ASTRONOMICAL AND ENGINEERING INSTRUMENTS

BAUSCH, LOMB,
SAEGMULLER CO.
ROCHESTER, N.Y.
U.S.A.

Astronomical, Engineering

AND OTHER

Instruments of Precision

SALES AGENTS

BAUSCH & LOMB OPTICAL CO.

ROCHESTER, N. Y.

BAUSCH, LOMB, SAEGMULLER CO.

ROCHESTER, N. Y.

Branch Office: WASHINGTON, D. C.

THE necessity for increased facilities due to the growth of the business, the close relations existing between Mr. George N. Saegmuller and the Bausch & Lomb Optical Company, the many advantages offered by the city of Rochester for the production of instruments of precision, led to the business association of the above named under the firm name of Bausch, Lomb, Saegmuller Company, and the removal of the factory from Washington to Rochester.

Here we are housed in a modern, up-to-date factory building and have all the advantages which such a structure and a well organized force of employees, under able management, can offer.

With the increased facilities resulting from this organization, we hope to add to the lines already established and to serve our patrons even better than we have been able to do in the past.

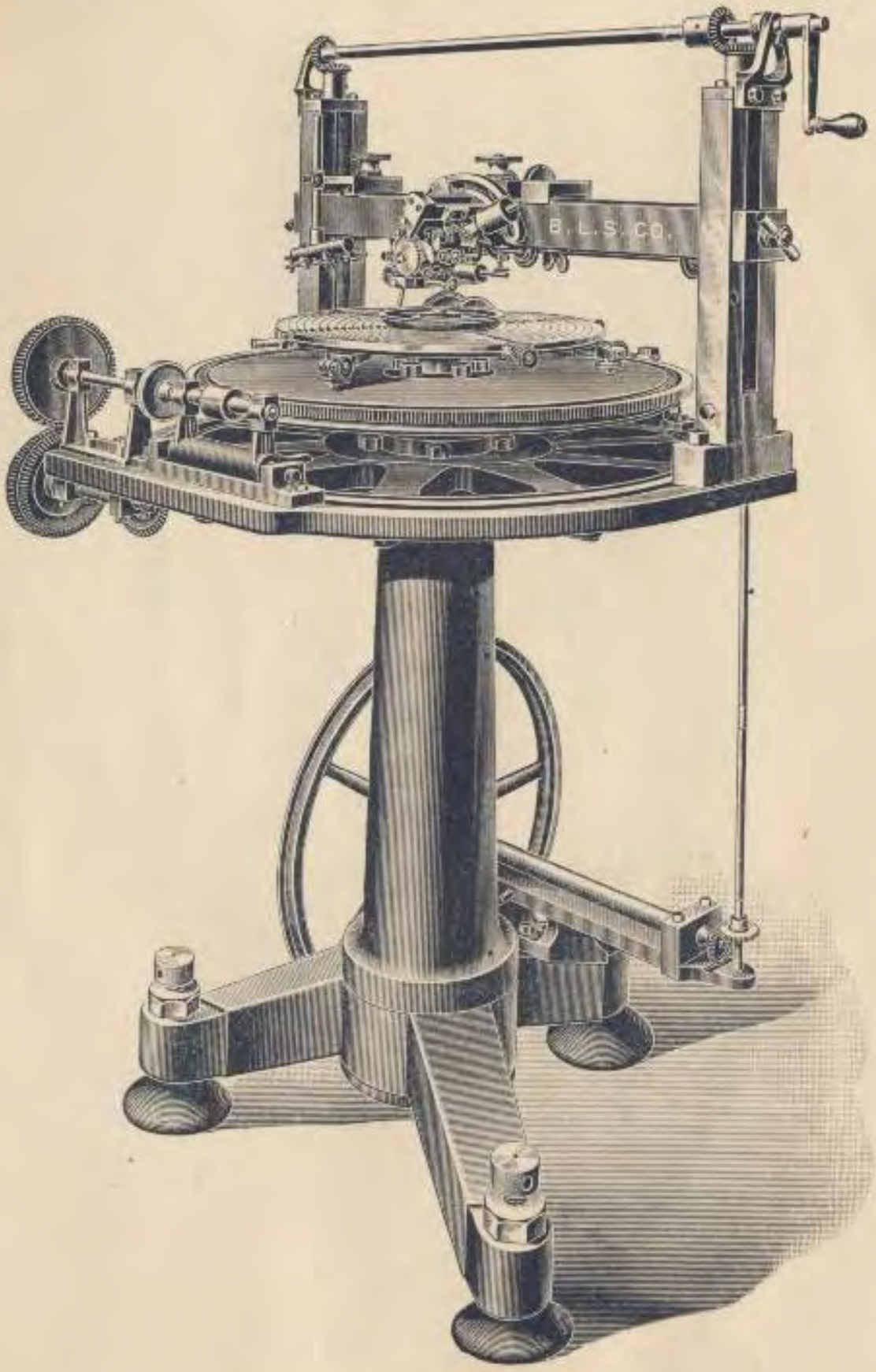
We shall continue to maintain our Washington office, where a line of samples will be shown.

The Bausch & Lomb Optical Company will act as our general sales agents and will have entire charge of the distribution of our products and the commercial end of our business. This, by reason of their large and well systematized organization, they will be able to do in the most efficient manner possible.

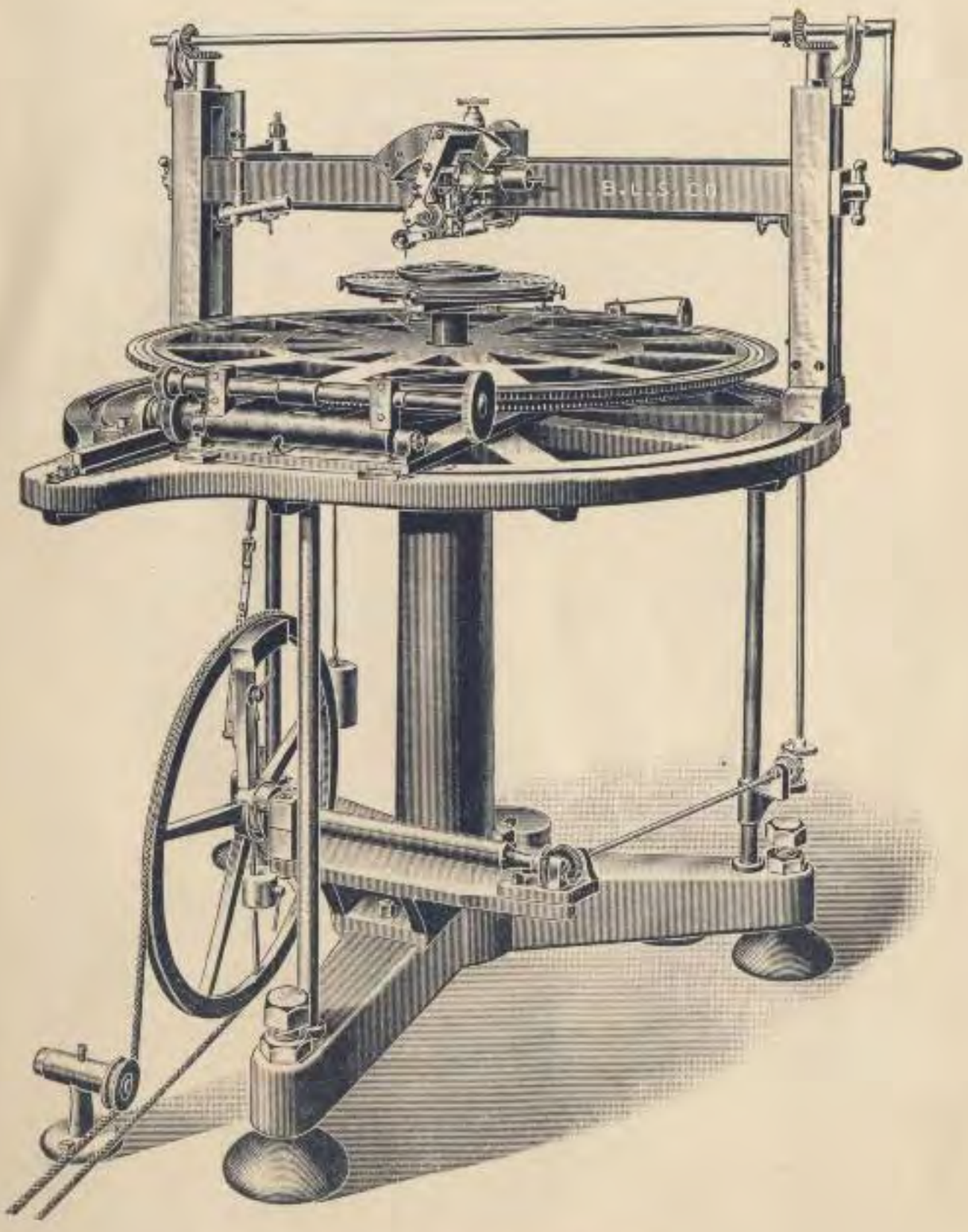
Our efforts will continue to be directed to the promotion of the best interests of our customers and will, we feel confident, redound to our mutual advantage.

BAUSCH, LOMB, SAEGMULLER CO.

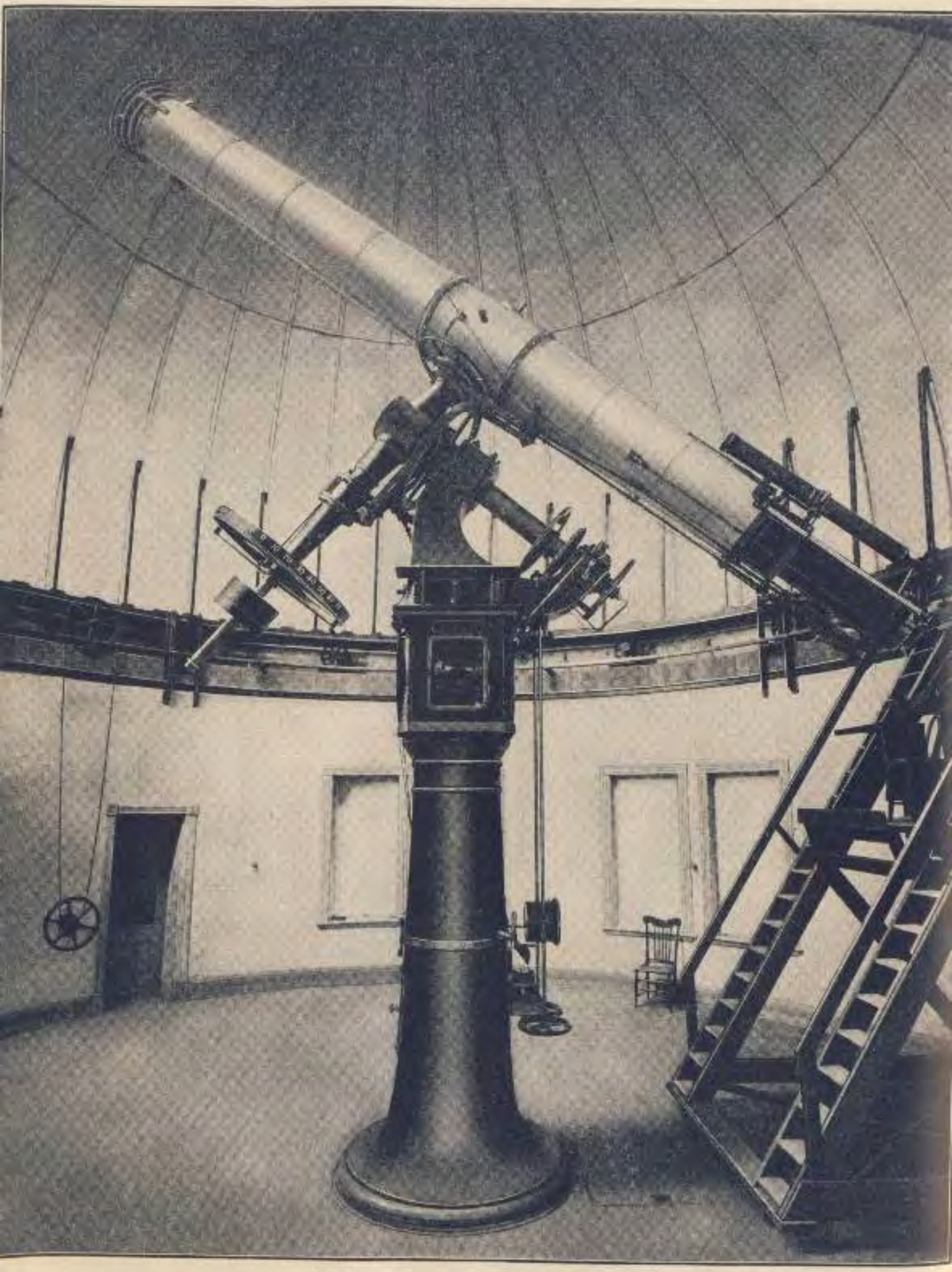
Rochester, N. Y.
May, 1907



SMALL DIVIDING ENGINE



LARGE DIVIDING ENGINE



Denver Equatorial 20 Inches Aperture

Designed and constructed by G. N. Saegmuller

Construction of Instruments

THE construction of our instruments keeps pace with the most exacting requirements made necessary by the progress attained in the sciences and engineering. We pride ourselves upon the fact that our engineering instruments especially, are unexcelled. The nature of the work demands that these instruments shall be light, have great optical power, accurate graduations which can be easily read, and that compasses and verniers shall be so protected as to be practically dust-proof and water-tight.

These requirements are all met in our instruments. They are of the highest type, and as regards general features are made of the very toughest material and are reduced in weight as far as is consistent with strength. The graduations are of the very greatest accuracy, and the levels of such sensitiveness as is proportional to the magnifying power of the telescope. The verniers are placed under the telescope and at an angle of 30° from it, thus allowing them to be read after sighting without changing position. By placing one plate level inside the compass box the overshadowing of one of the verniers is avoided.

Variable Power Eyepiece

The inverting telescope without doubt possesses advantages over the erecting or terrestrial telescope, inasmuch as an increase of power, field, and light is obtained with the same length. Morever, it is very easy to remove the astronomical eyepiece and substitute another of different power; but since most engineers prefer the terrestrial telescope, which shows objects in their true relation, and right side up, we have of late introduced the variable power terrestrial eyepiece which we are supplying on all of our engineering instruments except inverting telescopes. This eyepiece, patented September 1, 1903, and used by us for several years on gun sights, is now being applied for the first time to engineering instruments.

By means of this invention the power of the telescope can be changed to suit the varying conditions of the atmosphere, thus enabling the engineer to make use of a telescope of high magnification which gives good results in favorable weather only, and when the weather is unfavorable to convert this high power into a low one with a consequent increase in illumination and field.

The transit telescopes are so arranged that the power can be changed from 12 to 25 diameters by simply turning the milled head "A" at the eye end to the desired power, as indicated by the fiducial line on the tube, and then focusing on the cross hairs by means of the other milled head "B". The focusing on the object is done in the usual manner. The cut shows the eyepiece set to magnify 20 diameters.

The use of the variable eyepiece produces no change in collimation, for cross hairs and objective are not altered, the change in magnifying power being effected solely in the eyepiece.

The power of the level telescopes can be changed from 18 to 36 diameters in precisely the same manner.

Our transits are further improved by the addition of a

NEW COMPASS NEEDLE

A compass needle is more effective the more magnetism it has and the less the moment of inertia possessed by the piece of steel composing it. Now it is a well-known fact that the magnetism imparted to magnets is confined chiefly to the outer layers of steel; therefore the central portion, or core of the bar forming a magnet, can be removed without any appreciable loss of magnetism but with a decided decrease in the moment of inertia, for as well known, a hollow cylinder possesses less moment of inertia than does a solid one of the same size.

We have therefore constructed our compass needles out of hollow steel tubes drawn for that purpose, from steel best adapted to take and retain magnetism. This hollow steel tubular compass needle was patented January 30, 1906 and is now supplied on all our instruments.

CONTINUOUS VARIATION PLATES

Our transits are also furnished with variation plates which are continuous. This is effected by screw holes arranged at regular intervals around the compass rim, which can then be moved in the desired direction by means of the screw between the standards, and when the range in the slot is not sufficient the screw is simply removed and inserted in one of the other screw holes. The advantage of this unlimited range will be appreciated.

NEW COAST AND GEODETIC SURVEY INSTRUMENTS

The United States Coast and Geodetic Survey has an unrivalled reputation for the highest possible degree of accuracy in its work. To attain this end its officers have spared neither effort nor expense, especially as concerns

instruments of precision, the result being that there have been designed various types of greatly improved instruments, among which may be mentioned the Pendulum Apparatus, the Iced Bar Base Apparatus, the Level of Precision, the new Tide Gauge, and others. Most of these instruments are illustrated herein.

The use of Invar steel which is composed of 34% nickel and 66% iron forms a material which has a very small coefficient of expansion and is therefore particularly well adapted for instruments of precision. The above-mentioned Level of Precision, which has done such excellent work in the Survey and is much more rapid than the ordinary levels doing inferior work, is made almost entirely of this compound.

We have devised special apparatus in order to manufacture these instruments with the highest degree of accuracy and have supplied these instruments to various countries abroad.

GRADUATIONS

The illustrations on pages 4 and 5 represent some of our large dividing engines which are of the best possible construction. While we do not claim for them perfection for the simple reason that we do not believe a really perfect circle has ever been made, we do believe we have reached the limit of attainment possible when we make an automatic graduation correct to within 2 or 3 seconds of arc.

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

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

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

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

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

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

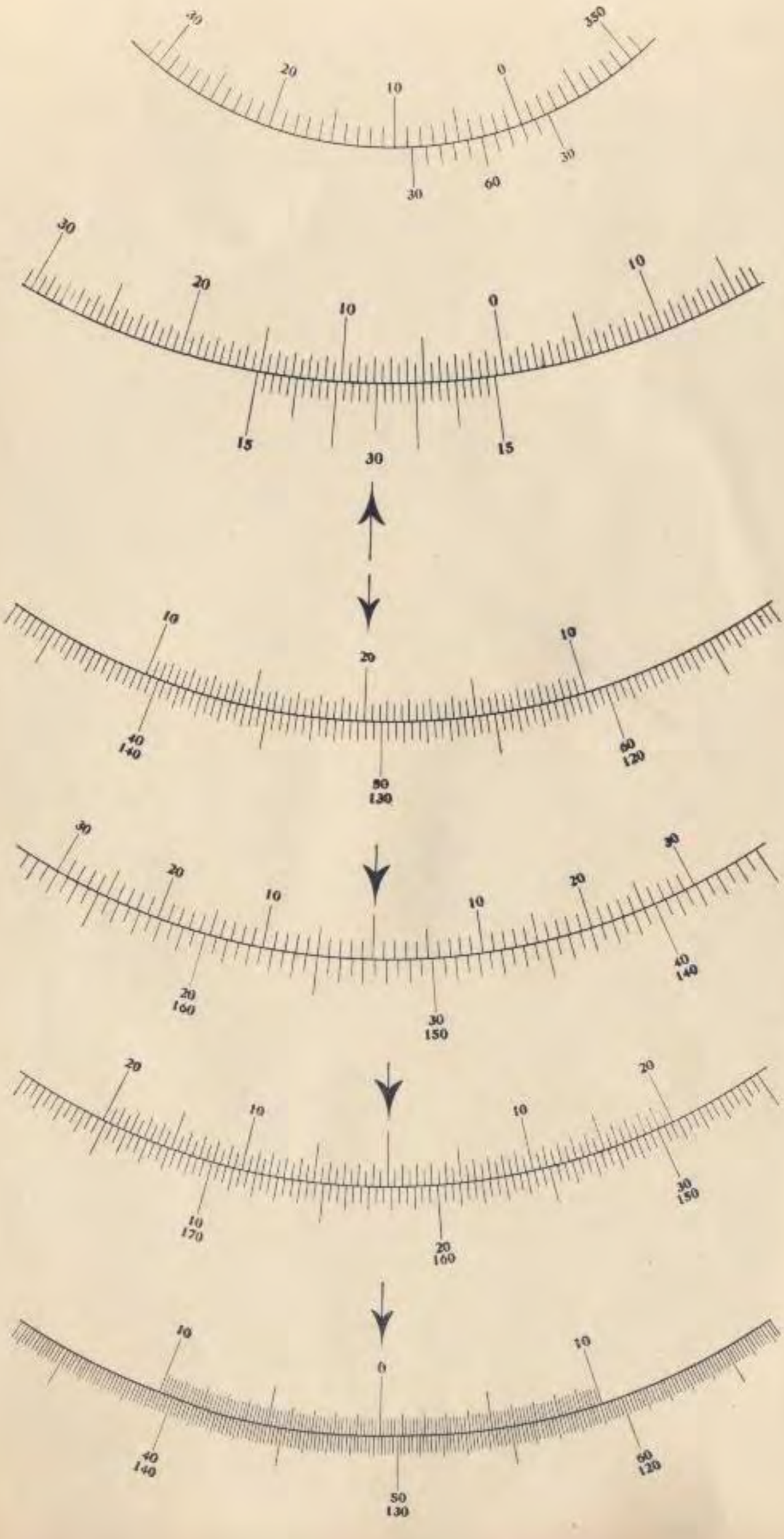
Our engineers' transits are graduated either into ½ degrees, reading to single minutes by the vernier having 29 circle parts divided into 30; or the circle is graduated into ⅓ degree spaces, reading to half minutes by the vernier having 39 circle parts divided into 40; or the circle is graduated into 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 anyone likely to read this catalog 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, the mean of both readings will then be correct.

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.

We present herewith various modes of figuring number circles and the verniers most generally used: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THE MICROMETER-MICROSCOPE

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

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

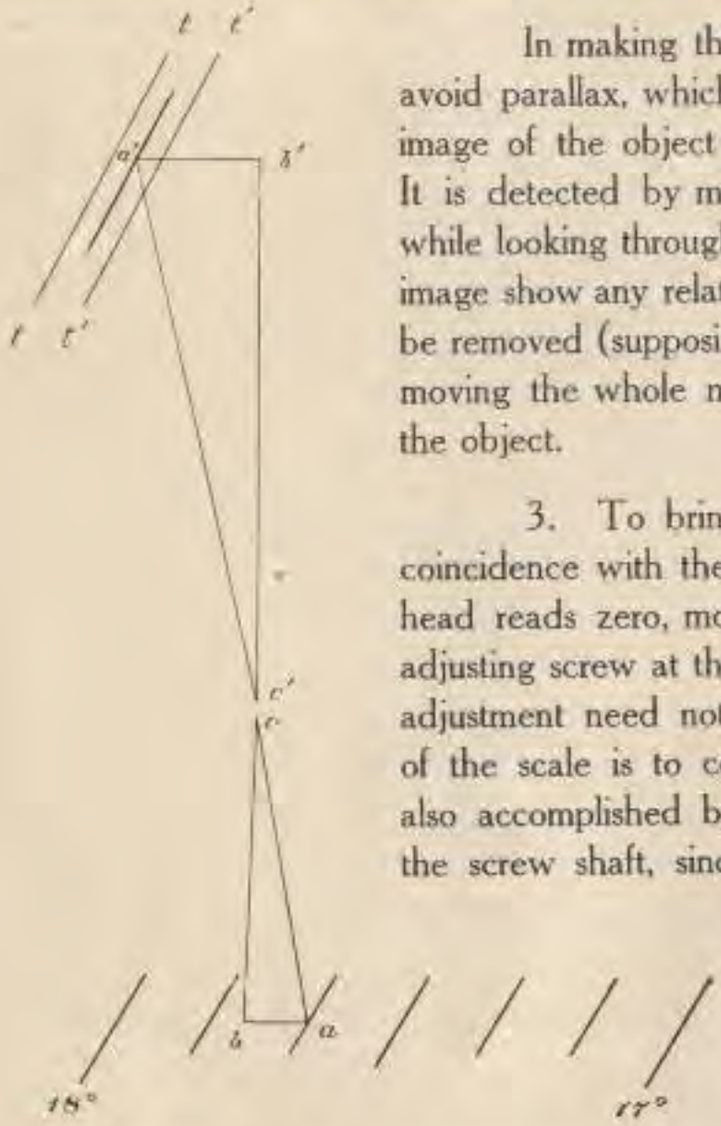
Where the micrometer-microscope is used to read circles it is convenient to have the pitch of the screw and the focal distances of the objective so related that an even number of turns of the screw will correspond to the smallest space on the circle. Thus, if the circle is divided into 10′ spaces it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

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

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

2. To make an even number of turns of the screw equivalent to a given space, measure the image of the space with the screw. If the image is too small the objective must be brought nearer to the object and the cross-threads moved

further from the objective; and opposite motions of the parts must be made if the image is too large. The tubes carrying the objective and micrometer box permit such motions. A few trials will make this adjustment sufficiently close.



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

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

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

Method of reading Micrometer-Microscopes.—This may be best understood by considering a special case. Thus, suppose it is required to read the two opposite micrometer-microscopes of a theodolite whose circle is divided into 10′ spaces. Let five revolutions of the screw be equivalent to one of these spaces. Then one revolution is equivalent to 2′, and the micrometer heads will be assumed to be divided into sixty equal parts and numbered from 0 to 30 twice. The relations to be considered are illustrated in the diagram above, which shows a degree of the circle, the positions of the principal points of the microscope objective, the position of the micrometer threads, *t*, *t*, etc. In this diagram the line *b c*, *b′ c′* is the line defined by the micrometer threads (or the point midway between them)

when the micrometer reads zero revolutions and zero divisions. This line falls between the 40' and 50' lines of the circle, and the reading of the circle is 17° 40' *plus* the distance *a b* expressed in angular measure. But the image and equivalent of *a b* is *a' b'*, and this is measured by moving the micrometer threads until the space between them is bisected by the image of the 40' line *a*, or by *a'*. Suppose the distance *a' b'* is three revolutions (counted by three notches of the comb scale) and 8.3 divisions of the head. Then the complete reading is 17° 46' 16".6.

If the opposite micrometer reads 197° 46' 11".9 divisions, the mean reading of the circle is (using the degrees from the first microscope) 17° 46' 20".2 since ½ (8.3 + 11.9) 2" = 20".2.

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

TELESCOPES

It is unnecessary to give the theory of the Telescope, which may be found in every book on optics. We add, however, a few remarks concerning objectives and different kinds of eyepieces.

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 dispersive powers, it is possible to correct the chromatic and spherical aberrations.

In using ordinary flint and crown glass it is not possible in a two-lens objective to perfectly correct the chromatic aberration, for only two colors can be united and brought to the same focal point. The remaining colors are each refracted differently and produce what is known as the secondary spectrum. Of course if three lenses are used three colors can be united and only a tertiary spectrum remains. By means, however, of the new glass now made, and known as Jena glass, it is possible by correct selection of the glasses to make a two-lens objective in which three colors are united.

In engineering instruments where the magnification is many times smaller than that employed in astronomical instruments much less is demanded of the objective and one composed of two lenses usually fulfills all requirements; for astronomical purposes, however, an objective consisting of three lenses is generally used since the additional lens allows a better correction to be obtained.

Objectives having a large ratio of aperture to focal length are not only more difficult to compute, but are also much more difficult to make than those having a small ratio. The smallest deviation in one of the surfaces would in the former have

a very appreciable effect upon its performance while in the latter it would probably be unnoticed. The advantage of an objective having a large ratio is, however, very great; suppose for example that we have two objectives one having a ratio of aperture to focal length of 1/5 while the other has a ratio of 1/10; if now they both have the same focal length the diameter of the first would be twice that of the second, and since the amount of light collected by an objective depends upon its area and since this varies with the square of the diameter, the one would collect just four times the amount that the other does and consequently the image formed by it would be four times brighter.

Small scratches and bubbles in the objective have no seriously 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 eyepiece. If the glass is evenly illuminated it shows that there are no such veins and that it is homogeneous.

EYEPIECES

The performance of a good telescope depends much more upon the eyepiece than is commonly supposed. Since 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 eyepiece will be most suitable, we give a simple description of the different kinds of eyepieces most in use, and the method of determining the power required.

And here we wish to remark that for most engineering instruments, where only a moderate size field is required, the Ramsden and Huyghens eyepieces are perfectly satisfactory and have the advantage of less cost.

It frequently occurs that eyepieces 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 eyepieces, simply means a comparison of the magnifying power of the compound eyepiece with that of a single lens of a certain focus; thus, a compound eyepiece 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 eyepiece, it follows that, in order to find the "equivalent" of the eyepiece 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 eyepiece. Accordingly, if a power of 60 is required with an objective of 30 inches focus, an eyepiece of ½-inch focus has to be used, since $\frac{30}{60} = \frac{1}{2}$.

Fig. 1

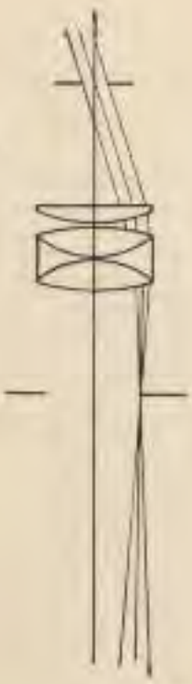


Fig. 2

Fig. 3

Eyepieces are of two types, positive and negative. In a positive eyepiece the focus of the combined lenses falls outside of the combination, while in a negative eyepiece the focus falls between the lenses. For this reason it should be kept in mind that for micrometer or cross-hair observations only positive eyepieces can be used.

The eyepieces illustrated have each an equivalent focal length of one inch and are drawn to half scale. Their relative positions are such that the focal plane of the objective falls on the same horizontal line, thus giving at a glance an idea of their position with regard to the objective.

The eye, in order to utilize the full field of the eyepiece must be placed at what is known as the eye point. This point is easily found by moving the eye back and forth along the optical axis. In all well-constructed instruments the eye cap should be about $\frac{3}{8}$ inch nearer the eyepiece than the eye point so as to allow room for the eye lashes.

The "Ramsden" eyepiece (Fig. 1).—This is a positive eyepiece and consists of two plano-convex lenses of equal focal length placed with the convex faces toward each other and at a distance apart equal to $\frac{2}{3}$ of the focal length of either. Its equivalent focal length is equal to $\frac{3}{4}$ that of either lens.

The "Kellner."—This eyepiece is an improvement on the Ramsden. It has an achromatic doublet for the eye lens.

The "Steinheil."—This is another positive eyepiece and consists of two achromatic doublets. It gives a field of moderate size, but of great flatness.

The "Orthoscopic" (Fig. 2) is also a positive eyepiece. It consists of a cemented triplet and a plano-convex eye lens. This is the best form of eyepiece where a very large and perfectly flat field is required; it has the additional advantage of having a very large eye distance. This last is an important feature in eyepieces of very short focal length ($\frac{1}{2}$ inch and under), for in most forms the eye point then lies so close to the lens that it is very inconvenient if not impossible to use them.

The "Huyghens" eyepiece (Fig. 3).—This is a negative eyepiece and consists of two plano-convex lenses with the plane faces next the eye. The ratio of the focal length of the field lens to that of the eye lens is as 3 to 1 and the

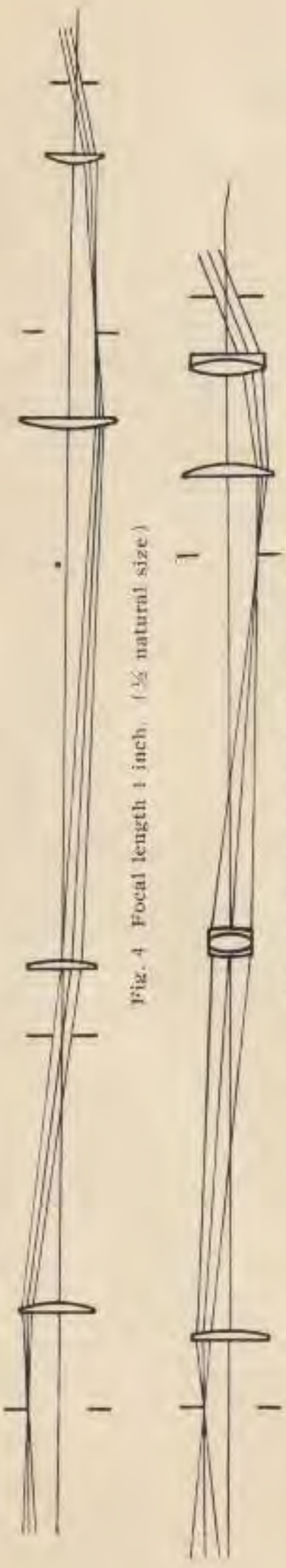


Fig. 4 Focal length 1 inch. (½ natural size)

Fig. 5 Focal length 1 inch. (½ natural size)

distance between the lenses is equal to twice the focal length of the eye lens. Its equivalent focal length is equal to ½ that of the field lens. This eyepiece is achromatic and gives a large but somewhat curved field.

The "Airy."—This is an improvement on the Huyghens in that the plano-convex field lens of the latter is replaced by a meniscus. It gives a flatter field than the Huyghens.

All the eyepieces above mentioned show the objects inverted. As this seems to be troublesome to the engineer, "erecting" or "terrestrial" eyepieces are mostly used on engineering instruments.

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

Of these terrestrial eyepieces we show two forms, the "Fraunhofer" and one with an achromatic reversing lens.

The Fraunhofer eyepiece (Fig. 4) consists of four plano-convex lenses arranged as shown in the figure. For objectives where the ratio of aperture to focal length is 1 to 10 or less this eyepiece is entirely satisfactory, but where this ratio is greater the marginal rays of the objective strike the eyepiece under such high angles that they cause both chromatic and spherical aberration. Its great length is another disadvantage.

Eyepiece with achromatic reversing lens. (Fig. 5). The construction of this eyepiece is fully shown by the figure. It is not only shorter than the Fraunhofer but has the advantage that it can be used with objectives where the ratio of aperture to focal length is as high as 1 to 5.

The terrestrial eyepiece is often made with a total reflecting prism between the anterior and posterior combinations. It is then called a "diagonal" or "elbow" eyepiece, and is very convenient when observing near the zenith.

Here we wish to draw attention to the fact that many makers, either intentionally or through ignorance, use an objective and eyepiece together which are entirely unsuited for one another, and by cutting off the marginal rays, by means of diaphragms, secure a good image producing at the same time an instrument which appears to have the advantage of a large objective. Fortunately the test of such a construction is most simple and is as follows: Focus the telescope upon any distant object; then withdraw the eye to a distance of 8 or 10 inches, or until the small disc of light which appears in the center of the eyepiece is distinctly seen. This disc is the image of the objective formed by the eyepiece, and any object resting anywhere upon the objective should therefore show in the corresponding part of the image. This object may be a small piece of paper about ⅛ of an inch square, moistened and placed upon the objective, or simpler still, the point of a pencil held against it. If now the objective be fully utilized the point of the pencil when held at the extreme margin of the objective should show itself as a dark spot or break in the edge of the image. If the image still remains an unbroken circular disc, it is evident that that part of the objective upon which the pencil rests is not utilized by the eyepiece. In order to find the part of the objective utilized move the pencil point gradually toward the center of the glass until it just shows itself in the image, then that part of the objective between the pencil point and the objective mounting is the part not used. Of course this part not used is the same all around the lens and to find the size of the part used we must subtract twice this amount from the diameter of the objective. This gives us the diameter of the part of the objective actually used.

As before stated, the magnifying power of a telescope is found by dividing the focal length of the objective by that of the eyepiece; but a more simple and practical method is to divide the diameter of the objective by the diameter of its image formed by the eyepiece. This is of course supposing that the objective is fully utilized; if such is not the case then we must find the diameter of the part used and divide this by the diameter of the image. In determining the part of the objective used care must be taken that the pencil does not slip after we once have it in position, and for this reason it is probably better to use the small piece of moistened paper and to move it into place by means of a pencil or the tip of the finger.

As an example of this method of determining the magnifying power of an instrument suppose the telescope to have a clear aperture of 2 inches, the diameter of the image being 1/16 of an inch, then the magnifying power of such a telescope would be 2 inches divided by 1/16=32 diam.

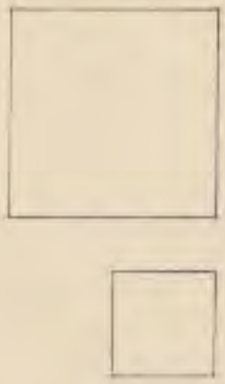
By means of a dynameter this image can be measured very accurately, but for all practical purposes it can be measured well enough by using a finely-divided scale.

Figures 6, 7 and 8 show in ¼ natural size three telescopes whose objectives have the same focal length (16 inches) and whose eyepieces, while of different form have each an equivalent focal length of 1 inch. Each telescope therefore has a magnification of 16 times and we can compare directly their advantages and disadvantages.

Fig. 6.

Fig. 7.

Fig. 9



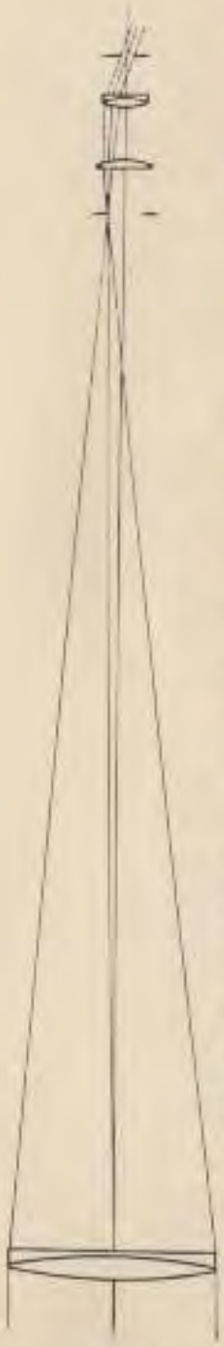


Fig. 8.

In the telescope shown in Fig. 6 a Fraunhofer eyepiece is used and an erect image is of course secured, but the main features which catch the eye are the small diameter of the objective and the large total length of the instrument. The small objective means that a relatively small amount of light is used in forming the image and a consequent lack of brightness. Enlarging the objective would not help any because the eyepiece would be incapable of using the added portion.

The telescope illustrated in Fig. 7 produces an erect image by means of an eyepiece with an achromatic reversing system. The advantage of this over the preceeding telescope is that an objective of double the diameter can be used, and also that the total length is less.

Fig. 8 represents a telescope with a simple astronomical eyepiece. This besides having an objective as large as that in Fig. 7 is much shorter. It gives however an inverted image and this is considered by many as a great disadvantage. Its advantages though so outweigh this one apparent disadvantage that we strongly

recommend its use. We admit that at first it is rather awkward to use an instrument such as this but after a few days one becomes accustomed to it and handles it as easily and as rapidly as one of the usual form.

Since the amount of light collected by an objective is proportional to the square of its diameter we can picture this amount by means of a square whose sides are equal in length to the diameter of the objective. This we have done in Fig. 9 for the three telescopes illustrated above; the small square represents the amount of light utilized by the telescope shown in Fig. 6; the large one the amount utilized by Figs. 7 and 8. It is to be remembered that other things being equal the more light utilized the brighter will be the image.

The power of a telescope can be increased by substituting an eyepiece 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 focal length 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 crosswires. It is therefore important that the magnifying power of a telescope and the sensitiveness of a level be proportionate to each other.

Take the case of a telescope for our accurate level, for instance; one division of the graduated level-bubble equals five 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 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 an old piece of linen which by repeated washing has become soft. If the glass is very dirty, use a little alcohol but be careful not to touch the mounting of the lens, as the alcohol dissolves the lacquer.

Dirt on the eyepiece, especially on the field-lens, is far more objectionable than on the objective; hence the former require more frequent cleaning.

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 radius of curvature or the flatter 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 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: $r = \frac{21600d}{6.2832}$

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

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

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

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

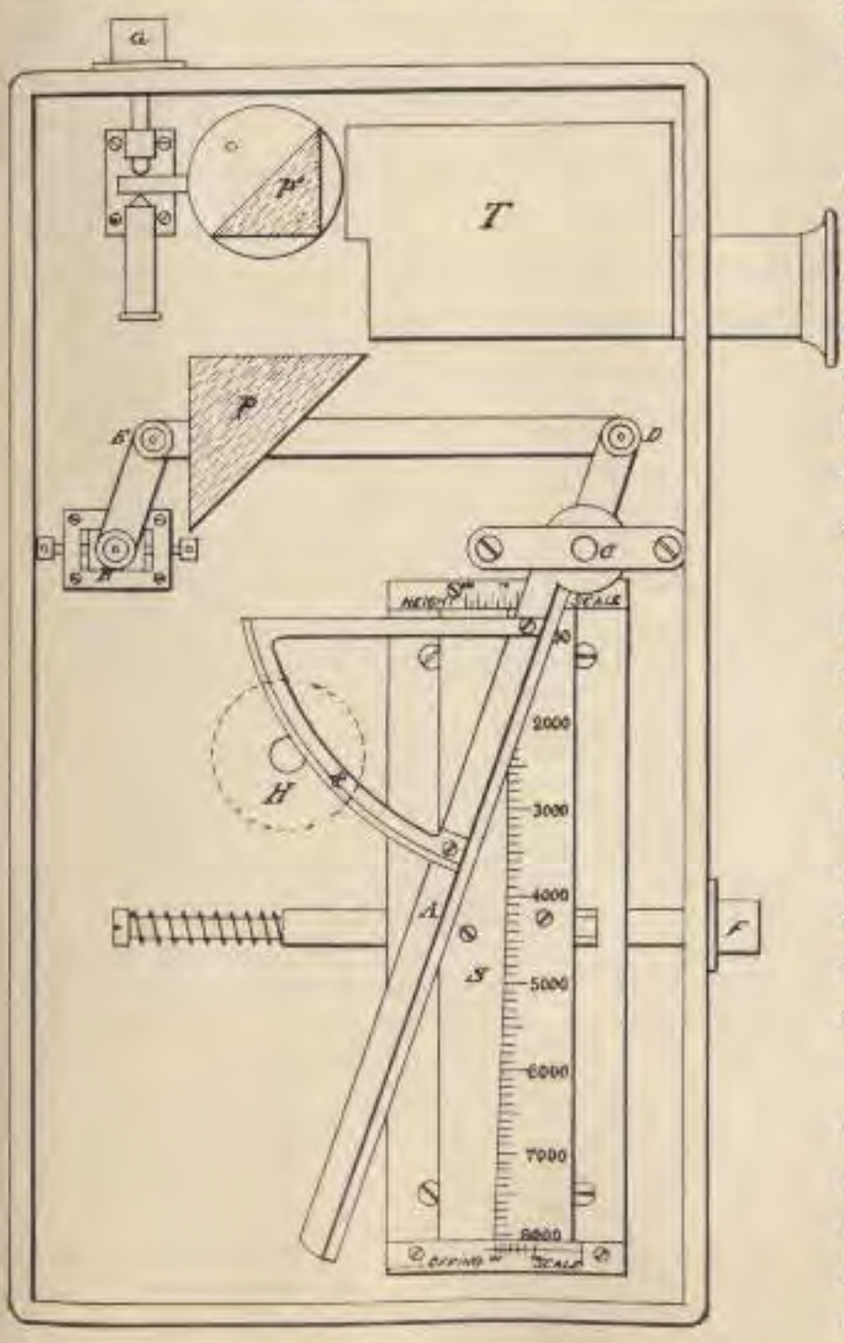
Our levels are ground by a machine which not only shapes them to a perfect curve of any desired radius, but at the same time grinds the entire interior surface, thus making them perfectly symmetrical and not liable to any of the above-mentioned defects.

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

inadmissable for any level of accuracy, as glass and brass will not expand or contract alike. We have lately improved the method of mounting fine levels by securing them in a Y placed in each end of the brass tube. By means of a spring just strong enough to insure a firm bearing the level-tube is retained in position without undue strain. All our sensitive levels are provided with chambers for altering the length of the bubble; they are also covered with a glass tube, to guard against sudden changes of temperature.

THE S. S. NAUTICAL RANGE-FINDER

This range-finder is a mathematical and mechanical device for obtaining immediately and simply by inspection the result of what is known as Buckner's method, which consists in measuring the angle between the visible horizon, or offing, and the water line of the object, the range or distance of which is required. To have sufficient accuracy in this method, or to make it available for long distances, the observation or measure should be made from a considerable elevation, say forty feet or more; the more the better, of course.



The optical construction and method of observing in this range-finder are the same as in a sextant. Two images are formed — one directly by one part of the object glass of the telescope T, the other by the other part after reflection by two prisms, P and P^1. The first of the two prisms, P, is, however, mounted on one side, DE, of a quadrilateral, $BCDE$, the opposite side of which is fixed and very slightly different in length from the one carrying the prism, the two remaining sides being exactly equal to each other.

Theory will show that, as the free sides are moved from the position in which one of the equal sides is perpendicular to the fixed one, the slight change of

direction of the prism side will be very nearly proportional to the tangent of the angle through which the equal sides move if this angle is moderate, say less than 45°, and a slight displacement of the image formed by the prisms will result, also, of course, proportional to this tangent. This, as will be seen without much difficulty, enables us to make in the instrument a construction or representation of the real elevation of our point of sight above the surface of the earth and the real distance of the object on that surface in which all the vertical dimensions are exaggerated, say forty or fifty times, relatively to the horizontal ones.

It is carried out practically as follows: An arm, *A*, centering at the end, *C*, of the fixed side of the quadrilateral (moved by a rack, *R*, and pinion with head, *H*), and coinciding with one of the equal sides or its prolongation, will represent the line of sight; its center of motion, *C*, the end of the side just mentioned, representing the point of sight. A graduated scale, *S*, at the outset perpendicular to the fixed side of the quadrilateral, and curving so as to represent the surface of the earth, is provided, movable in the direction of the fixed side, or perpendicular to itself. The point where the line of sight, as represented in this construction (in which it will be remembered that all the vertical dimensions, including the drop in the curve of the earth, are exaggerated), intersects the scale, will correspond to the distance of the object (being, in our illustration, about 2,550 yards) if some preliminary adjustments, which can be made in about a minute, on deck or below, at leisure, are first attended to. These adjustments are explained in the pamphlet accompanying each instrument. One of these adjustments is, of course, the setting of the scale at the distance from the center of motion corresponding to the actual elevation above the water. This adjustment is made by a fine screw actuated by the sunken head, *F*; others by the head, *G*, and the offing scale. In the construction, ordinary or normal refraction is allowed for.

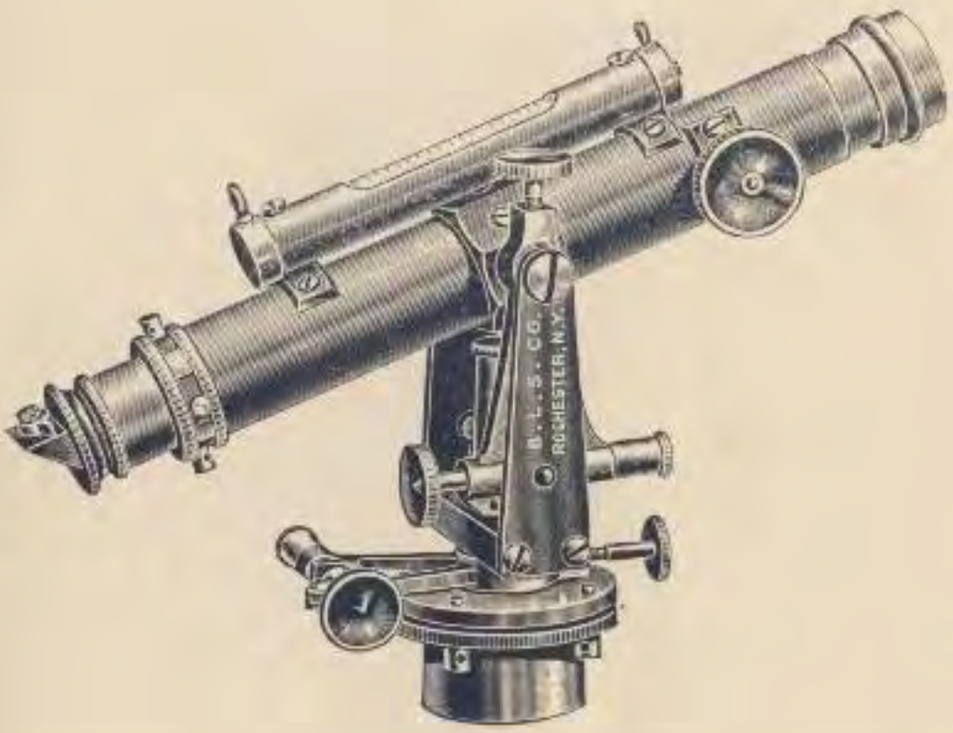
The observation, as has been said, is the same as with a sextant; the water line of the object in one image is brought into coincidence by moving the arm with the offing in the other image. The distance is then instantly read on the graduated scale.

OBSERVATIONS WITH HORIZON IN THE REAR

In order to be able to make observations toward shore, a double reflecting mirror is attached in front of the instrument and the rear horizon is projected on the image of the object whose distance is to be measured. The observation is then made in the same manner as when looking toward the horizon.

Experience with the instrument in actual use on board ship has yielded excellent results.

The instrument is box shaped measuring about 3 x 6 x 8 inches and weighs about 4 lbs. It is light, is held like a sextant, and is completely boxed in and protected from smoke and dirt, the rays entering through a glass window, and the scale being read through another. These windows can be readily cleaned when necessary. For a detailed description send for pamphlet.



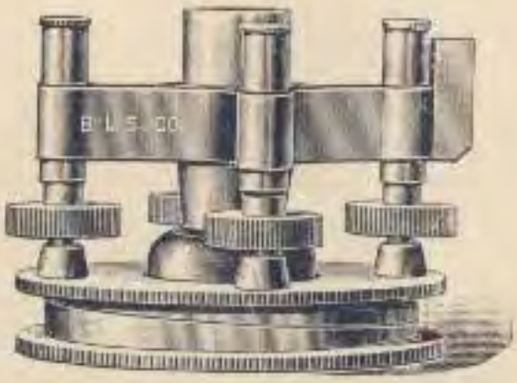
THE SAEGMULLER PATENT SOLAR ATTACHMENT

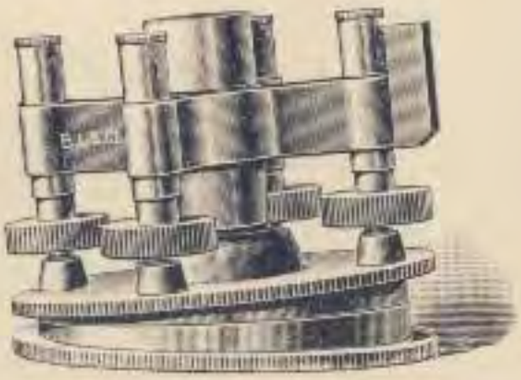
Since its introduction this attachment has been greatly improved, and as now made is well nigh perfect.

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

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

*A booklet of directions for using the Solar Attachment and containing Refraction Correction Tables and the Solar Ephemeris for the year will be sent free on request.





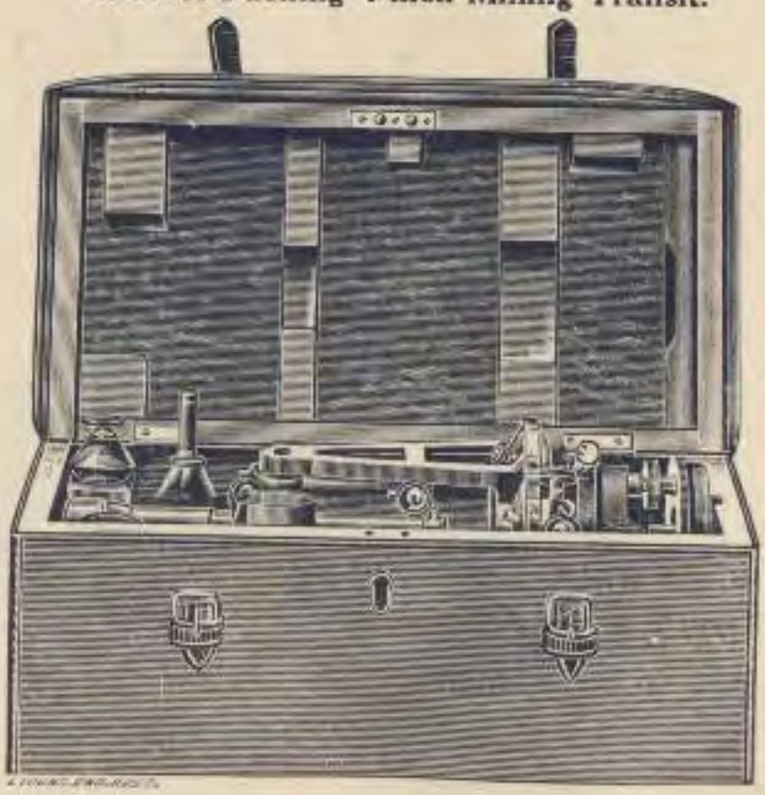
NEW QUICK-LEVELING TRIPOD HEAD

With shifting-plate

This form of quick-leveling tripod is the simplest and most convenient yet devised. It consists of two circular discs thicker on one side than the other. They are interposed between the leveling screws and tripod head proper. By turning one or the other of them around their common center the instrument can gradually be brought to a vertical position. The final leveling touches are given by means of the usual leveling screws, which at the same time clamp the instrument firmly.

The great advantage of this quick-leveling tripod over other forms is that the instrument will not fall over even if it is not clamped, and no accident can occur from this cause.

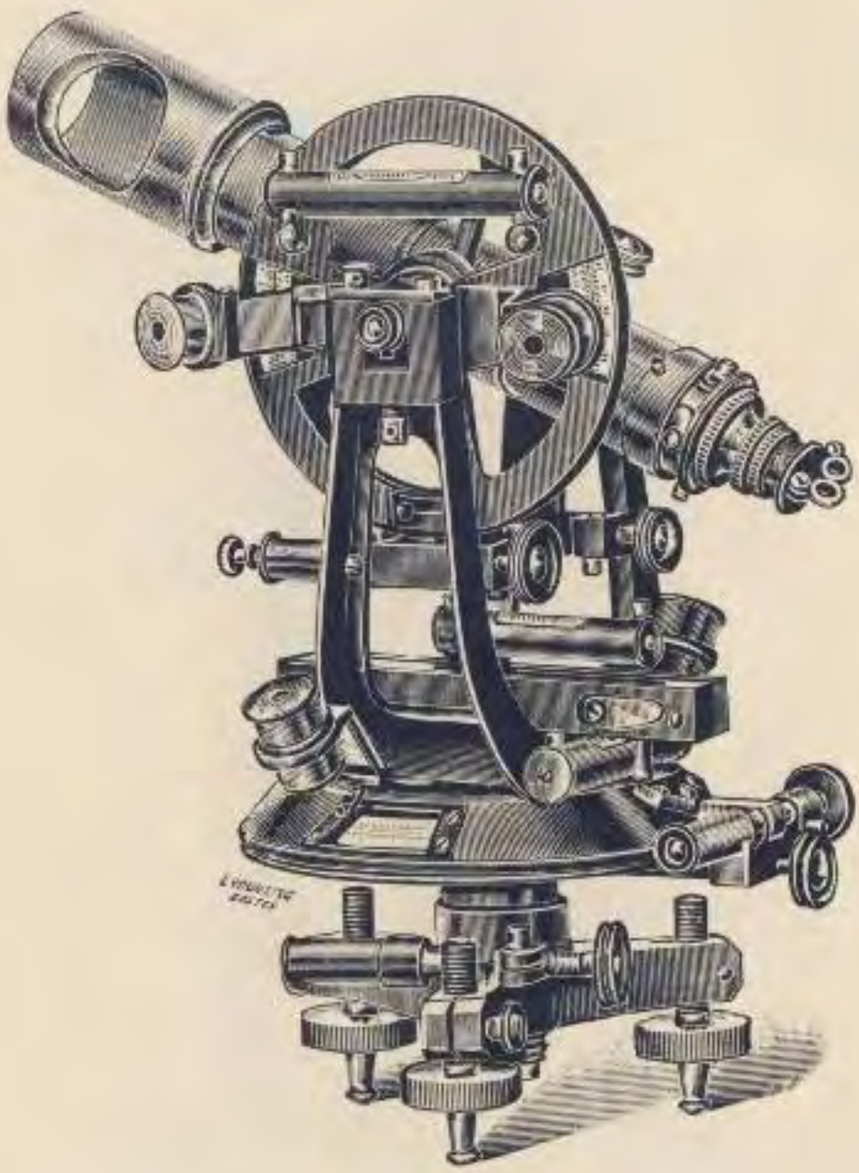
Mode of Packing 4-inch Mining Transit.



4-INCH MINING TRANSIT, NO. 0

This transit being designed for use in rough country and mine work, is made lighter and smaller than our regular transits. It will do the most accurate work. In order not to sacrifice the optical power we make the telescope of the inverting kind. It is 7½ inches long and magnifies about 16 diameters. It has a sensitive level and there is a dust guard to the object slide. The axis of the long telescope is so arranged that the Saegmuller Solar can be attached to it at any time. The circles are 4 inches in diameter, graduated on solid silver and read to minutes. The instrument weighs about 10 pounds.

Price of above instrument without full vertical circle but with large arc reading to minutes, without striding level and without attached reading glasses, $225.00
Price, as shown in cut, - - - - - $275.00
Extension tripod weighing about 10 lbs., extra - - 10.00



4-INCH STANDARD THEODOLITE, NO. 1

As furnished to the U. S. Government Surveys and also used for the Magnetic Survey as instituted by the Department of Terrestrial Magnetism of Carnegie Institute.

The horizontal circle of this theodolite has beveled edge and opposite verniers and reads to 30 seconds by means of attached reading glasses. The vertical circle also reads to 30 seconds by means of opposite verniers and is provided with a cover for protection. The long compass box is not furnished with this instrument unless specially ordered. This instrument is made with three leveling screws only.

Packed complete, with tripod - - - - -	$300.00
Long compass box, - - - - - -	15.00

5-INCH AND 6-INCH MINING TRANSITS, NOS. 2 AND 3

With vertical arc, level, clamp and tangent to telescope

5-inch Mining Transit, No. 2

With vertical arc, level, clamp, and tangent to telescope

The circle on this transit is 5¼ inches in diameter with graduation on silver into ½°. It reads to single minutes by double opposite verniers. The 5-inch vertical arc is also divided on silver and reads to minutes. The plate level is protected by being inside the compass box and the compass and vernier openings are watertight. The *hollow steel tubular compass needle* of our new type (see page 8) is 3⅛ inches long. The telescope is erecting, 10 inches long with 1 3/16 inches aperture, and is provided with a sensitive level, and with *variable power eyepiece* (see page 8). The axis carries on top a center mark which is exactly over the vertical axis, hence in the center of the instrument, when the instrument is level and the telescope horizontal. The instrument weighs about 13 lbs. and the tripod about 8 lbs.

Price, variation plates and vernier shades, included, - - $225.00
Above transit plain, without clamp and tangent, vertical arc and level, price 180.00

These transits are made with erecting or inverting telescope at same price.
Variable power eyepiece (see page 8) is $5.00 additional.
Instrument complete packed for shipment weighs about 36 lbs.
Tripod " " " " " " 20 lbs.

6-inch Mining Transit, No. 3

With vertical arc, level, clamp, and tangent to telescope

This instrument is much like the preceding differing from it chiefly in size. It is intended for the most accurate work where a few pounds added weight is of no consequence. It is particularly adapted for city surveys requiring very accurate graduations and great telescopic power to enable the observer to use the instrument late in the day or in cloudy weather. *For this reason the telescope is provided with an objective of the highest excellence* possessing a clear diameter of 1¾ inches (giving an effective aperture of 1⅝ inches) and also provided with a *variable power eyepiece* giving the observer the possibility of adjusting the magnifying power to suit the state of the atmosphere. This telescope is also made with inverting eyepiece if so desired. The circle is 6½ inches in diameter; the needle 4½ inches long; weight of instrument about 16 lbs., the tripod weighing about 9 lbs.

Price - - - - - - - $235.00
Above transit plain, without clamp and tangent, vertical arc and level, price 195.00
Instrument complete packed ready for shipment weighs about 40 lbs.
Tripod " " " " " " " 22 lbs.

EXTRAS

If it be desired to have graduation to read to 30 seconds, limb being graduated into ½°, the cost on above instrument will be $10.00 extra.

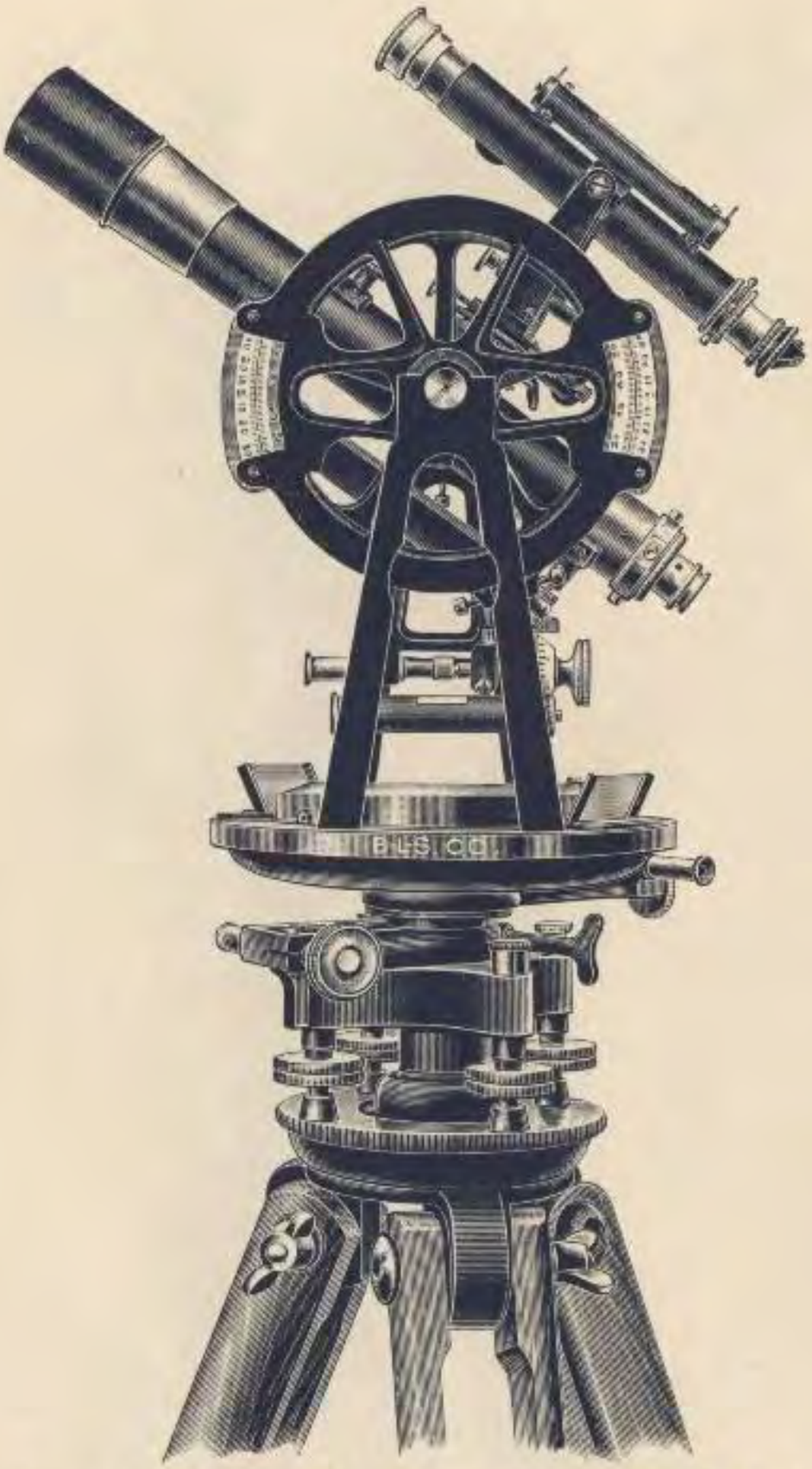
Gradientor - - - - -	5.00	Extension tripod (in place of ordinary)	10.00
Fixed stadias - - - - -	3.00	Saegmuller Solar Attachment - -	50.00
Adjustable stadias - - - -	10.00	Eyepiece prism and sunglass - -	6.50
Saegmuller's Quick Levelling Head -	10.00	Illumination for crosswires - -	4.00

5-INCH AND 6-INCH MINING TRANSITS, NOS. 4 AND 5

Like the preceeding, but having vernier to vertical arc adjustable by means of tangent screw. The position of the vernier is controlled by sensitive level attached to the arm carrying the vernier.

Price of 5-inch transit, - $245.00 6-inch transit, - $255.00

For extras see page 30

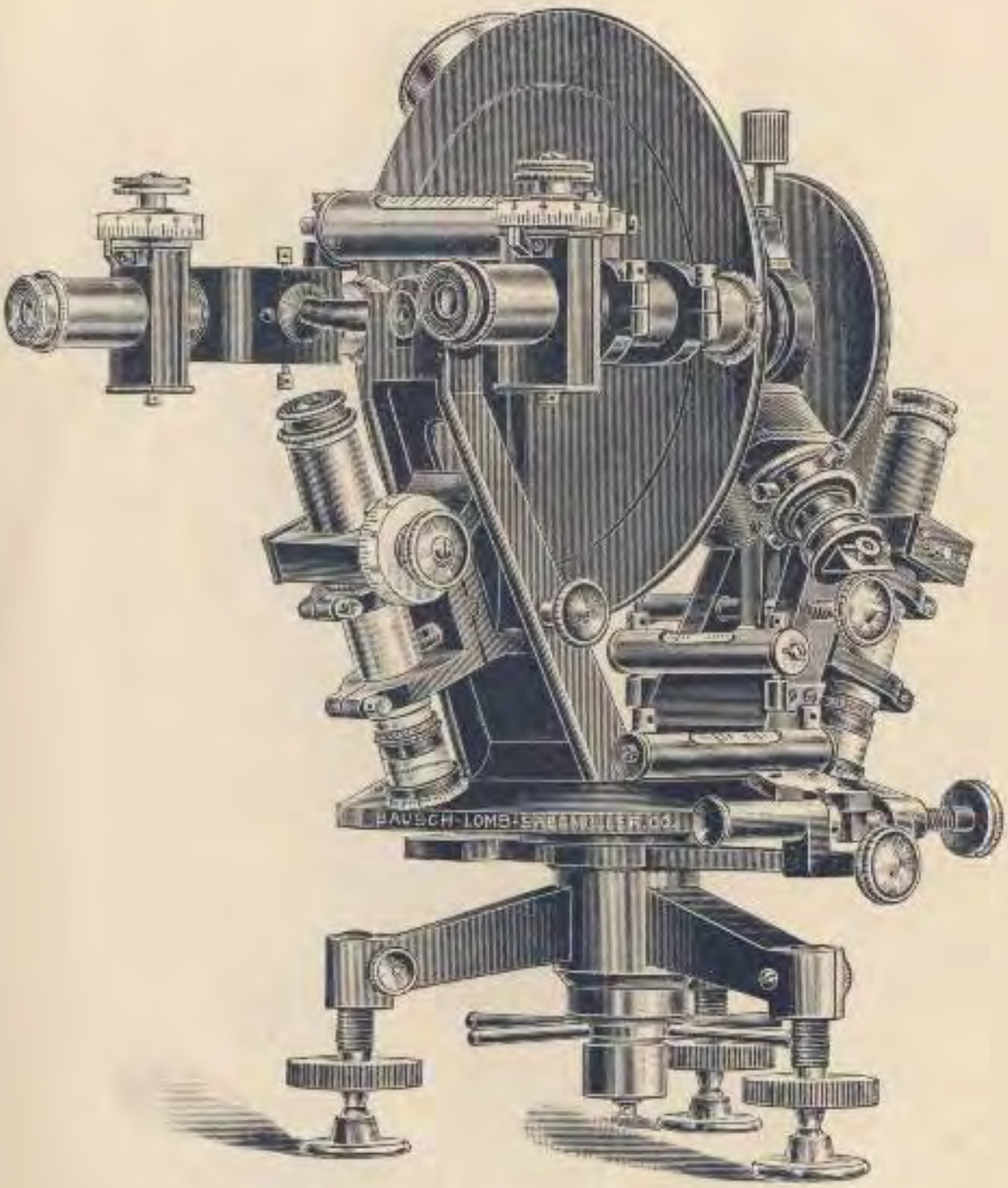


5 INCH AND 6 INCH MINING TRANSITS NOS. 6 AND 7

These instruments are in most respects similar to Nos. 2 and 3 but differ in having vertical circle with two opposite verniers attached to the cover guard and are provided with Saegmuller Solar Attachment.

Price of 5 inch Transit with Solar attachment - -	$290.00
6 inch with Solar attachment - - - - -	305.00

For price without Solar attachment, deduct $50.00



EXPEDITION THEODOLITE NO. 8

This instrument is designed for expedition work and on this account is made very light and compact. It is arranged for astronomical and geodetic work and for this reason is provided with sensitive striding and latitude levels and cross wire illumination with electric lamps. The circles which are 5 inches diameter are read by means of opposite micrometer microscopes to 5 seconds; the telescope has an aperture of 1⅛ inches and magnifies 20 diameters. The value of 1 division of striding and latitude level (both are chambered) equals + or − 2 seconds of arc; in the plate level 20 seconds for each division. The entire instrument is designed with a view to obtaining great lightness and portability and weighs only about 8 lbs.; with tripod about 15 lbs.

Price - - - - - - - $650.00

7-inch Complete Transit-Theodolite, No. 9

This instrument is particularly adapted for time and latitude observations as well as triangulation and general survey work. We have supplied them to nearly all the leading colleges in the country.

The horizontal circle is 7 inches in diameter with beveled edge graduated on solid silver into ⅓° and reading by opposite verniers to 30 seconds. The 5-inch vertical circle is also graduated on silver and reads to 30 seconds by double opposite verniers. The circle and vernier are fully protected, being completely covered. The value of one division of telescope and striding level is 10 seconds.

The telescope is inverting and has the following dimensions: 1½ inch aperture, 11 inches focus, with two eyepieces magnifying 20 and 30 diameters. Three leveling screws are usually supplied with this instrument. Weight of instrument is about 14 lbs., tripod about 8 lbs.

Price, - - - - - - - $300.00

EXTRAS

Graduation to read to 10" - - - - -	$25.00
Attached reading glasses to both circles - - -	25.00
Sensitive striding level to telescope axis - - - -	25.00
Illumination through axis with lamp - - - -	15.00
Eyepiece prism and sunglass - - - - -	6.50
Saegmuller Solar Attachment - - - -	50.00
Electric lamp attached to instrument for illumination of cross hairs with dry batteries and switch, - - - - -	7.50
Electric hand lamp (without batteries) to read verniers and levels.	5.00

The instrument just as shown in cut with horizontal circle reading to 10 seconds, attached reading glasses to both circles, illumination for telescope, and eyepiece prism for same, - - - $390.00

7-INCH COMPLETE TRANSIT-THEODOLITE, NO. 9

8 INCH TRANSIT-THEODOLITE NO. 10

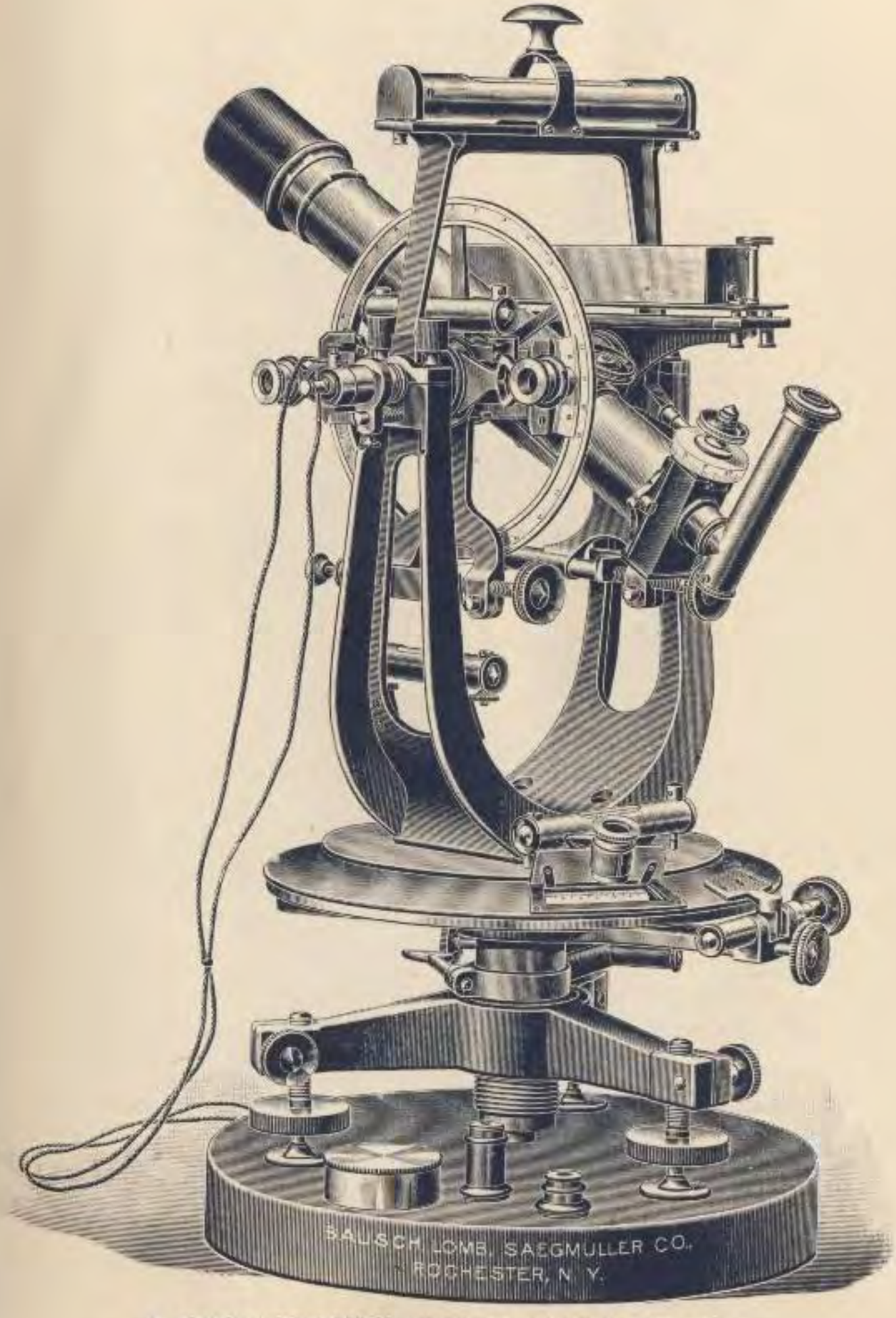
This instrument is particularly adapted for field astronomy and high grade triangulation work. It has a horizontal circle of 8 inches diameter, reading by opposite verniers to 10 seconds. The vertical circle is 6 inches in diameter, reading to 30 seconds.

Both circles are covered and are provided with attached reading glasses.

The telescope has an aperture of 1¾ inches and is provided with micrometer, direct and diagonal eyepieces magnifying 36 and 50 diameters, making it suitable for time and latitude observations. For this purpose the horizontal axis carries a latitude level, one division of which equals 2 seconds of arc.

Sensitive striding level, of which one division equals 2 seconds, over the telescope axis and means for illuminating the crosshairs through the axis are provided.

Price complete with tripod - - - - $550.00



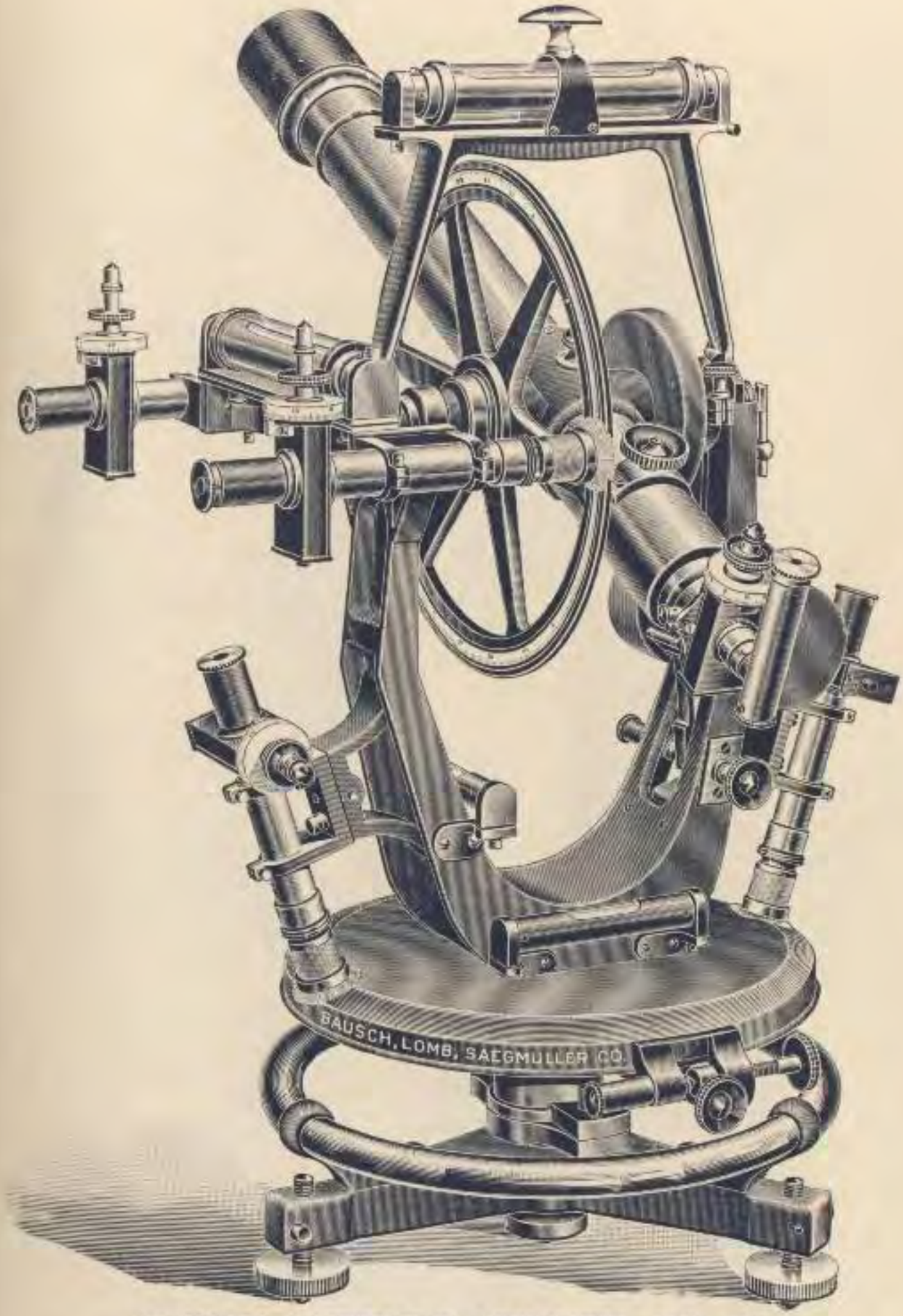
8 INCH TRANSIT-THEODOLITE NO. 10

8-INCH THEODOLITE, NO. 11

As used in U. S. Coast and Geological Survey for triangulation work.

Above cut represents an 8-inch theodolite which is a non-repeater, and is especially adapted for triangulation. This is the kind of instrument which is used in the triangulation work of the U. S. Geological Survey for which we have made a great many. It reads to seconds by opposite micrometer-microscopes, and every degree is numbered with minute numbers, nearly 1000 figures, visible only in the microscope, being engraved on the circle. Telescope 2 inches aperture, about 18 inches focus, with two eyepieces magnifying 20 and 36 diameters; improved clamp, sensitive striding level (value 5 seconds for one division) and field illumination. Price, with stand, - - - - $475.00

An exhaustive examination of the errors of graduation of ten theodolites of this kind furnished to the Geological Survey gave 1.2″ as the largest + and — errors in the division lines



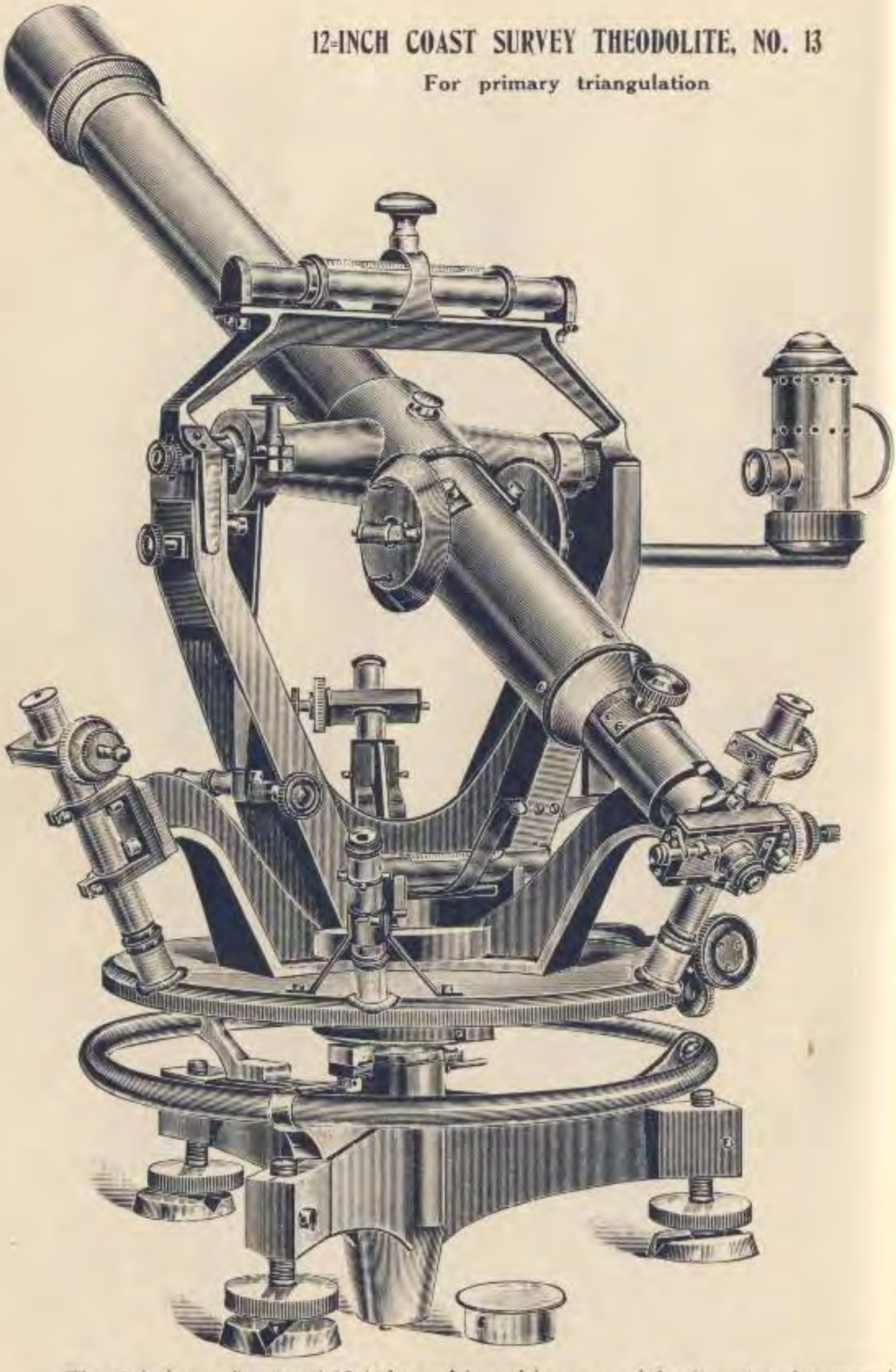
10-INCH ALTITUDE-AZIMUTH, NO. 12

This instrument has a horizontal circle of 10 inches diameter reading by opposite micrometer microscopes to single seconds, every degree figured and one being always visible in the field of the microscope. The vertical circle is of the same diameter and reads in the same manner. The zero is controlled by a sensitive chambered level having a value of 2 seconds for one division. The striding level is the same quality. The telescope has an aperture of 2 inches, is about 18 inches focus and is provided with eyepiece micrometer; it has direct and diagonal eyepieces magnifying 20 and 50 diameters respectively. Price - - - - $1,050.00

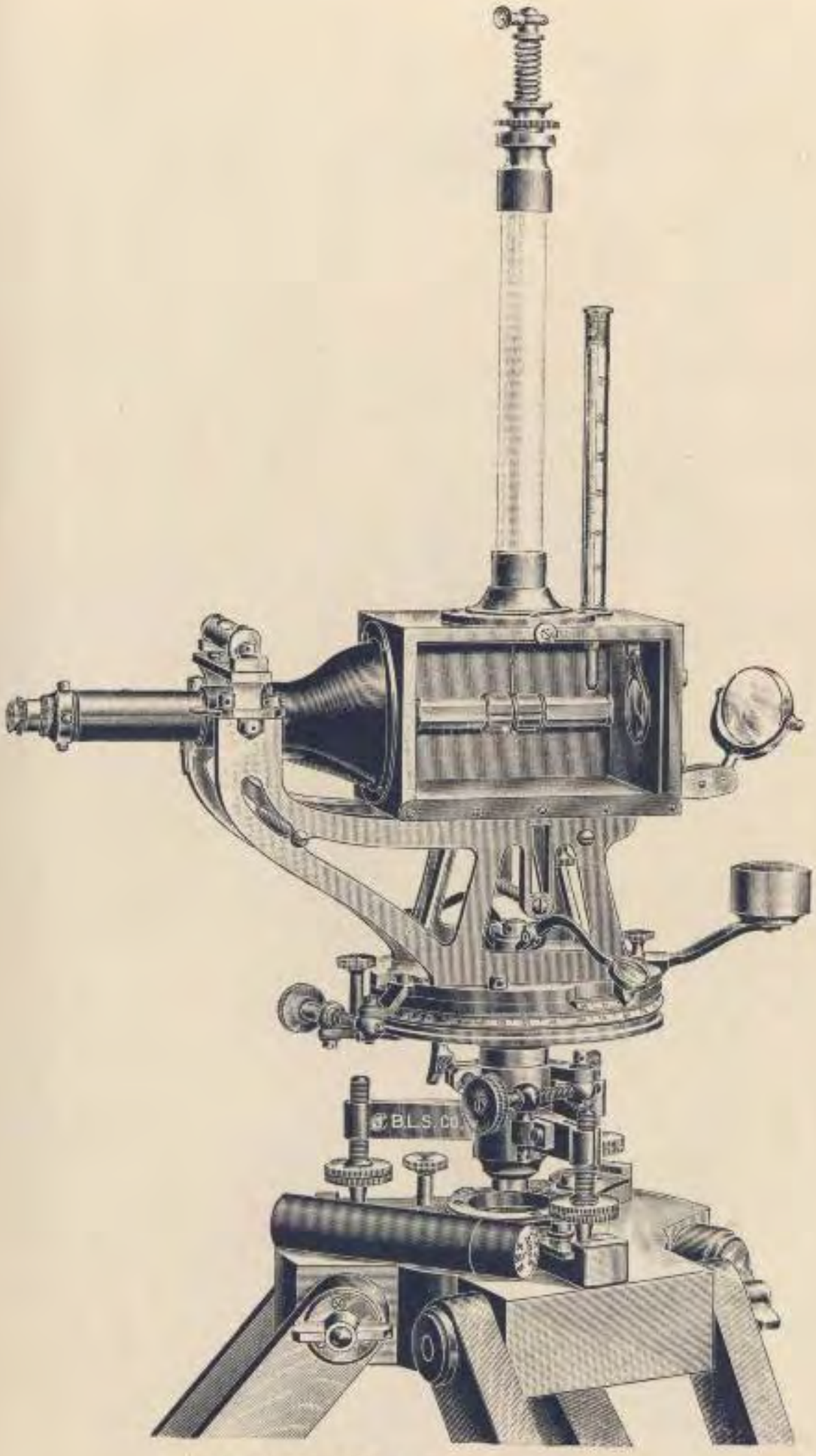
Same instrument with vertical circle 7 inches diameter reading by opposite verniers to 10 seconds, Price - - - - - $750.00

12-INCH COAST SURVEY THEODOLITE, NO. 13

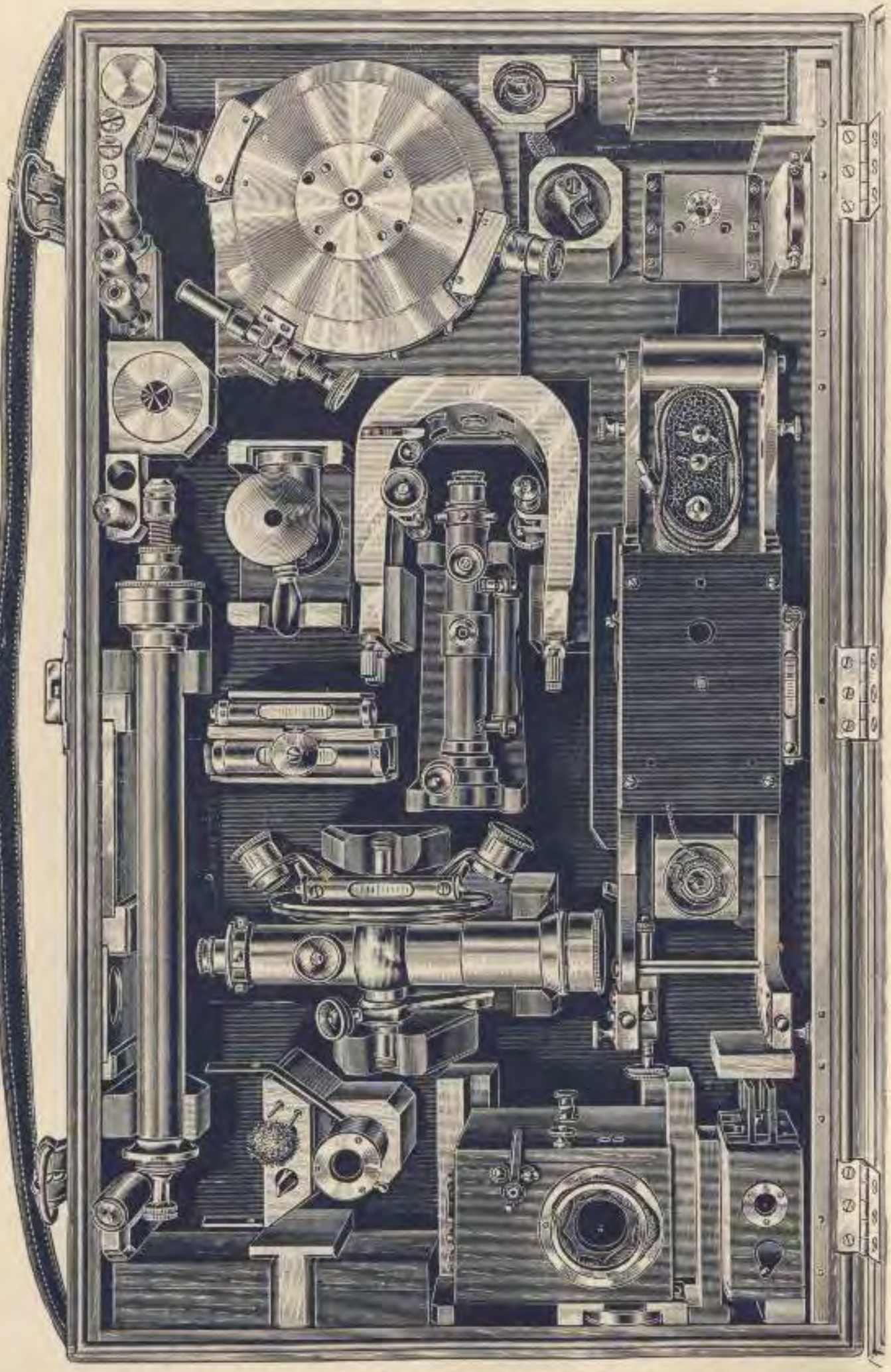
For primary triangulation



The circle has a diameter of 12 inches and is read by means of 3 micrometer-microscopes to single seconds. The telescope has an objective of 2½ diameters and is provided with micrometer; two eyepieces, magnifying 30 to 60 diameters; sensitive striding level over telescope axis, reading to seconds and chambered. No stand accompanies this instrument. Price - $1200.00



MAGNETOMETER, NO. 14



Magnetometer in case showing various accessories

MAGNETOMETER

The foregoing illustration represents a magnetometer which is built on the same lines as the kind so long used by the U. S. Coast Survey, but which has been very much improved and perfected by Dr. L. A. Bauer, Director of the Department of Terrestrial Magnetism, Carnegie Institution, for whom we have built a number of these instruments.

It is really a combination instrument, the lower part with circle and vernier plate being so arranged as to carry either the upper parts of a theodolite or the magnetometer proper. The illustration on page 41 shows it as a magnetometer; this part of the apparatus being taken off and the upper portion of a theodolite substituted, it becomes a complete theodolite as No. 1, shown on page 28. This is of sufficient size and power to obtain with sufficient accuracy for magnetic work time, azimuth and latitude. The horizontal circle is nearly 5 inches diameter and reads with opposite verniers to 20 seconds; the vertical circle of nearly 4 inches reads to 30 seconds and both circles are encased and protected and read by means of attached reading glasses. The telescope is provided with prism and sunshade. It has an objective of 1¼ inches aperture and 7 inches focus and magnifies 28 diameters.

The illustration shows the instrument as formerly made for the U. S. Coast Survey, but it has been very much changed and improved. The telescope is provided now with attached level, as well as a striding level over the axis; the suspension tube is made of brass and provided with graduation for azimuth and height. The magnets are round and encased in aluminum to prevent them from rusting. The deflection bar is of metal, one meter long. The magnets carry a collimating lens at one end, and a glass plate with cross lines on the other. The reading scale is placed in the observing telescope with the resulting advantage that, no matter how long or short the magnet, the scale value in arc is always the same. The greatest care has been exercised to obtain absolutely pure metal to ensure its being non-magnetic. No effort or expense has been spared to make the instrument as complete and perfect as possible. The various accessories and mode of packing are shown in the cut on page 42 The tripod and deflection bar are packed in canvas case.

Price of complete instrument, - - - - $700.00

Builders' Combination Transit & Level No. 15

We claim that this instrument is the very best on the market for the work for which it is intended. It is, in fact, almost good enough for any kind of work. It differs from our standard transits only in that it does not transit through because of the greater length of the telescope, which is very powerful to make it available for leveling. This, however, makes absolutely no difference for the use intended and we have no hesitation in recommending it for any sort of building operation.

The transit has a circle of 5 inches diameter, graduated on solid silver reading to single minutes, and the quality of graduation is precisely the same as on our other transits since all are graduated on the same dividing engines.

It has the compound centers and by repeating angles the accuracy with which an angle can be measured is, of course, far below single minutes and depends on the number of repetitions.

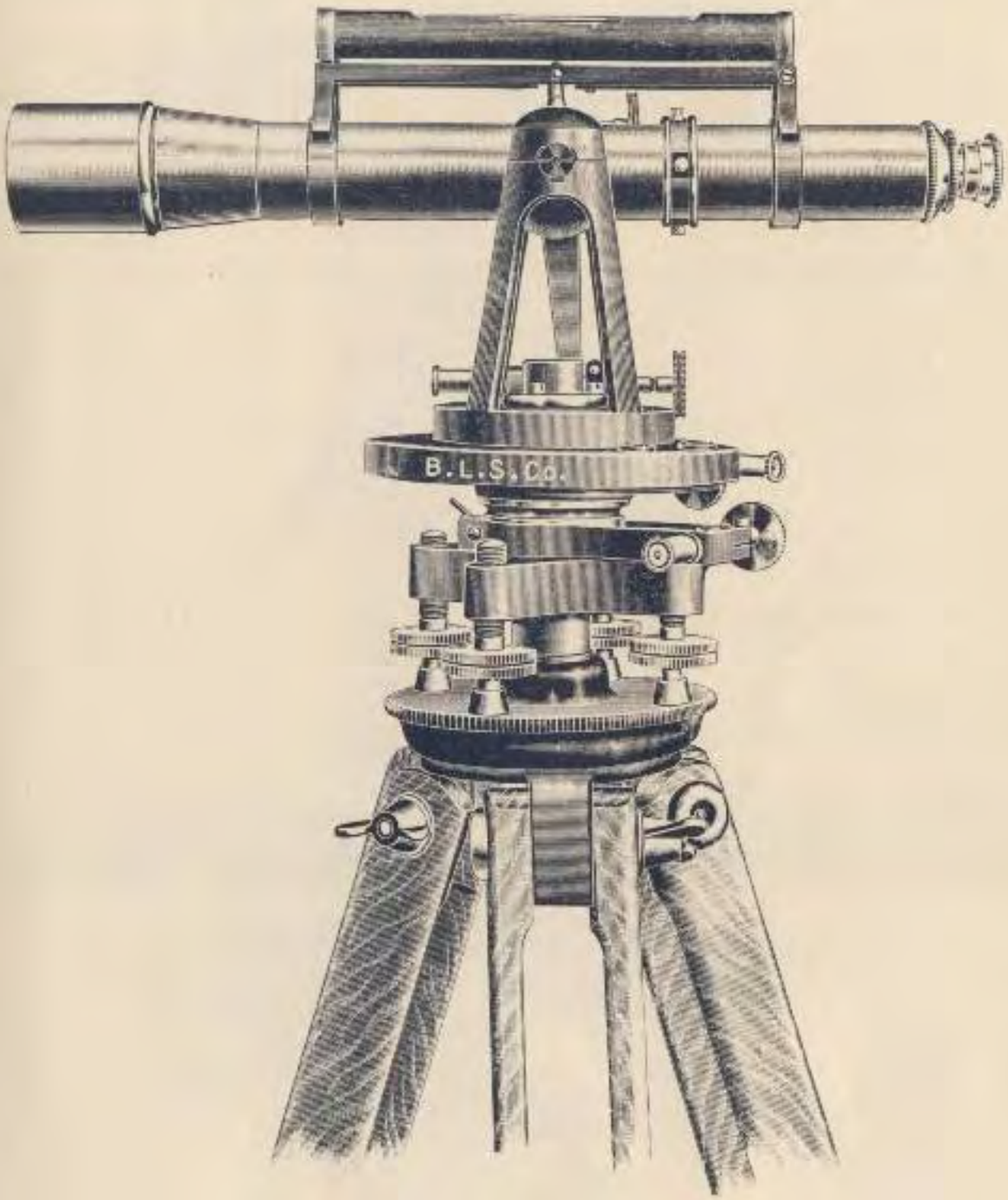
The telescope is of the erecting type and has a clear aperture of 1⅜ inches and is 12½ inches long. It magnifies 20 diameters and is really an inverting Wye level since a sensitive striding level is placed on top of the telescope where it rests on two accurately turned hard metal rings which are of exactly the same diameter. Since the level, which has a value of 10 seconds for every 2 mm. space, can be turned end for end, and since the rings are of the same diameter, it is evident that a perfect level line can be established with this instrument. Weight of instrument about 10 lbs., tripod about 8 lbs.

Price of instrument packed, complete with tripod - - $110.00

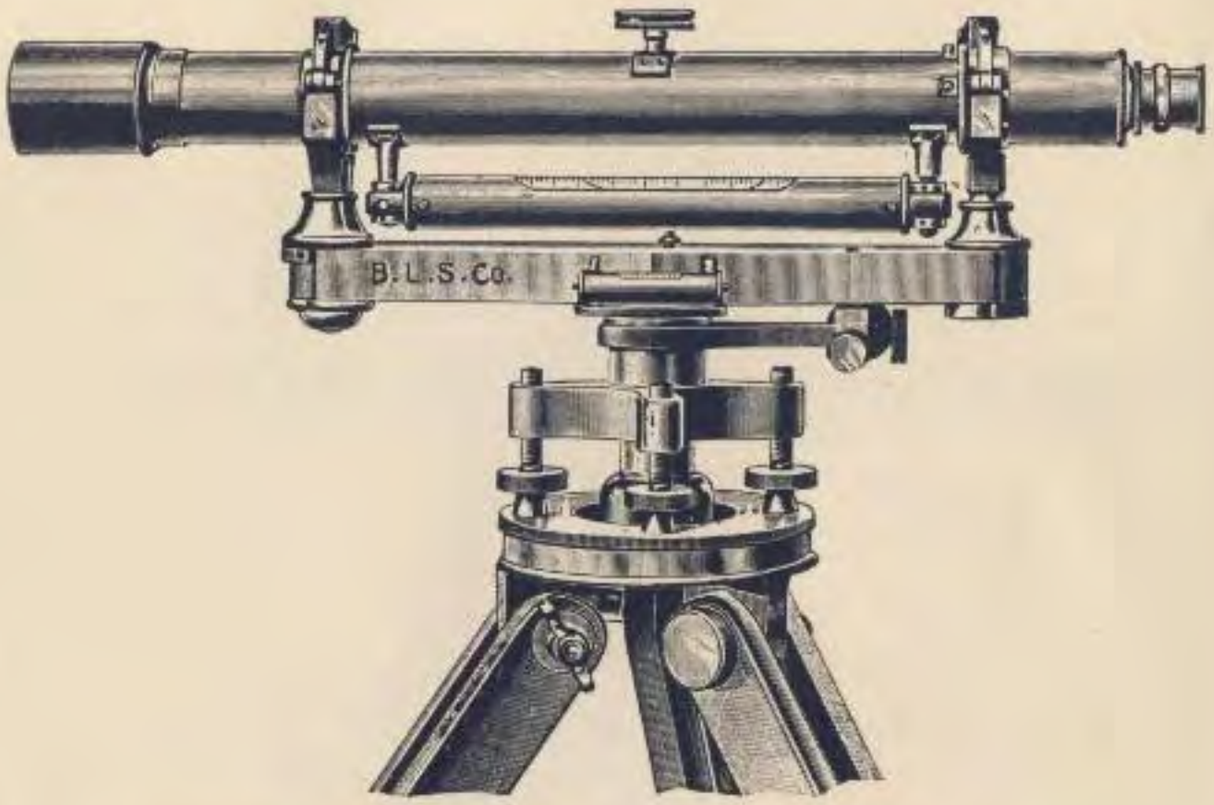
EXTRAS

The horizontal circle can be provided with two, opposite verniers at an additional cost of - - - - - - $10.00

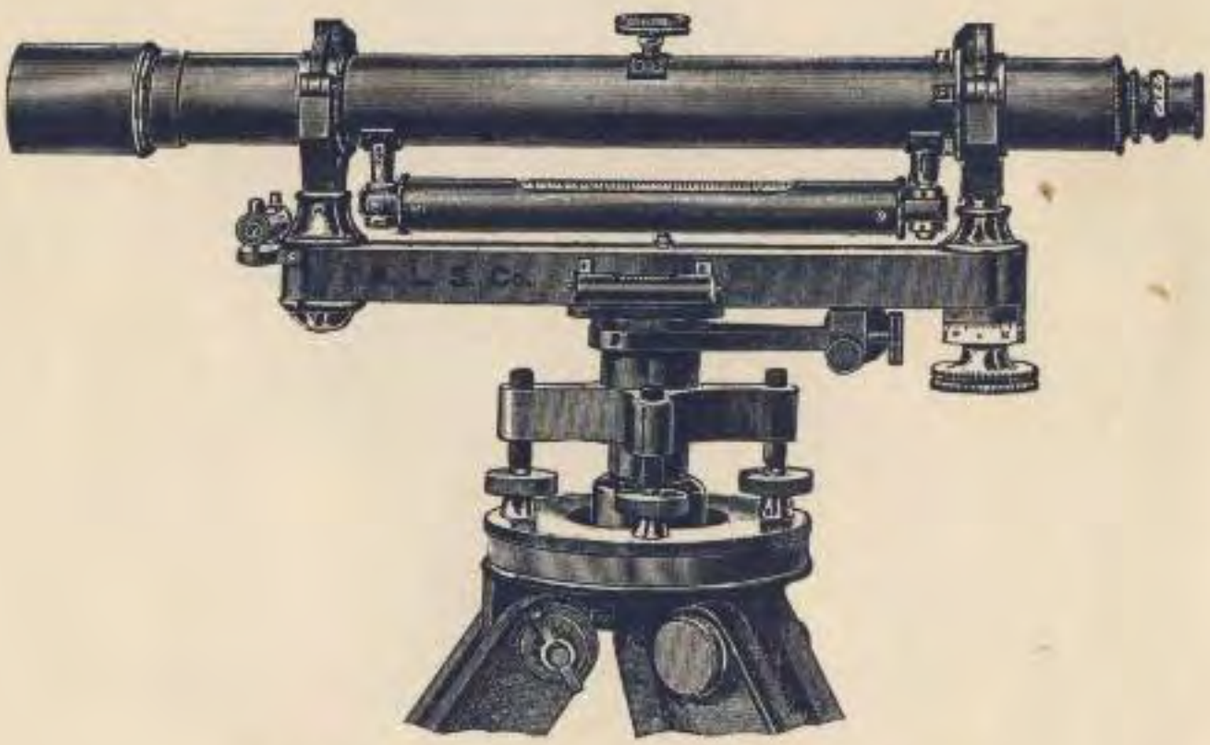
Stadias, 1 in 100 - - - - - - 3.00



BUILDERS' COMBINATION TRANSIT AND LEVEL, NO. 15



18-INCH ENGINEER'S WYE LEVEL, NO. 16



PRECISION WYE LEVEL, NO. 17

18-inch Engineer's Wye Level No. 16

The telescope of this level has an aperture of 1⅜ inches and is provided with a variable power eyepiece. An improved arrangement has been provided to bring the cross wire into exact focus. The object slide is protected. The rings and centers are of hard bell-metal. The long sensitive level is graduated on the glass and the clamp and tangent are attached to the level bar under the eyepiece. The level vial has a value of 10 seconds of arc for every division. The telescope is balanced when focused for mean distance. The wires are set horizontal and perpendicular by abutting stops. The telescope will allow focusing to a distance of 6 ft. The instrument is made either inverting or erecting as desired.

The instrument does not detach from the level head but packs into the case erect. The case contains sunshade, screw-driver, and adjusting pins.

Weight of instrument about 11 lbs., weight of tripod about 7 lbs.

Price - - - - - - - $140.00

For ordinary in place of variable power eyepiece, deduct $5.00 from above price.

Extras to Wye Levels

Attachable mirror, to read the level from the eye end -	$10.00
Hardened steel center - - - - -	10.00
Fixed stadias (1 in 100) - - - - -	3.00
Gossamer cover - - - - - -	1.00

Precision Wye Level, No. 17

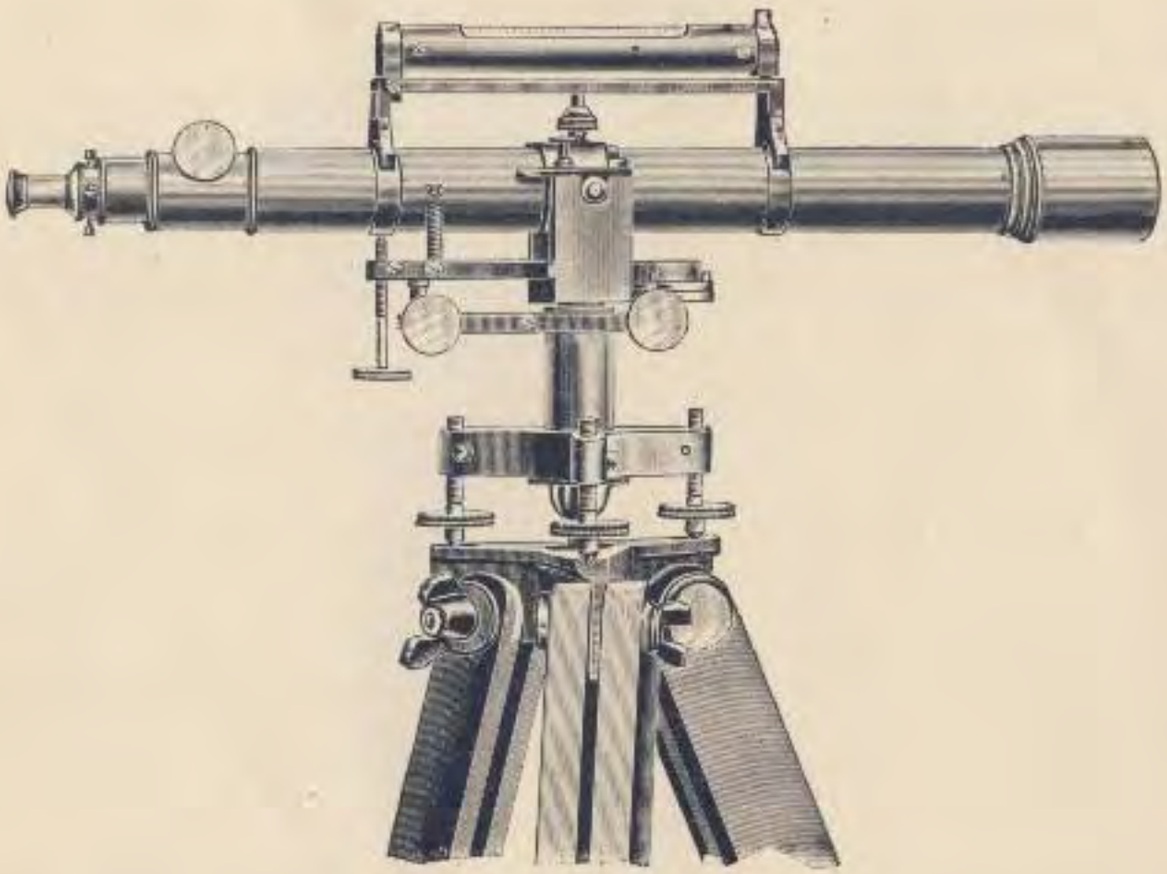
Same as No. 16, but with one of the Wye's movable by means of a graduated micrometer screw. It is intended for very accurate work. The level vial has a value of 5 seconds of arc for every division.

Price - - - - - - - $150.00

Reversion Levels

Are ground barrel shape on the inside and serve the same purpose as two levels placed parallel on opposite sides of a telescope.

Even if the cross wires should be out of adjustment and the collars of unequal diameter, still the mean of a double observation will give the true result. The additional cost of such a level is $20.00.



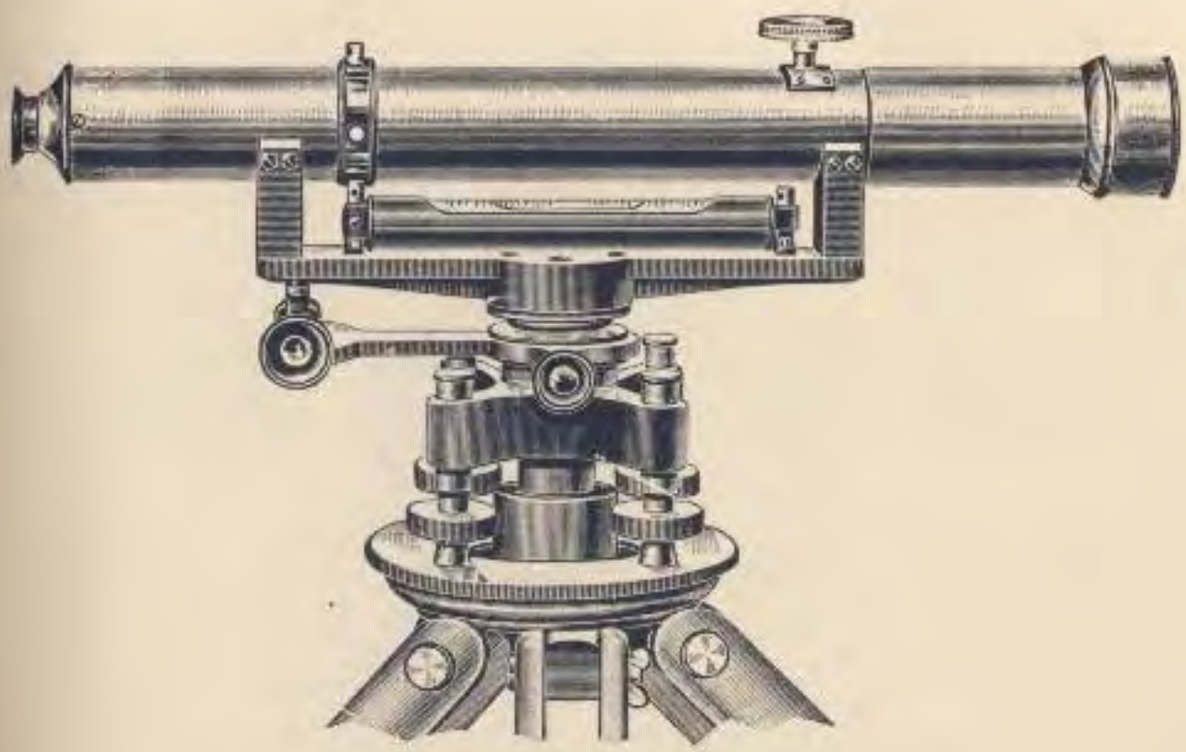
WURDEMANN'S PIVOT LEVEL, NO. 18

This is a very accurate leveling instrument. The telescope rests in pivots, and can be elevated or depressed by a fine micrometer screw. The horizontality of the telescope is determined by the delicate level which rests on top of the telescope upon two rings of equal diameter. Both level and telescope can be reversed and the adjustments accurately made and verified. It is in fact an inverted Wye level.

This instrument is made in two sizes:

15-inch Telescope - - - - -	$125.00
10-inch Telescope - - - - - -	90.00

These levels are also made with 4 leveling screws and erecting eyepiece at the same price.



14-INCH DUMPY LEVEL, NO. 19

At the time of going to press we are engaged in constructing a new dumpy level which is a great improvement upon the ordinary type represented above. We regret that we are unable to show a cut of the new instrument but are unwilling to delay longer the issuing of our catalog in order to do so. The telescope is 1¾ inches aperture, which large diameter allows us to sink the level vial into the body of the telescope thus bringing the level curve nearer the line of collimation and making the entire instrument more compact. The bubble is read off from the eye end by a mirror which folds when not in use and serves as a protection to top of the level.

The entire instrument above the leveling head is cloth finished. It is packed in a mahagony case with sunshade, screwdriver, wrench and adjusting pin and its weight is about 10 lbs. Weight of tripod about 7 lbs.

Price of 14 inch level, either erecting or inverting - - $100.00

Extras to Dumpy Level.

Fixed stadias - - - - - -	$3.00
Hardened steel center - - - - -	10.00

The Coast and Geodetic Survey Precise Level

Instead of brass and steel, with temperature coefficients of 0.000018 and 0.000011 respectively, nickel iron and nickel steel, with coefficients of 0.000004 and 0.000001 per degree Centigrade, are used in the construction of those parts upon which depends the relation between the line of sight and the level. The distance between the level and the line of sight is reduced to a minimum by placing the level vial partially within the telescope, and as near to its axis as the cone of rays from the objective to the eyepiece will permit. The middle portion of the telescope, with the level so mounted, is placed within a tubular support, which affords to the vial protection from heat rays and air currents.

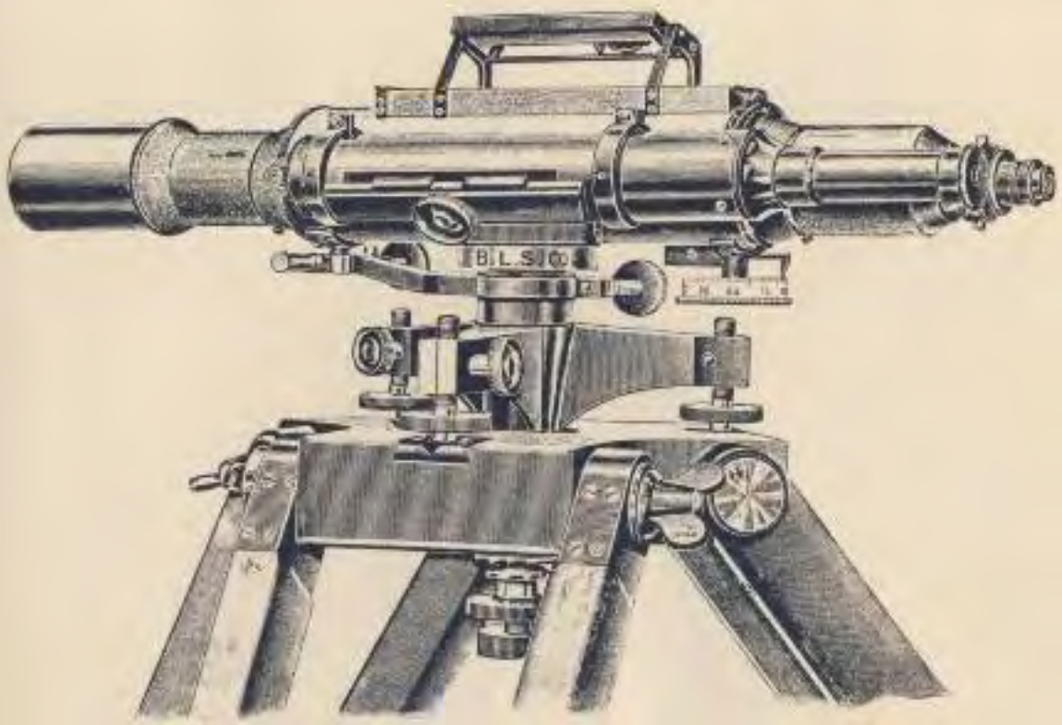
Instead of carefully leveling the instrument by means of the foot screws, as is done with the Wye level, that adjustment is here made only approximately, and the telescope, which is pivoted at the forward end of the tubular support, is put in the exact horizontal position by a fine motion screw mounted at the eye end.

The most important feature of this instrument is the prismatic level reading attachment. It permits the mounting of the instrument at such a height as to allow the observer to stand erect and make the observations upon both the rod and the level without shifting the weight of the body upon the ground, even from one foot to the other; his right eye being at the telescope and the left at the level reading tube (which is adjustable to the distance between any observer's eyes), he reads the rod at practically the very instant when, with his hand at the fine motion screw, he has put the bubble in the middle of its scale. The reading of three horizontal wires upon a direct reading rod and the repetition of the reading of the middle one for a check completes a sight; swinging the telescope around and repeating the same process upon the forward rod completes the work at the station.

With this instrument and simple method a Coast Survey observer in the course of his regular work has occupied 120 stations in less than eight hours, the average time per station being 4.6 minutes, including setting up and dismounting the instrument and the walking from station to station. The same observer has completed the leveling between Bowie, Texas, and Anthony, Kansas, in but little more than three months at an average speed of 91 miles of progress per month, each section of the line being leveled twice, in the forward and backward direction, and a few sections four times. This is equivalent to about 200 miles of single line per month. The average length of sight on this work did not exceed 250 feet. These records, made with a level vial with a value of 2" per 2 mm., and satisfying the high standard of accuracy required by the Coast Survey, show that this level can be and is manipulated more rapidly than the Wye level used on a much lower grade of work.

For a discussion of the methods upon which the design of this instrument is based see Transactions of the American Society of Civil Engineers, June, 1901, pp. 135 to 175, and Appendix No. 4, Coast and Geodetic Survey Report for 1902. Detailed descriptions of the instrument will be found in the same volume of "Transactions" (pp. 127 to 135), and in Appendix No. 6, Coast and Geodetic Survey Report for 1900.

COAST SURVEY PRECISE LEVEL, NO. 20



This instrument is constructed without regard to cost, extreme accuracy being the governing consideration. This fact accounts for the seemingly high price, which is for the complete instrument, with two achromatic eyepieces, magnifying 20 and 40 diameters, graduated and chambered level-vial having a value of 2 seconds per division. Completely packed, with extra heavy tripod, - $300.00

Two precision rods, Coast Survey design, thoroughly saturated with paraffine, packed in box, - - - - $150.00

We make this instrument without the vial reading telescope, the vial being read off by viewing it in a mirror attached over the level. The level is once for all made parallel to line of sight and is not adjustable. The scale however can be slightly shifted longitudinally.

These changes reduce the cost to - - - $200.00

LARGE PLANE-TABLE, NO. 21

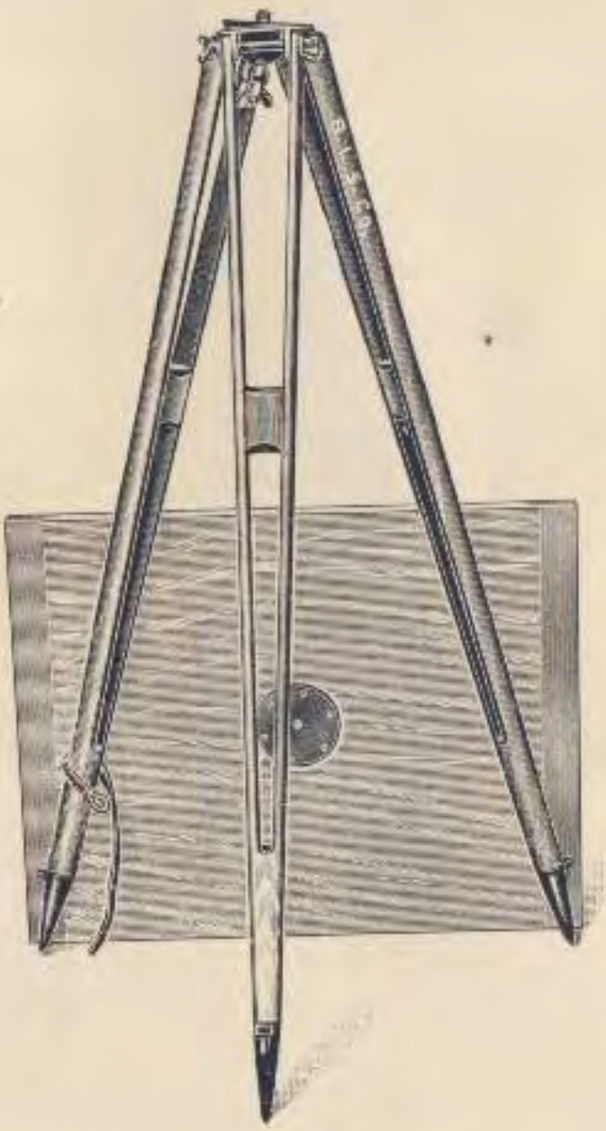
The above cut represents one of our large plane-tables such as is used in the Coast and Geodetic Survey. A portion of the board is cut out to show the motion-work. It is the most simple and effective form of plane-table made. The bearing surface of the motion-work being 8 inches in diameter, the table, when clamped, is perfectly firm. The alidade rule is 20 inches in length, and carries a powerful telescope of 1¼ inches aperture and 15 inches focus. For easier adjustment of collimation the telescope can be turned in its axis

180°. The compass-box is detachable; needle 5 inches long; striding-level reading to minutes. Stadia lines for measuring distances, besides the ordinary cross-line, are ruled on glass diaphragm. The vertical arc reads to minutes. The board is 24 by 30 inches and is packed in an extra box. The alidade together with a number of paper clamps and the usual accessories, is packed in a box, and the motion-work is packed in a separate box.

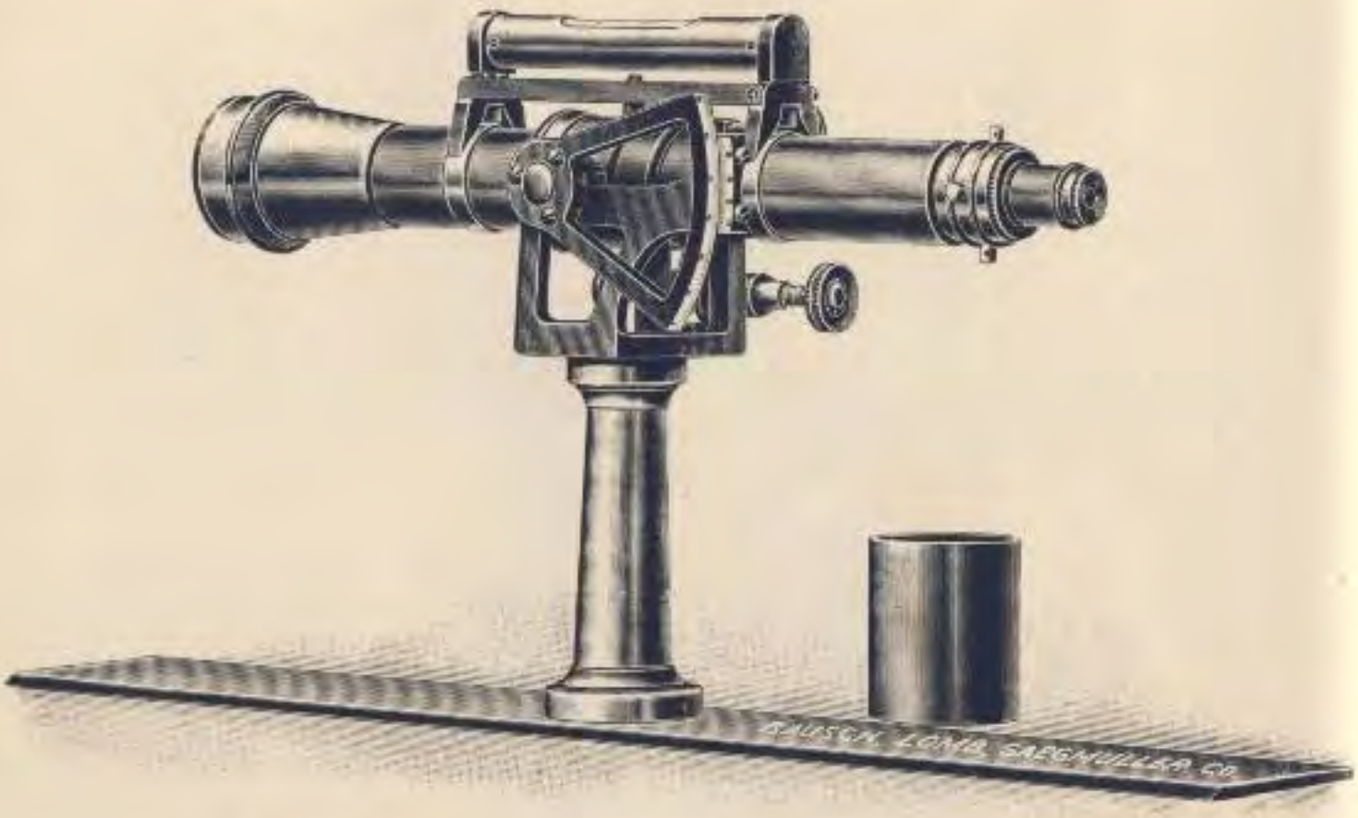
Price, complete, with firm tripod stand - - - $275.00

PLANE-TABLE, NO. 22

(U. S. Geological Survey Pattern, Johnson Movement.)



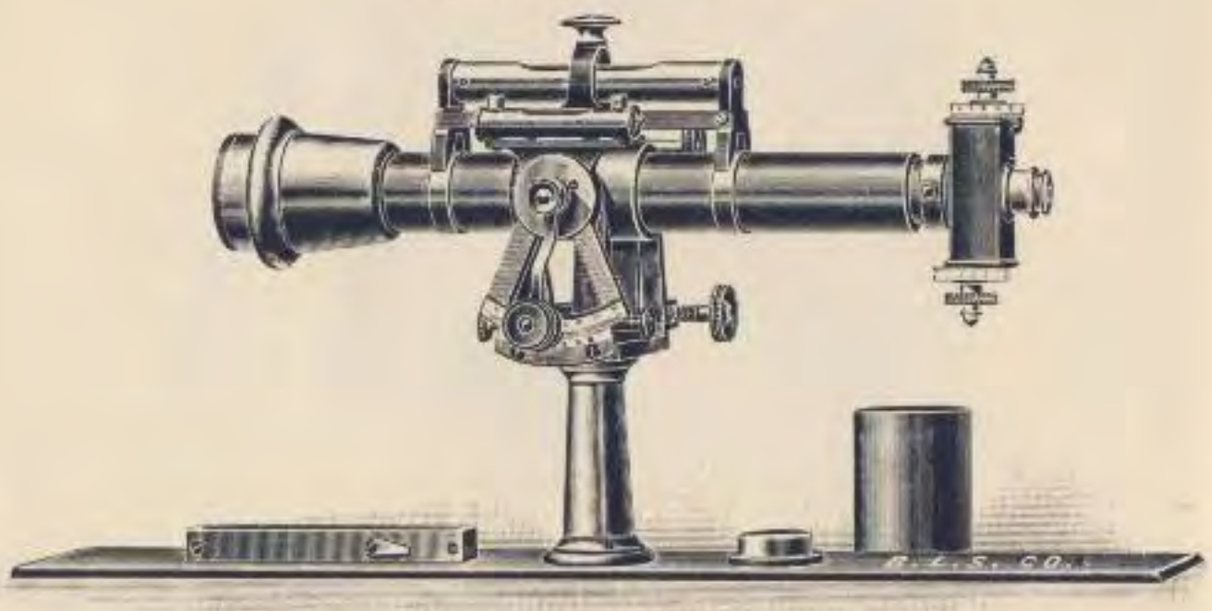
Plane-Table with tripod and board 30 x 24, with compass, $75.00
Complete, with alidade (see next page) - - - 170.00



The alidade for foregoing plane table has a very powerful telescope of 12 inches focus, 1½ inches diameter, magnifies 24 diameters, and for easier adjustment for collimation can be turned in its axis 180°; graduation on arc on edge, and can be read from eye-end; striding level over telescope, 1 division equals 1 minute.

Price - - - - - - - $95.00

ALIDADE, NO. 23



Same as above, but with double micrometer eyepiece and movable vernier arm and controlling level bubble, 1 division equals 30 seconds.

Price - - - - - - - $200.00

SEXTANT, NO. 24

Standard sextant of the most improved construction, free from excentricity; the mirrors perfectly plane parallel. Sextant of 7½ inches radius, divided on silver, and reading to ten seconds. Accessories as shown above.

In box complete - - - - - - $130.00

SMALL SURVEYING SEXTANT, NO. 25

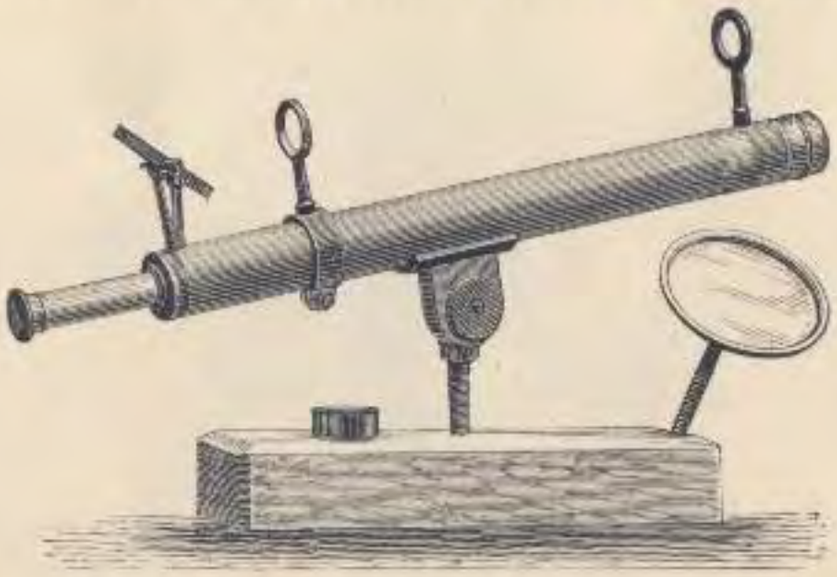
Six inch radius, reading to minutes - - - - $100.00

ARTIFICIAL HORIZON, NO. 26

Artificial horizon, with optically plane-parallel glasses, mercury bottle and trough, rectangular plate glass cover, packed in mahogany box - $50.00

Same, with select plate - - - - - 30.00

WURDEMANN'S HELIOTROPE, NO. 27



The telescope body is a heavy brass tube; in the middle, a hinged wood screw with joint for attaching the instrument to a tree or post. Mirrors of plate glass.

Price, boxed - - - - - - $50.00

HELIOTROPE, NO. 28

The same as above but on tripod, with horizontal and vertical movement, and graduated circle for reading angles.

Price, in box - - - - - - - $75.00

STEINHEIL'S HELIOTROPE, NO. 29

An instrument whose construction is such that it requires no adjustment. The rays of the sun must go in the direction pointed at.

In case, with back mirror, - - - - - $35.00

Coast Survey Iced Bar Base Apparatus

We have made several of the above-named instruments as described in the Coast Survey Report for 1892, Appendix No. 8.

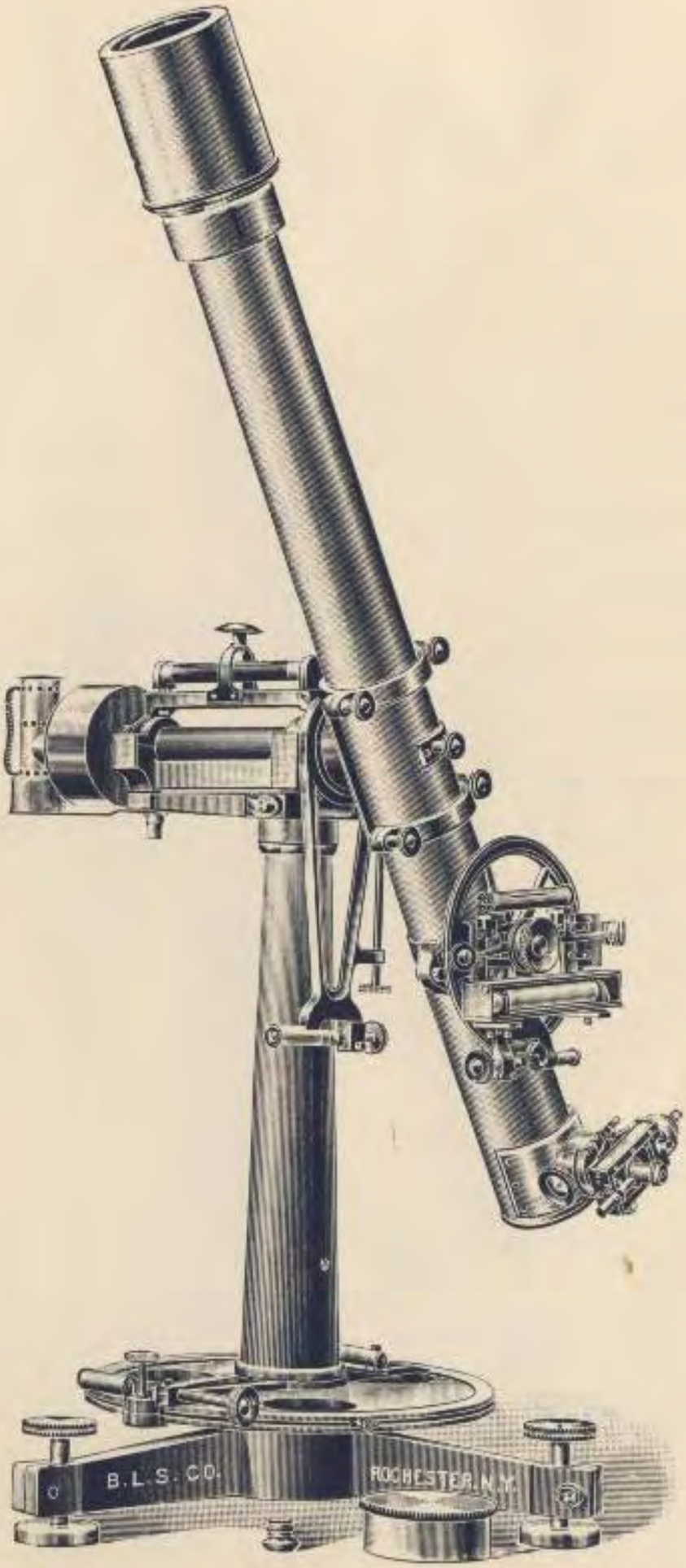
This apparatus consists of a 5-meter standard steel bar, an iron trough to hold the same surrounded by melting ice, two ends and four intermediate micrometer-microscopes with iron stands having the requisite slide motions to move them in all directions, cut-off apparatus to define end of base, striding level for alignment, sector attached to trough, two cars, and three sections of track, each about 6 meters long. One 100-meter, two 50-meter tapes, two tape stretchers, twenty-four breaking links and an ice-crusher are also supplied with the apparatus.

Price, depending upon number of accessories, furnished on application.

Zenith Telescope, No. 30

This cut represents the most improved form of zenith telescopes. The telescope swings on a horizontal axis, which is fastened to a vertical axis, and can therefore be moved into any position. It is especially adapted for the determination of differences of zenith distances. Graduated horizontal circle with clamp and tangent. The telescope, of 3-inch aperture, about 30 inches focus and magnifying 60 and 100 diameters, carries a circle with the fine latitude level, and is provided with a micrometer eye-piece. The levels are of the highest excellence; they are chambered and one division equals about one second of arc.

Price, - - - - - - $1,200.00



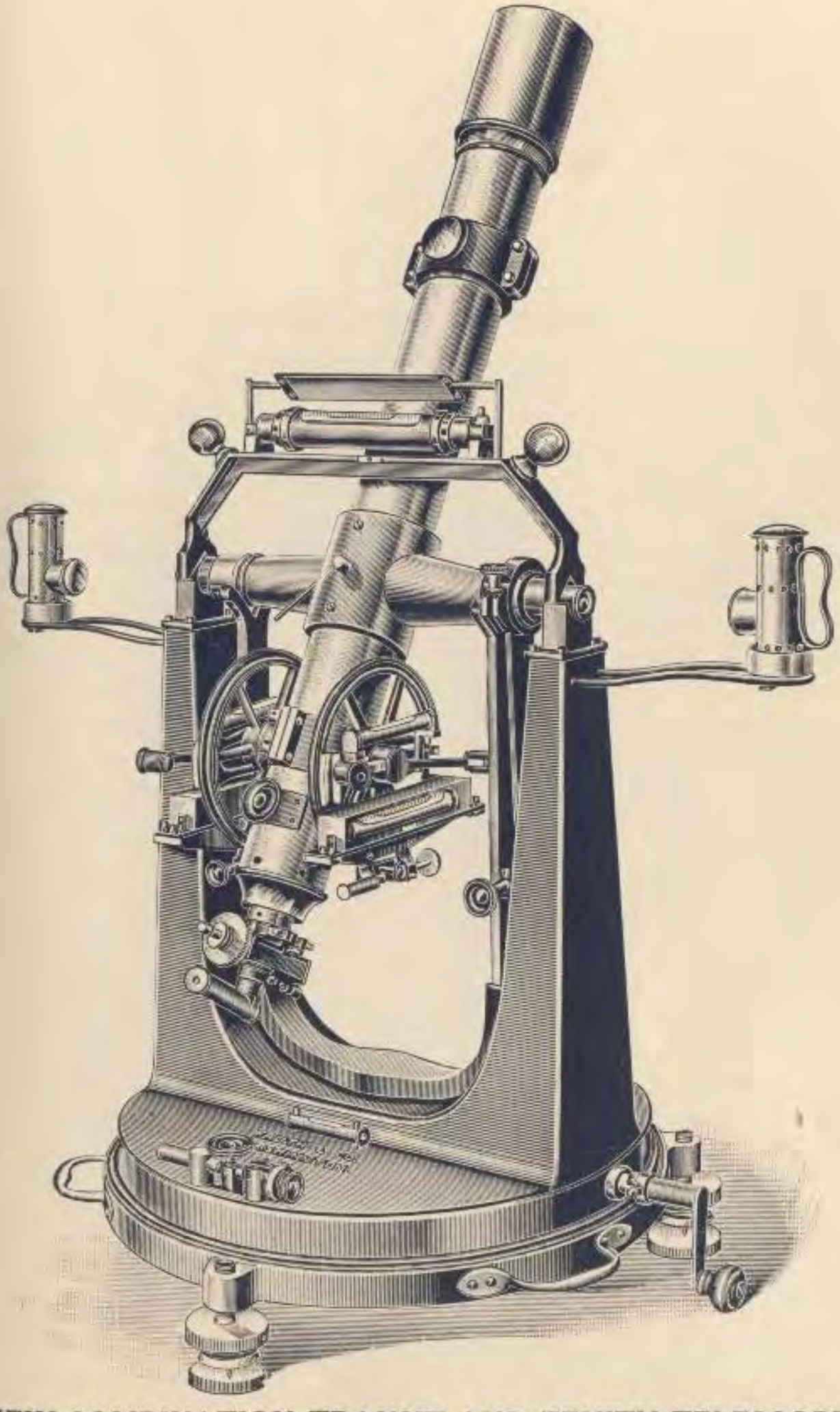
ZENITH TELESCOPE, NO. 30

New Combination Transit and Zenith Telescope No. 31

This instrument possesses several advantages over older forms. The base is circular, and the upper part moves smoothly upon the lower without disturbing the azimuth; this latter is provided with a graduation.

The instrument is provided with a reversing apparatus, and can be manipulated with the greatest ease. It is very rigidly built, although the entire instrument weighs less than 100 pounds. Telescope 3 inches aperture, about 30 inches focus, with direct and diagonal eyepieces magnifying 40 and 50 diameters, striding and latitude levels, chambered, reading to single seconds, eyepiece micrometer with diagonal eyepiece and swivel adapter, packed in two boxes.

Price - - - - - - - $1,300.00



NEW COMBINATION TRANSIT AND ZENITH TELESCOPE, No. 31

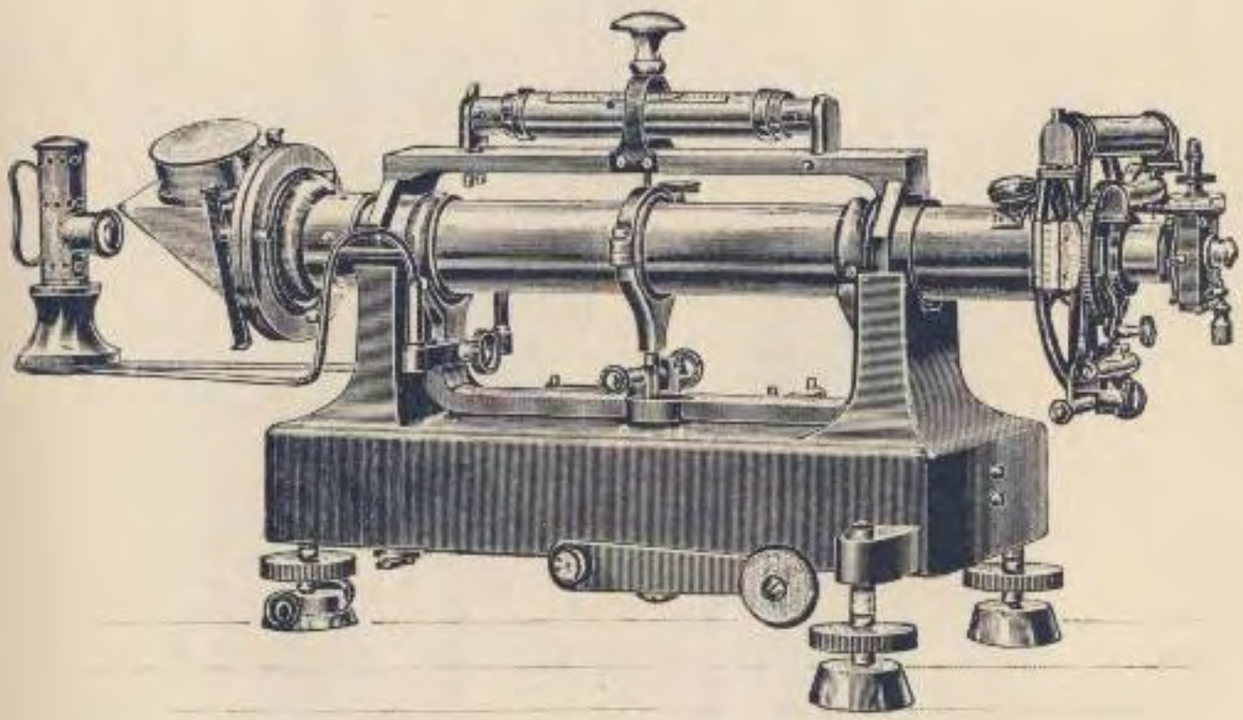
TRANSIT INSTRUMENTS

Improved Prismatic Transit, No. 32

It has been found that the objections heretofore made to this class of instruments are entirely overcome by the use of the Jena glass. The instrument 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 with a value of one second per division 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 eyepiece 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 and mountainous country; two eyepieces magnifying 60 and 100 diameters.

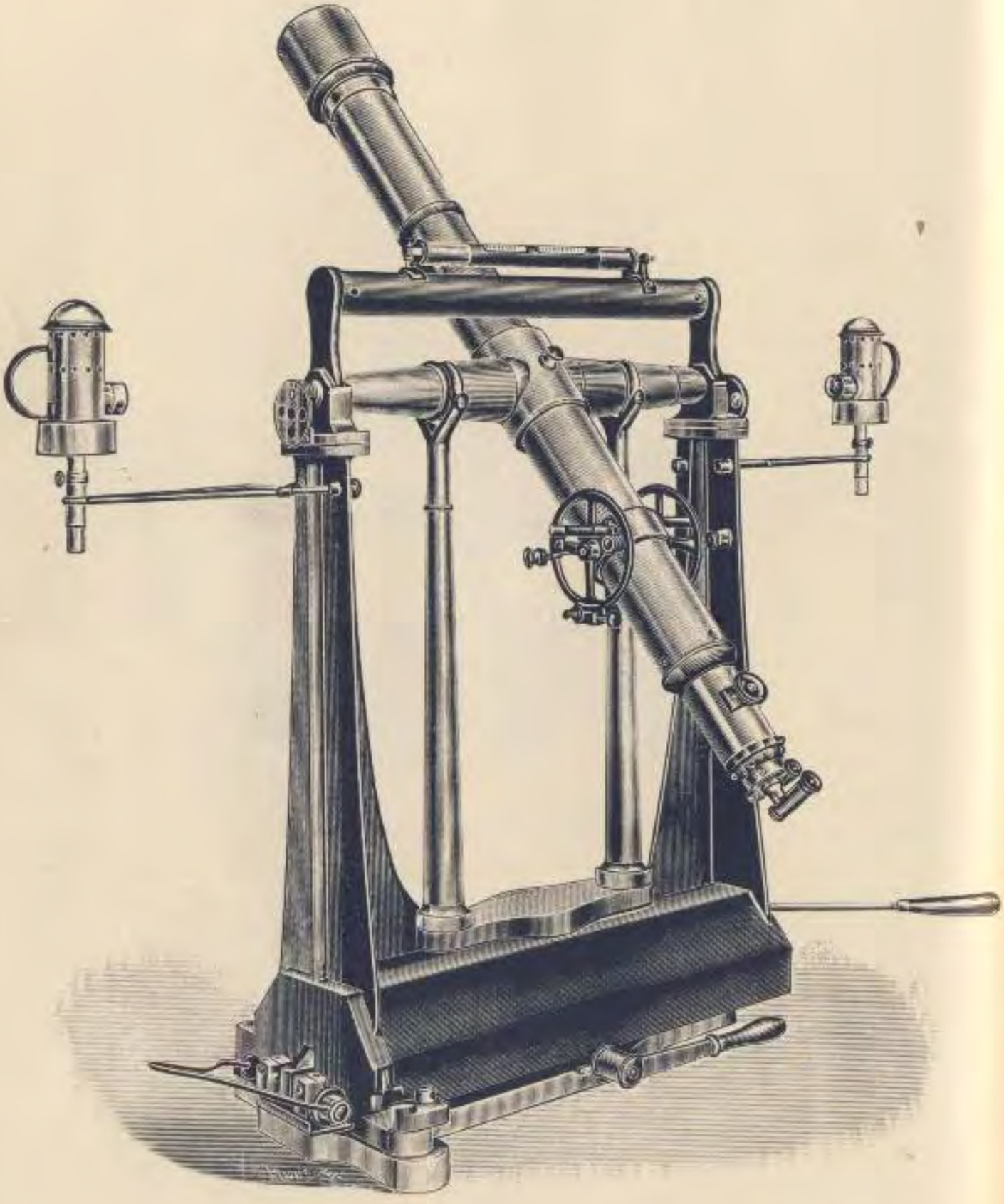
Telescope of 2½-inch clear aperture, packed complete in box with two eyepieces, illuminating and reading lamp, and all accessories $1,200.00

Same with 3-inch telescope - - - 1,500.00



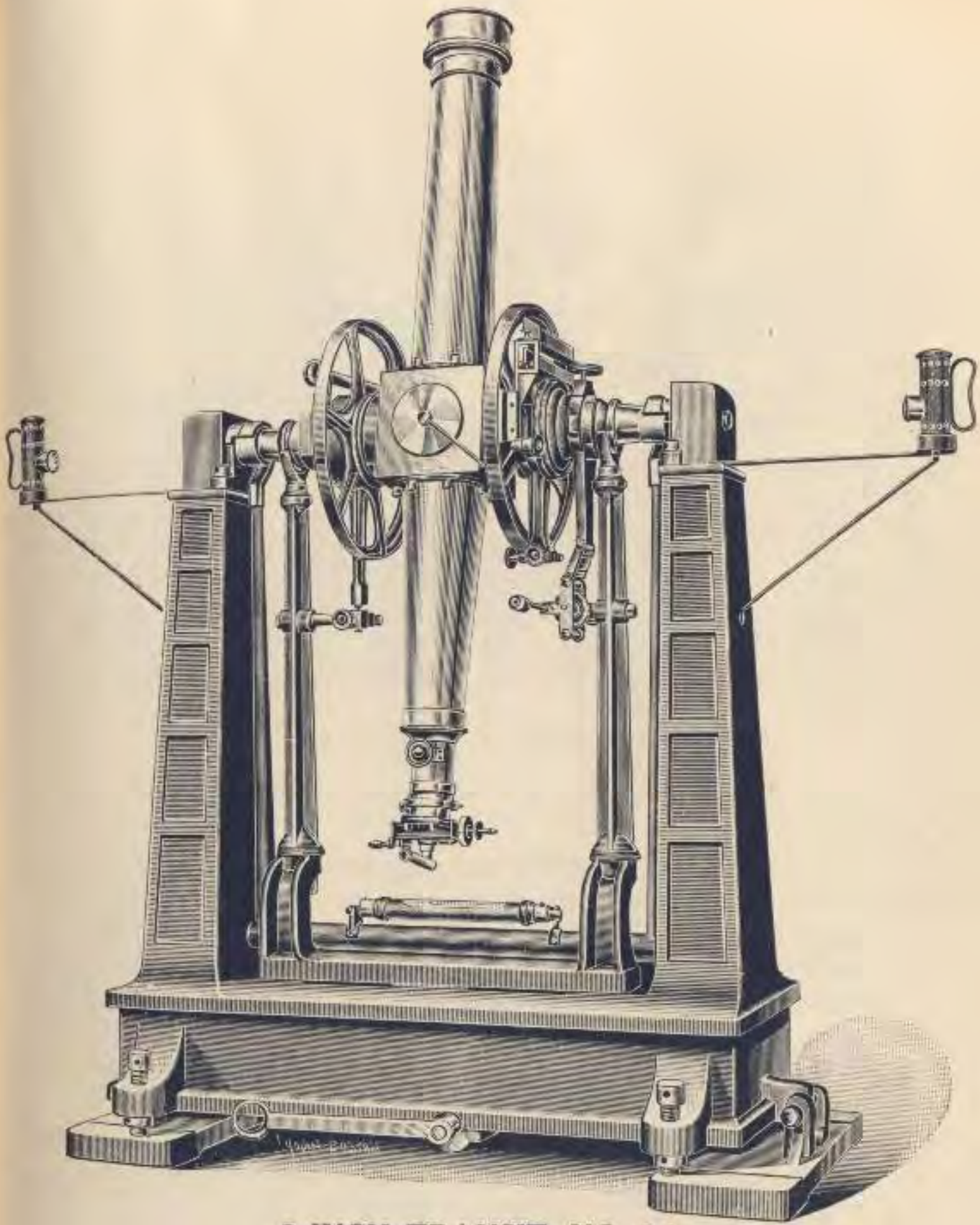
IMPROVED PRISMATIC TRANSIT, NO. 32

COAST SURVEY TRANSIT, NO. 33



The above illustration represents a transit used by the Coast Survey for time observations only.

Price, with 3-inch telescope - - - - $900.00



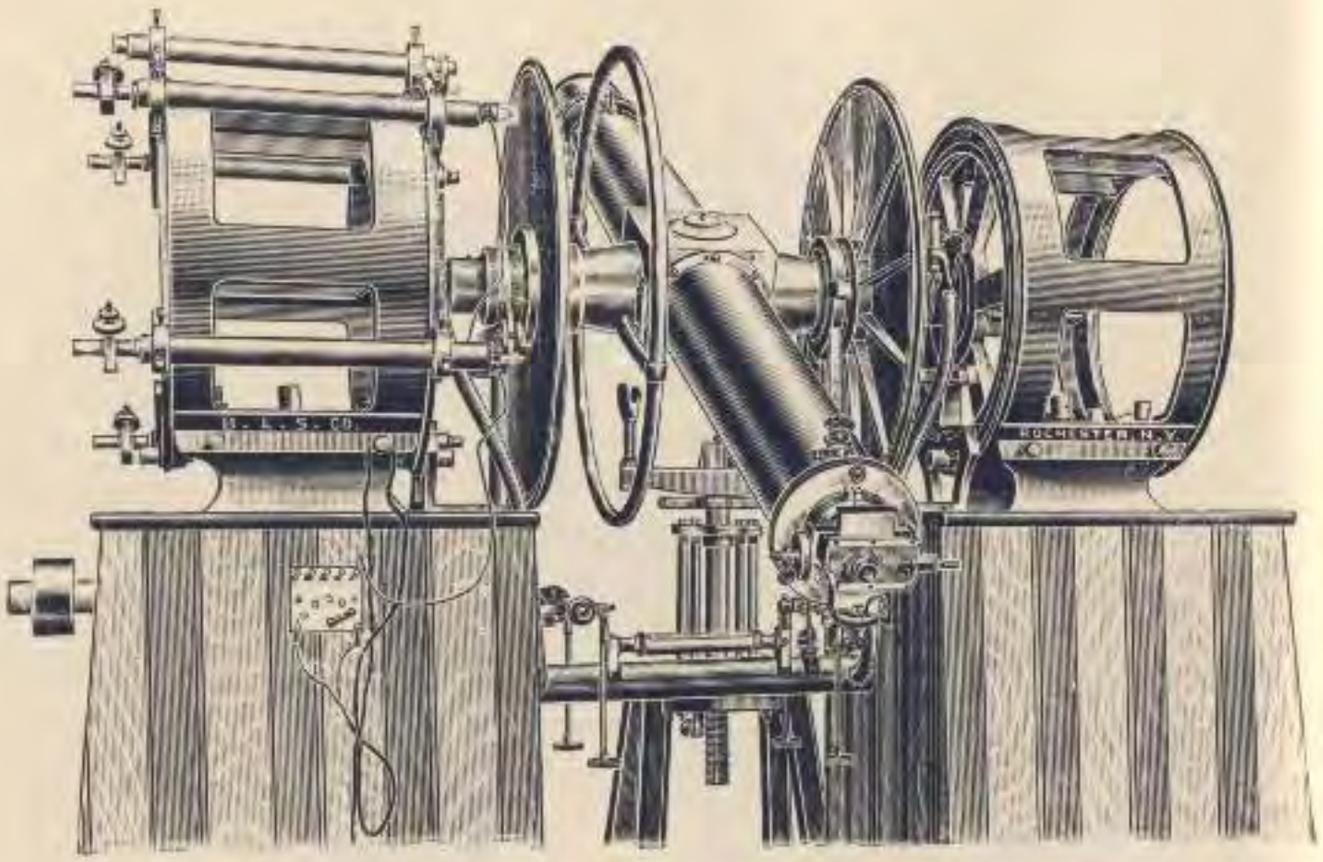
3-INCH TRANSIT, NO. 34

Transit instrument, of 3 inches aperture, 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 hanging level is entirely free and stays on during reversal. Levels chambered and with a value of about 1 second. The counterpoises hang on the inside of the pillars. The iron stand has the necessary adjustments for altitude and azimuth. Reversing apparatus, mercurial basin, diagonal, direct and collimating eyepieces, eyepiece micrometer with parallactic movement to turn in any position, lamps, etc.

Price, - - - - - - - $1,300.00

The same, with 6-inch setting circle, and level alidade on axis; delicate striding level; glass micrometer instead of spider-lines; direct and diagonal eye-pieces, improved clamp. One of the Wye's can be moved in azimuth, the other in altitude, and there be firmly clamped. Reversing apparatus, lamps, etc.

Price - - - - - - $790.00



CINCINNATI MERIDIAN CIRCLE, NO. 35

The above cut represents a meridian circle of the first-class as made for the Cincinnati observatory.

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

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

Anyone who has worked with the old style reversing wagons will appreciate this improvement. There is absolutely no danger of injury to the instrument during reversal. The operation can be performed in the dark, and it takes but very little time to do it. By an ingenious arrangement the level can be conveniently read by means of a small telescope.

Wherever it has been possible we have simplified the instrument, and have constructed it with a view to the use of steel throughout. The instrument is lighter, stronger than if made of brass, and has but few polished parts.

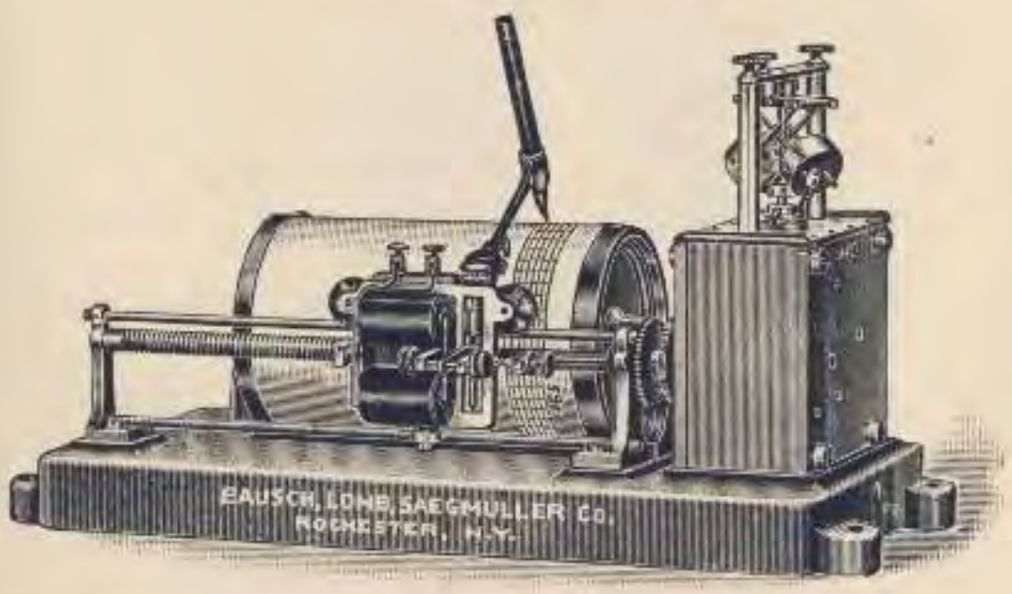
Professor Porter, the director of Cincinnati observatory, testifies as follows, regarding the efficiency of this instrument:

"The five-inch meridian circle has now been in constant use for nearly ten years, and has proved to be a most satisfactory instrument in all respects. It is simple in construction and very convenient in manipulation. One person can readily reverse it in less than five minutes. The accuracy of the circle is certainly remarkable. Though it is only two feet in diameter, yet so far as investigation has been made the errors of division seldom amount to a second of arc.

In our determinations of declination no corrections for division errors are applied, but they are to a large extent eliminated by shifting the circle each year and observing the same stars on different divisions. The probable error of a single determination of declination in the work of the last five years is only 0".4, which, of course, includes both division errors and accidental errors of observation. We are, then, I think, justified in the belief that the tedious investigation of division errors is no longer necessary, and that we can rely to a greater extent than formerly on the skill of our mechanicians.

After having made nearly 20,000 observations with our instruments, I am unable to suggest any material improvement."

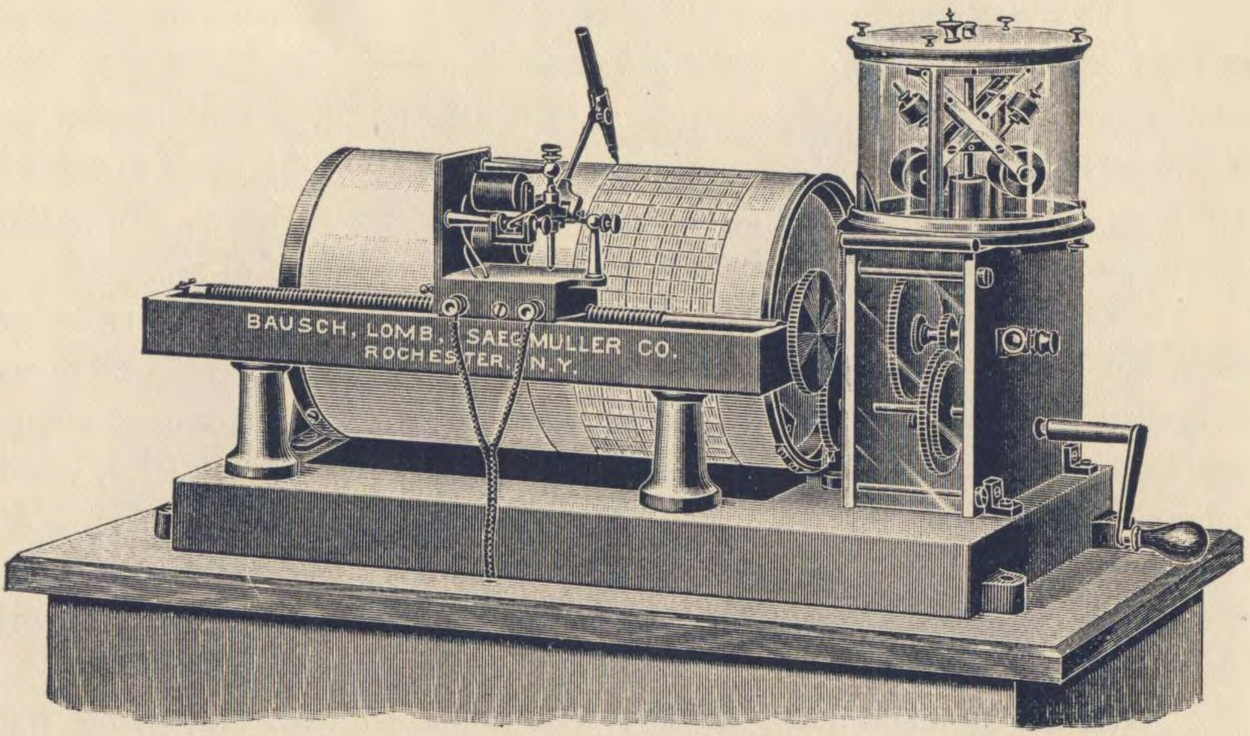
CHRONOGRAPHS



SMALL PORTABLE CHRONOGRAPH, NO. 36

Above chronograph is an instrument suitable for ordinary time observation. It has a barrel 7 inches long, 4 inches diameter; one second is thus a little more than 5 mm.

Price of chronograph, including weights - - - $150.00



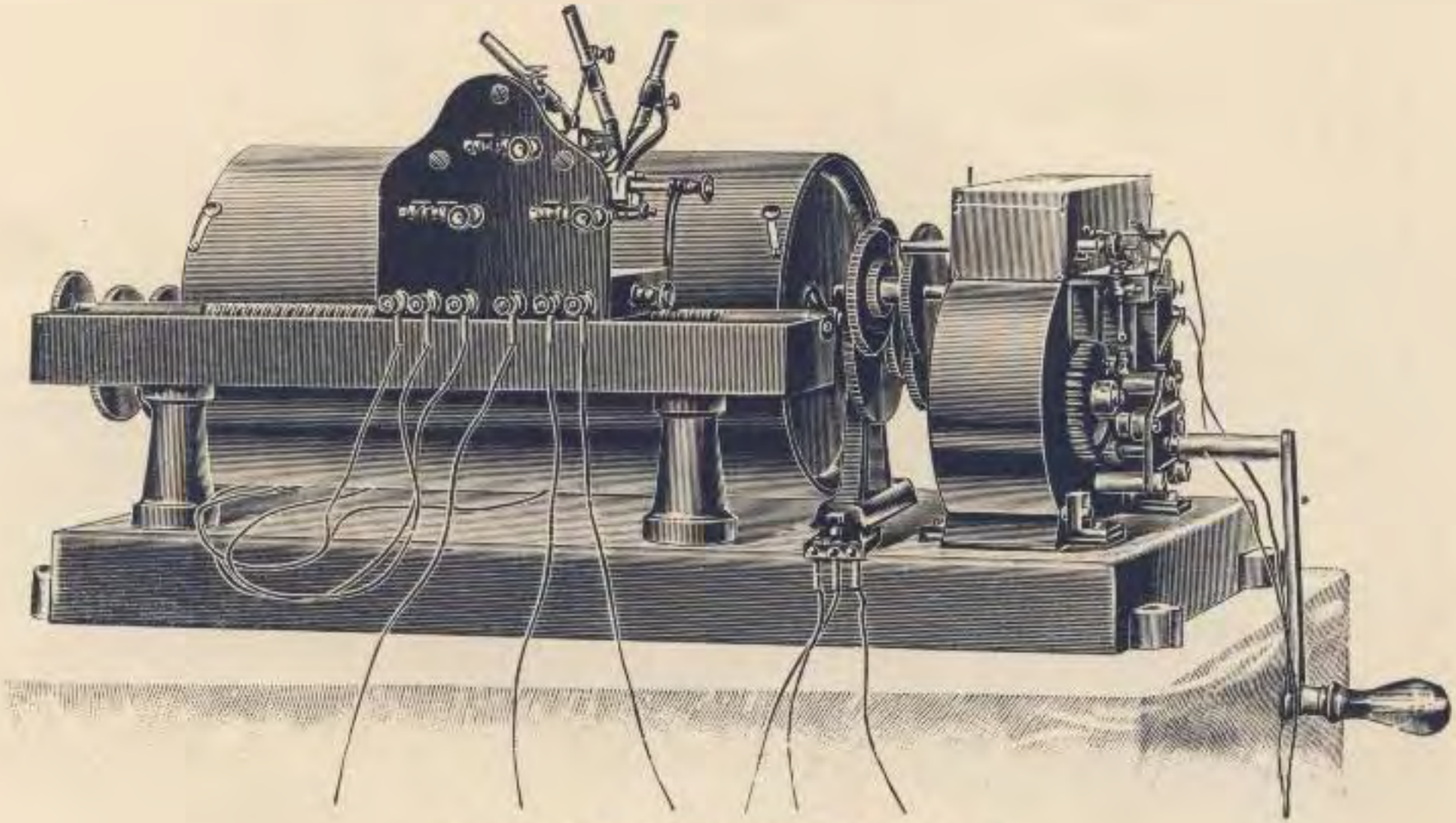
STANDARD CHRONOGRAPH, NO. 37

Our standard chronograph is unsurpassed for compactness and regularity of action. In order to reduce to a minimum the effects due to changes of temperature the governor is made almost wholly of "Invar" steel, and is inclosed in a glass case. The cylinder is 14 inches long, 7½ inches diameter, so that one second is exactly 10 mm. long.

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

Price, with single pen, 100 sheets of paper and reading scale	-	$375.00
" " double " " " " " "	-	425.00

Note.—Our chronographs are not provided with electric control. It is not only entirely unnecessary, but its use is absolutely wrong in connection with a chronograph.



3-PEN CHRONOGRAPH, NO. 38

SPRING MOVEMENT

Three-Pen Chronograph for physical research, driven by spring motor - $600.00

SPHEROMETER, NO. 39

An exceedingly accurate instrument for measuring the inequality of pivots. It is 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 center, and the nut is so constructed that there can be no dead motion.

Price, as shown in cut, with adjustable frame, in box - $60.00

COLLIMATORS

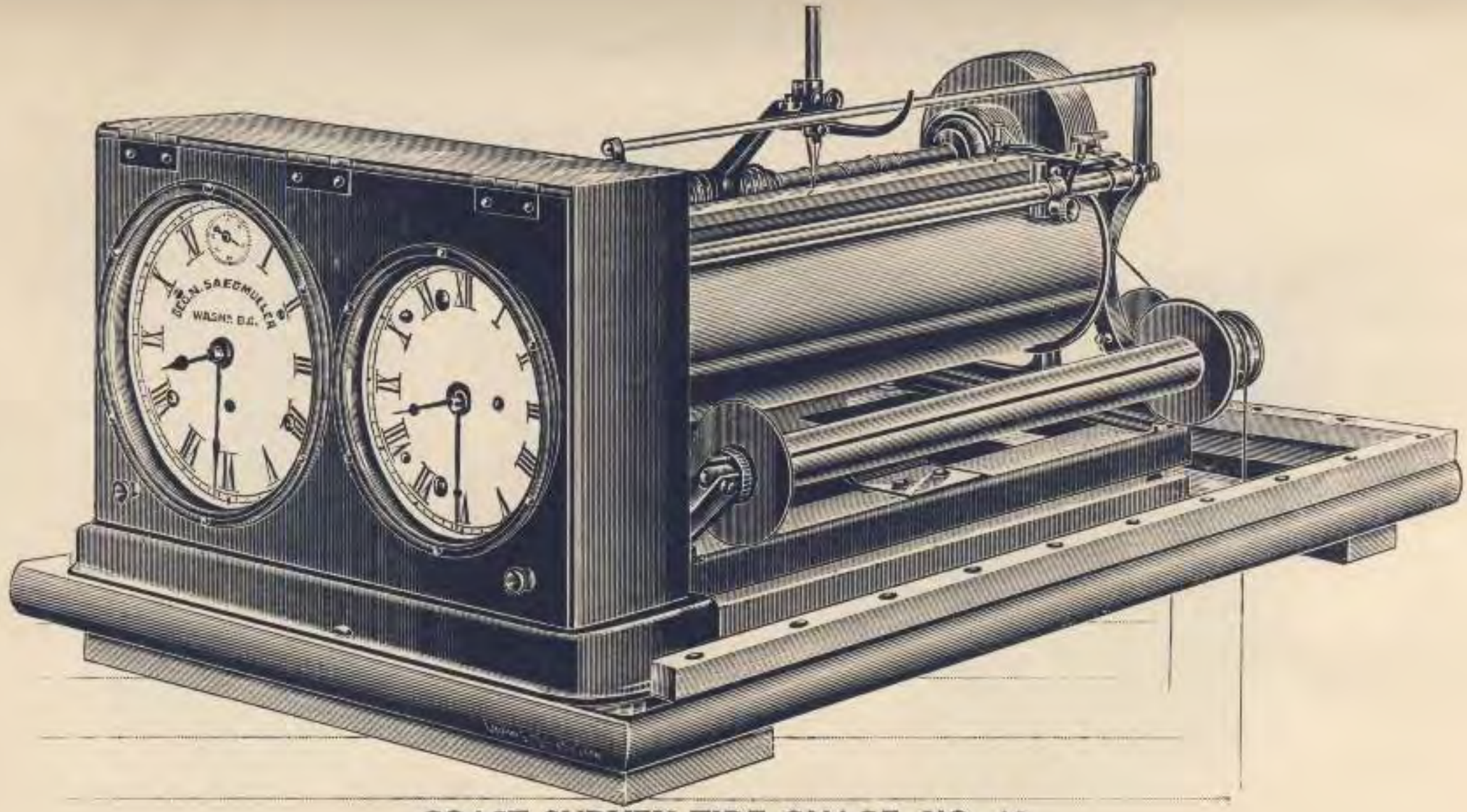
All sizes, horizontal and vertical, with telescopes from 2 to 6 inches aperture.

ASTRONOMICAL CLOCK

We make only one kind of clock, which we supply with our cheap outfit. It is a well-made clock, having dead-beat escapement, mercurial pendulum, and break-circuit attachment. The break in this clock is effected by the pendulum. 9-inch full minute dial, extra second and hour dial.

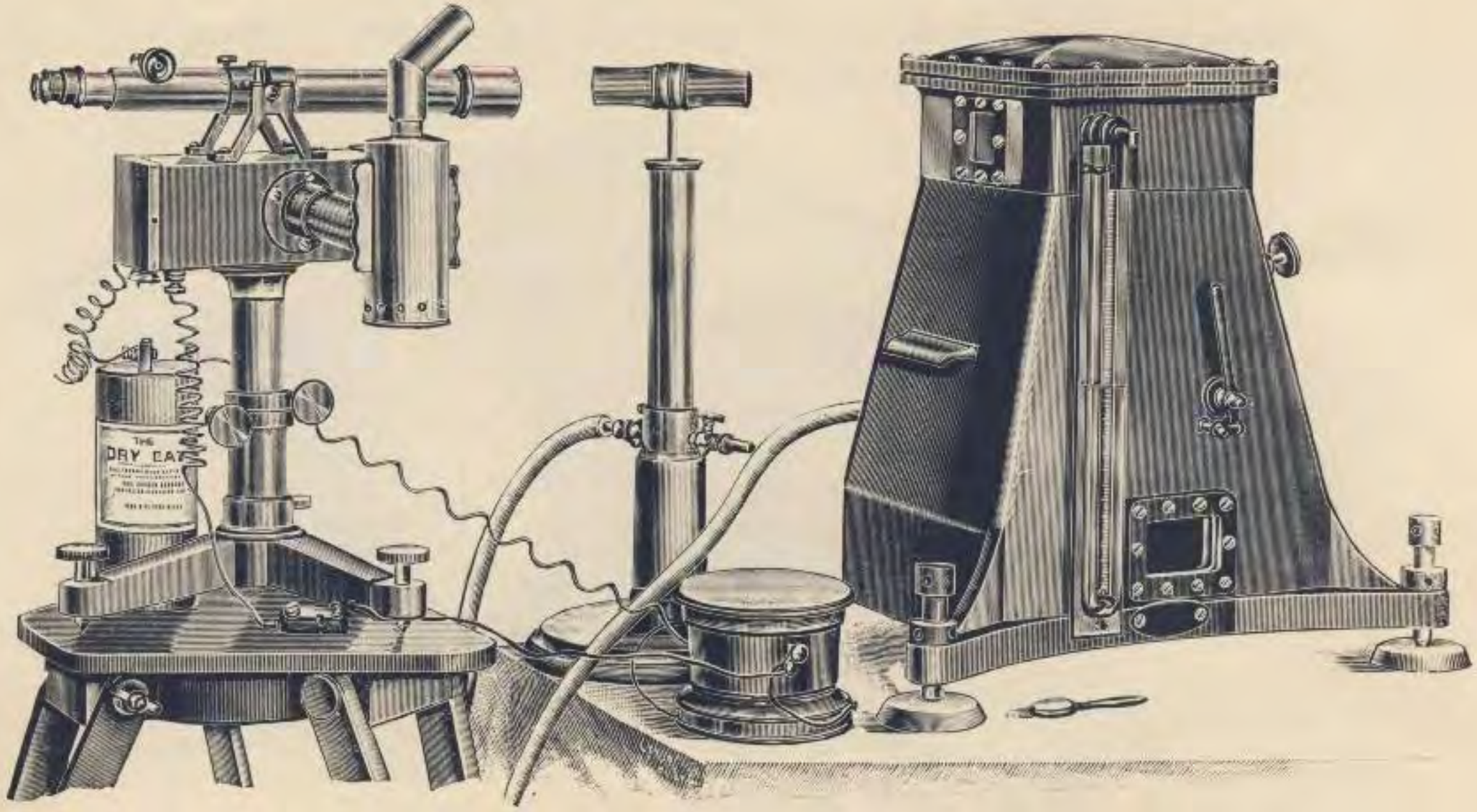
Price - - - - - - - $160.00

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



COAST SURVEY TIDE GUAGE, NO. 40

Two clocks are used, one for driving, the other for keeping time. 4 interchangeable scales and pulleys; packed complete. Price - - - $250.00



COAST SURVEY PENDULUM APPARATUS, NO. 41

Coast Survey Pendulum Apparatus

This apparatus consists of a set of three-second pendulums, an airtight receiver in which the pendulums swing, a flash-light apparatus wherein an electro-magnet in the circuit of a chronometer moves a shutter and throws out a flash of light each second, an observing telescope mounted above the flash apparatus, an air pump, a manometer, thermometers, and a sensitive level for adjusting the agate plane on which the pendulums are swung.

The receiver is a heavy gun-metal casting, galvanized to render it airtight.

A shelf on the inside carries the dummy pendulum and the agate plane on which the pendulums swing. It also holds the pivots for the lever used in raising and lowering the pendulums, which is done from the outside.

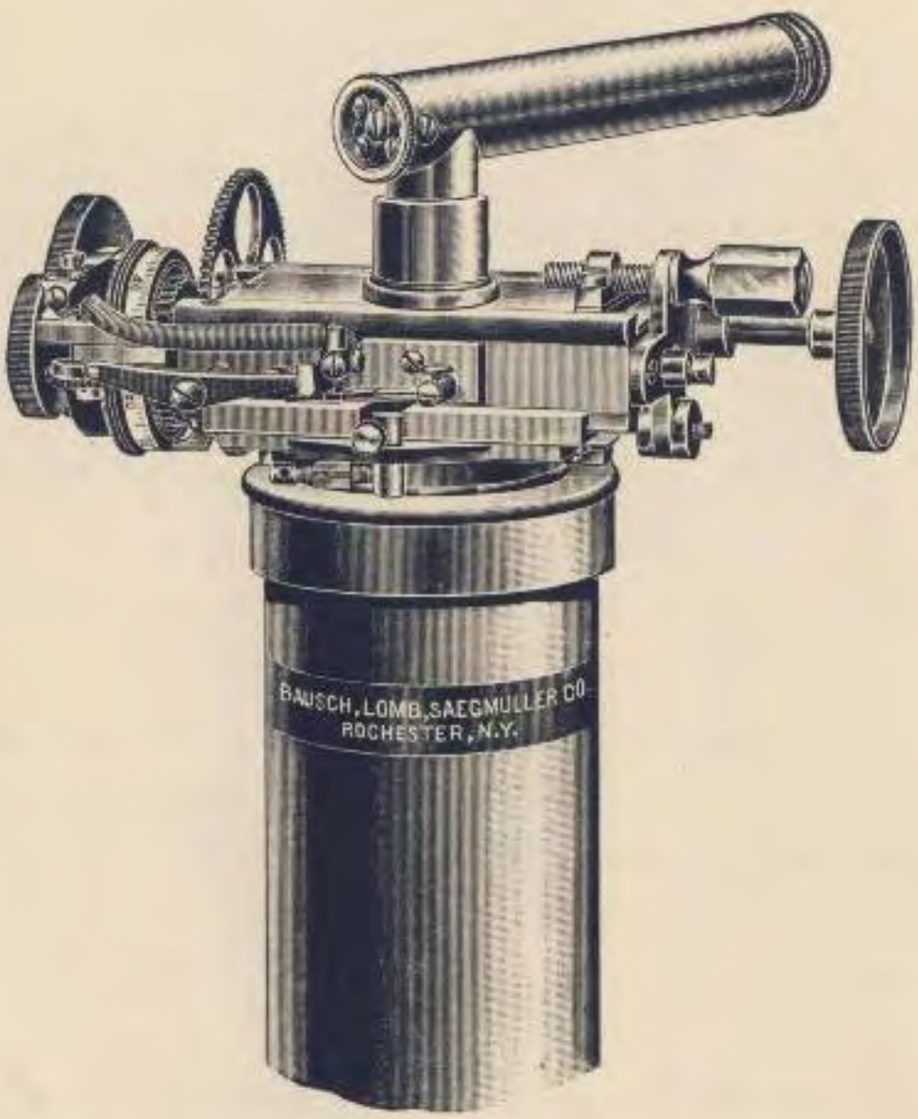
The plate carrying the agate plane also carries a fixed mirror so adjusted that the image of the slit, as seen in the observing telescope, reflected from this mirror, and from that on the pendulums when hanging freely at rest, will appear in the same horizontal line and slightly overlapping each other.

The pendulums differ slightly in length, and are so adjusted as to swing in periods of 2' 35", 2' 40", and 2' 45", approximately. They are made of an alloy of aluminum 10 per cent. and copper 90 per cent., and are highly polished, but not lacquered. A small mirror is set in each side of the pendulum head, and is so adjusted that from any of the pendulums with either face front the image of the slit is reflected into the same portion of the field of the observing telescope.

The entire apparatus is packed in two boxes. Weight about 400 pounds.

The price of the apparatus depends upon the accessories furnished.

A detailed description of this apparatus can be found in the Coast Survey Report for 1891, Appendix No. 15.

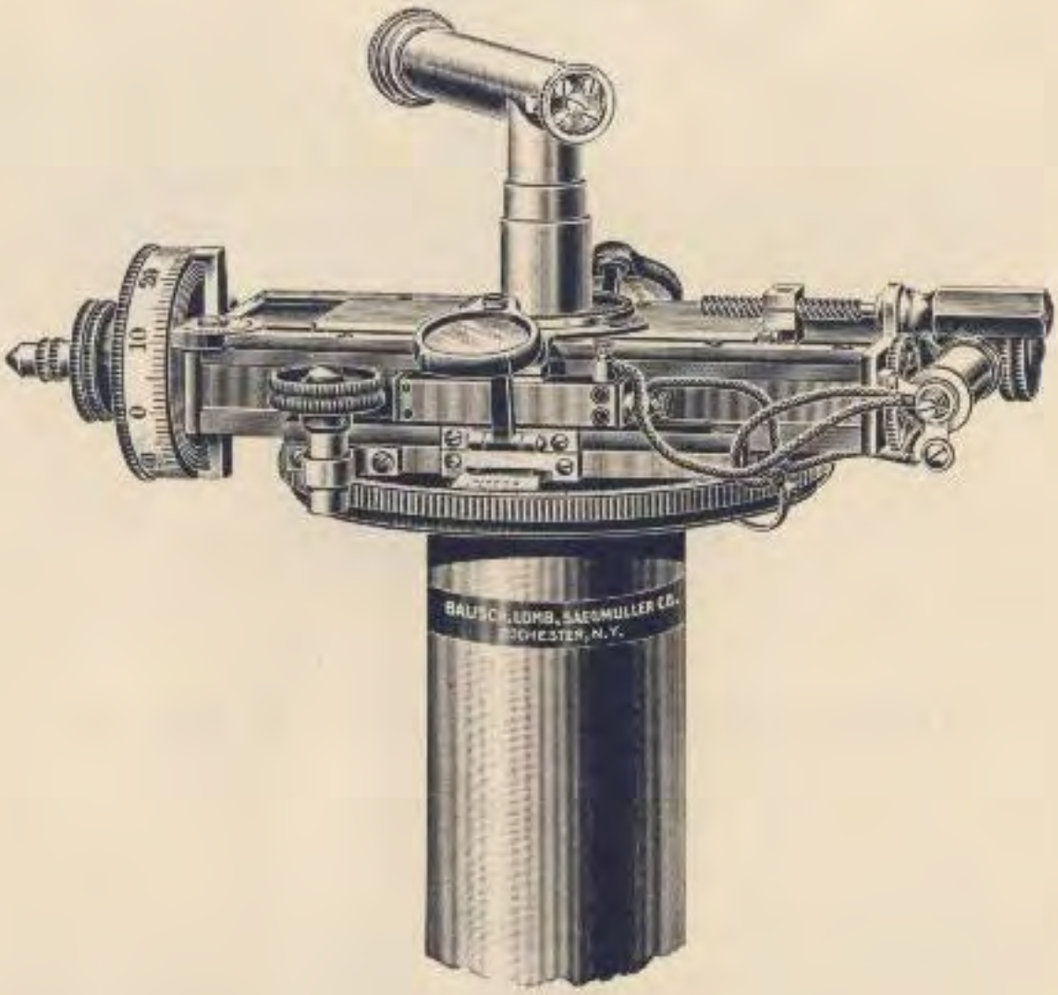


SELF-RECORDING TRANSIT MICROMETER, NO. 42

By means of which personal equation is eliminated

For detailed description of above instrument we refer to Appendix No. 8, Report for 1904, Coast and Geodetic Survey.

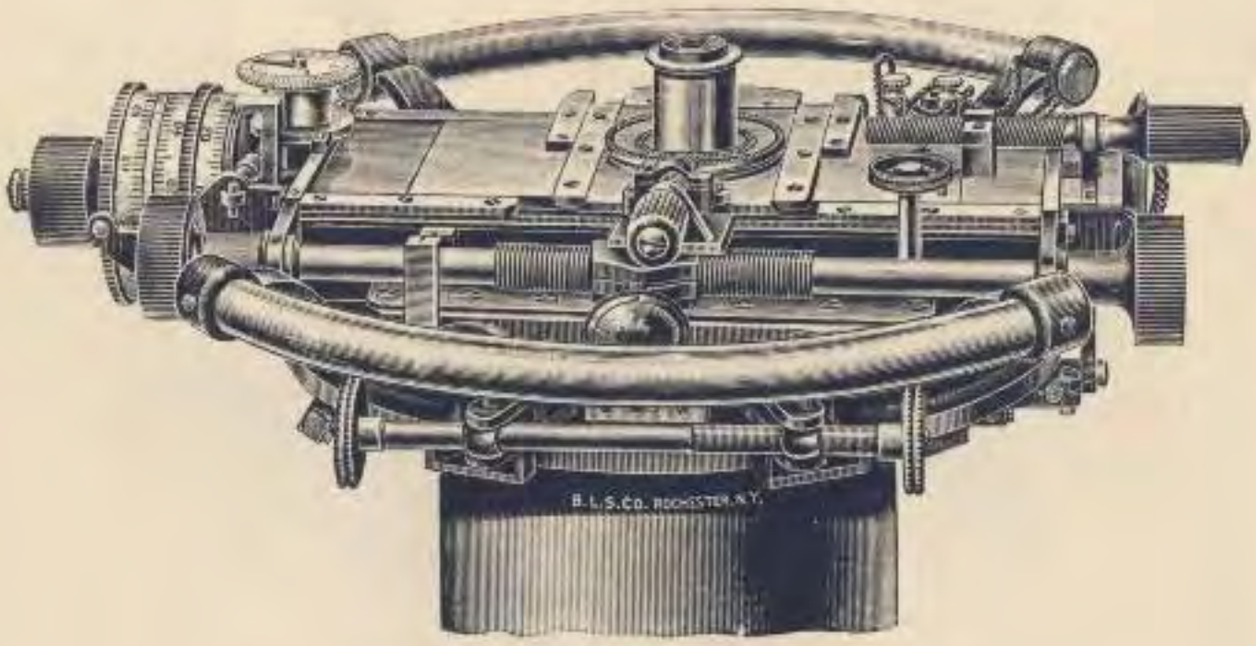
Price, - - - - - - - $250.00



4-INCH POSITION MICROMETER, NO. 44

This micrometer revolves on a circle 4 inches in diameter which is graduated on silver to minutes. The micrometer has transverse movement for the entire box, parallactic movement for the eyepiece, full revolution counter, and electric illumination for bright wires.

Price - - - - - - - $250.00



LARGE POSITION MICROMETER, NO. 46

(Bruce Micrometer)

This is one of the most complete micrometers ever constructed and embodies the ideas of Prof. H. A. Howe of the Chamberlin Observatory, Denver, Col. The circle of 9 inches diameter turns with the micrometer thus leaving the vernier always in the same position. The entire micrometer box has transverse motion; the eyepiece can be moved in two co-ordinates at right angles to each other. The measuring screw is provided with triple heads allowing 3 bisections for one observation, full revolution counter actuated by the screw; electric illumination for bright lines controlled by rheostat is attached to the micrometer.

Prof. Howe has used this micrometer for many years and considers it superior to any he has ever seen.

We have supplied the Cincinnati telescope with one of the same kind.

Price - - - - - - - $650.00

OBSERVATION TELESCOPE, NO. 48

Large Aperture Prismatic Telescope with Short Focus

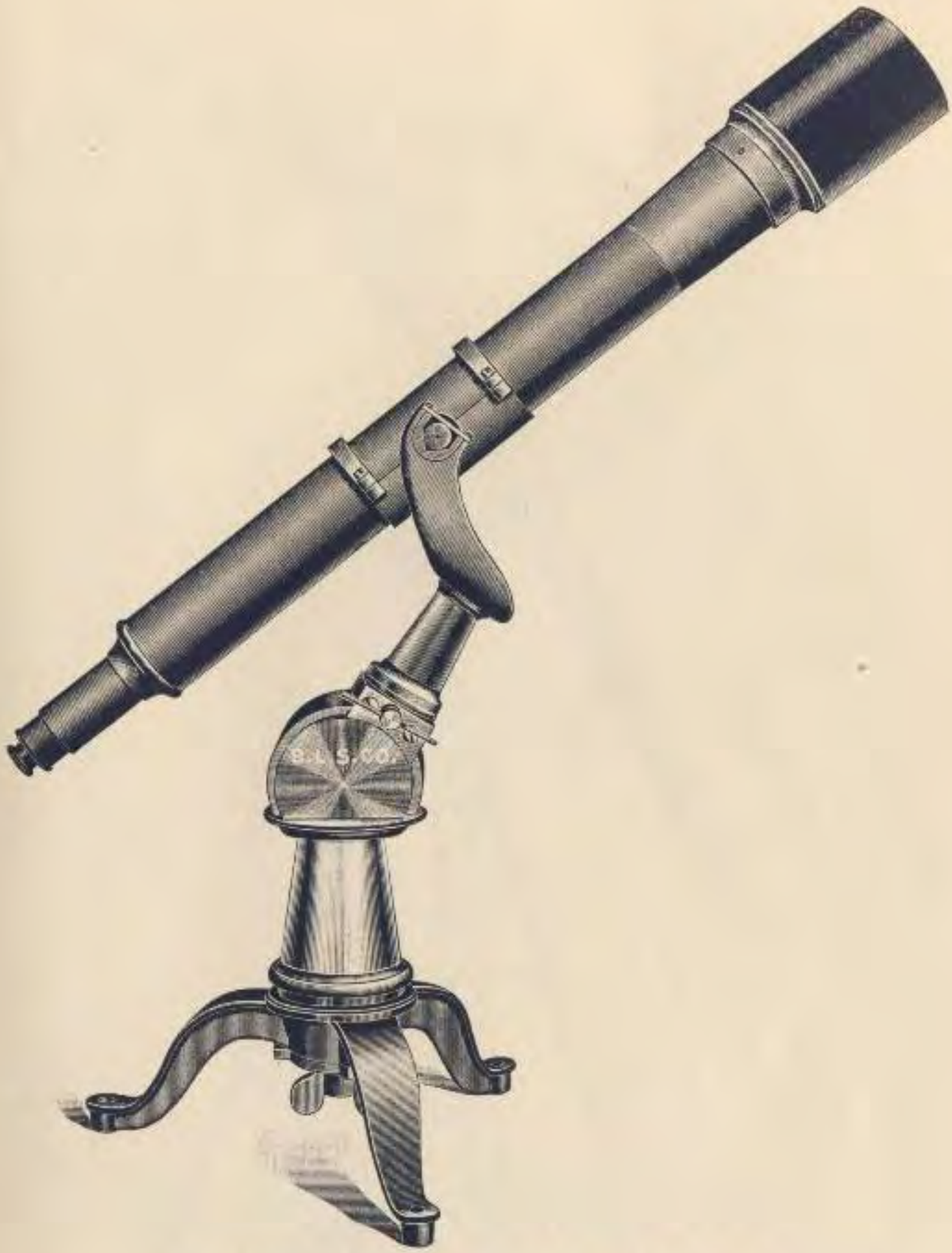
This telescope is to be suspended from the ceiling and has motion in all directions. 2¾ inches aperture, about 12 inches focus. Two magnifications, 12 and 24.

Price, - - - - - - - $125.00

OBSERVATION TELESCOPE, NO. 50

Prismatic type; 2¼ inches aperture; 24 inches focus 2 eyepieces magnifying 24 and 50 diameters.

On universal extension stand, the whole packed in case, $85.00

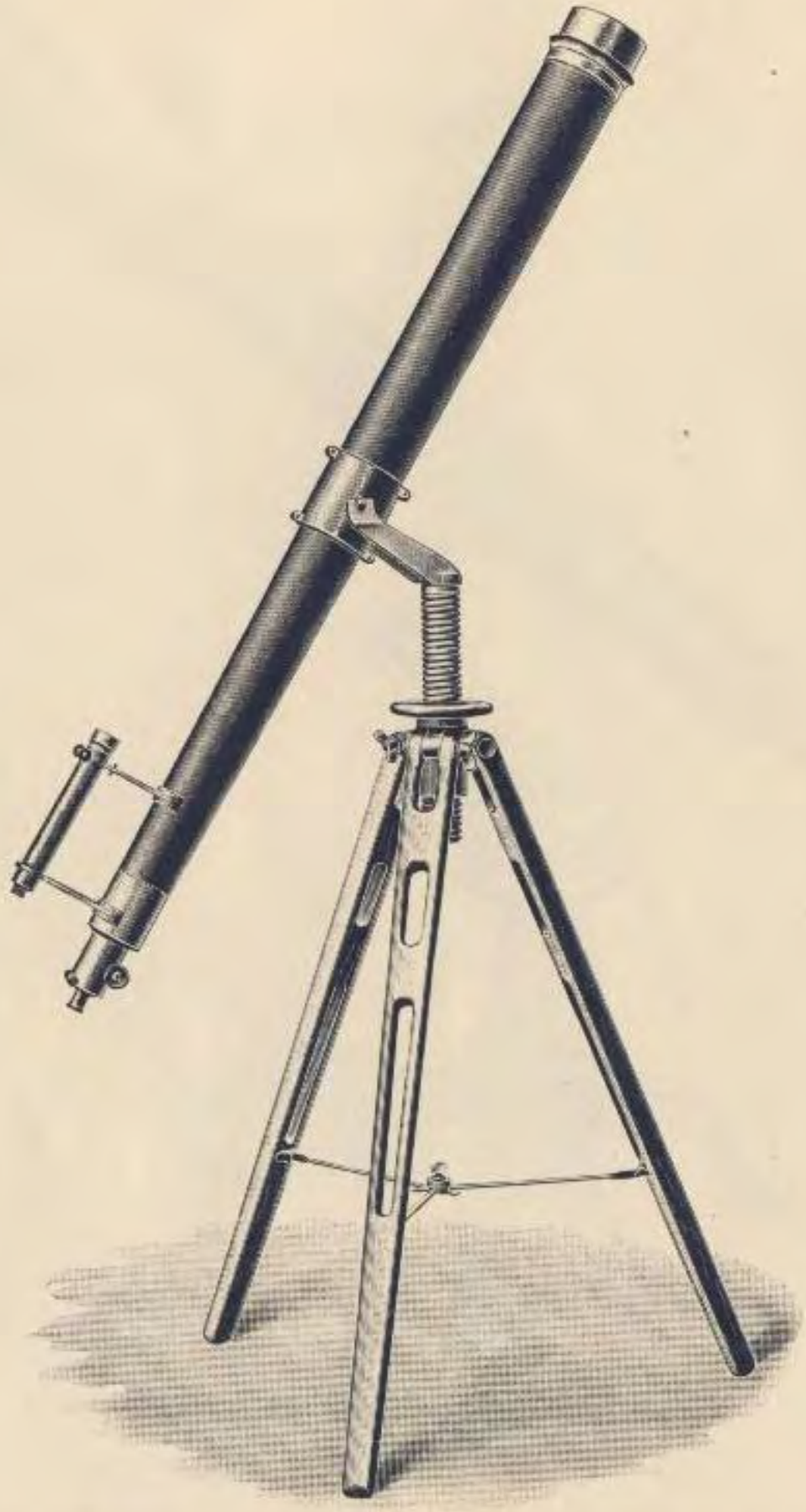


STUDENT'S TELESCOPE, NO. 52

ON COMBINATION STAND

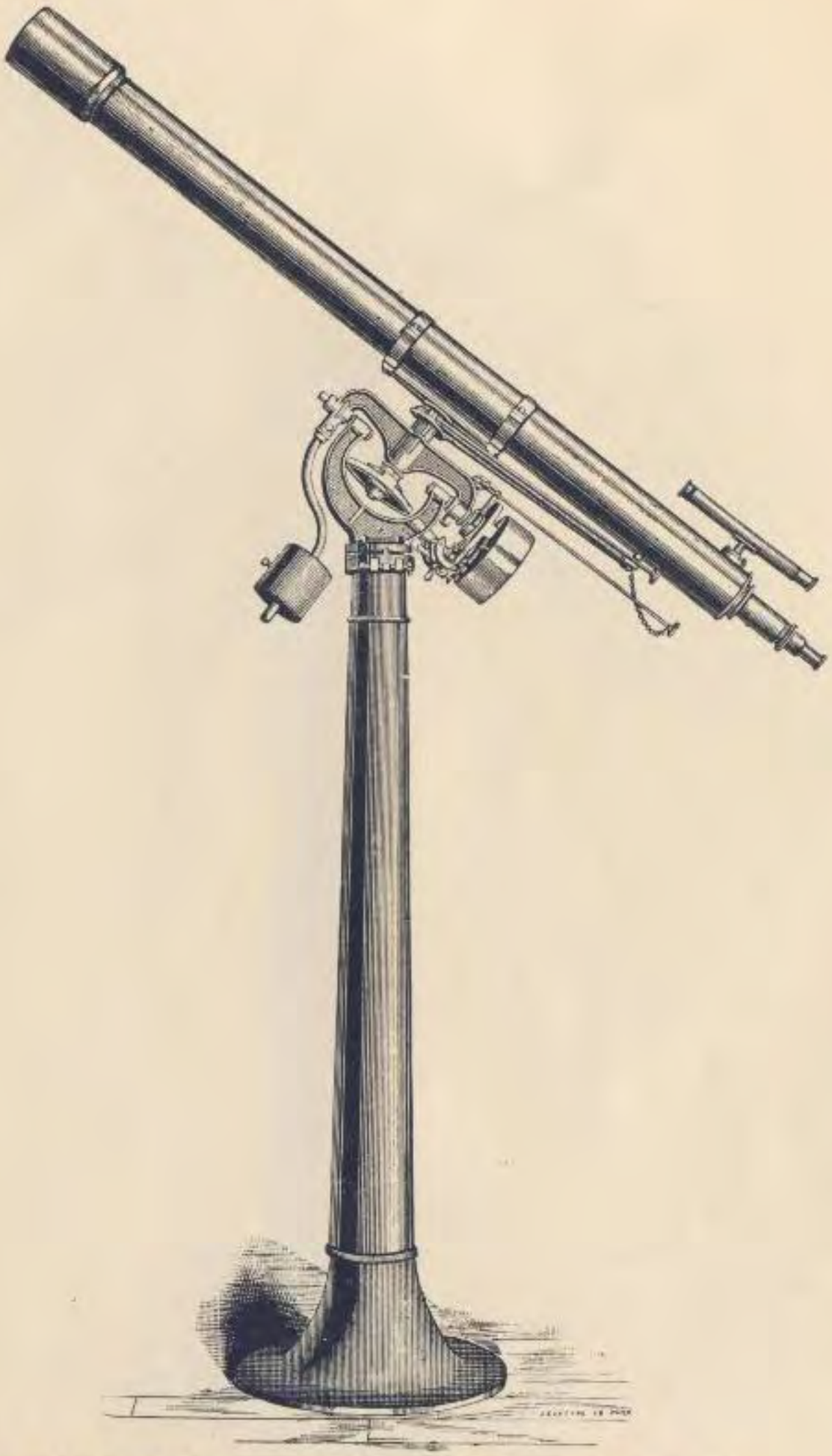
Easily convertible from alt-azimuth into an equatorial. The telescope has a clear aperture of 3 inches; focal length 36 inches; 2 eyepieces magnifying 36 and 72 diameters.

With stand, as shown in above cut, for use on table, packed in case,	$125.00
Additional tripod, for use on ground - - -	15.00



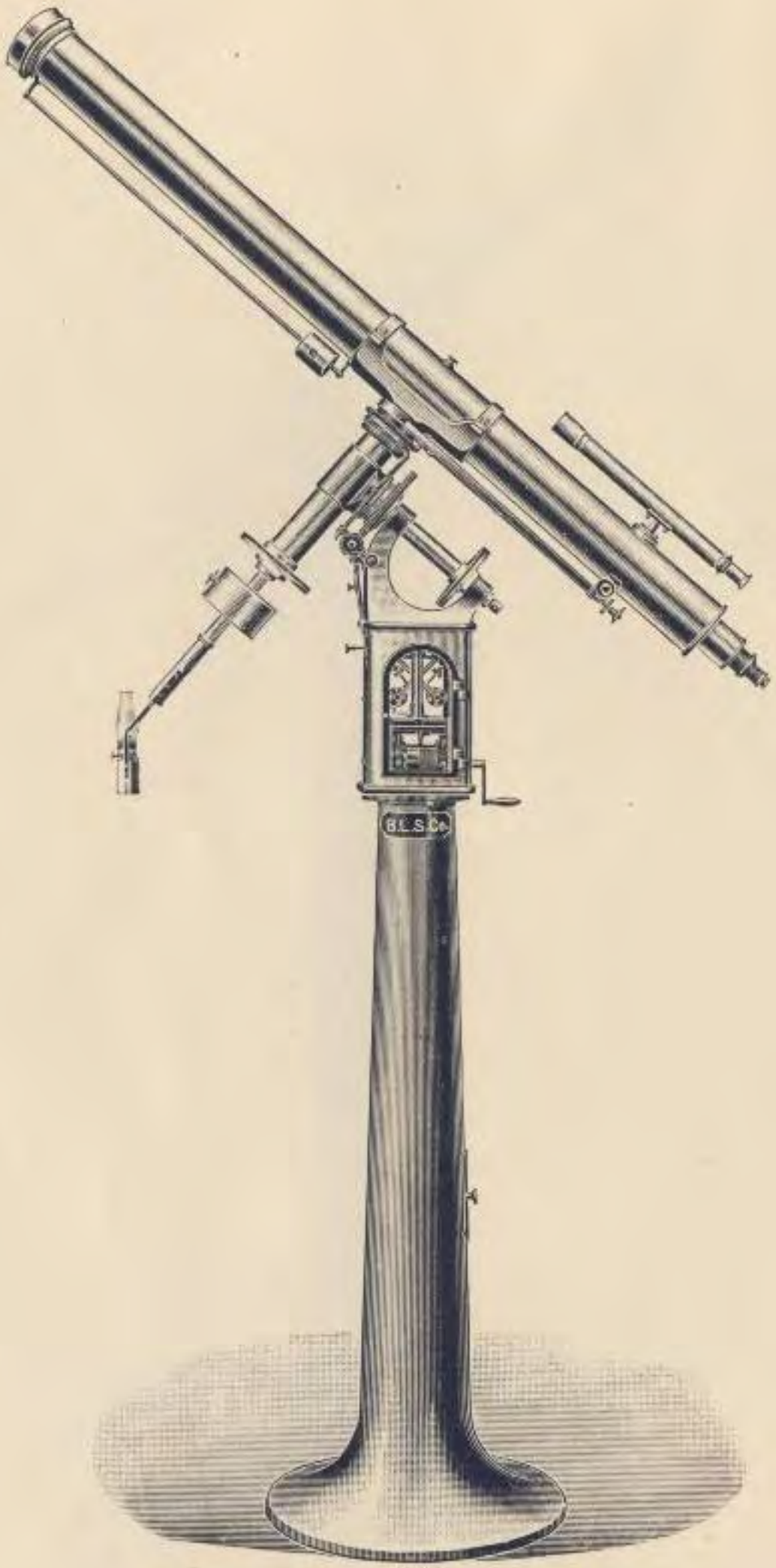
PORTABLE TELESCOPE, NO. 54, ON TRIPOD

For price see page 87



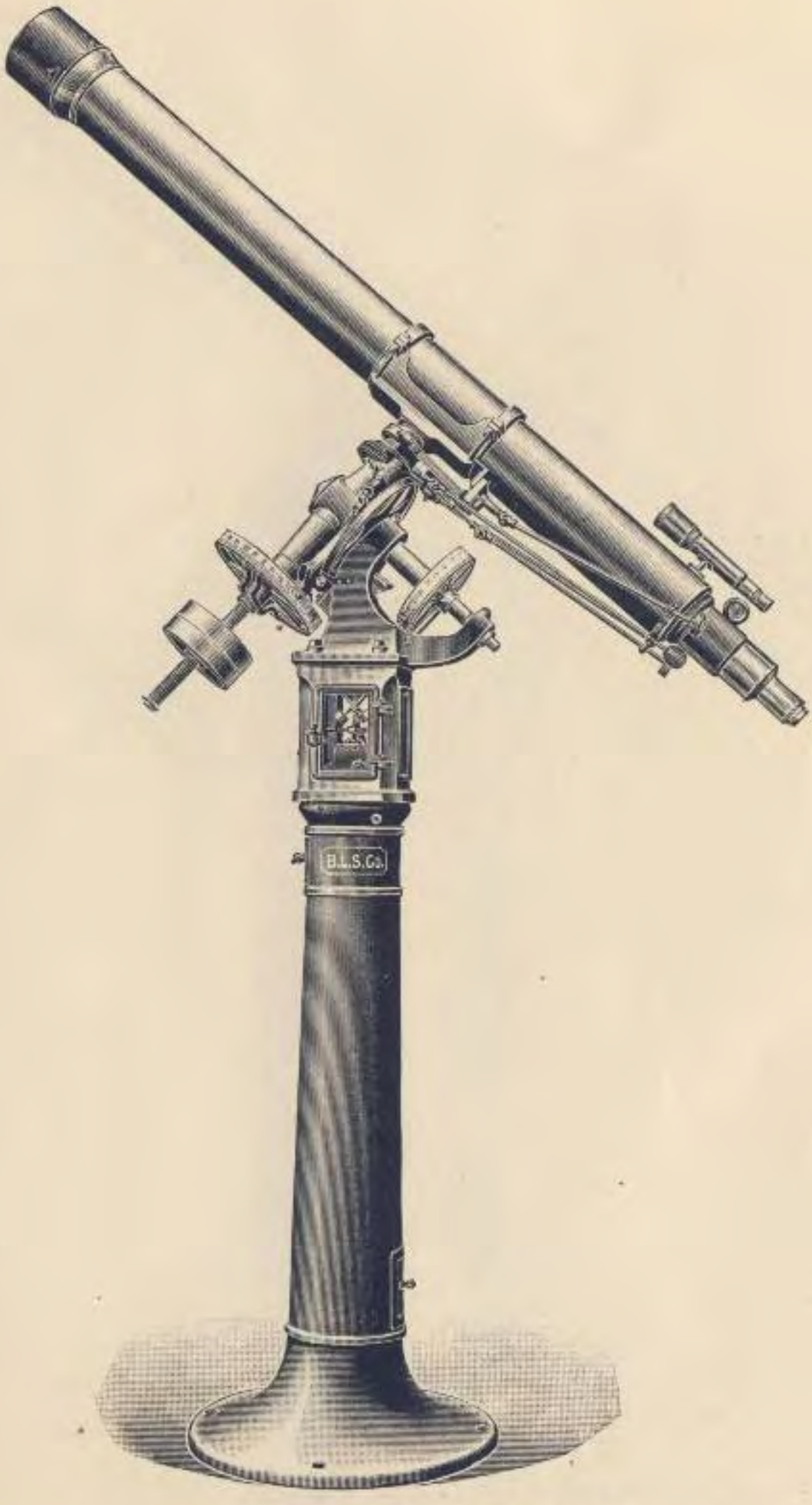
4 & 5 INCH EQUATORIAL TELESCOPE, NO. 56

Price of 4 inch without clockwork - - - $500.00
" 5 " " " - - - - - 600.00

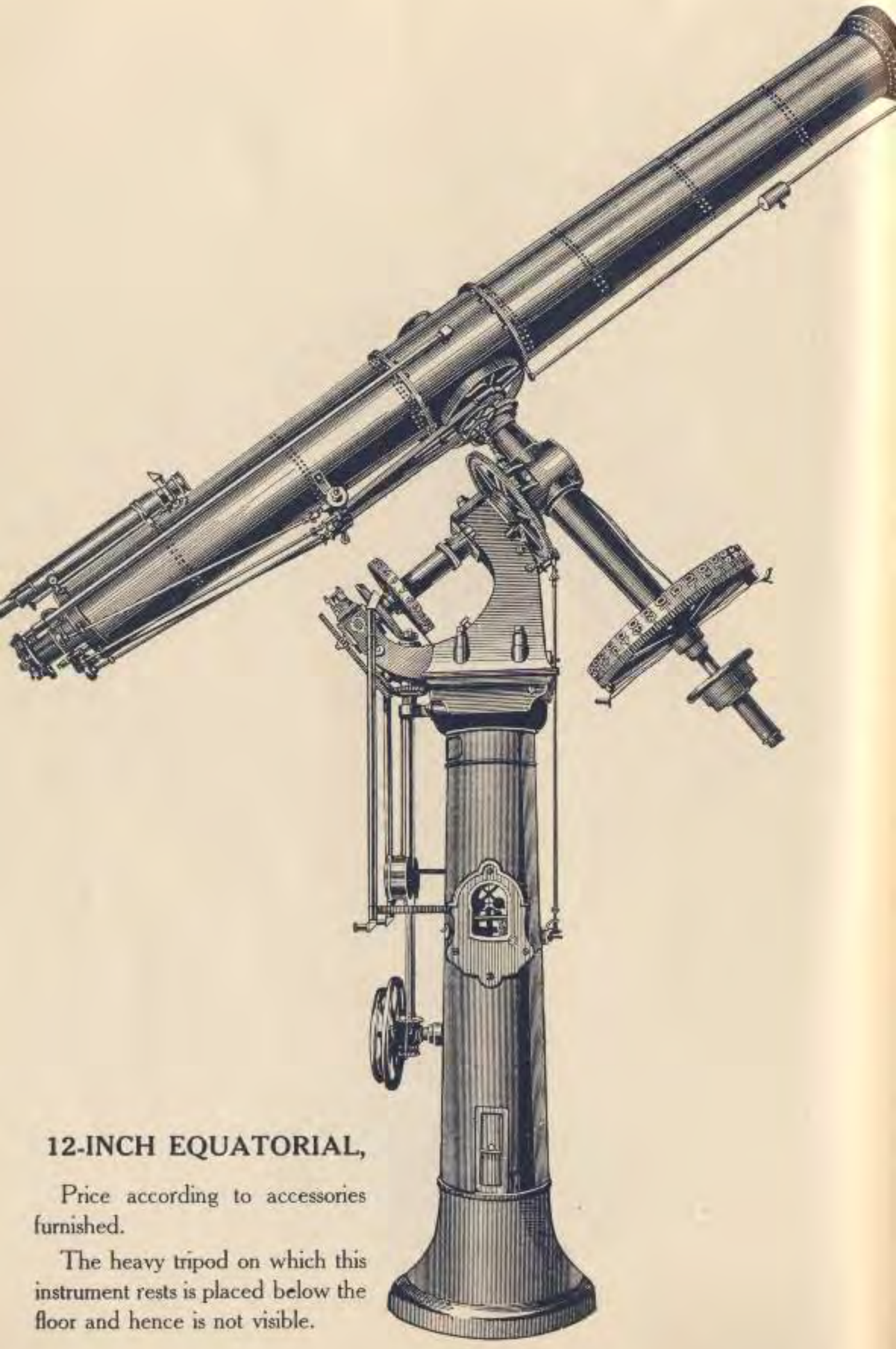


6 & 7 INCH EQUATORIAL

The price of larger sizes equatorials depends on accessories and will be furnished on application.



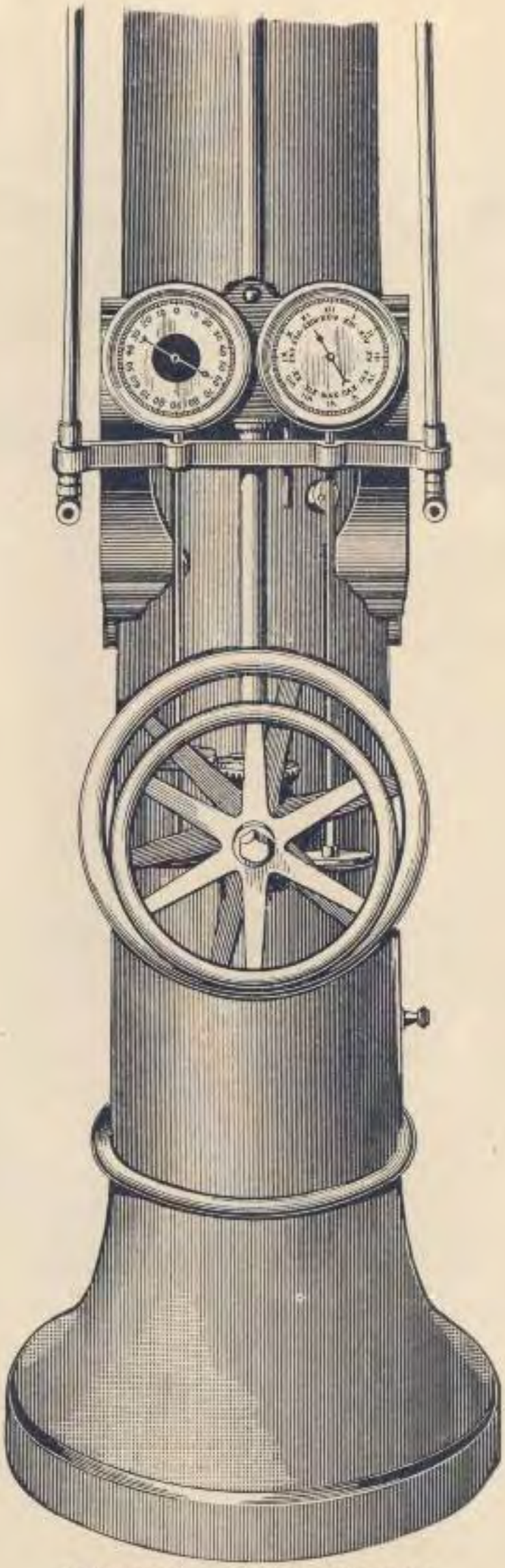
8 & 9 INCH EQUATORIAL



12-INCH EQUATORIAL,

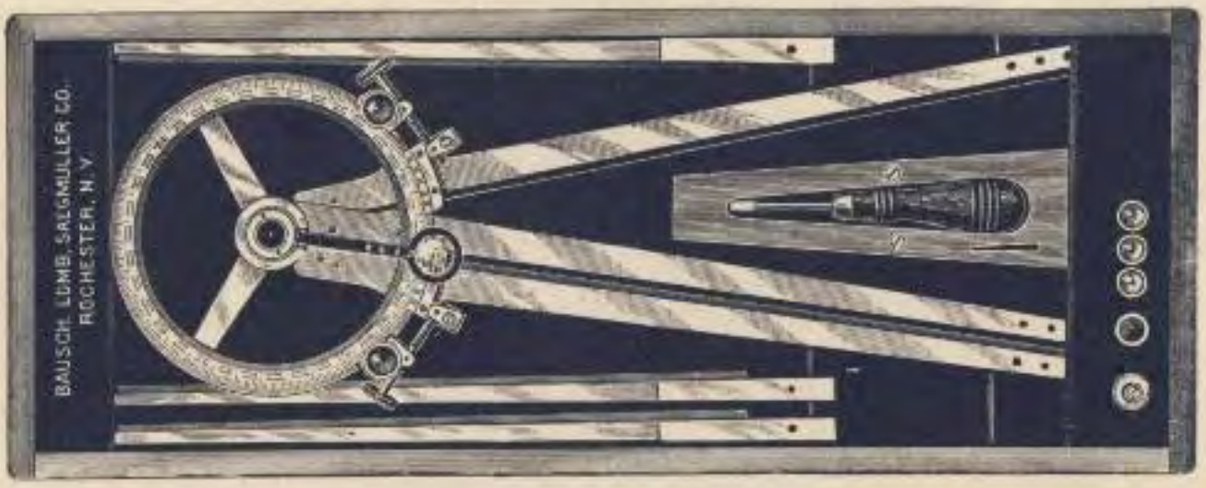
Price according to accessories furnished.

The heavy tripod on which this instrument rests is placed below the floor and hence is not visible.



12-INCH EQUATORIAL

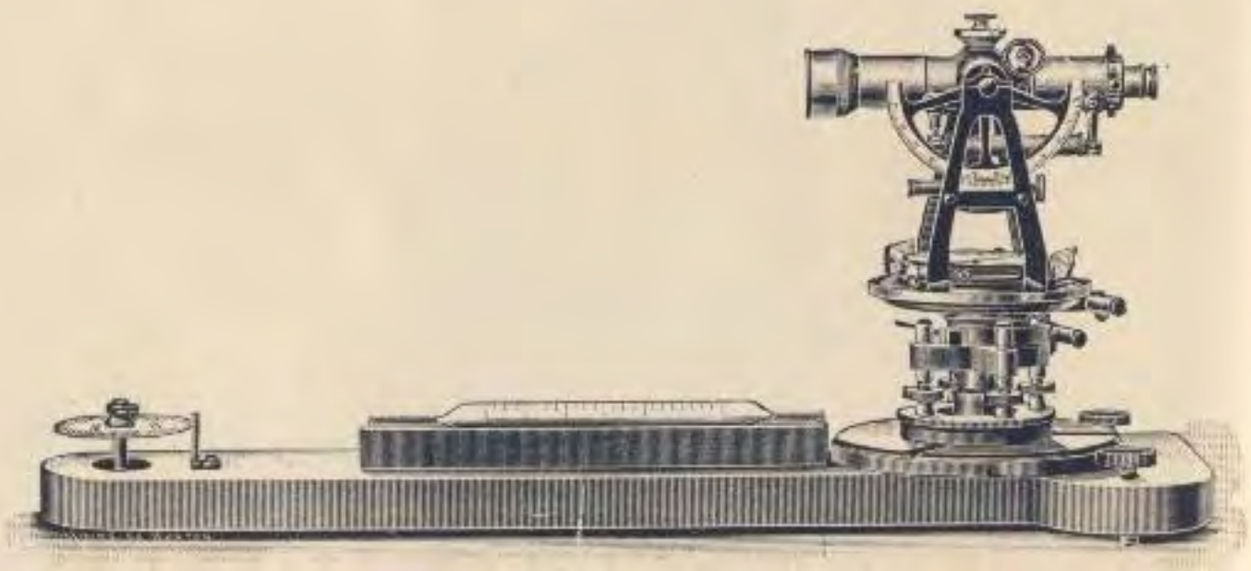
Showing finding circles and stand wheels to turn the instrument R. A. & Decl.



3-ARM PROTRACTOR, NO. 58

Three-arm Protractor, 6-inch circle, divided on silver, extension arms, 30 inches long.

Price, - - - - - - - - - - - - $110.00



UNIVERSAL LEVEL TRIER, NO. 60

24-inch iron base with fine micrometer screw, 1 division equals 1 second.

Price, - - - - - - - - - - - - $35.00

DIAGONAL EYEPIECE, NO. 65

With swivel adapter

For price see page 102

EYEPIECE PRISM NO. 75

Swiveled with sunglass

For price see page 102

SPIRIT LEVEL NO. 80

On 10'' metal base level adjustable, 1 division equals 10 seconds

Price - - - - - - - $20.00

Price list of Portable Telescope, No. 54 (Page 80)

Telescope, with object glass 4 inches in diameter and about 60 inches focal length, fitted in finished brass tube with finder and 4 celestial eyepieces (power of eyepieces from 50 to 200 diameters), Price - $250.00

Telescope, with object glass 5 inches in diameter and about 75 inches focal length, fitted in finished brass tube with finder and 5 celestial eyepieces (power of eyepieces from 75 to 300 diameters), Price - $425.00

Telescope, with object glass 6 inches in diameter and about 90 inches focal length, fitted in finished brass tube with finder and 5 celestial eyepieces (power of eyepieces from 90 to 400 diameters), Price - $650.00

POCKET ANEROID, NO. 101

This pocket aneroid is a portable surveying aneroid, no vernier or magnifier being used. The dial is arranged to show an altitude of 5000 feet in single 5 feet divisions in a repeating circle of divisions. The outside scale is divided to 10 feet, while the scale directly beneath it subdivides it to 5 feet divisions, and by careful reading it is possible to read it even closer. Mounted in a 2½-inch gilt metal case.

Price complete, $50.00

POCKET SIZE ANEROIDS

No. 103—This aneroid is 4½ inches in diameter; gilt case. Outside morocco snap case. Compensated for temperature. It has a silvered metal dial with revolving altitude scale 5000 feet.

Price, - - $21.00

No. 105—Same as above with altitude scale 5,000 feet.

Price, - - $22.20

SURVEYING ANEROID BAROMETER, NO. 120

Special Surveying Aneroid Barometer

Reading to single feet of altitude scale. Compensated for temperature.

This instrument has been designed and constructed specially to ascertain readily slight variations in gradients, levels, etc. Its readings can be easily and rapidly taken. In addition to its extreme sensitiveness the instrument has an arrangement of the scale of altitudes which admits of subdivisions by a vernier. For mining purposes the entire circle of the dial is graduated to represent 6 inches of the mercurial column, i. e., from 27 to 33 inches. This scale will register about 2000 feet below sea level, to 4000 feet above. The divisions of the altitude scale represent 10 feet measurements, which can again be subdivided by the vernier to single feet. The vernier scale is moved by a rackwork adjustment, and a magnifying lens which rotates upon the outer circumference of the instrument facilitates the reading of minute quantities.

In using the surveying aneroid to obtain the difference of level of any two stations or positions, it is only necessary to place it horizontally at one of the two stations, adjust (by means of the rack motion) the zero of the vernier, until it coincides with the point of the indicating hand, and read off the number of feet indicated by the altitude scale and vernier; then remove the instrument to the other station and place in the same position; adjust the zero of vernier as before and the difference of the two readings gives the difference of level.

No. 125—3 inch stout bronzed metal case, silvered metal dial, with vernier scale moved by rackwork motion, reading lens arranged to traverse the entire circle, altitude scale arranged for mining purposes 4000 feet ascent, 2000 descent, in sling leather case - - - - $60.00

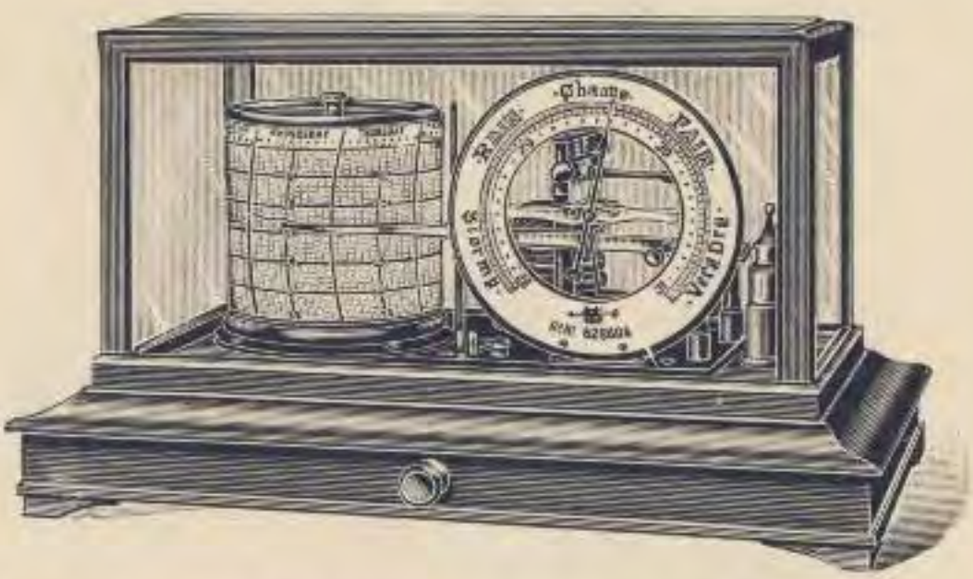
WATCH FORM ANEROID BAROMETER

No. 128 A.--Watch form aneroid silvered metal dial, with revolving altitude scale 8000 feet. 1¾ inches diameter. Gilt or nickeled. In best snap morocco case.

Price - - - - - - - $19.25

RECORDING BAROMETERS (BAROGRAPHS)

8-day Clock

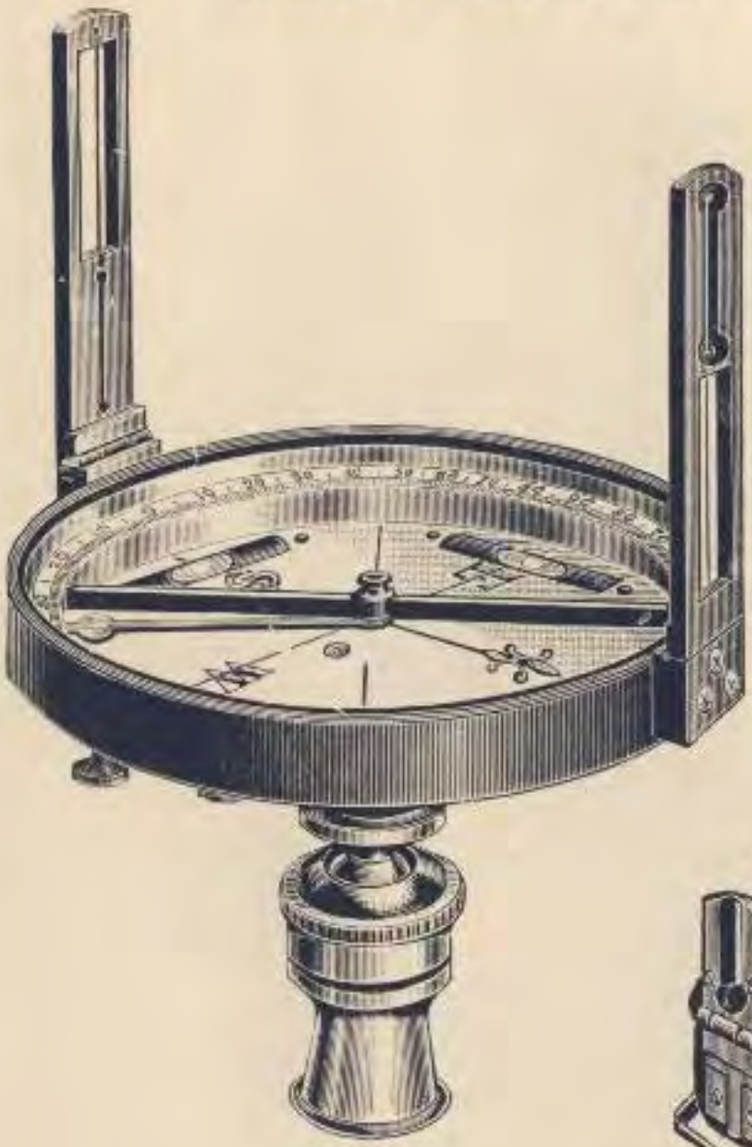


These instruments give a complete record by means of a pen upon a printed chart for an entire week, and by its form the exact barometric reading can be seen at any moment as well as the varying line traced by the pen for the time preceding. The charts also, which are changed at the commencement of each week, can be retained as a record for the entire year. Full descriptions and directions for use, are supplied with each instrument.

No. 130, as illustrated above - - - - - $60.00

No. 135, above instrument without metal dial aneroid attachment $50.00

SURVEYING AND SIGHT COMPASSES



No. 140

Surveying Compass

No. 140—Surveying compass with folding sights on revolving ring, with vernier and scale for magnetic variations, with 3½ inch bar needle, jeweled, ball and socket mounting (Jacob-Staff) complete in mahogany case - $25.00

No. 145

Sight Compass

No. 145—Bronze metal case, sight in lid and folding sight, card dial, bar needle, jeweled

2 inch	2½ inch	3 inch	3½ inch	4 inch
$5.50	6.50	8.00	9.50	11.00

No. 150

Plain Prismatic Compass

No. 150—Card dial, jeweled center, in sling case with azimuth shade and mirrors

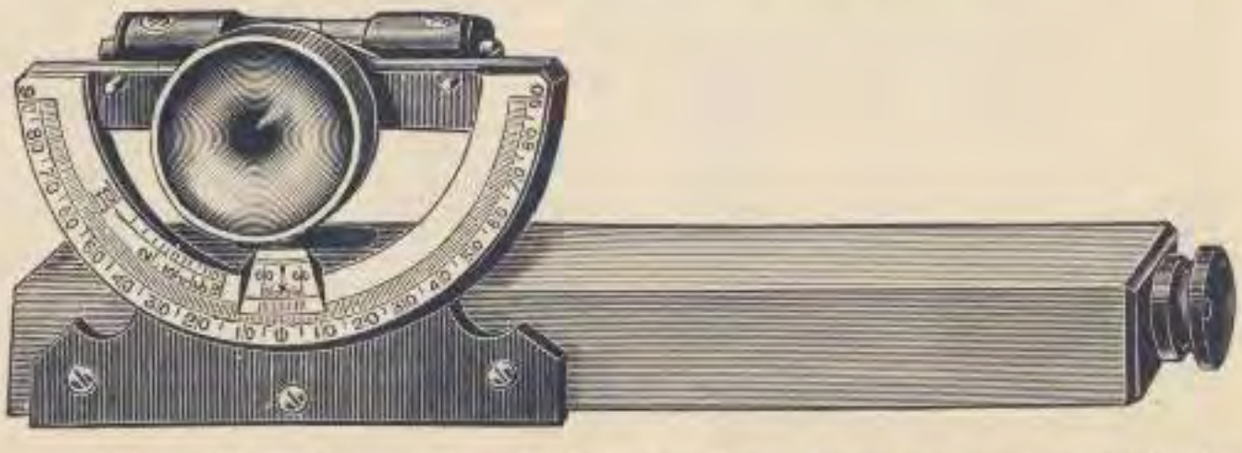
2½ inch	3 inch	3½ inch	4 inch
$23.00	27.00	29.25	31.25

MINER'S COMPASS OR DIPPING NEEDLE

No. 160—In this instrument the magnetic needle is carefully balanced upon a horizontal axis within a graduated circle, and in which the needle will be found to assume a position inclined to the horizon. This angle of deviation is called the inclination or dip, and varies in different latitudes, and even at different times in the same place. When used for tracing ore the observer should hold the ring in his hands and keep the needle north and south, standing with his face to the west. The inclination of the needle as read off on the graduated scale will show the dip. If the compass is held horizontal it serves of course as an ordinary compass.

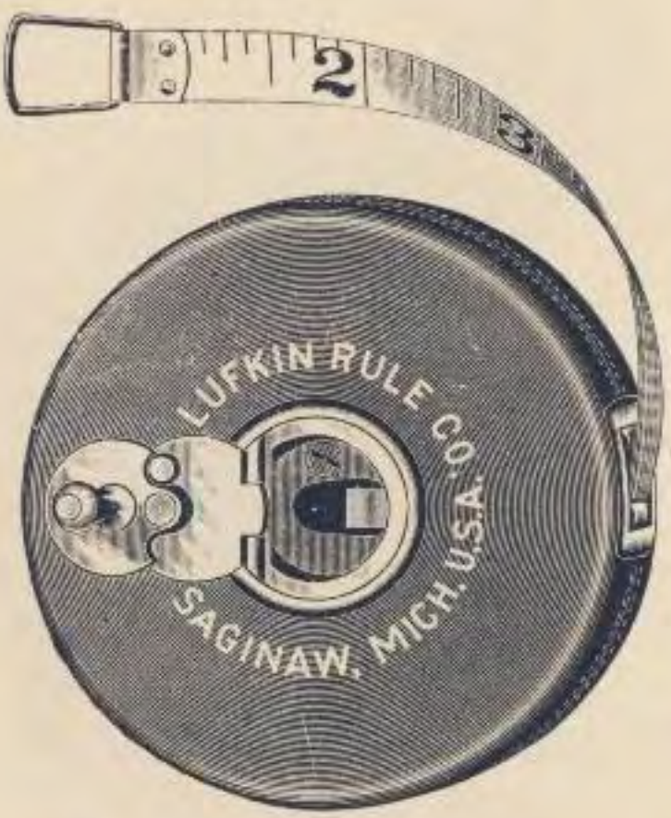
No. 165—3 inch Dip Needle Mining Compass in velvet lined case $12.00

CLINOMETER OR ABNEY'S LEVEL



No. 170—Abney's Level, 5 inches long, large arc pattern with draw telescope, complete in leather case - - - - $17.00

"RELIABLE" STEEL MEASURING TAPES



With double folding flush handle, opened by pressing small pin or button on opposite side. Hard leather cases. Nickeled plated trimmings. Measurements guaranteed to be perfectly accurate.

With ½ inch Tape

Marked feet and 12ths (inches and 8ths.)	Marked feet, 10ths and 100ths of feet, for Surveyor's use.	Length	Diameter of Case.	Each
No. 180	No. 180 D	50 ft.	3¼ in.	$8.10
" 185	" 185 D	100 ft.	4½ in.	14.40

We can supply other sizes of tapes, namely ⅜ inch, ⅝ inch and ¾

' RELIABLE JUNIOR" STEEL MEASURING TAPES

With double folding flush handle, opened by pressing small pin or button on opposite side. Hard leather cases. Nickel plated trimmings. Measurements guaranteed perfectly accurate.

With ¼ inch Tapes

Marked feet and 12ths (inches and 16ths.)	Marked feet, 10ths and 100ths of feet, for Surveyor's use.	Length	Diameter of Case.	Each
No. 190	No. 190 D	50 ft.	2¾ in.	$4.50
" 195	" 195 D	66 ft.	3 in.	5.25

Tapes marked feet on one side, metric measure on the other, add 2 cents per foot to list price.

"RELIABLE" FRAME STEEL TAPES

Nickel plated brass frames and trimmings and patent double folding flush handle, opened by pressing small pin or button on opposite side. Marked either in 10ths or 12ths and links on back.

With ½ inch Steel Tapes

Marked feet and 12ths (inches and 8ths)	Marked feet, 10ths and 100ths of feet, for Surveyor's use	Length	Each
No. 200	No. 200 D	50 ft.	$7.50
" 205	" 205 D	100 ft.	13.50

Tapes marked feet on one side, metric measure on the other, add 2 cents per foot to list price.

ENGINEER'S PATTERN STEEL TAPES

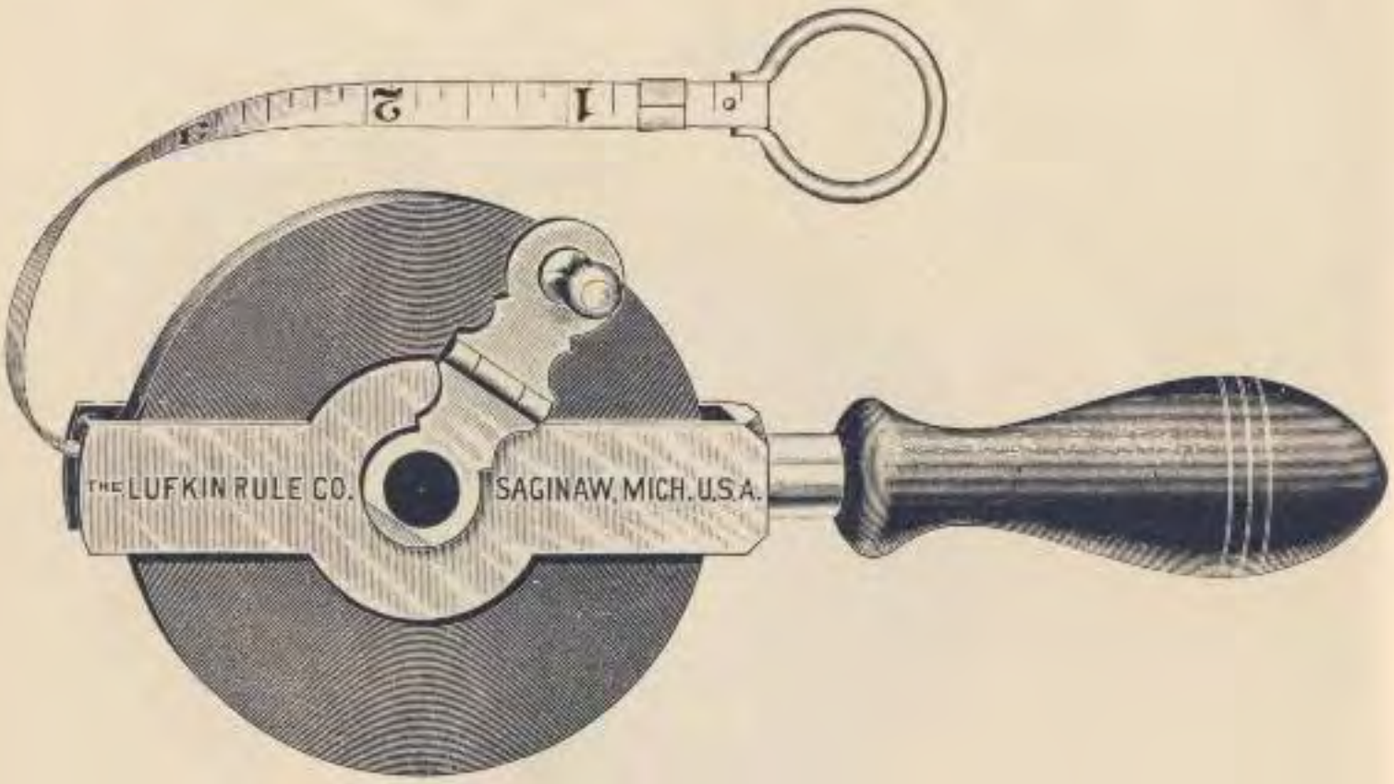
LEATHER CASES

With ¼ inch Heavy Tapes

Hard leather steel lined cases, nickel plated trimmings, two detachable rings. The tape can be readily detached from the case, and we furnish an extra ring for the other end. The steel is heavier and stronger than used in the regular steel tapes, and the cases are thinner. Marked on one side in tenths or twelfths.

Marked feet and 12ths, (inches and 8ths)	Marked feet, 10ths and 100ths of feet, for Surveyor's use	Length	Diameter of Case	Each
No. 210	No. 210 D	33 ft.	3½ in.	$5.00
" 212	" 212 D	50 ft.	4¼ in.	6.00
" 214	" 214 D	66 ft.	4¾ in.	8.00
" 216	" 216 D	100 ft.	5¼ in.	12.00

ENGINEER'S PATTERN FRAME STEEL TAPES



With ¼ inch Heavy Tapes

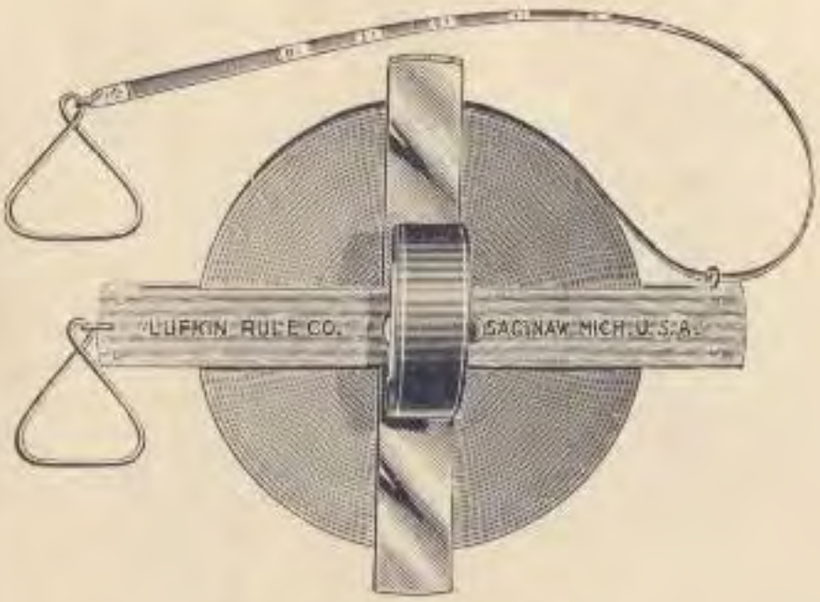
Two detachable rings. Folding winding handle. The tape can be readily detached from the frame when not in use and we furnish an extra ring for the other end.

Marked on one side in 10ths or 12ths.

Marked feet and 12ths (inches and 8ths)	Marked feet 10ths and 100ths of feet for Surveyor's use	Length	Each
No. 220	No. 220 D	50 ft.	$5.25
No. 222	No. 222 D	100 ft.	9.00

Tapes marked feet on one side, metric measure on the other, add two cents per foot to list price.

SURVEYOR'S CHAIN TAPES



Tape complete, with Reel

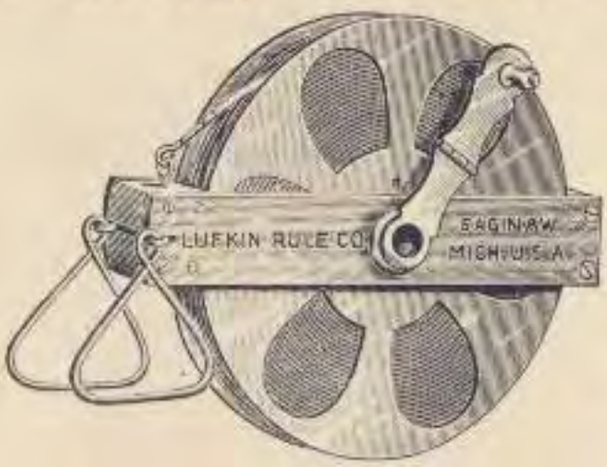
Reel only, when folded

With heavy ¼ inch steel tapes. Hardwood reel with steel cross-arms. The tape can easily be detached from the frame. *These reels are especially desirable for the longer tapes.*

Tapes complete, with Reel

No. 230	100 ft.	Each	$7.50	No. 234	300 ft.	Each	$14.00
" 232	200 ft.	"	10.50	" 236	500 ft.	"	21.50

SURVEYOR'S CHAIN TAPES



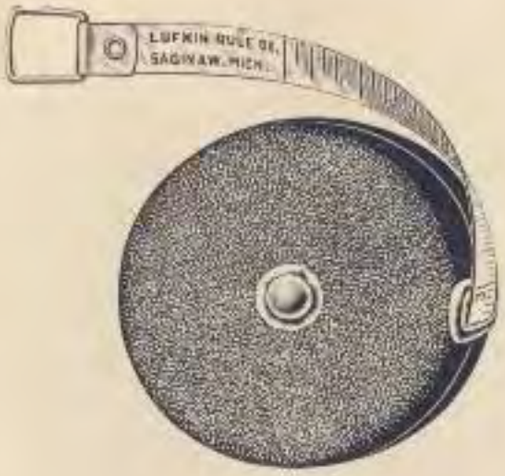
Tape complete, with Reel

With heavy ⅛ inch steel tapes, hardwood frame with substantial sheet steel open reel. Large metal folding winding handle and two large detachable rings.

No. 240	100 ft.	Each	$7.50	No. 244	300 ft.	Each	$14.00
" 242	200 ft.	"	10.50	" 246	500 ft.	"	21.50

The graduations on the chain tapes illustrated above are made by giving the steel a bright raised surface with the figures etched in. This makes them always show up clear and distinct.

POCKET TAPES IN LEATHER CASES



With ¼ inch Steel Tapes

The cases for these tapes are made of metal lined leather of the very best quality. They are spring wind with center stop and all trimmings are silver plated.

No. 250, — 60 inches, 1½ meter, inches and 16ths one side, millimeters on other.

Each, - - - - - - - $1.75

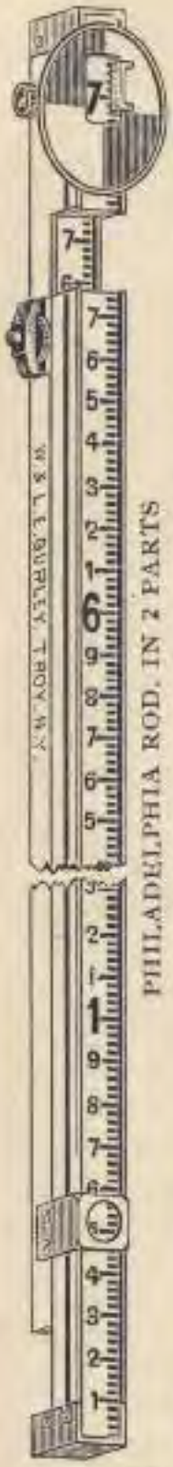
TAPE STRETCHING APPARATUS

During the past few years we have made tapes and tape stretching apparatus as used in the U. S. Coast and Geodetic Survey. There can be no question about the superiority of measuring a base line by means of tapes as compared with the laborious method of measuring it with base bars. But there is no need of the elaborate apparatus used to stretch the tape to therequired tension. We find that by driving an ordinary crossbar firmly into the ground and slipping the spring scale over it, the required tension can be easily obtained.

We recommend this method as quite as efficient as the former. We can furnish the tapes any required length (and the spring scales and thermometer), tested by the Bureau of Standards, the price being dependent upon the length and the accuracy required in the comparison.

LEVELING RODS

The Philadelphia Rod



No. 260.—This rod is made in two parts, each about ¾ inch thick by 1½ inches wide and 7 3/10 feet long, the parts connected by two metal sleeves, the upper one of which has a clamp screw for fastening the two parts together when the rod is raised for a higher reading than 7 feet.

The front piece reads from the bottom upward to 7 feet, the foot figures being red and the 10th figures black. When the rod is extended to full length the front surface of the rear half reads from 7 to 13 feet, and the whole front of the rod is figured continuously and becomes a self-reading rod, 13 feet long, reading to 100ths of a foot.

The back surface of the rear half is figured from 7 to 13 feet, reading from the top down; it has also a vernier scale by which the rod is read to 1000ths of a foot as it is extended. The target is round, made of brass raised on the perimeter to increase its strength, and is painted in white and red quadrants; it has also a vernier scale on its chamfered edge, reading to 1000ths of a foot.

Price, - - - $14.00

The Boston Rod

No. 265.—This rod is formed of two pieces, each about 6 feet long, sliding easily by each other in either direction.

One side is furnished with a clamping piece and screw, with a small vernier at each end; on each side is an inlaid strip upon which graduations of feet, 10ths and 100ths are marked and figured.

The target is a disk of brass, painted red and white and having its middle line just 3/10ths of a foot from the end of the rod.

Each 10th graduation is figured decimally in three figures, or to 100ths of a foot, and by the verniers is read to 1000ths.

The target being fixed, when any height is taken above 6 feet, the rod is changed end for end and the graduations read by the other vernier, the height to which the rod can be extended being a little over 11 feet.

Price, - - - - $14.00

The New York Rod

No. 270—This rod is made in two parts, the pieces sliding one from the other, the same end being always held on the ground, and the graduations starting from that point.

The graduations are made to 10ths and 100ths of a foot, the 10th figures being black, and the feet marked with a large red figure.

The front surface, on which the target moves, reads to 6½ feet on the two part rods. When a greater height is required, the horizontal line of the target is fixed at the highest graduation, and the upper half of the rod carrying the target is moved out of the lower, the reading being now obtained by a vernier on the graduated side, up to an elevation of 12 feet.

The face of the target is graduated into quadrants by horizontal and vertical diameters, the quadrants being painted alternately white and red, or white and black.

The opening in the face of the target is nearly $\frac{2}{10}$ths of a foot long, so that in any position a figure noting a 10th of a foot can be seen on the surface of the rod.

The right edge of the opening is chamfered, and graduated into 10 equal spaces corresponding with $\frac{9}{100}$ths on the rod. The graduations start from the horizontal line which separates the colors of the face.

The vernier, like that on the side of the rod, reads to 1000ths of a foot. The rod is fitted with an improved clamp.

Price - - - $14.00

The New York Rod
In 3 Parts

No. 275—In this rod, as shown, a third piece is added, giving a rod of greater length, and at the same time making it more compact and portable.

The graduations, verniers, and readings are the same as those of the rod in two parts.

The three-part rod allows a reading of 12½ feet, and when closed is 5 feet long.

Price - - - - $18.00

The Telescopic Rod

TELESCOPIC ROD

No. 280—This rod is made so that the two smaller upper parts slide out of a larger and lower part which answers as a case. When closed the rod is 5 feet long, and it extends to 14 feet. It is graduated on a recessed face to feet, 10ths and 100ths, the graduations being painted and figured like those of the Philadelphia rod.

Price - - - $22.00

Wood and Iron Flagstaffs

We supply three sizes of the common wood flagstaffs, or ranging-poles, octagonal in form, tapering from the bottom to the top, 6, 8, and 10 feet long, and having steel shoes. (See cut No. 285)

We also supply a convenient ranging-pole consisting of an iron tube $^{11}/_{16}$ inch in diameter, hung in gimbals so that it can be readily set over a given point. (See cut No. 290) Similar iron poles are made without gimbals, 6, 8 and 10 feet fong.

These staffs are graduated to feet, and painted alternately red and white.

They are also graduated metrically, when desired, 5 spaces to each meter.

No. 285.	Wood staff, 6 ft. long, with metal shoe, -	$2.00
No. 286.	" " 8 " " " " " -	2.25
No. 287.	" " 10 " " " " " -	2.50
No. 290.	Ranging-pole, 6 ft. long, $^{11}/_{16}$ in. diameter, hung in gimbals, - - -	4.00
No. 291.	Iron Ranging-pole, 6 ft. long, $^{3}/_{16}$ inch diameter, without gimbals, - - -	2.75
No. 292.	Iron Ranging-pole, 8 ft. long, $^{3}/_{16}$ inch diameter, without gimbals, - - -	3.00
No. 293.	Iron Ranging-pole, 10 ft. long, $^{3}/_{16}$ inch diameter, without gimbals, - - -	3.50

We also supply wood ranging-poles, round, 6 and 9 feet long, and with screw joints at each 3 feet. Prices, $4.50 and $7.50 respectively.

No. 285 No. 290

EYEPIECES

Positive Eyepieces

Ramsden — (See fig. 1, page 17)

¼ inch to	¾ inch equivalent, each	- - - -	-	$5.50
1 " "	1½ " " "	- - -	-	6.00
1¾ " "	2¼ " " "	- - -	-	7.00

Kellner (achromatic)

⅓ inch to	¾ inch equivalent, each	- - - -	-	7.50
1 " "	¾ " " "	- - -	-	8.00
1¼ " "	¾ " " "	- - - -	-	9.50
1½ " "	¾ " " "	- - -	-	12.00

Steinheil (achromatic)

⅓ inch to	¾ inch equivalent, each	- - - -	-	10.00
1 " "	¾ " " "	- - -	-	12.50

Orthoscopic — (See fig. 2, page 17)

⅓ inch to	¾ inch equivalent, each	- - - -	-	10.00
1 " "	¾ " " "	- - -	-	12.50

Negative Eyepieces

Huyghens — (See fig. 3, page 17)

¼ inch to 1	inch equivalent, each	- - - -	-	5.50
1¼ " "	1½ " " "	- - -	-	6.00

Airy (giving a large and perfectly flat field)

¼ inch to	½ inch equivalent, each	- - - -	-	7.00
	¾ " " "	- - -	-	8.00
	1 " " "	- - - -	-	9.50
	1¼ " " "	- - -	-	10;50
	1½ " " "	- - - -	-	12.50
	2 " " "	- - -	-	17.00

Terrestrial or Inverting Eyepieces for Direct Vision

Fraunhofer — (See fig. 4, page 18)

¼ inch to	½ inch equivalent, each	- - - -	-	9.50
¾ " "	½ " " "	- - -	-	10.00
1 " "	½ " " "	- - - -	-	12.00
1½ " "	2 " " "	- - -	-	18.00

Above with achromatic reversing lens (See fig. 5, page 18) $2.00 extra.

Diagonal Terrestrial Eyepieces

(No. 65, page 87)

½ inch to	¾ inch equivalent, each	- - - -	-	18.00
1 " "	1½ " " "	- - -	-	20.00
Swivel adapters for the above		- - - -	-	3.00

Eyepiece Prism

No. 75 (See page 87), swiveled with sunglass	- -	6.50

Reflecting Prisms

First surface-reflecting prisms (solar)	- - - -	-	15.00
⅜ inch square, mounted with sunshade	- - -	-	10.50
½ " " " " "	- - - -	-	12.00
¾ " " " " "	- - -	-	15.00
1 " " " " "	- - - -	-	20.00

POCKET MAGNIFYING GLASSES

Rubber Mounting

No. 102 S

No. 103 S

The mountings are of vulcanized rubber and the lenses are accurately ground and polished.

The two lenses may be combined to give three different magnifications and the three lenses five.

TWO LENSES			THREE LENSES		
CATALOG No.	DIAMETER Inches	PRICE	CATALOG No.	DIAMETER Inches	PRICE
102 S	5/8, 3/4	$.35	103 S	1/4, 5/8, 3/4	$.50
111 S	3/4, 7/8	.40	112 S	5/8, 3/4, 7/8	.60
120 S	7/8, 1	.50	121 S	3/4, 7/8, 1	.75

Nickeled Mounting

These mountings are of metal nickel plated. The lenses are well ground and polished.

No. 103 NKS

CATALOG No.	DIAMETER Inches	PRICE
103 NKS	3/4, 3/4, 3/4	$.85
112 NKS	1, 1, 1	1.00
121 NKS	1 1/4, 1 1/4, 1 1/4	1.20

Coddington Magnifiers

The Coddington is a cylinder of glass with spherically cut end surfaces, and has a groove equally distant from its ends which acts as a diaphragm, reducing aberration and giving clear definition. The field is somewhat limited but higher powers can be used than in simpler lenses.

CATALOG No.	DIAMETER Inches	FOCUS Inches	PRICE
160 S	1/2	1/2	$1.50
161 S	5/8	3/4	1.50
162 S	3/4	1	1.50
163 S	1	1 1/2	1.75

Nos. 160-163 S

Triple Aplantas

These lenses are thoroughly achromatic, being composed of two flint lenses between which a crown lens is cemented. They give very clear, flat images with large field free from distortion and chromatic aberration. The mounting is nickeled German silver.

Nos. 164-168 S

CATALOG No.	MAGNIFICATION Diameters	FOCUS Inches	FOCUS Mm.	PRICE
165 S	20	1/2	13	$3.50
166 S	14	3/4	18	3.50
167 S	10	1	25	3.50

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