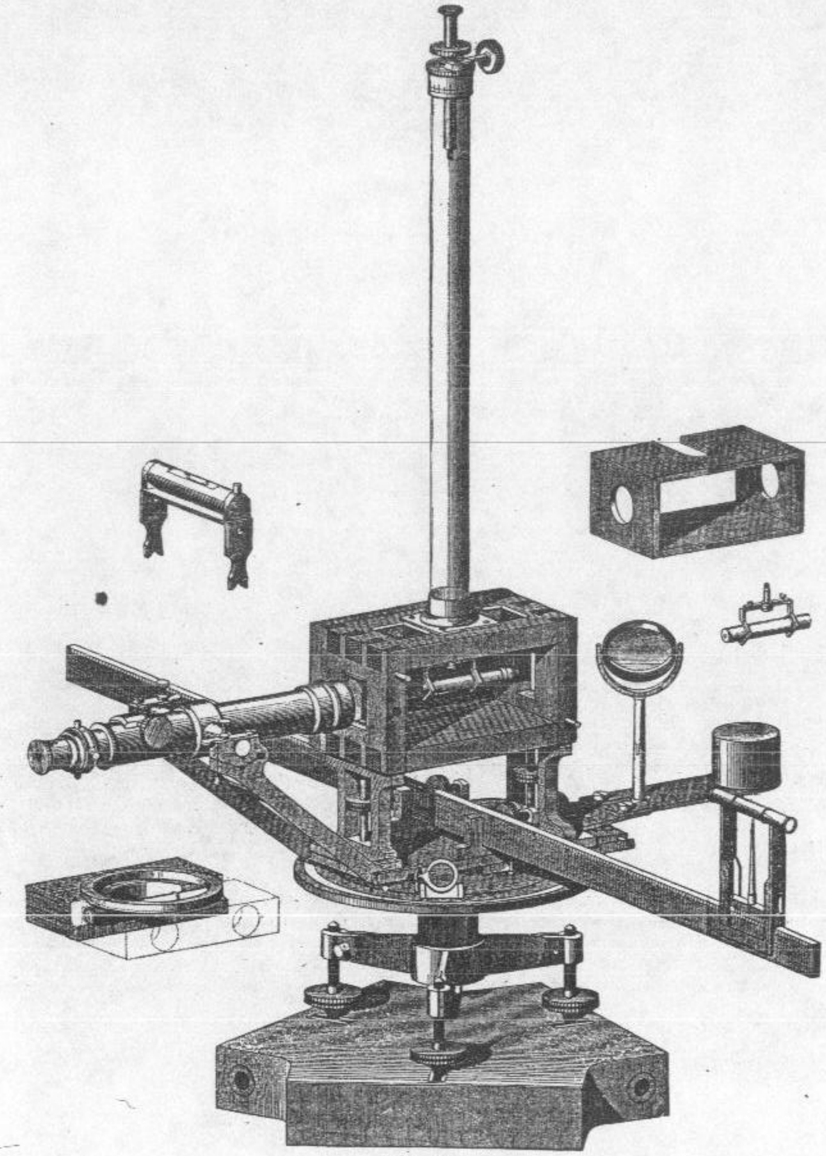
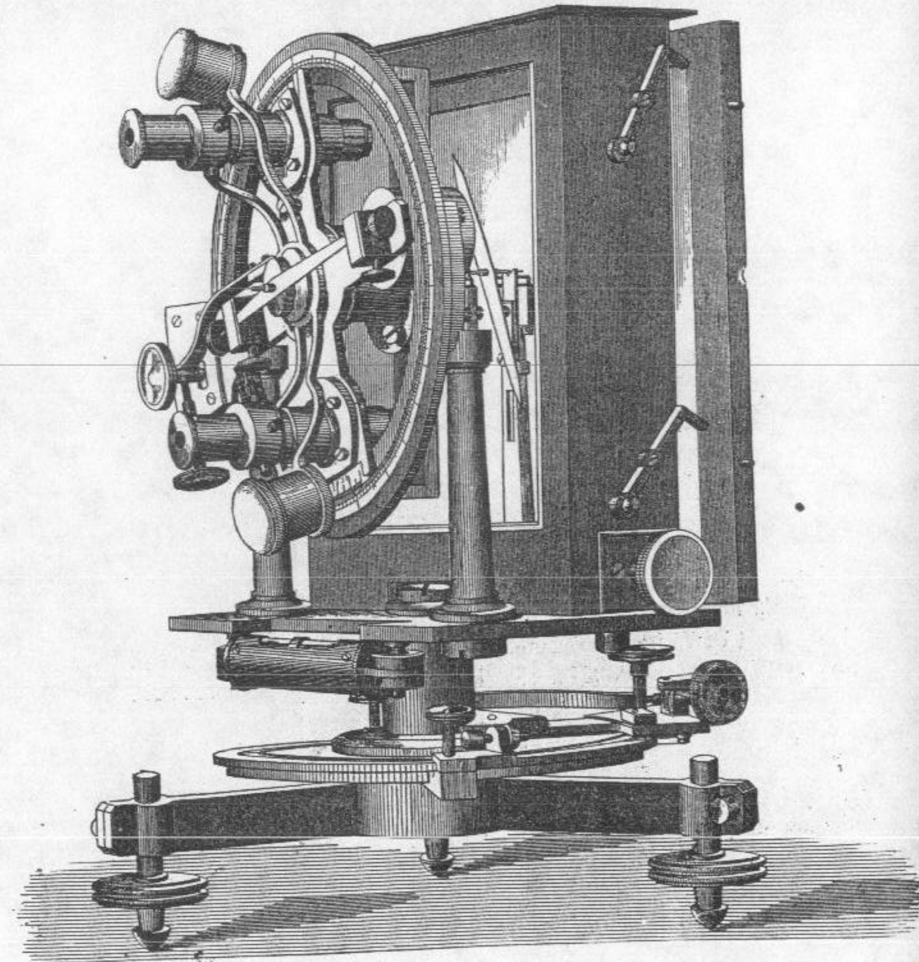


FIG. 24.

No. 24.—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

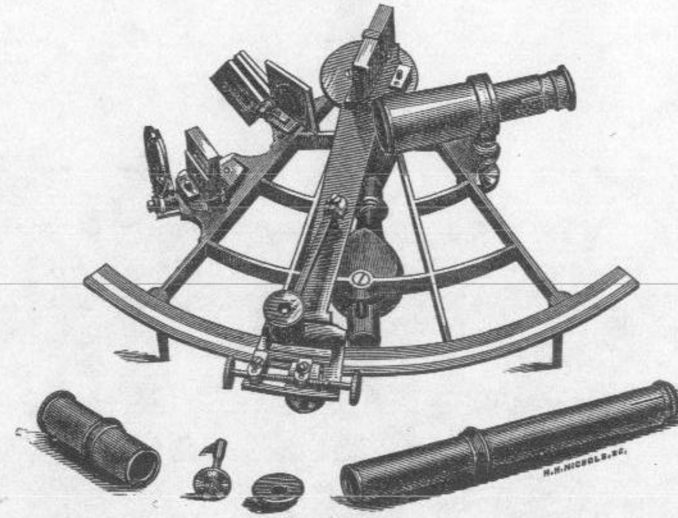
DIP CIRCLE.



No. 25.

No. 25.—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 0

SEXTANT.



No. 26.

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

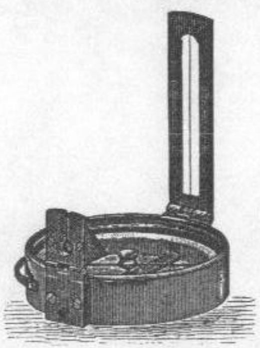
No. 26. Sextant of 7½ inches radius, divided on silver, and reading to ten seconds. The cut shows all accessories. In box complete.......... $110 00

ARTIFICIAL HORIZON.

No. 27.—Artificial Horizon, with mercury bottle and trough, rectangular plate-glass cover, packed in mahogany box.......................... $25 00

POCKET COMPASS.

No. 28.—Prismatic Compass, 3 inches diameter, with divided ring on needle and folding sights; packed in neat case, very convenient for reconnoissance.................................. $30 00

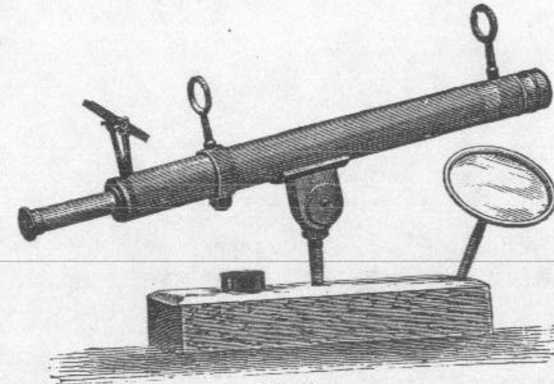


No. 28.

HELIOTROPES.

No. 29.—Gauss Heliotrope.. $150 00

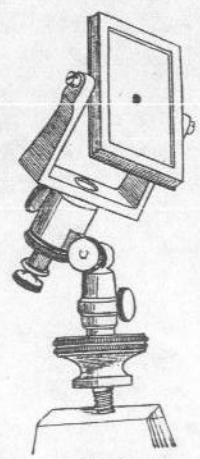
No. 30.—Revolving Heliotrope.. 45 00



No. 31.

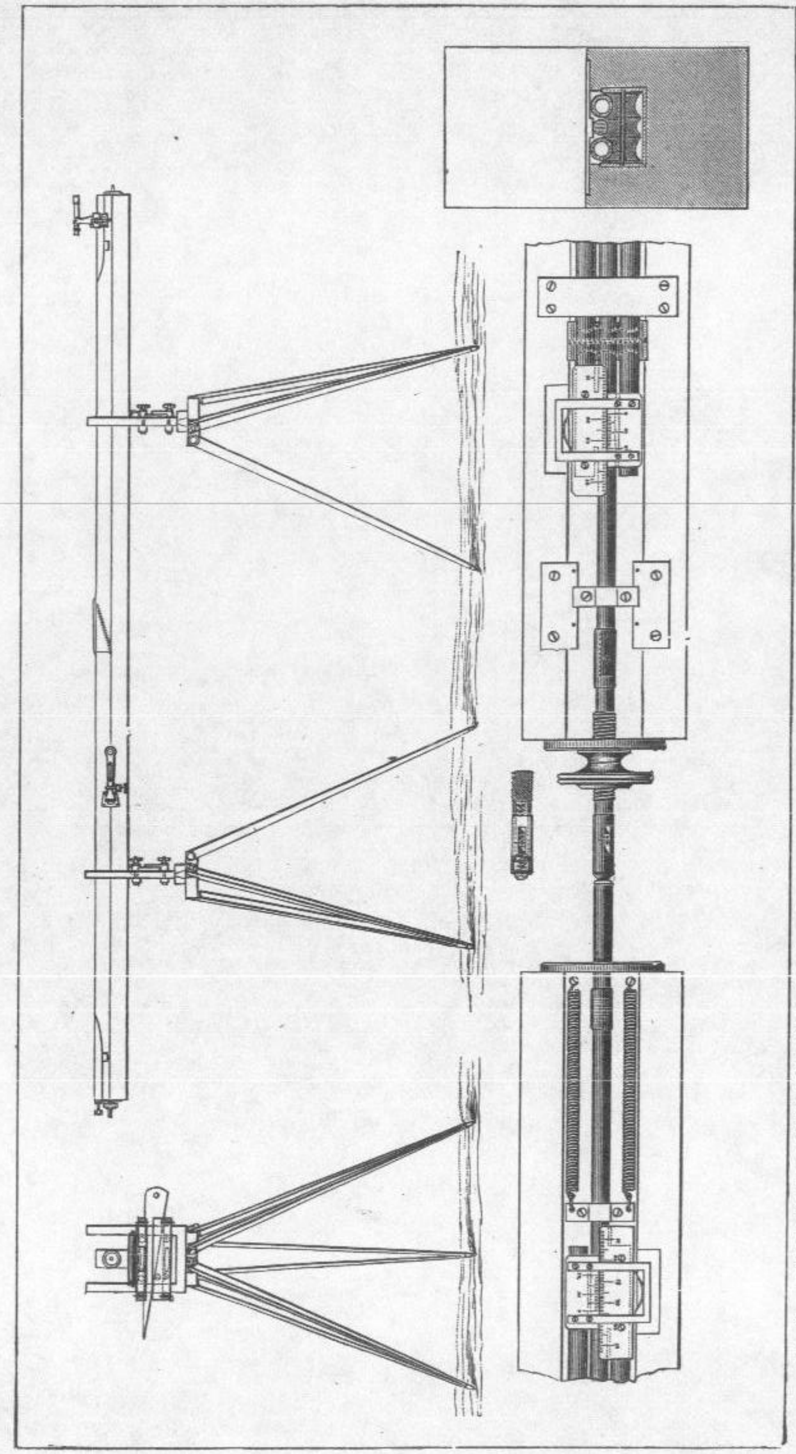
No. 31.—As made by us for the United States Coast and Geodetic Survey. The telescope body is an iron tube; in the middle is a wood screw with joint for attaching the instrument to a tree or post. Mirrors of plate-glass. Price, in box.............................. $30 0

No. 32.—Heliotrope, on tripod, with horizontal and vertical axis; a graduated circle for reading angles. Price, boxed...................... 75 0



No. 33.

No. 33.—Pocket Heliotrope, Steinheil's, a beautiful instrument that requires no adjustment. In case.............................. $25



No. 34.—FOUR-METER CONTACT-SLIDE BASE APPARATUS, after the design of Prof. J. E. Hilgard, Sup't U. S. C. & G. Survey.

Cut. No. 34 represents a perfected form of the Contact-Slide Base Apparatus, designed by Prof. J. E. Hilgard, Superintendent of the U. S. Coast and Geodetic Survey. We have made several of this pattern for colleges and Government Departments.

The apparatus consists of two measuring bars 4 meters long, exactly alike, supported on trestles. The measurement is made by bringing these bars suc- cessively 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 than 4 meters long, firmly screwed together. Between the pieces of wood is a brass frame carrying three roll ers, 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 through out their length on similar systems of rollers. The zinc tubes form with the steel ro a metallic differential thermometer, and are so arranged that one tube is secure to one end of the rod, being free to expand in the other direction, the other tub being in a like manner fastened to the other end of the rod. The zinc tubes, there fore, with any change of temperature, expand or contract in opposing direction and the amount by which the expansion of the zinc exceeds that of the steel i measured by a fine scale attached to the rod, while the zinc tube carries a corre ponding vernier. The cut shows this arrangement, which is identical on both end of the bars; a perforation in the wood of the bar allows this scale to be rea In addition to these metallic thermometers a mercurial thermometer is attache to the bar about midway of its length.

The rods and tubes thus forming a united whole are lengthwise movable the rollers by means of a milled nut working in threads cut on the steel rod, whi passes through a circular opening in the brass plate screwed to the wooden b and against which the nut presses. Two strong spiral springs pull the ro 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; t other end carries the contact-slide, having an agate with a horizontal knife ed This slide is a short tube, fitting over the end of the rod, and pushed outward a spiral spring. A slot in the tube shows an index-plate, with a ruled line faster to the rod.

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

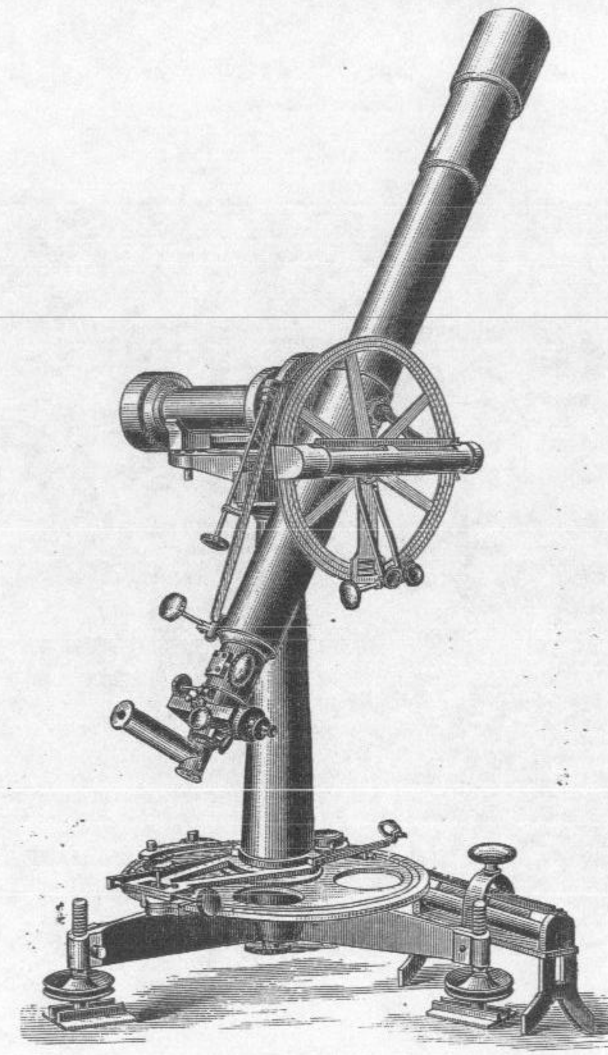
NOTE.—Bars of the same construction, in feet instead of meters, can be furnished.

ZENITH INSTRUMENTS.

Following cut represents the form of Zenith Instrument as used in the U. S. Coast and Geodetic Survey and the U. S. Corps of Engineers. 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 carries a circle with the latitude level, and is provided with a micrometer eye-piece. We make several sizes of these instruments.

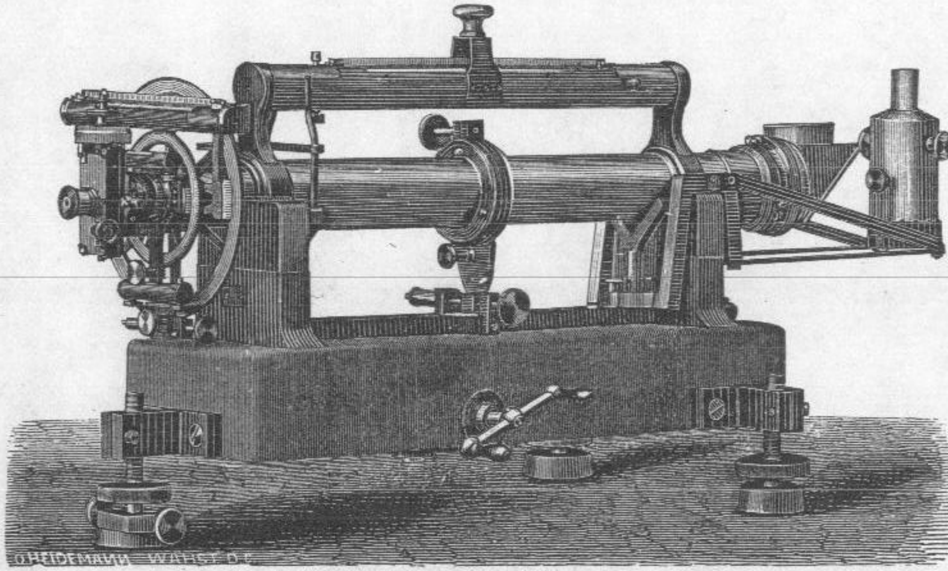
No. 35.—Zenith Instrument, of 2 inches aperture, about 28 inches focal length; 10-inch horizontal circle; striding-level over horizontal axis; fine latitude level attached to circle; micrometer eye-piece; packed complete $700 00

No. 36.—Zenith Instrument, as above, with telescope of $1\frac{1}{2}$ inches aperture 450 00



No. 35.—ZENITH INSTRUMENT.

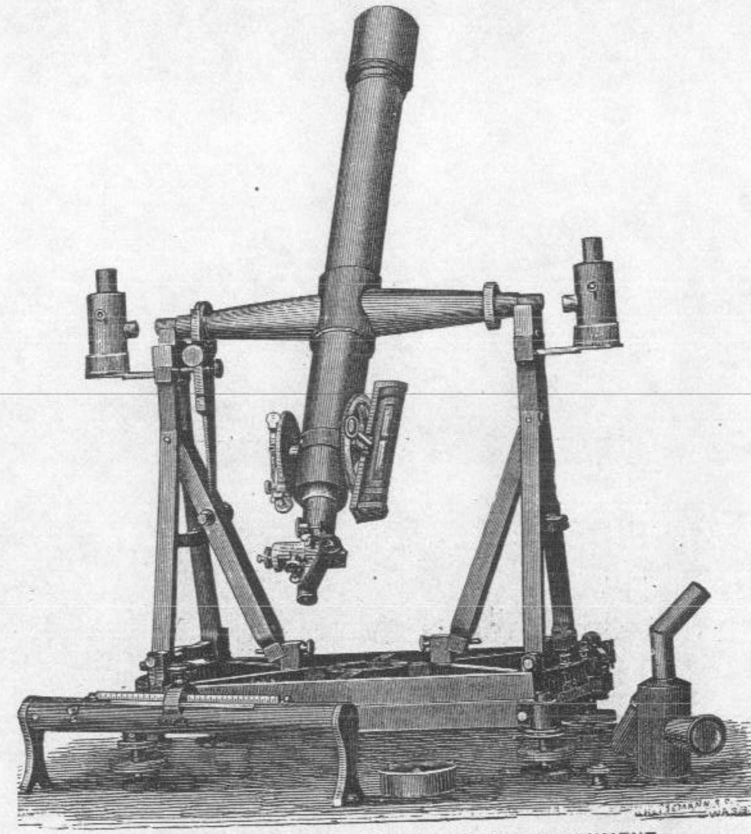
TRANSIT INSTRUMENTS.



No. 37.—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.

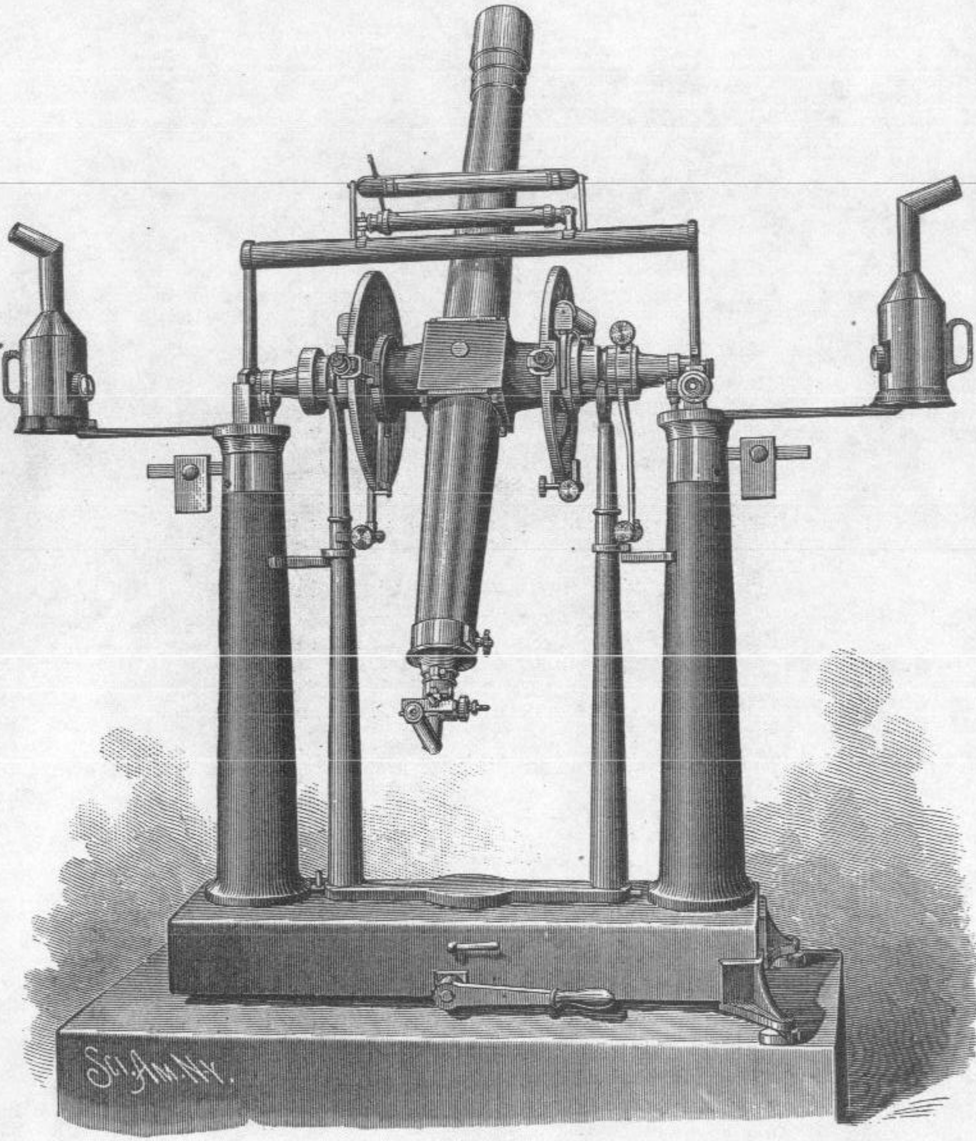
No. 37.—Telescope of 2½-inch clear aperture, packed complete in box, with two eye-pieces, illuminating and reading lamp, and all accessories.... $790 00



No. 38.—COMBINED TRANSIT AND ZENITH INSTRUMENT, as devised by Prof. G. Davidson, U. S. Coast and Geodetic Survey.

No. 38.—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 phosphor bronze, 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, $990 00

No. 39.—Same, with Telescope of 3 inches aperture, the whole instrument being correspondingly larger.......................... 1,200 00

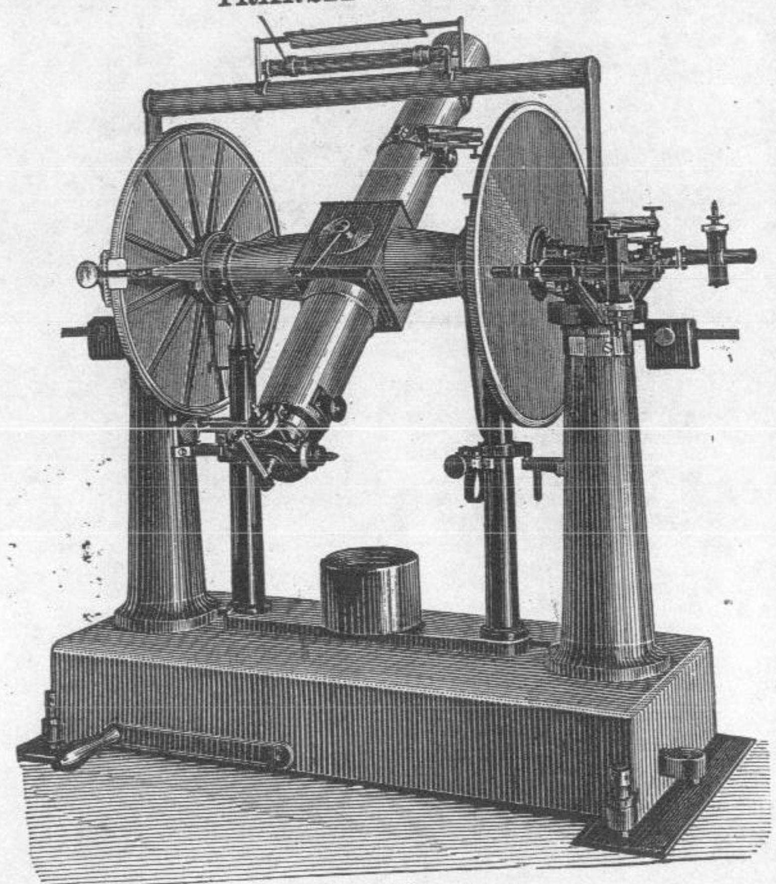


No. 40.—3-INCH TRANSIT.

No. 40.—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. The striding-level over the axis is read by means of a mirror. 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. 41.—The same, with telescope of 3 inches aperture and about 3½ feet focal length. 6-inch setting circle, with level alidade on axis; delicate striding-level; glass micrometer instead of spider-lines; direct and diagonal eye-piece, with parallactic movement; 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

TRANSIT CIRCLES.



No. 42.—TRANSIT CIRCLE.

No. 42.—Transit Circle, of three inches aperture, and circles of 16 inches diameter. One of the circles is coarsely divided on the edge, and serves as a finder. The other is divided into 5-minute spaces, and reads by two micrometer-microscopes to single seconds. The micrometers can be transferred from one pier to the other. Sensitive striding-level, read by means of a mirror. R. A. and Decl. micrometer, level over micrometer-holder; a level is also attached to the telescope for measuring differences of zenith distance. The reversing apparatus allows the instrument to be reversed with the greatest ease. The iron stand is provided with the necessary adjusting screws for movement in altitude and azimuth. The instrument is complete in itself, ready to be mounted, and is provided with mercury basin, diagonal, direct and collimating eye-piece, lamps, etc. Price $1,650 00

No. 43.—The same, with four-inch telescope 1,800 00

No. 44.—Transit Circle, with telescope of about 8 feet focal length and 6 inches aperture. Circles three feet in diameter, one divided into 5-minute spaces, which are read off by means of 4 micrometer microscopes to single seconds. The microscope-holder is in the form of a pulley concentric with the circles, allowing the ready shifting of the microscopes to any part of the graduation. The other circle serves as a finder, and is provided with a coarse graduation. Clamp and tangents by means of rods and handles. Illumination regulated by means of a milled head near eye-end. The pivots are about two inches in diameter, made of hardened steel or phosphor bronze. The level, of best quality, is read by means of a mirror. R. A. and Decl. micrometer with parallactic eye-piece motion. Iron piers coated with asbestos and covered with mahogany; the cut shows it without this covering. Six micrometer and one diagonal eye-piece. Price...... $4,000 00

No. 45.—Same, without circles and microscopes; two 6-inch setting circles with level alidades attached near the eye-end....... .... 2,500 00

No. 46.—Same as No. 16; telescope 5 inches aperture; circles 30 inches diameter; 4 microscopes 3,000 00

No. 47.—Same, without the large circles, but with two finders....... 2,000 00

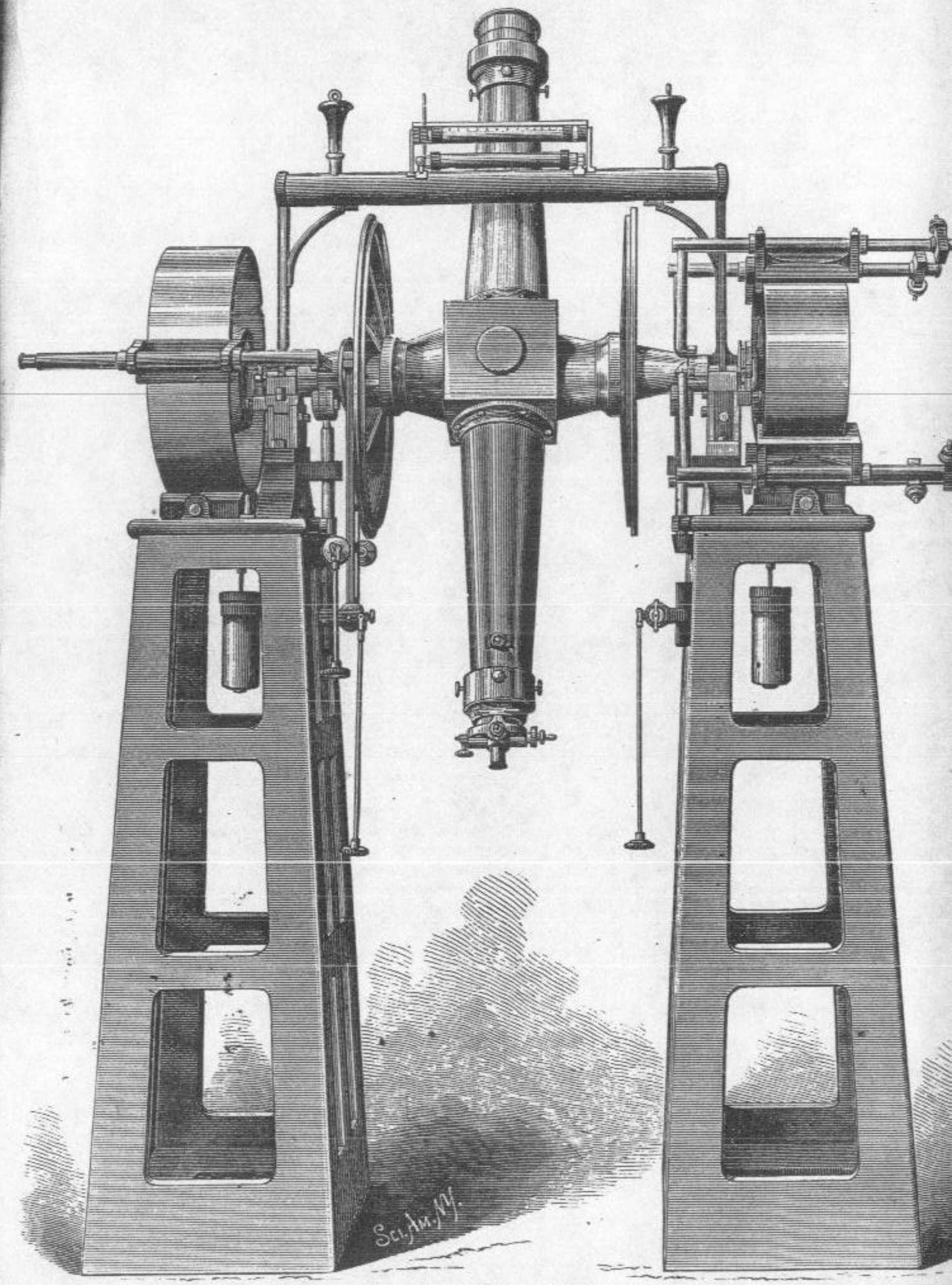
No. 48.—Transit Circle, with telescope of 4 inches aperture; circles 24 inches diameter; in other respects like No. 44.................. 2,400 00

No. 49.—Same, without the large circles, but with two finders....... 1,900 00

Collimators, revolving in Y's, with sensitive level over telescope; micrometer eye-piece according to size of objective.......from $250.00 upwards.

The above prices include reversing apparatus and observing chair of approved pattern.

NOTE.—These instruments may be mounted upon stone or brick piers, which is, perhaps, the better plan.



No. 44.—TRANSIT CIRCLE.

SMALL TRANSITS.

Small Transits, suitable for watch and clock makers for taking time. The stand is similar to the one shown on cut No. 26. The Y's have no adjustment, and the telescope is without clamp or circle; a good striding-level, prismatic eyepiece with sun-shade and glass micrometer are provided.

No. 50.—Transit, with telescope of $1\frac{1}{2}$ inches aperture, 16 inches focus.. $165 00

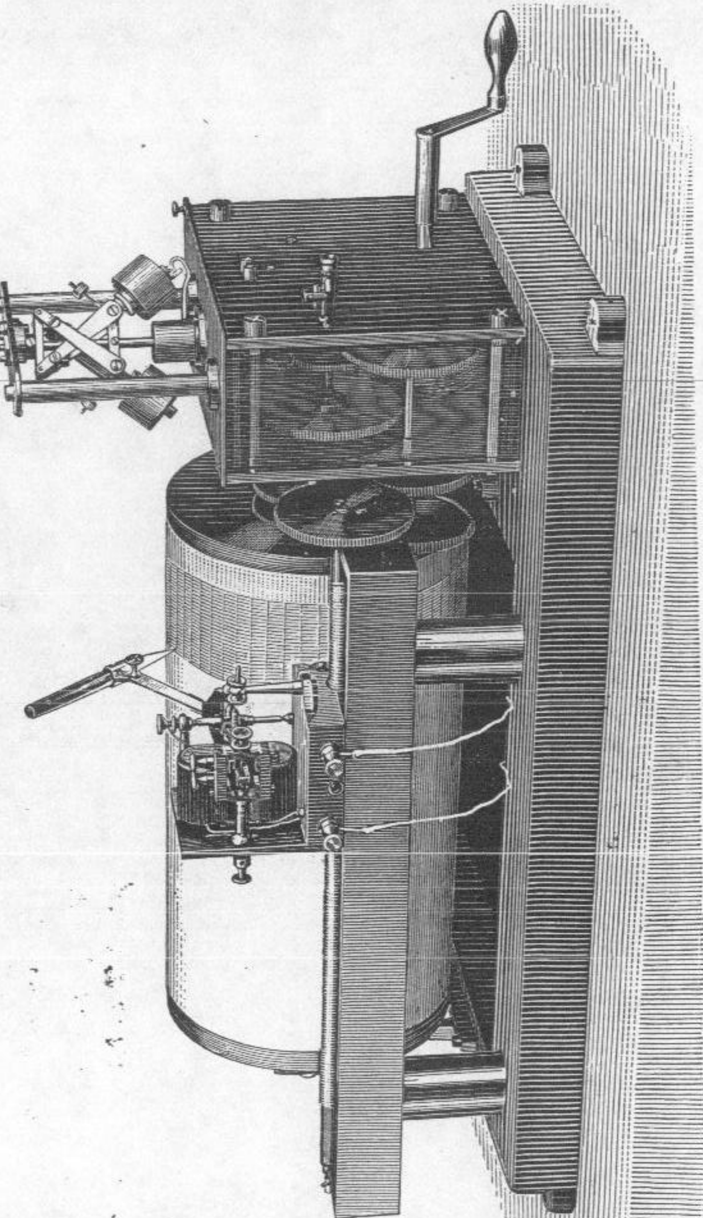
No. 51.—Same, with telescope of $1\frac{1}{4}$ inches aperture.................. 140 00

CHRONOGRAPH.

Cut No. 52 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 a perfect straight line. The cylinder is 14 inches long, 7 in diameter, and with three feet fall and a weight of about 18 pounds, runs $2\frac{1}{2}$ hours. Saegmuller's maintaining power, however, permits winding up without retarding motion. The clock-work is strong enough to drive 3 or 4 cylinders, which can readily be attached. By pushing a button the speed of the cylinder is doubled, which is convenient in exchanging clock-signals in longitude work and other purposes............ $350 00

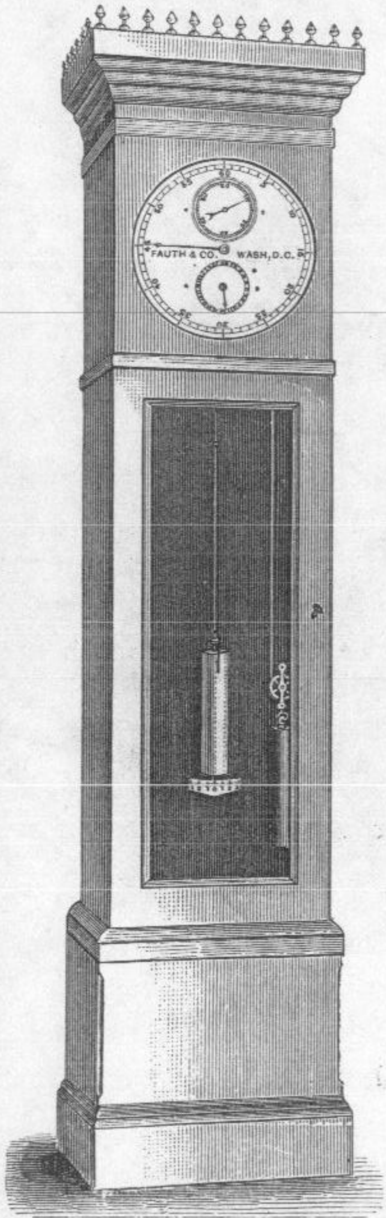
Each additional cylinder, with frame, carriage-slide, and magnet....... 150 00

Chronograph paper for the above, per 100 sheets.................... 1 50



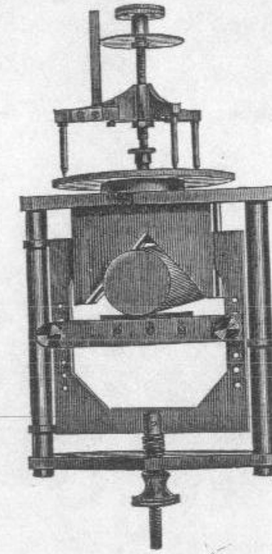
No. 52.—CHRONOGRAPH.

ASTRONOMICAL CLOCK.



No. 53.

No. 53.—The cut No. 53 shows one of our Astronomical Clocks. We make them either with long or short case. Dennison's gravity escapement, compensated 60 pounds pendulum; break circuit arrangement with rheostat, which prevents sparks, thus saving contact joints from oxidation. Price........... $450 00

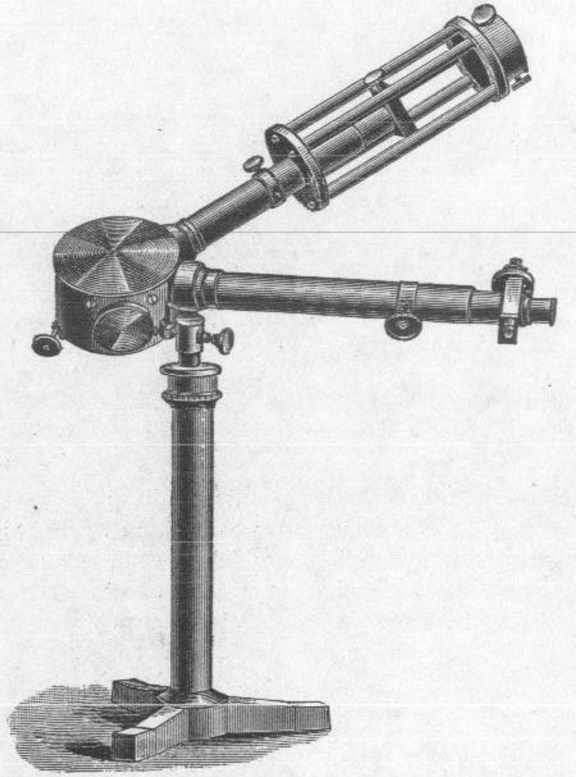


No. 54.—SPHEROMETER, as devised by Prof. Wm. Harkness, U. S. N.

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, in box.................................... $50 00

SPECTROSCOPE.

The following cut represents a Spectroscope which answers both for physical and astronomical research, and is arranged to be used either with diffraction grating or prism. It consists of a circular box into which the collimator and observing telescope are screwed. The collimator slides in a tube so as to bring the slit into the focus of the objective. This tube is connected with the adapter by four stiff rods, leaving the slit easily accessible. The collimator tube is graduated into millimeters. Grating or prism can readily be placed in the box on a small table which has all the necessary adjustments. By means of a milled head, projecting through the bottom of the box, the grating or prism can be rapidly rotated. A slow motion can at once be obtained, without previous clamping, by turning a tangent-screw fitted into the periphery of the grating holder, which is held by friction to a plate to which the projecting knob is fastened. The amount of rotation is measured to single minutes by a graduation on bottom of box. When the grating is in use the collimator and view telescope are placed as shown in cut, forming an angle of about 38 degrees. When the prism—which is a dense flint—is to be used, the view telescope is changed and screwed into a collar on the side of the box. The two telescopes are then placed in a position of minimum deviation for the ultra-violet rays. The instrument can be put into any position by means of a universal joint. It is readily lifted off the stand when intended to be used with the telescope.



No. 55.—SPECTROSCOPE.

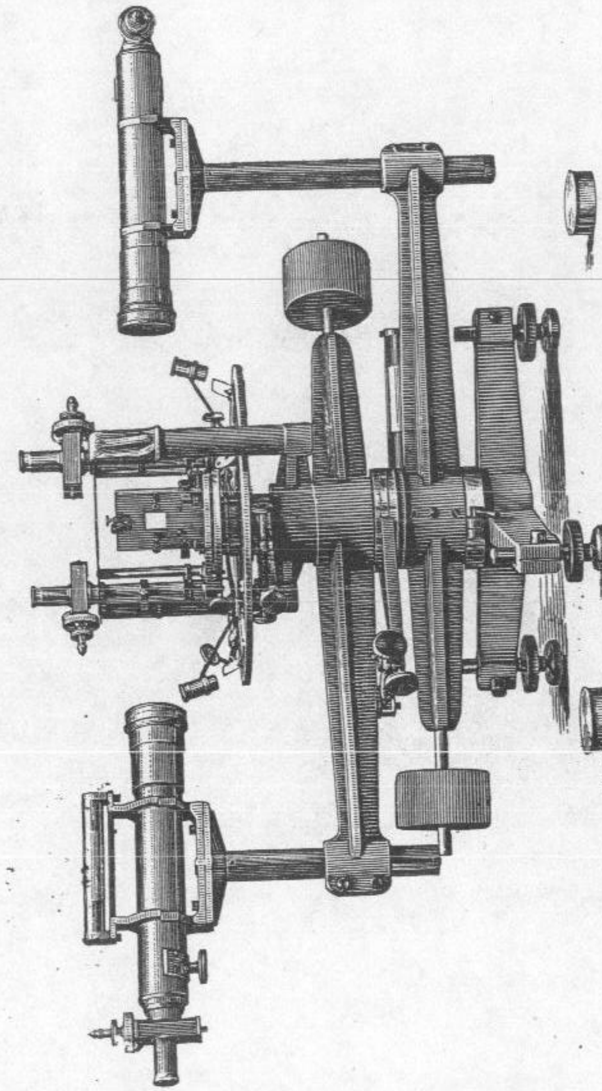
No. 55.—Spectroscope as above, with telescopes of one inch aperture, about 9 inches focus, extra dense flint-glass prism $250 00

No. 56.—The same, with telescopes of 1½ inches aperture and 12 inches focus 300 00

No. 57.—McLean's Star Spectroscopes, consisting of a cylindrical concave lens in front of a direct vision prism 25 00

Cut No. 58 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

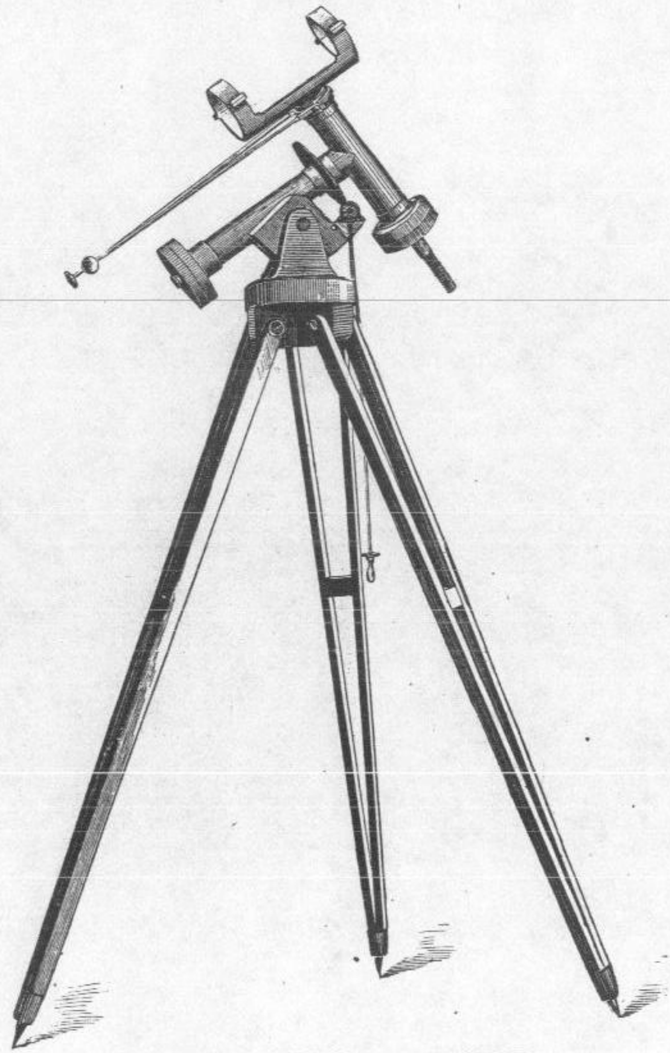


No. 58.—SPECTROMETER.

of its own and has attached to itself two verniers reading to five 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, from $600 to $1,200.

EQUATORIALS.

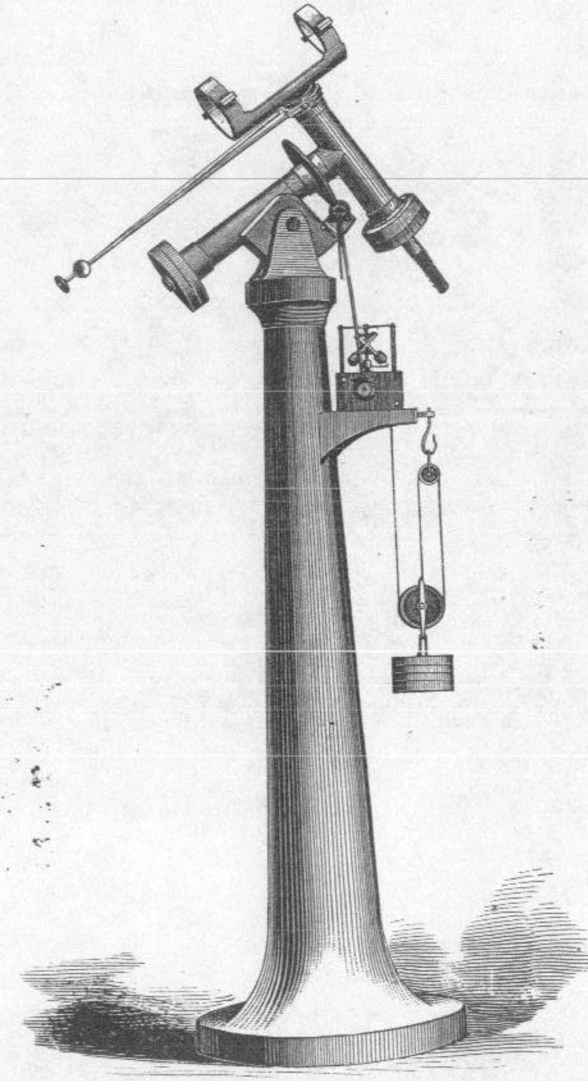


No. 59.—PORTABLE EQUATORIAL MOUNTING.

Above cut represents a Portable Equatorial Mounting, suitable for telescopes up 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.

No. 59.—Equatorial Mounting, as above, for 3-inch telescope.......... $200 00
No. 60.—Same, without circles or tangent-screw movements.......... 140 00

No. 61.—Equatorial Mounting for 4-inch telescope, with circles and tangent-screw motion.......... $300 00
No. 62.—Same, without circles, etc.......... 225 00
No. 63.—Equatorial Mounting for 5-inch telescope, with circles and tangent-screw motion.......... 400 00
No. 64.—Same, without circles, etc.......... 300 00



No. 65.—EQUATORIAL MOUNTING ON IRON PILLAR.

The preceding cut represents a complete Equatorial Mounting on hollow iron pillar, with clock-work, circles, and tangent-screw motion.

No. 65.—Equatorial Mounting, as represented in cut, with clock-work, circles with silvered graduation, and tangent-screw motion suitable for a 4-inch glass $575 00

No. 66.—Same, see cut, for a telescope of 5 inches aperture 675 00

Telescopes for above mountings. Fine achromatic objectives mounted in brass tube with focussing rack and pinion; 3 astronomical eye-pieces.

No. 67.—Telescope of 3-inch aperture..........
Mounted with 1½-inch finder $140 00

No. 68.—Telescope of 4-inch aperture ....
Mounted with 1¾-inch finder 240 00

No. 69.—Telescope of 5-inch aperture..........
Mounted with 2-inch finder.......... 350 00

RECONNOITRING DRAW-TELESCOPE.

These are very convenient to carry. The Telescope, which has a fine objective of two inches aperture, closes up in a leather case about 12 inches long, with straps attached, and is easily fastened to the stand by a circular clamp. The stand has a small divided circle for roughly measuring angles. Stadia wires are inserted in the eye-piece for measuring distances. The stand, when folded, forms a round staff of about 2 inches diameter.

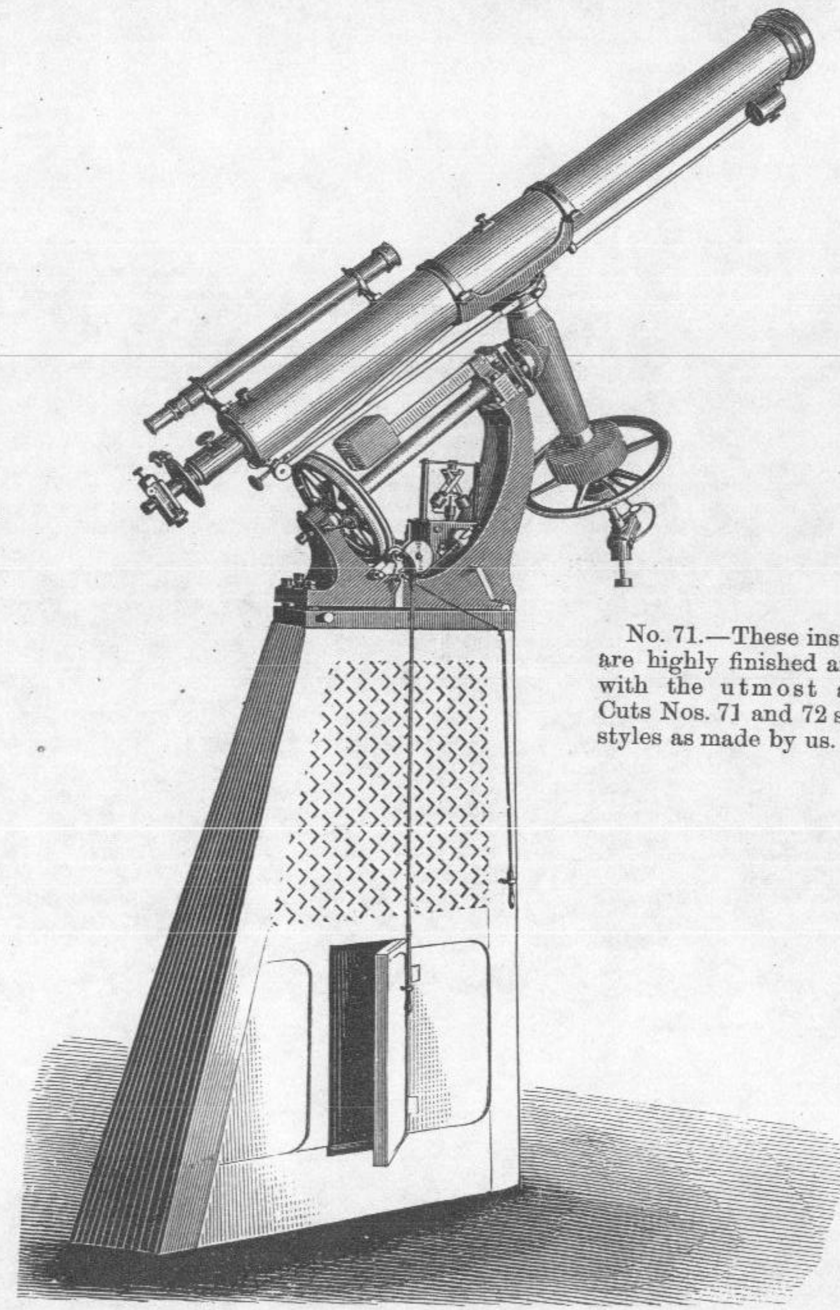
No. 70.—Reconnoitring Draw-Telescope, 2-inch aperture, as described above $80 00

NOTE.—If Heliotrope fixtures are desired, (see cut No. 31,) consisting of two plate-glass mirrors and two sight-rings, it increases the price.... 20 00

Clamp and screw attachment, to screw into a tree or post, extra....... 7 50

The above Telescope, without the stand 30 00

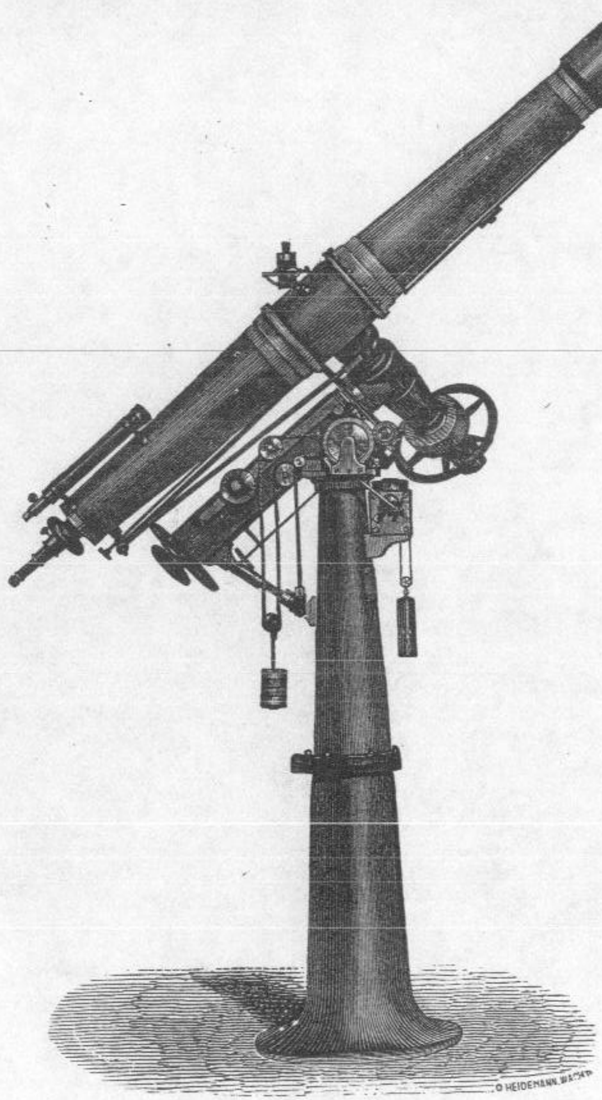
COMPLETE EQUATORIAL TELESCOPES.



No. 71.—EQUATORIAL.

No. 71.—These instruments are highly finished and made with the utmost accuracy. Cuts Nos. 71 and 72 show two styles as made by us.

No. 71 is intended to be mounted on a brick or stone pier, which is especially to be recommended for Telescopes of large size. We have, however, built several



No. 72.—EQUATORIAL.

of them with iron piers. No. 71 is then like No. 72, complete in itself, ready to be set up in the observatory.

We have added several important improvements to these instruments:

The Telescope can be moved in R. A. without stopping the clock or disengaging

the worm. When moved sufficiently the clock acts again with the regular rate without previous clamping. If desired, an additional R. A. circle is provided driven by an auxiliary clock-work, which is kept running. An index shows th R. A. of the point to which the Telescope is then directed.

The rate of the driving-clock is readily changed from sidereal to lunar. Thes Equatorials are constructed with the utmost exactness, and each one is provide with a finder; a number of micrometrical and astronomical eye-pieces; transi eye-pieces and sun-shades.

Large Declination and Hour Circles, divided on silver, and reading with tw verniers and microscopes to five seconds of arc and single seconds of time respec tively. Coarse graduation on the edge with pointer, for convenience in setting

Driving-Clock with conical pendulum connected with polar axis; can be throw in and out of gear from eye-end of Telescope; additional tangent-screw motio in R. A. and Decl. by means of rods and handles. Illuminating lamp attache to end of declination axis.

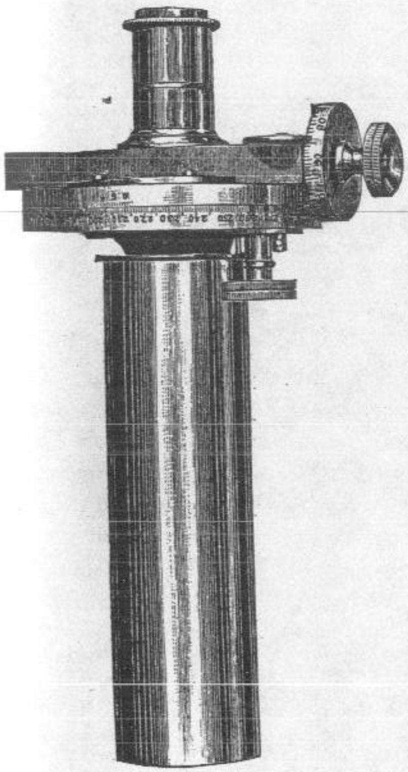
No. 73.—Equatorial Telescope, of 4-inch aperture, with six eye-pieces, fitted up as above	$975 0
" 74.—Same, without clock-work or micrometer	700 0
" 75.— " 5-inch aperture	1,400 0
" 76.— " without clock-work and micrometer	1,100 0
" 77.— " 6-inch aperture	1,800 0
" 78.— " without clock-work and micrometer	1,500 0
" 79.— " 7-inch aperture	2,500 0
" 80.— " 8 " "	3,000 0
" 81.— " 9 " "	4,000 0
" 82.— " 10 " "	5,500 0

The prices of larger instruments may be had on application.

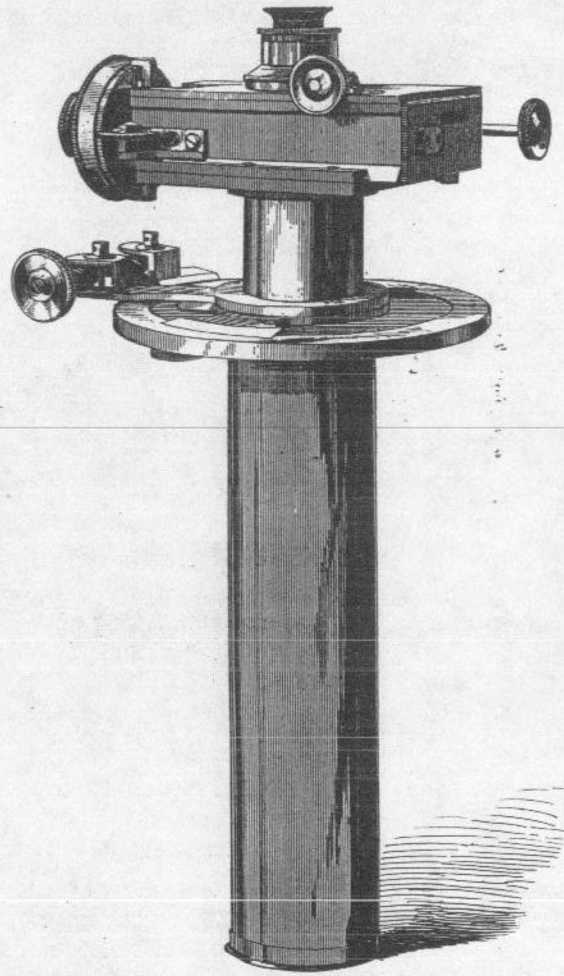
MICROMETERS.

Cut No. 83 represents a simple form of position micrometer; micrometer-screw 100 to the inch; head divided into 100ths; provided with full revolution index; four-inch circle reading by vernier to single minutes; micrometer box turns by rack and pinion motion. Price... $75 0

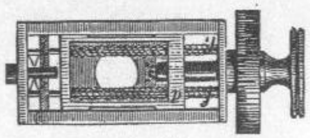
No. 84 is a position micrometer of the highest class; parallactic movement for the eye-piece; fine movement to spider-line, and rapid movement for entire micrometer to traverse the field. Micrometer head is divided on silver; whole revolutions read off on a separate dial—the prettiest device for recording whole turns. Position circle 5 in. diameter, divided on silver, reading by two opposite verniers to 30 seconds, or $\frac{1}{100}$ of a degree. Clamps and tangent-screw to circle, arrangement for dark and bright field illumination. Packed in box............$200 0



No. 83.



No. 84.



No. 85.

Eye-piece Micrometer, (filar,) each..$50 00
Reading Micrometer, with achromatic objective........................ 65 00
Double Image Micrometer, according to style, from $75 up.

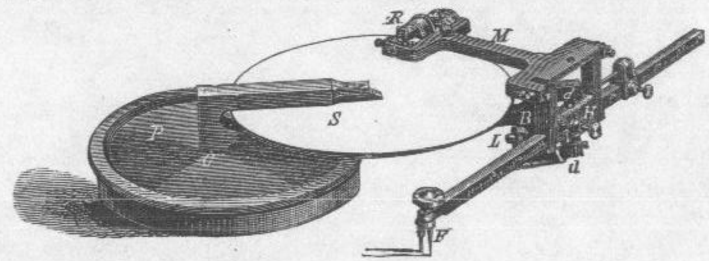
PRECISION PLANIMETERS.

(See pages 42–51.)

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*, as shown in the table on page 51. The roller does not run directly on the paper, but on a perfectly flat disc, and, consequently, the results of the instrument are in no wise 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.

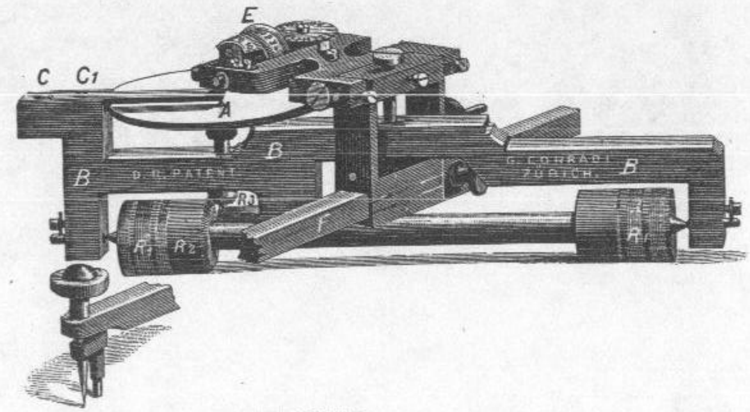
These new Planimeters have been described in all the leading engineering papers in Europe, and we have no doubt but that they will be welcomed by every engineer in this country who desires a really first-class instrument.

No. 86. Simple Precision Planimeter, in case........................ $40 00



No. 87.—SUSPENDED PLANIMETER.

No. 87. Suspended Planimeter, in case $100 00



No. 88.—ROLLER PLANIMETER.

No. 88. Large Roller Planimeter, in case.............................$120 00

PROTRACTORS.

No. 89. Three-arm Protractor, 6-inch circle, divided on silver, extension arms 30 inches long $110 00

TIDE-GAUGES.

No. 90. 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—$\frac{1}{4}$ inch to $\frac{3}{4}$ inch equivalent, each	$4 50
1 " $1\frac{1}{2}$ " " "	5 00
$1\frac{3}{4}$ " $2\frac{1}{4}$ " " "	6 00
Kellner (achromatic)—$\frac{1}{3}$ inch to $\frac{3}{4}$ inch equiv., each	6 00
1 " " "	7 00
$1\frac{1}{4}$ " " "	8 50
$1\frac{1}{2}$ " " "	10 00
Steinheil (achromatic)—$\frac{1}{3}$ inch to $\frac{3}{4}$ inch equiv., each	9 00
1 " " "	12 00

Negative Eye-Pieces.

Huyghens—$\frac{1}{4}$ inch to 1 inch equiv., each	$5 00
$1\frac{1}{4}$ " $1\frac{1}{2}$ " " "	6 00
Airy (giving a large and perfectly flat field) $\frac{1}{4}$ inch to $\frac{1}{2}$ inch equiv., each	6 00
	7 00
$\frac{3}{4}$ inch equiv., each	9 00
1 " " "	10 00
$1\frac{1}{4}$ " " "	12 00
$1\frac{1}{2}$ " " "	16 00
2 " "	

Terrestrial or Inverting Eye-Pieces for Direct Vision.

Fraunhofer—$\frac{1}{4}$ inch to $\frac{1}{2}$ inch equivalent, each	$7 50
$\frac{3}{4}$ " " "	8 00
1 " " "	10 50
$1\frac{1}{2}$ " to 2 inches " "	15 00
Airy (large and perfectly flat field)—$\frac{1}{3}$ inch to $\frac{1}{2}$ inch equiv., each	8 50
$\frac{3}{4}$ inch equiv., each	10 00
1 " " "	12 00
$1\frac{1}{2}$ " to 2 inches equiv., each	16 00

Diagonal Terrestrial Eye-Pieces.

$\frac{1}{2}$ inch to $\frac{3}{4}$ inch equiv., each	$
1 " $1\frac{1}{2}$ " " "	

REFLECTING PRISMS.

First surface-reflecting prism (solar)	$
$\frac{3}{8}$ inch square, mounted with sun-shade	
$\frac{1}{2}$ " " " " "	
$\frac{3}{4}$ " " " " "	
1 " " " " "	

Helioscopic eye-piece, Merz, modified by Prof. Young, according to size, $50 up.

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

DIFFRACTION GRATINGS.

Gratings with 12,000 and 24,000 lines per inch are now being ruled for u our new engine by Mr. Chapman.

LEVEL VIALS.

Of all sizes and grades of sensitiveness, from $0.75 to $1.00 per inch. Chamb Levels, reading to seconds, from $3 to $5 per inch.

LEVELLING RODS.

New York Rod	$1
Philadelphia Rod	1
Boston Rod	1
Ranging Poles, painted red and white alternately, made of wood with steel shoes, 6 to 8 feet long	

HAND LEVELS.

Locke's Hand-Level, nickel-plated	1
Abney Level and Clinometer	1

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, 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 2 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 50
" " 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