examples of its use. Figs. 109 and 110 will sufficiently explain it for the purpose of this notice. Fig. 109 is a plan of the instrument, as seen from above, and Fig. 110 a lateral view of the telescope and vertical circle.

Combes calls the instrument a mine-theodolite; and it is a theodolite in a common, wide sense of the word. But the telescope has the characteristic that distinguishes the transit from the theodolite; namely, the capacity of completely revolving in a vertical plane. The telescope, however, is supported on only one side, just as it is in the astronomical mural circle, first devised by Maskelyne and used at the Greenwich Observatory in 1811; and just as it had been in the *lunette murale*, and again in the yet older mural quadrant, first described (of course, with sights instead of the telescope) by Ptolemy* about A.D. 150, and constructed, avowedly on his model, by Nasir-eddin in Persia in 1260, but formerly supposed to have been invented by Tycho Brahe about 1581. Since the telescope supported on only one side tends by its weight and wear to sag downward, so as not to revolve in a truly vertical plane, it is now discountenanced, especially for observing, not a vertical angle, but the transit of a star across the meridian; and preference is given to the astronomical transit-telescope, which is supported on both sides, and has, moreover, an axle capable of reversion, end for end,—the invention of Roemer in 1700.

History of Solar Surveying Instruments.

BY J. B. DAVIS, CLEVELAND, OHIO.

(Canadian Meeting, August, 1900.)

THIS paper has been prepared at the suggestion of Mr. Dunbar D. Scott, to supplement his "Evolution of Mine-Surveying Instruments."†

Before entering into a detailed history of solar instruments, a few remarks will be made touching upon land-surveys in general, and on what has led to the development of these instruments.

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* *Tycho Brahe*, by J. L. E. Dreyer, Ph.D., Director of the Armagh Observatory; Edinburgh, 1890; p. 320.

† *Trans.*, xxviii., 679.

IMPORTANCE OF SOLAR SURVEYING.

The True Meridian Needful.—First of all, there is strong reason for the opinion that *all* land-surveys should be referred to the true meridian.

Description by courses and distances is found in most deeds conveying real estate, and in records perpetuating the results of surveys. There are two noteworthy exceptions: namely, in cities and villages, conveyances of land are often made by lot-numbers; and the United States government describes the land granted by its patents by reference to its general rectangular system of public land-surveys, without special rehearsal of the courses and distances bounding each grant. Outside of these exceptions, the description by courses and distances is perhaps the most simple and comprehensive available method; at all events, long custom has decreed its employment.

Survey-lines are usually marked or monumented; but the marks are not always suitably clear and prominent, and duly recorded in the conveyance. Moreover, they may be lost or destroyed through carelessness and ignorance of their value; and, sooner or later, the lines must be retraced by a new survey—with what difficulty, when the original courses were taken by needle, only the surveyor knows. All that he can do is to turn for help to the facts of possession, or to adjacent surveys; or, if an original corner can be found as a starting-point, to satisfy himself, as to courses, with the limit of error in a needle-instrument, while, as to distances, he must determine, as nearly as may be, the difference in length between his steel tape and the worn and kinky Gunter's chain of the former survey. These perplexing problems we must continue to encounter until more accurate modern surveys shall have replaced the original ones.

The remarks apply also to the rectangular system of surveying United States lands, so far as the relocation of sub-divisional lines may be affected by the uncertainty of the indications of the magnetic needle.

But I wish to call particular attention to what may be termed an inconsistency in our modern land-surveys. Increased accuracy in them is demanded by the increase of land-values. Hence, measurements are more accurately made; a transit is used; and more care is taken in monumenting; so that the surveys may be retraced with little difficulty, provided monuments enough are left for starting-points. At the same time, custom having prescribed the method of description, we still use courses, determined not by the needle, as originally, but by deducing the bearings from the transit-angles taken; and we use as a base the bearing of some one line, either measured in the field or copied from a deed. Right here comes in the inconsistency: we care nothing whether the bearing of the line we start from be a true one or not. We are well satisfied if it be only approximately true; we rely on the harmony of our survey, the fact that we have set monuments, have taken the angles with a transit, and have made our measurements carefully; and we assume that there can be no future difficulty in retracing the survey we have made. But the bearings of the lines in this modern and accurate survey, taken individually, mean absolutely nothing so far as the retracing of an accurate survey is concerned; only collectively are they of any value.

If we are to make an accurate survey, and are by custom forced to the use of bearings in our descriptions, why not have the bearings mean something, and be consistent with the rest of the survey? But that is not all: monuments are lost, and the cases are not infrequent when only one can be found; and then trouble begins, and care and good judgment are required in the solution of the problem. Evidently, the remedy is to refer the survey to the true meridian. This can be done by observing the north star, or an altitude of the sun, or by a solar instrument. Only by a reference to the true meridian can the "one stone problem" be at all times satisfactorily solved.

Old Methods of Meridian Determination.—The earliest instrumental methods of determining the true meridian in this country, as well as in Europe, were, first, by observing the polar star, taking into account its travel in an orbit the distance of which from the projected axis of the earth is known; secondly, by an altitude-observation of the sun and the subsequent calculation of the spherical triangle of which the sun, the zenith and the pole are at the vertices.

Surveyors do not take very kindly to observing the north star, and will resort to it only when absolutely necessary, because they object to the requisite night-work. The method of determining the azimuth by an altitude of the sun does not seem to be popular, since it requires too much time for the calculation of the spherical triangle.

Davis's Solar Screen.—It is appropriate here to mention the solar screen invented by Prof. J. B. Davis, of the University of Michigan, Ann Arbor, Mich., and perfected by the firm of Buff & Berger, Boston, Mass. It has been illustrated and described by Mr Scott,* Fig. 59. The invention does not belong in the same class as the mechanical solars to be described below; for it is not, strictly speaking, a solar attachment, but rather an appliance for more conveniently sighting the sun centrally in a direct solar observation. The use of the solar screen does not reduce the necessary computation, so far as the solving of the spherical triangle is concerned; for this work must still be done after the altitude of the sun is observed.

HISTORICAL SKETCH OF SOLAR SURVEYING-INSTRUMENTS.

As the theory and practice of solar work are now fully treated in all standard text-books on surveying, their full discussion is not deemed desirable here, and in what follows, a sufficient knowledge of astronomy in its application to solar work is presupposed.

Government Land-Surveys.—On May 7, 1784, the committee appointed by the Continental Congress, of which Thomas Jefferson was chairman, recommended that all public lands be divided into squares ten geographical miles on a side, and these sub-divided into lots of one square mile; but a subsequent amendment, made April 26, 1785, in which is recorded the first mention of "townships" and "sections," required that the main divisions should be only seven miles square, marked by lines running *due north and south*, and others crossing at right-angles. This ordinance, as still further amended, May 20, 1785, with a provision for townships containing thirty-six sections each, must be regarded as the actual beginning of our present government system of land-surveys; and General Rufus Putnam must be looked upon as its founder.†

Burt's Solar Compass.—In 1833 Wm. A. Burt, of Mt. Vernon, Mich., received an appointment as U. S. Deputy Surveyor, and

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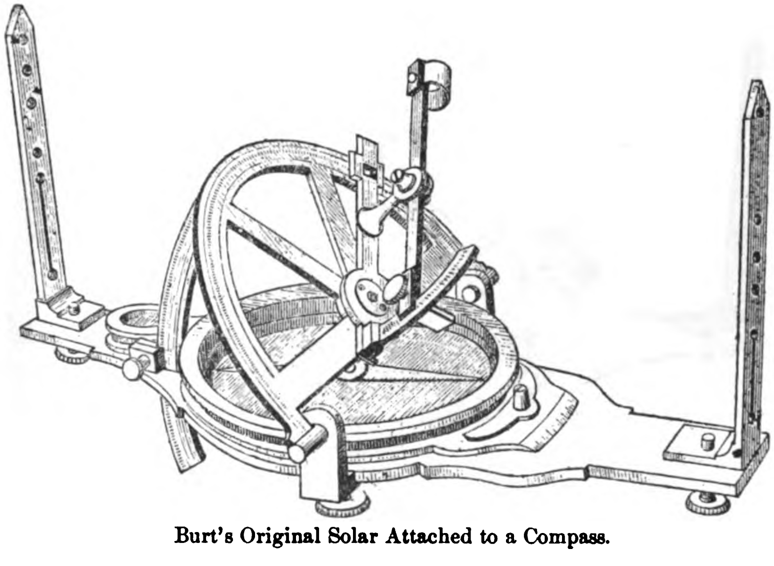
* *Trans.*, xxviii., 743.

† See the article by Col. H. C. Moore in the *Jour. Ass'n Engineering Societies*, vol. ii., p. 282.

began work with an ordinary compass-instrument, as prescribed by the government. He found frequent occasion to reprove his chainmen, believing them to be guilty of gross inaccuracies. It turned out that the chainmen were correct enough in their work, and that the trouble was due to the treacheries of the magnetic needle. Mr. Burt satisfied himself that he could not sufficiently rely upon the accuracy of the indications of the needle; and he must also have concluded that the methods of determining the meridian by sighting Polaris or observing the sun's altitude were not practicable in the class of surveys upon which he was engaged. At all events, he began systematical work in developing a mechanical solar. By 1835 he was in Philadelphia, placing the model of his device in the hands of instrument-maker Wm. J. Young; and in the same year his completed instrument received the Scott medal from the Franklin Institute. That instrument, shown in Fig. 111,* was designed to solve mechanically the celestial triangle, and consisted mainly of three arcs—the latitude-arc, the declination-arc, and the hour-circle.

Fig. 111.



Burt's Original Solar Attached to a Compass.

Burt's solar compass did not attain perfection until about

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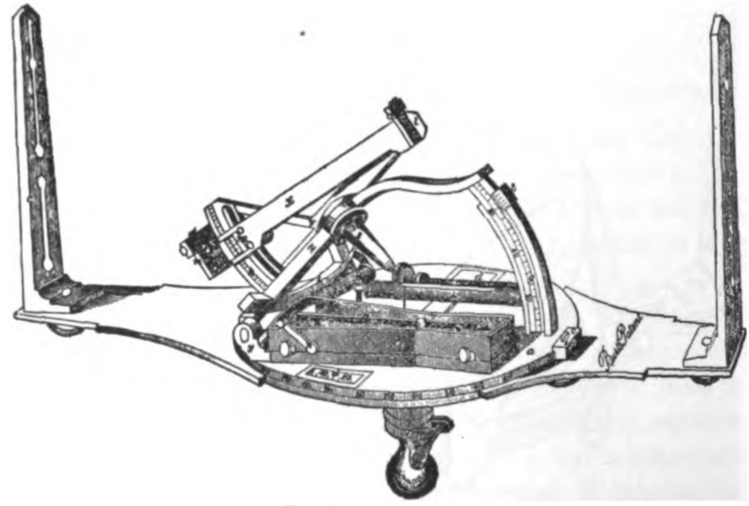
* The figures of this paper are numbered consecutively with those of the Discussion of Mr. Scott's paper, *ante*, p. 783.

1850. It then came into general use, and was for many years the standard instrument used in surveys of the United States public lands. He exhibited the perfected instrument (Fig. 112) at the London Exhibition of 1851; and Sir John Herschel then said: "I have long understood the elements of your instrument, but could not see how they would be carried out mechanically. It has fallen to your lot, Sir, not only to conceive the necessary astronomical elements, but also to carry them into practical effect mechanically." The same instrument was a part of the government exhibit at the Columbian Exposition in Chicago, and has now been added to the instrumental collection prepared for Paris. It is probably not too much to say that with Burt's solar, or some adaptation of it, fully 80 per cent. of the public lands of the United States have been laid out. The opinions of authorities on solar work in connection with government surveys would indicate that Prof. Baker's broad statement, quoted by Mr. Scott,* is without warrant and misleading.

FIG. 112.



Burt's Improved Solar.

Yeiser's Meridian Instrument.—In 1861 Frederic Yeiser, of Danville, Ky., introduced a meridian-instrument, Fig. 113, the operation of which was founded on the ancient method of

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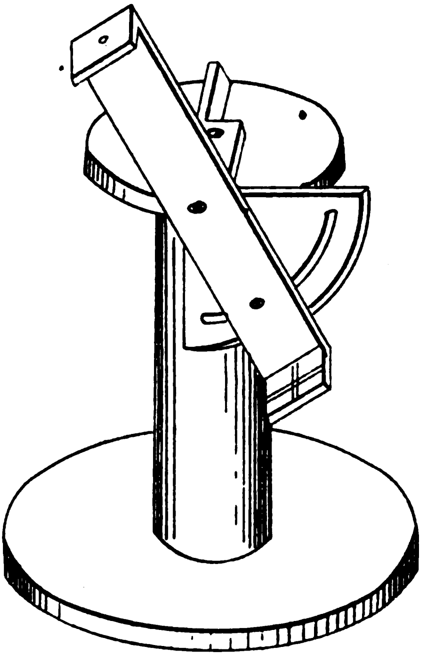
* *Trans.*, xxviii., 721.

bisecting the arc found by the observation of equal altitudes of the sun. Two parallel disks were connected by a vertical pillar. On the face of the upper plate revolved a sort of alidade beveled along one edge at one end, and carrying at the other end the lens-bar of the Burt solar. An observation was made at a certain hour in the morning, and the lens-bar was clamped to the vertical quadrant. In the afternoon, at a corresponding hour, the upper part of the instrument was moved about on the central pivot until the sun's image fell at the intersection of the "equatorial" and "hour" lines. Having drawn a pencil-line along the beveled edge of the alidade at each observation, the line that bisected the intervening space or arc was accepted as the meridian.

FIG. 113.



Yeiser's Meridian Instrument.

Schmoltz's Solar Transit.—The next modification of the Burt solar has been referred to by Mr. Scott* as having been introduced in 1867, when the transit was coming into more general

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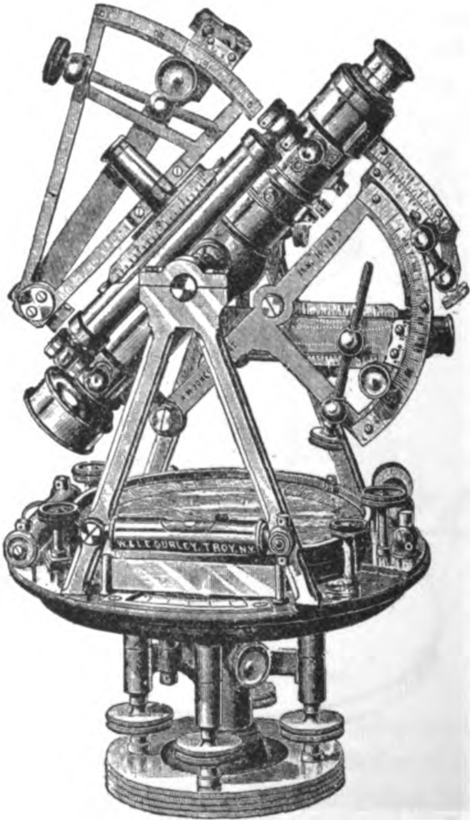
* *Trans.*, xxviii., 721.

use, by Wm. Schmoltz, an instrument-maker of San Francisco. Since 1874 it has been mounted by Gurley, as in Schmoltz's model, upon the transverse axis of the transit-telescope, but with a means of adjusting the polar axis to movement in a truly vertical plane (see Fig. 38*). It is essentially the Burt declination-arc mounted upon its polar axis, which is now reversed from its position in Burt's compass, and may be secured to the telescope, or removed, by means of the thumb-screw at the top of the polar axis. It was customary to lay off the latitude on the transit's vertical circle or arc; but in the Schmoltz-Gurley model, reproduced in Fig. 114, the patent latitude-arc introduced by R. M. Jones in 1883 is used instead.

Fig. 114.



Schmoltz-Gurley Solar Transit, with Jones's Latitude-Arc.

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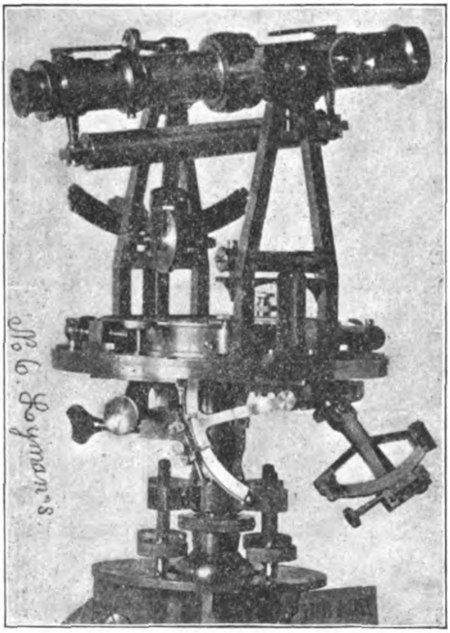
[*] *Trans.*, xxviii., 720.

This arc consists of an inner quadrant reading to minutes, and an outer segment reading to ten seconds of arc. The inner quadrant carries a reversible bubble-tube, which is adjusted for exact horizontality when the sun is in the meridian; and in all subsequent settings of the latitude the bubble is simply brought back to the center of its scale. This design of Schmoltz was one of the first, if not the very first, of the successful attempts to combine the solar attachment with the ordinary transit-instrument; though there had been a great deal of experimenting to improve on Burt's last model, in which a small telescope was mounted upon one of the sights, or set in Y-bearings across the top of both sights.

FIG. 115.



Lyman's Solar Transit.

Lyman's Solar Transit.—In 1869 Benjamin S. Lyman, of Philadelphia, devised the solar apparatus shown in Fig. 115. Wm. J. Young & Co. (that is, Mr. Young and his partner, Charles S. Heller) had strongly advised him against placing the solar apparatus on the top of the telescope, and against using inclined standards for the telescope. The apparatus was, therefore, placed beneath the plates, for steadiness and protection against exposure; and was so designed that it could be used with a plane-table or other surveying instrument. The usual six-inch lens-bar was reduced in length to only two inches; but the proper focus and size of the sun's image was maintained by the total reflection of two rectangular prisms. Mr. Lyman filed a caveat of his invention in September, 1869, had the same description privately printed as specifications in December, 1870,* secured letters-patent in 1871, and the first instrument was made in 1872.

> "It is true," says Mr. Lyman, "that, owing to the greater length of the lens-bar in Burt's compass, the latitude-arc has a decidedly longer radius and the declination-arc one slightly longer; but the radius of both arcs in the solar transit is two inches and a half, or the same as for the vertical and horizontal graduations of the transit proper, the size that is usually found convenient for reading to a single minute with a vernier."

When the vernier of the latitude arc reads 90°, the polar axis is truly vertical. The entire attachment weighs about a pound. In 1877 Young & Sons so constructed it that it could be attached and detached at pleasure.

Seibert's Solar Transit.—About 1869 (but it is not now possible to determine the exact year) F. R. Seibert, then with the U. S. Coast Survey, had Wm. J. Young & Co. make for him a transit with inclined standards, and place the solar apparatus directly over the compass, very much as in the original Burt instrument. The standards were inclined forward, so as not to cast a shadow, or otherwise interfere with the successful manipulation of the solar apparatus. It was to this instrument (Fig. 116) that Mr. Scott assigned† the probable origin of the inclined-standard mine-transit; but from Mr. A. C. Young's contribution it appears that inclined standards were used as early as 1854 in Mr. Roberts's instrument.‡ Still, it is possible that the inclined standards made for him were inclined toward each other, forming a truss-support for the telescope.

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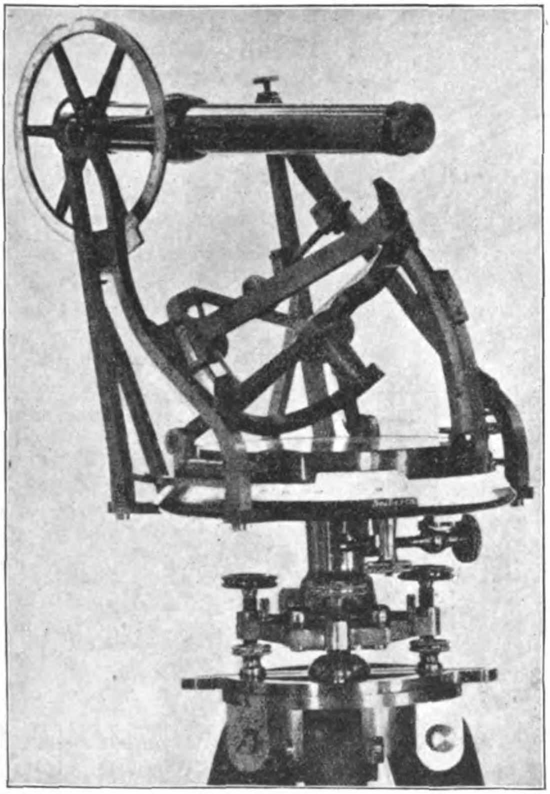
* *Specifications of Improvements in Solar Compasses.* B. S. Lyman. Bengal Printing Co., Calcutta, 1870. The specifications and caveat mention the former use of inclined standards, undoubtedly Seibert's plan, showing that it dates at least as far back as 1869.

† *Trans.*, xxviii., 725.

‡ *Ante*, p. 789.

Pearsons's Solar Attachment.—On July 27, 1875, Harrison C. Pearsons, of Ferrysburg, Mich., patented an attachment (Fig. 117), having the polar axis parallel to the optical axis of the telescope, and the hour-circle at right angles to it. As usual, the declination-plate revolved upon the polar axis; but the lens-bar was provided with a vernier as well as a lens and equatorial lines at *each* end, and was mounted upon gimbals or a universal joint, whereby it could be brought at will to the surface of either broad face of the declination-plate. Also, the declination-plate was graduated on both its broad faces, so that it was possible to reverse the apparatus, in order to correct errors arising from unavoidable imperfection of construction and adjustment. It was the inventor's idea, as expressed in his letters

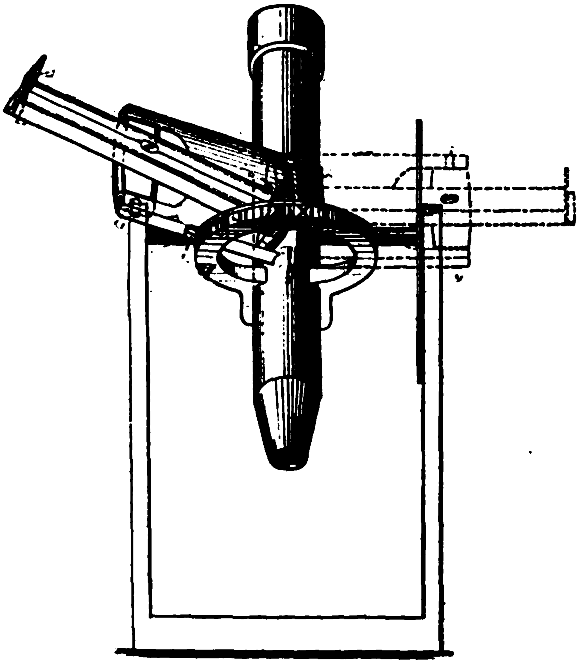
FIG. 116.



Seibert's Solar Transit.

patent, to utilize the telescope itself as the axis of the hour-arc; and this, to the best of my knowledge, is the first suggestion of letting the telescope of the transit-instrument become the polar axis. The manufacture of the attachment was first placed in the hands of the Gurleys, but the alliance between the manufacturers and the inventor was not a successful one.

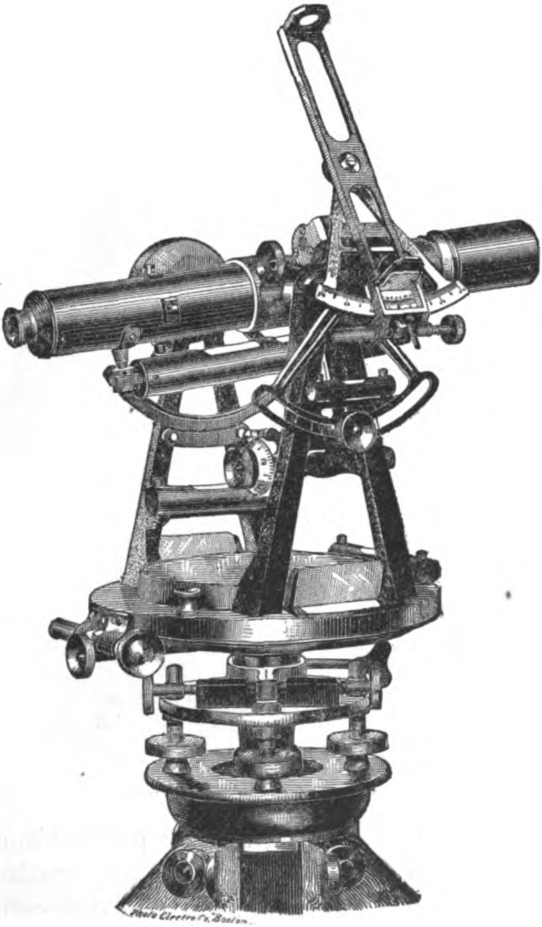
FIG. 117.



Pearsons's Original Attachment.

Buff & Berger's Pearsons Solar Attachment.—As first made by Buff & Berger, in 1878 (Fig. 118), the polar axis, while still parallel to the optical axis of the telescope, was placed over the bearings at one side, and was provided with a spirit-level on the "clamping-arc," to regulate it for true horizontality before elevation to the observer's latitude. This was especially desirable, as it was a part of the improvement to make it possible to attach or detach the whole apparatus as desired. After the latitude was set off, and the "clamping-arc" carrying the solar was clamped to the standard, the telescope was free to move in altitude without interfering with the position of the attachment. The lens-bar was made single, instead of double, with a ground-glass focal plate, so that the sun's image could be observed from the rear with the ordinary reading-glass. But in 1879 Mr. Berger began substituting for it a small telescope of half-inch aperture and six-inch focus.

FIG. 118.

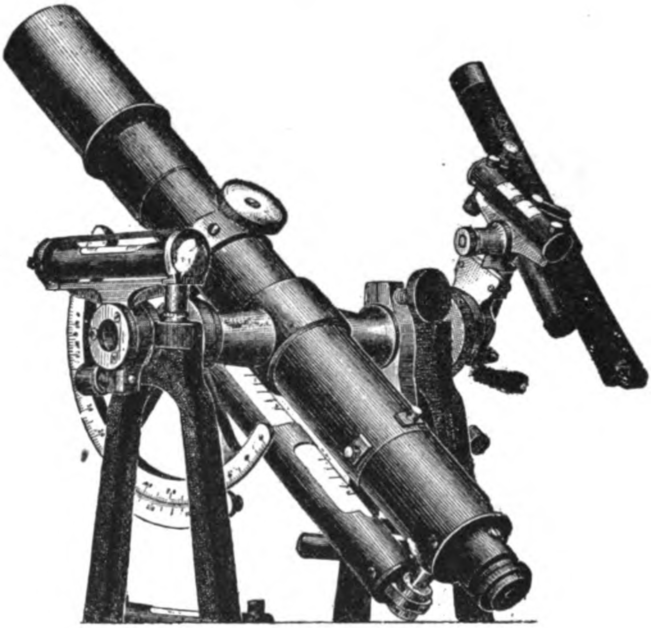


Buff & Berger's Pearsons Solar.

Buff & Berger's Solar Attachment.—In 1882 the Pearsons patents were assigned to Buff & Berger; and in 1885 the general design was changed so that the declination, as well as the latitude, could be laid off by the vertical circle. Fig. 119 shows this last-mentioned model. The attachment is fastened by a screw to an extension of one end of the transverse axis of the telescope, and to the other end is clamped the latitude-level.

Holmes's Solar Theodolite.—In 1878 J. W. Holmes, instrument-maker in Batavia, N. Y., placed the telescope of a theodolite so as to work upon the declination-arc, or circle, in a very remarkable manner (Fig. 120). Between the standards, in the usual position of a telescope in an ordinary transit, he placed, in a plane at right angles to the vertical, a second circle, called the "dial-plate," graduated to read minutes. Within this ring revolved, upon what might be termed the polar axis, a disk that, together with the "dial-plate," was also journaled at right-angles in the axis of the vertical arc. The disk carried the telescope on Y-bearings centered over the plates below; and upon the disk was fastened the declination-arc at one side of the telescope. The telescope was pivoted to the declination-arc by means of the Y-bearing nearest the ocular and could be moved in altitude at the objective end as required, and regulated to the nearest ten seconds of arc. Mr. Holmes's instructions for the use of the instrument are:

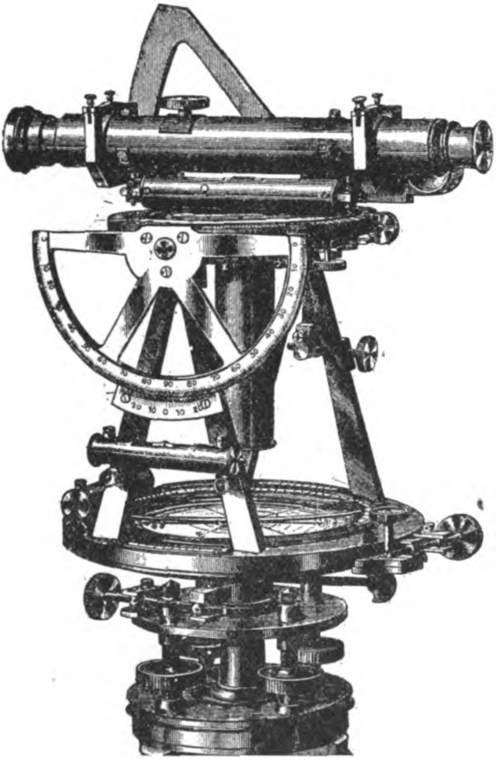
Fig. 119.



Buff & Berger's Solar Attachment.

"Clamp the vertical arc to the latitude of the place, turning the dial-plate toward the north, if in north latitude. Move the telescope upon the declination-arc to the angular value of the sun's declination, corrected for time and refraction. But if the observation is made in south latitude, the telescope should be reversed in its Y's so that the object-glass shall be at the pivot of the declination-arc. Turn the upper part of the instrument upon the dial-plate, and the whole instrument upon its vertical axis, if need be, until the telescope can be centered upon the sun. Now the upper, or equatorial plates, are in a plane parallel to that of the equator; and when [ever] the telescope is [afterwards] brought back to the zero of the graduations, it is in the true meridian."

FIG. 120.

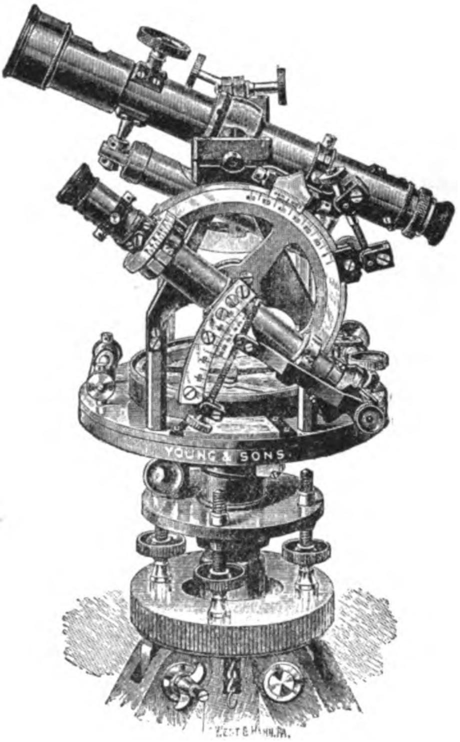


Holmes's Solar Theodolite.

The theodolite-type of the instrument made it necessary to counterbalance the eccentricity of the telescope and the other superimposed parts, by elongating the polar axis and considerably increasing its weight.

Smith's Solar Transit.—On September 14, 1880, Benjamin H. Smith, of Denver, Colo., made the telescopic polar axis a practical invention. To do this, however, he employed an entirely separate telescope, to which are attached declination- and latitude-arcs, as shown in Fig. 121. To the side of a specially-designed standard is fixed a latitude-arc, in the form of a semicircle, carrying two collars or bearings on its diameter, in which the solar telescope is free to rotate on its axis to any required position, as indicated by the hour-circle which circumscribes it. At the object-end of the telescope is a prism or reflector, to which is attached an arm, at whose opposite end is a vernier that reads zero on the declination-arc when the plane of the reflector is at 45° to the optical axis of the telescope. Hence, if, after the proper latitude and declination are set off, the telescope is rotated on its own longitudinal axis, the reflected line of collimation will describe a celestial equator; and, both telescopes being in parallel planes, each will be in the plane of the meridian.

FIG. 121.



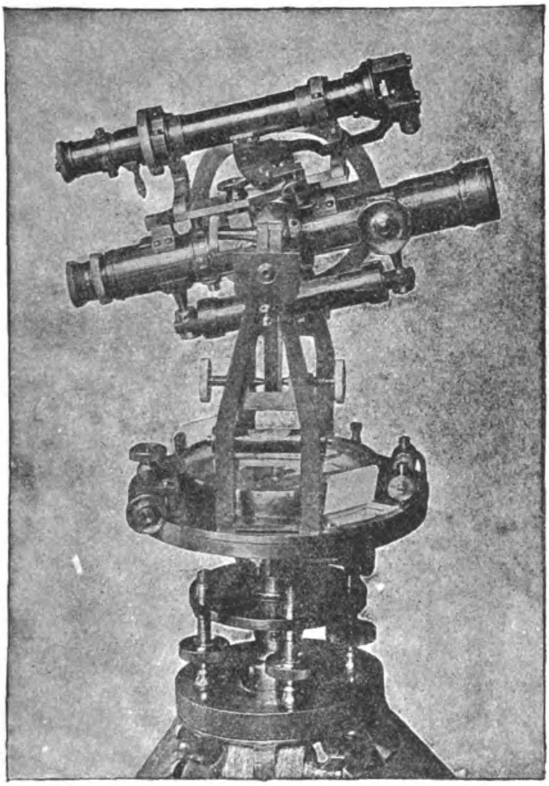
Smith's Solar Transit.

Since 1895, Mr. Young has mounted the solar telescope in

Y-bearings on the top of the main telescope, as shown in Fig. 122; and so has dispensed with the original design of the latitude-arc, in favor of the vertical circle.

Gardam's Solar Transit.—In the next year (1881), Joseph Gardam, of Brooklyn, N. Y., patented a device, in which the main telescope became the polar axis, upon principles very similar to those suggested by Pearsons. As shown in Fig. 123, a flanged collar about the telescope is fixed and adjusted to the hub of the telescope by means of angle-pieces and capstan-head screws. A semi-annular ring, with its attached hour-circle and declination-arc, is placed over this collar, and held in any position by a set-screw that travels in a groove provided specially for it. In revolving on this collar-bearing about the telescope,

Fig. 122.

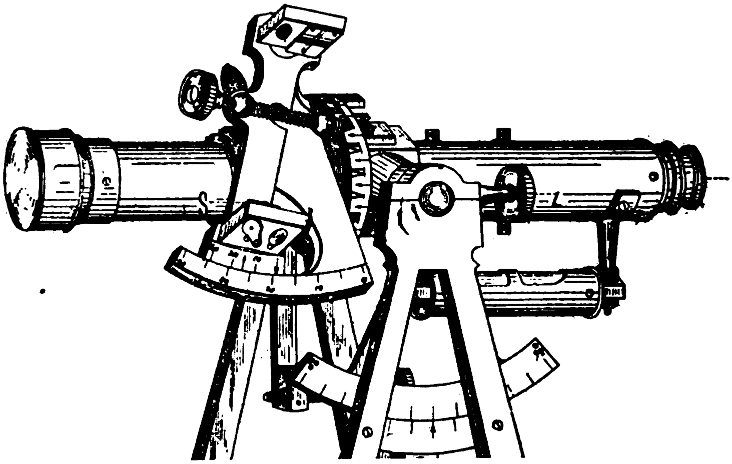


Smith's Improved Solar.

the declination-arc took up so much room that the length of the telescope-bubble was reduced to about half the ordinary length.

Saegmuller's Solar Transit.—In 1881 Geo. N. Saegmuller, instrument-maker, in Washington, D. C., with the advice of certain government officials on the Coast Survey (with which department he was at one time connected), designed and patented a telescopic solar attachment, shown in Fig. 124, mounted upon an instrument of his own make. Mr. Scott has discussed the application of the enlarged attachment to mine-surveys;* but only the use of the smaller model in solar work will be touched upon here. The attachment is fastened to the top of the main telescope upon a polar axis very similar in design to Schmoltz's modification of Burt, and is kept at right angles to the main telescope by means of capstan-head screws operating between the plates. The angular value of the declination, corrected for refraction and hourly change, is laid off on the vertical circle; the transit-telescope being depressed or elevated as the declination is north or south. The solar telescope, being previously adjusted to the same vertical plane with the main telescope, is then brought to a horizontal position, as indicated

Fig. 123.



Gardam's Solar Transit.

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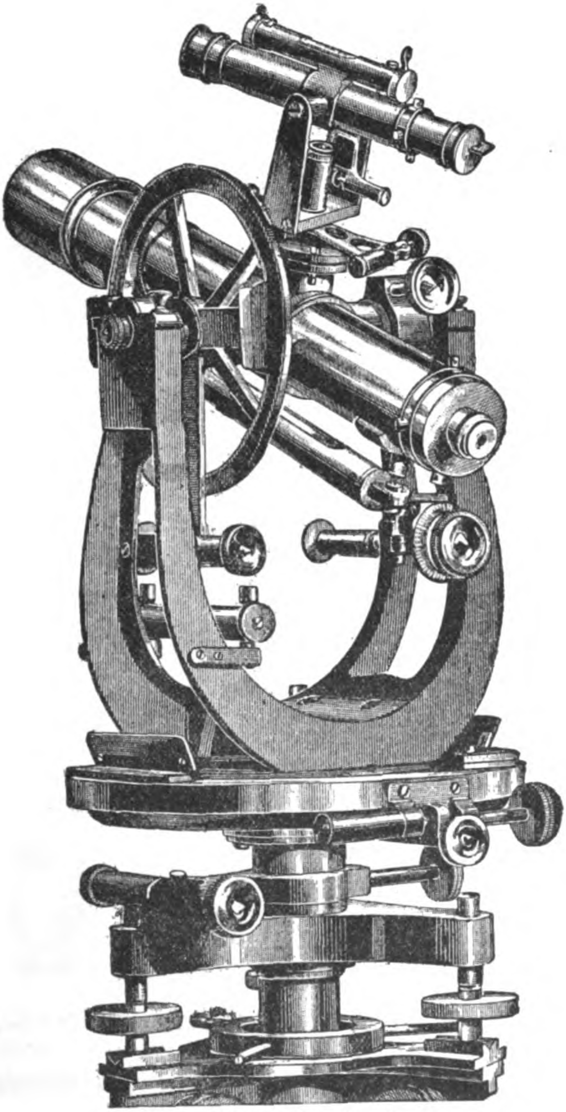
* *Trans.*, xxviii., 729.

by its own longitudinal bubble. This arrangement, as already noted, makes it possible to employ the vertical or latitude-circle

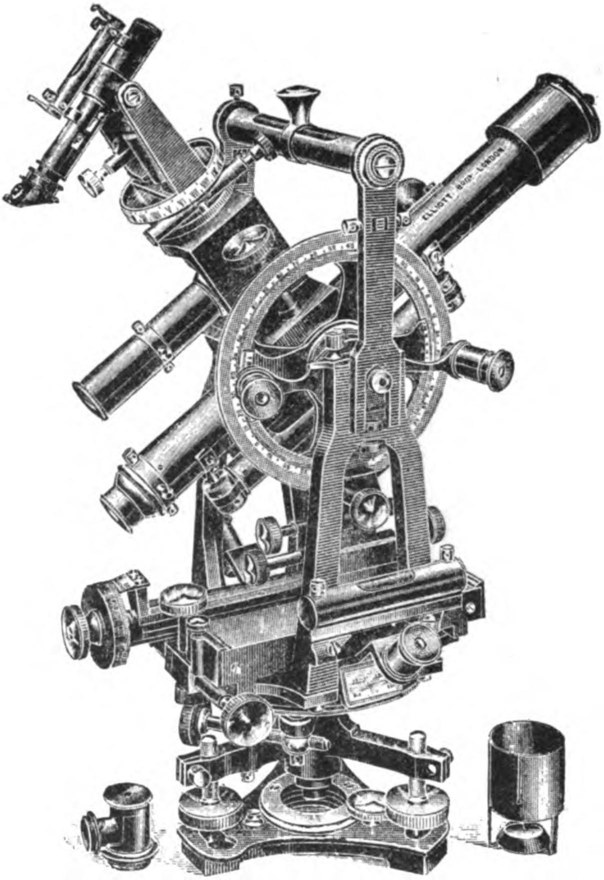
FIG. 124.



Saegmuller's Solar Transit.

as a declination-arc. The two telescopes will now form an angle equal to the declination, and the inclination of the solar telescope to its polar axis will be equal to the polar distance of the sun. In this relative position, both telescopes are now so inclined that the vernier of the vertical circle indicates the co-latitude of the observer; and thus, on rotating the instrument upon its vertical axis until the sun's image is brought into the solar's field of view, the transit-telescope will be in the meridian. In recent years Elliott Brothers, of London, have been adding this attachment, provided with its own hour-circle, as shown in Fig. 125, to the Bell-Elliott improved Eckhold Omnimeter.

Fig. 125.

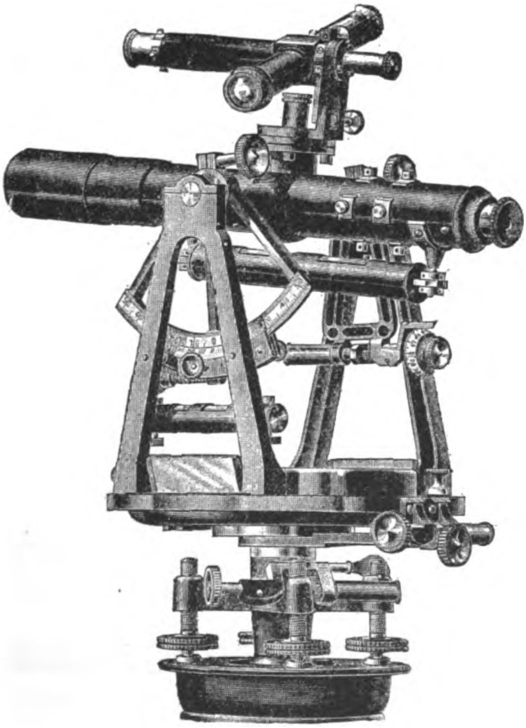


Bell-Elliott-Eckhold Omnimeter, with Saegmuller's Solar.

In 1887 F. E. Brandis' Sons, of Brooklyn, N. Y., introduced a modification of the Saegmuller solar (Fig. 126), in which the small telescope is "broken" in the usual way, by placing a prism between the objective and ocular. For this device is claimed greater convenience in sighting the sun, as the eye-piece is always at the side of the instrument. The attachment is nicely balanced by placing the bubble opposite the objective-end of the broken telescope.

Walter Scott's Solar Attachment.—July 1, 1890, Walter Scott, of Hot Springs, Dak., patented an attachment of the Smith type, which he claimed could be readily attached to any ordinary transit-instrument. This, no doubt, is too great a claim. The sighting-tube having a single smoked lens in the ocular, and cross-hairs only at the objective-end, rested upon a base-plate pivoted to the lower end of one of the standards. The latitude-arc was permanently fixed to the same standard, and extended somewhat beyond at the upper end (Fig. 127), terminating in three extra perforations for the reception of the swivel-

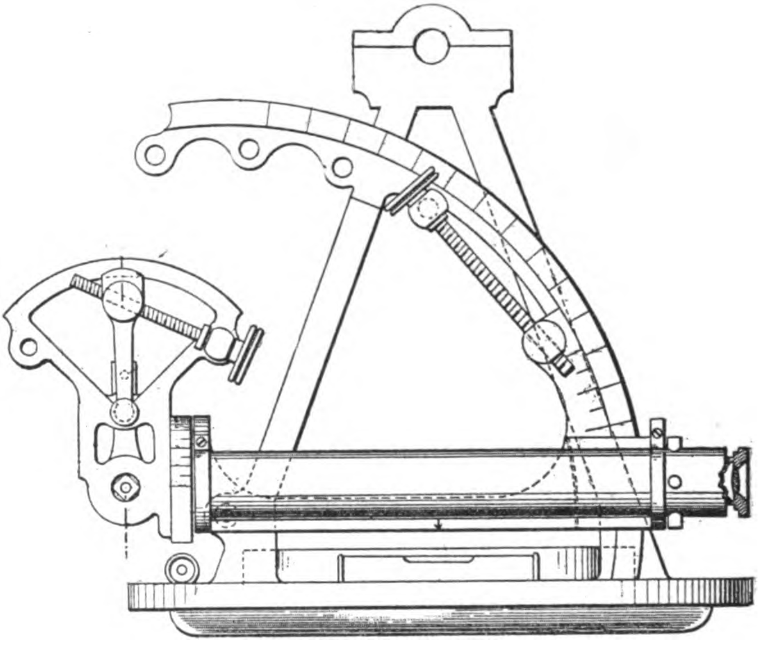
FIG. 126.



Brandis Solar Transit.

block of the tangent screw. At the lower end of the vernier-arm of the declination-arc is a prism, or mirror-reflector, whose plane of reflection is at 45° to the axis of the sighting-tube, when the vernier of the declination-arc reads 0; and at the upper end of the vernier-arm there is a convex lens to converge the sun's rays upon the reflector. The vernier of the time-circle is a part of one of the collars which supports the sighting-tube. What has been said concerning the operations of the Smith solar will apply generally in this case: the main difference in construction being the rigidity of the latitude-arc in the Scott attachment.

Fig. 127.



Walter Scott's Solar Attachment.

The Davis Solar Transit.

History of Origin.—It having been claimed that solar instruments, or attachments for solving the spherical triangle mechanically, were not sufficiently accurate and certain in their indications to be used in transit-surveys, a committee was appointed, in 1894, by the Ohio Society of Surveyors and Civil Engineers, to test the accuracy of solar transits. The members of this committee were Charles S. Howe, Professor of Mathematics and Astronomy, Case School of Applied Science, Cleveland; C. H. Burgess, a civil engineer of Cleveland; and the writer. Mr. Burgess being unable to give to the matter his personal attention, the investigations were made by Prof. Howe and myself. The committee succeeded in getting together solar instruments of all the prominent makers except one, so that ample opportunity was had for tests.

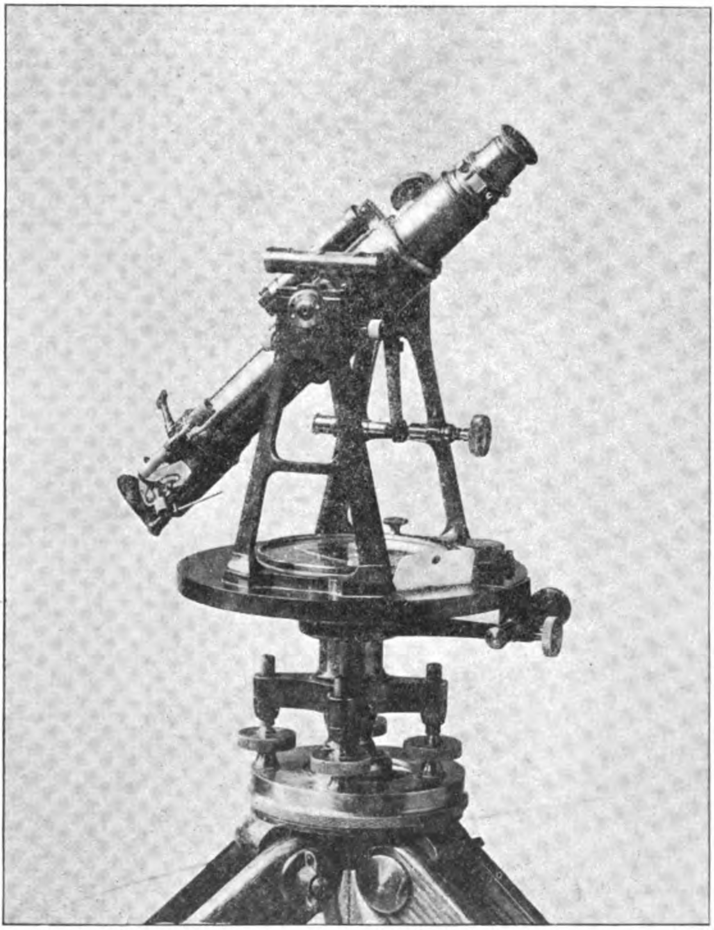
The report of the committee will be found in the annual volume of the Society for 1895. It states the conclusion that "errors of one minute, or even one and one-half minutes either way, are not infrequent, and any single observation would be uncertain to this extent." The observations referred to fall within an arc of three minutes. The committee also found it essential to have an accurately established meridian on which first to test the solars; since, when the sun was brought into its proper relation to the equatorial lines, the true meridian would not at all times be indicated. In order, therefore, to get close to the meridian, the instrument must first be set on an established meridian, and the actual relation of the sun's image to the equatorial lines must be determined. It was found that the sun's image would be sometimes above and sometimes below its proper central position. The further work had to be done in accordance with that determined position. We concluded that the difficulty arose from our inability to adjust the instrument exactly. From experience gained in these tests, the writer became satisfied that much of the objection of the profession to the mechanical solar is due to the fact that additional adjustments are required, that the adjustments are difficult to make, and that their maintenance is a matter of some uncertainty.

Believing that an instrument from which these difficulties are eliminated would be desirable, the writer began experiments to that end; and the first instrument, constructed by Ulmer & Hoff, Cleveland, O., was shown before the Ohio Society of Surveyors and Civil Engineers at their annual meeting at Dayton, O., in February, 1896. This transit-instrument had a vertical- or latitude-arc and a telescope capable of rotating in a sleeve about its longitudinal axis. The telescope had a fixed object-end, before which a mirror was so securely attached as to partake of any rotative motion of the telescope, yet capable of revolving about an axis at right angles with the line of collimation. In 1898, the writer discovered that a small level placed upon the transverse axis of a telescope so constructed would enable the vertical- or latitude-arc to be eliminated. For, by setting off the latitude-angle on the horizontal limb, the mirror, reflecting a target, could be placed at the proper angle with the optical axis of the telescope, and then, by rotating the telescope through 90°, the same angle could be transferred to the vertical plane. As to measuring a vertical angle on the horizontal limb, it is not intended to do away with the vertical-arc in general practice, but only to replace the latitude- or vertical-arc in the J. B. Davis solar transit when the arc is only wanted for solar work. For practical reasons, this method of setting off a vertical angle is not applicable for latitudes much lower than 20°; but these are much lower than any within the boundaries of the United States. Articles describing the J. B. Davis solar transit have appeared in the *Journal of the Association of Engineering Societies*, November, 1896; *The Colliery Engineer*, July, 1897; *Engineering News*, April 28, 1898; and *Mines and Minerals*, April, 1899. It was patented January 21, 1897, and February 28, 1899.

Description.—Figs. 128 and 129 represent the J. B. Davis solar transit, as made by Ulmer & Hoff, Cleveland, O., without vertical-, latitude- or declination-arc; all angles being measured upon the horizontal limb. Fig. 128 shows the solar transit with the reflector attached, and Fig. 129 with it detached. The solar transit is constructed with or without a vertical-arc, as may be desired. As the construction of a solar transit without a vertical-arc is a new departure, the method of operation without the arc will be described; the operation with a vertical-arc will then be obvious.

The transit-telescope is the polar axis in this instrument, and is so constructed inside a sleeve as to be capable of rotating on its longitudinal axis. Its object-end is fixed, and a reflector is securely attached to it. The usual vertical- or latitude-arc is dispensed with; but a level is placed upon the transverse axis of the telescope. The reflector is so constructed as to be capable of rotating with its frame about the line of collimation of the telescope as an axis, and also of revolving on an axis in its own plane at right angles to that line; so that by sighting to a target the reflector may be placed in proper angular relation to the line of collimation in each meridian and latitude observation. This reflector-construction, together with the rotating transit-telescope, results in doing away with the maintenance of all solar adjustments. Thereby, as the transit-telescope is used for solar work, not only is the accuracy of the instrument increased, but the certainty of its indications as well; because adjustments of special solar apparatus are difficult to make, are sensitive, and conse-

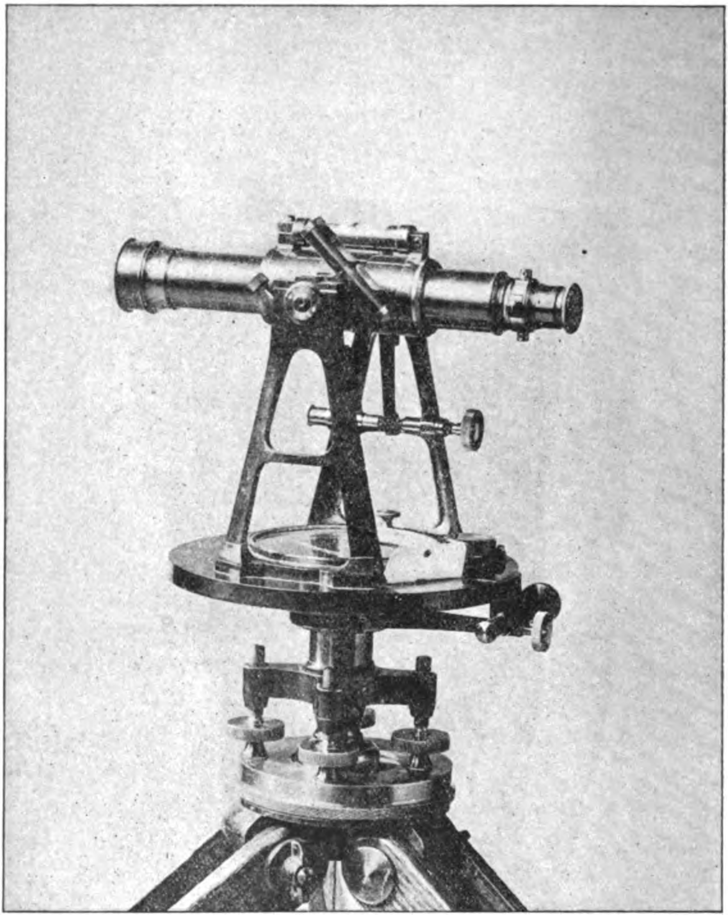
Fig. 128.



J. B. Davis Solar Transit, Reflector Attached.

quently easily disturbed. All solar transits heretofore constructed require the maintenance of certain adjustments additional to those of the engineer's and surveyor's transit; and the majority have separate latitude- and declination-arcs. In this solar these arcs are dispensed with, and all angles are measured on the horizontal limb of the transit.

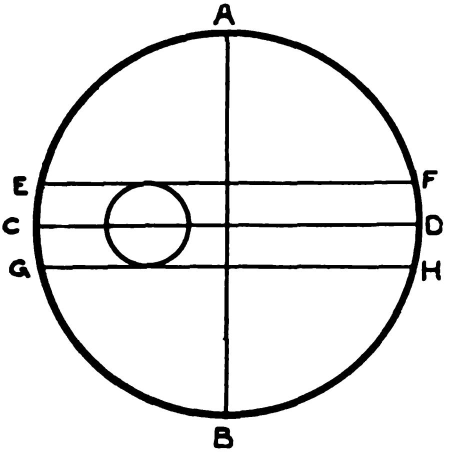
FIG. 129.



J. B. Davis Solar Transit, Reflector Detached.

At the eye-piece end of the telescope is placed the cross-hair ring, or diaphragm, provided with the usual vertical and horizontal transit-hairs, AB and CD, and the two solar hairs EF and GH, Fig. 130. The small circle between the solar or equatorial hairs represents the sun in the field of view. Fig. 130 shows the diaphragm in its normal position for terrestrial work. The line of collimation can be adjusted on a fixed point by rotating the telescope in its sleeve, as an engineer's wye-level on its wyes. The solar hairs and rotating telescope are a convenience, even when only terrestrial work is required of the transit; for the solar hairs can be used for stadia-work, and the operator can, by rotating the telescope, quickly provide himself with a single hair for either transit- or level-work. At the eye-end of the telescope there is a shaded glass slide for use in observing the sun. A diagonal prism is not required, as the eye-piece is elevated, in the position most favorable and convenient for the observer. The needle and the time-graduations on the telescope act jointly as a finder, to bring the image of the sun within the field of view. When the transit is not required for solar work, the reflector can be removed from the object-end of the telescope, and the telescope secured in its normal position by a set-screw. The central cross-hair is then vertical, and the telescope is firmly fixed in its sleeve.

Fig. 130.

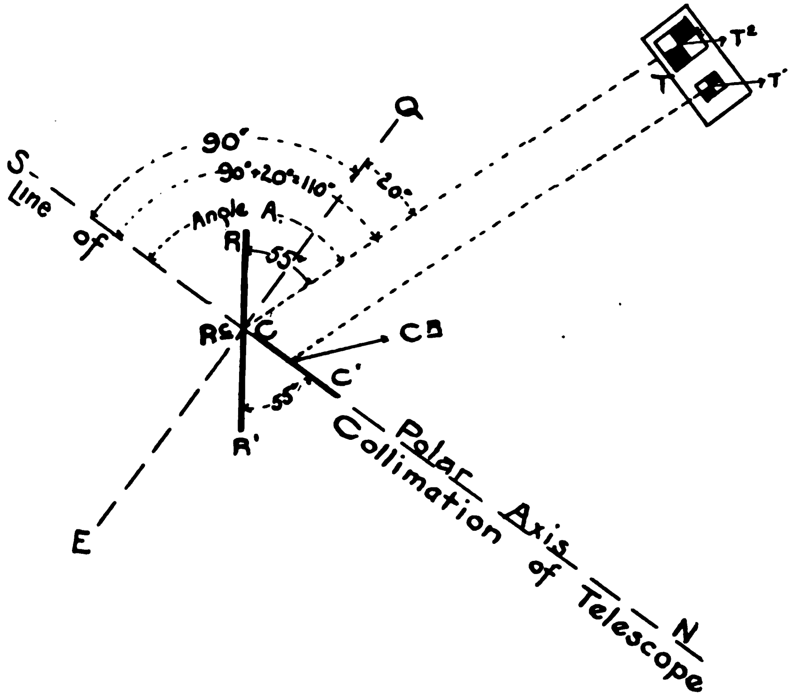


Transit and Solar Cross-Hairs.

The advantages obtained in this solar transit are: (1) simplicity; (2) the use of but one telescope for solar and transit work; (3) the omission of the usual declination- and latitude-arcs, the graduated horizontal limb of the transit serving their purpose; (4) the elimination of the maintenance of all adjustments of solar parts; (5) the obviation of all necessity of counterpoising the solar parts or attachments—the reflector weighing no more than the sun-shade; (6) the absence of projecting parts liable to injury.

With this instrument, solar work in keeping with the accuracy of an engineer's transit can be done, if the proper hours of the day for doing it are selected. The writer is satisfied that solar work requiring the closest possible results can only be done in the middle of the forenoon or afternoon. Close work cannot be done, and need not be attempted, with any solar, very near noon; because an error then made in setting off

FIG. 131.

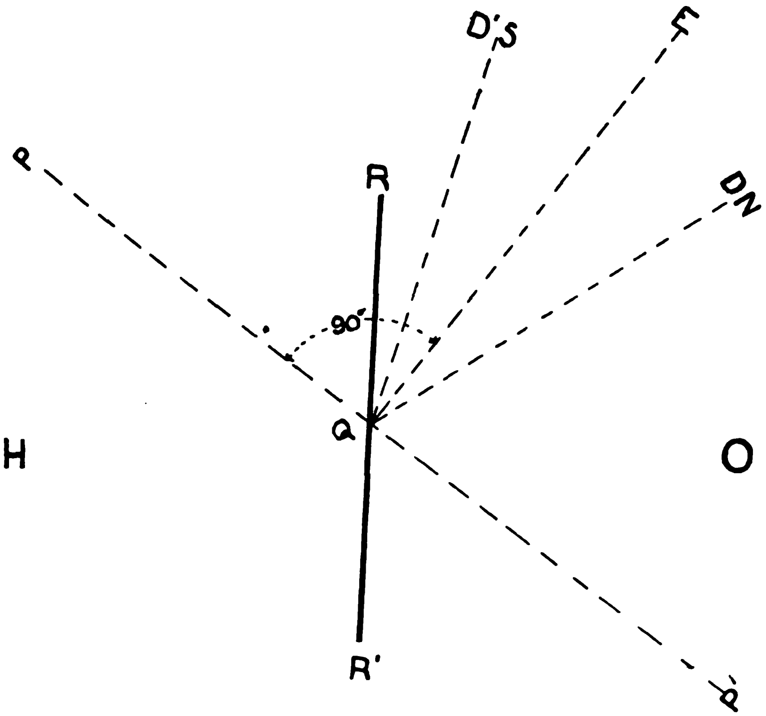


NS, Line of collimation of the telescope and polar axis. EQ, Equator. CC¹, Transit-telescope. RR¹, Reflector. R^c, Position of the image in the reflector-plane. C^s, Center of revolution of the transit-telescope. T, Target. T¹, Stationary sighting-point. T², Movable sighting-point. Angle A, South polar distance of the sun. The declination of the sun, corrected for refraction, = 20°.

the exact latitude or declination is considerably multiplied in the azimuth. A want of knowledge on this point has led many into error, and some to doubt the efficacy of solar work entirely, under the wrong presumption than any hour of the day is equally favorable to such work.

Operation.—Fig. 131 illustrates the target-sighting method of setting the reflector in its proper relation to the line of collimation for a meridian or latitude observation, and will be referred to, as the operation of the instrument is described in detail.

FIG. 132.



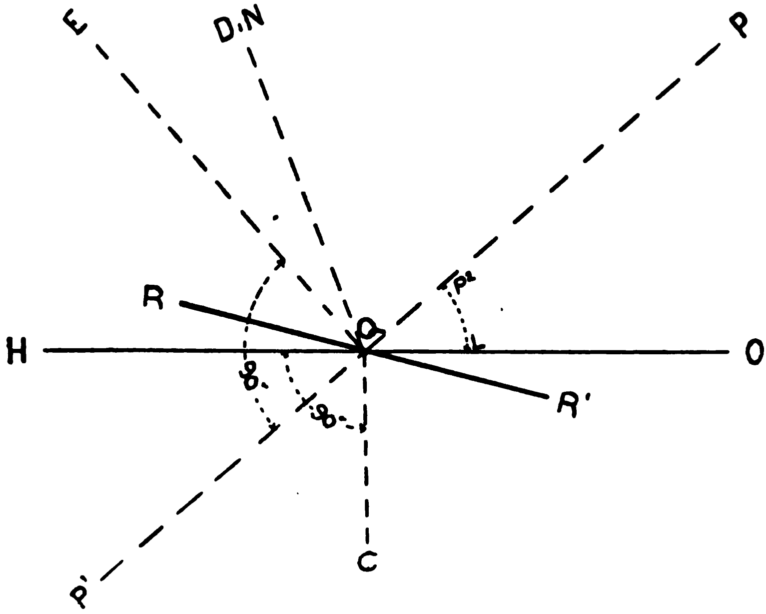
HO, A horizontal plane. PP¹, Line of collimation of the transit. RR¹, Reflector-plane. EQ, Line from the point Q at right angles to the line of collimation. QDN and QD¹S, Declination-lines.

The optical axis of the telescope CC¹, the sighting-point, T¹ or T², and the image of the same in the reflector RR¹, are all in the same horizontal plane when the image of T¹ or T² is thrown into the line of collimation. When the reflector is placed at an angle of 45° to the line of collimation, the line of sight of the telescope is deflected 90°, and will represent the equator; and when the reflector is placed at an angle to the line of collimation of 45° plus or minus one-half the declination of the sun (according as the declination is north or south), the line of sight of the telescope will be deflected by an angle equal to the south polar distance of the sun. The target, as indicated in Fig. 131, has two sighting-points, T^1 and T^2; T^1 alone is used in setting off the latitude; T^1 and T^2 are together used in setting the reflector in a meridian observation, as will hereafter be explained. The target T remains stationary and is set at right angles to a line drawn from the target-point T^1 to the transit-center; therefore, when the angle A is 90°, the distance $T^1 T^2 = C^R R^c$. When the angle A becomes more or less than 90°, the distance $T^1 T^2$ must be reduced, so as to equal the perpendicular distance of R^c from the line $C^R T^1$. To provide for this, the sighting-point T^2 is movable on the target, and an index-point and graduations enable the operator to set it in proper position for any angle A. The following statement will show the principles on which the operation of the solar is based.

Place the line of collimation of the transit-telescope PP^1 (Fig. 132) in the horizontal plane HO, and intersecting the reflecting-plane RR^1 at Q, with the reflecting-plane so placed (at 45°) that any point E situated in the horizontal plane and in a line at right angles to the line of collimation from the point Q will be reflected along the line of collimation; or, again, in such other position that reflection in the line of collimation will take place from any point, such as D N and D^1S, lying in the horizontal plane and situated either to the right or left of the point E and in the line from the point Q that makes an angle with the line EQ equal to the declination of the sun at the time. The reflecting-plane will now be perpendicular to the horizontal plane, in which the line of collimation lies; and the horizontal angle between the line of collimation and the intersection of the two planes will be such as the declination of the sun at the time of observation may require.

If, then, keeping this angle unchanged, the line of collimation PP^1 be inclined, as in Fig. 133, to the horizontal plane HO, at an angle equal to the latitude of the place, P^2L (in the manner to be presently described), and the reflector-plane be rotated about that line as an axis, the sun can be followed in its passage from east to west, in case the line of collimation is in the plane of the meridian. The line of collimation may be brought into that plane by a horizontal circular motion about QC, the vertical axis of the instrument, at right angles to the horizontal plane. At the same time the line of collimation, and with it the reflecting-plane, is rotated about itself as an axis, until the center of the image of the sun is seen exactly in the line of collimation. The line of collimation will then be in the meridian plane of the observer.

FIG. 133.



Again, returning to Fig. 131, let it be understood that in the operation of this instrument the optical axis of the telescope, or the line of collimation, is what is termed the polar axis in other solar instruments; so that any line perpendicular to the optical axis from a point in the reflector-plane at its intersection with the optical axis of the telescope produced will be in the plane of the equator. The sun in its position, on one or the other side of the equator, in its varied positions of declination throughout the year, will be represented by the correspondingly varied horizontal-angular position of the target as sighted to in each observation. This varied position of the target with reference to the aforesaid equatorial line is determined by the angle A, which varies with the sun's declination. It will thus be seen that the target is made to bear the same relation to the optical axis of the telescope, and the aforesaid line perpendicular thereto, as the sun bears to the polar axis and equatorial line at the time of observation; and that if the telescope be dipped, with reference to a horizontal plane, sufficient to conform to the position of the earth's axis at the point of observation, *the sun's image can only be seen in the optical axis of the telescope when the telescope has been brought into the plane of the meridian.*

To Set the Telescope to the Latitude-Position.—1. See that the usual transit adjustments are carefully made. Loosen the set-screw which passes through an arm of the telescope-axis and engages the telescope, so that the telescope can be rotated in its sleeve until the solar lines have become vertical. When the rotation has been made, secure the telescope by the same set-screw. Clamp the solar reflector-frame to the object-end of the telescope, placing it so that the reflector will be approximately in a vertical plane and parallel to the line of collimation, so as not to obstruct the view through the telescope. Place the transit-center vertical by means of the plate-levels and the telescope-level; and then, while the telescope is level, sight a target (at any convenient distance, 20 to 200 feet from the transit) with the stationary sighting-point T^1 on both the central vertical and the horizontal cross-hairs, and the movable sighting-point T^2 on the horizontal cross-hair only. (See Fig. 131.)

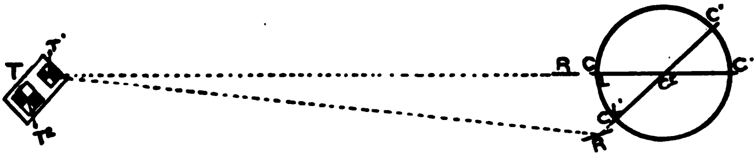
2. Observe the reading of the horizontal limb, and then set off on that limb an angle equal to the latitude of the place of observation; and, with the telescope still horizontal, by rotating the reflector about its own, then vertical, axis, bring the image of the target-point T^1 into the line of collimation of the telescope. (See Fig. 134.)

3. Without changing the angle made by the reflector with the line of collimation, return to the first reading of the limb; the telescope will then again be directed to the target-point T^1. Loosen the set-screw before referred to, and rotate the telescope 90°, securing it by the set-screw in this position. Dip the telescope until the reflected image of the target-point T^1 appears

in the line of collimation; and then bring the bubble of the transverse-axis level to a central position. (See Fig. 135.) The telescope is now dipped to the required latitude-angle, and the axis-level enables the operator at any time to restore the telescope quickly and accurately to the proper latitude-position.

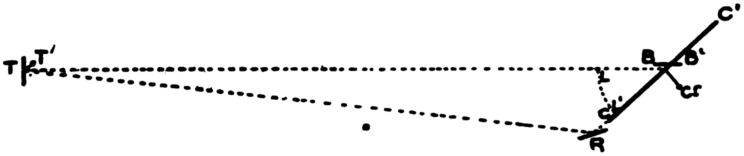
To Determine the Meridian.—1. Again place the solar hairs perpendicular, remembering that the transit-telescope will be directed to the target-point T¹, when the transit-limb is made to indicate the first angle read in the operation of dipping the telescope to the latitude position. Now, set off an angle equal to 90°, plus or minus the corrected declination of the sun at the time of observation, according as the sun is north or south of the equator. This angle is the south polar distance of the sun, and is indicated as angle A in Fig. 131. With the telescope level, place the reflector in such a position that the image of the target-point T² will appear exactly in the line of collimation of the telescope. (The target-point T² is sighted to, for the purpose of allowing for the parallax due to the reflector's being at the object-end of the telescope, and not at the transit-center;

FIG. 134.



Showing the Latitude-Angle in a Horizontal Plane. T, Target. T¹, Stationary sighting-point. T², Movable sighting-point. C C¹, Transit-telescope in two horizontal positions. Cʳ, Center of horizontal revolution of the transit-telescope. R, Reflector. L L¹, Latitude angle. T¹, Cʳ and the image of T¹ in R are in a horizontal plane.

FIG. 135.



Showing the Latitude-Angle in a Vertical Plane. T, Target. T¹, Stationary sighting-point. C C¹, Transit-telescope. Cʳ, Center of revolution of the transit-telescope. R, Reflector. L L¹, Latitude angle. B B¹, Transverse-axis level. T¹, Cʳ and the image of T¹ in R are in a vertical plane.

and the distance T^1 T^2 is controlled by the angle A, as before explained.) By this operation, the plane of the reflector is made vertical, and at the same time its intersection with the horizontal plane of the collimation of the telescope will be at such a horizontal angle with the collimation as the declination of the sun at the time of observation requires. (See Fig. 131.)

2. Having now placed the reflector in proper angular relation to the line of collimation, turn the object-end of the telescope south; dip it from a horizontal position by an angle equal to the latitude of the place of observation, by means of the transverse-axis level (previously set to indicate the proper latitude); and securely clamp the telescope. Loosen the set-screw, so that the telescope rotates in its sleeve. It will be seen that the sun can then be followed in its daily motion. Rotate the telescope in its sleeve, and at the same time turn the whole instrument horizontally, until the sun appears exactly between the solar hairs, and the perpendicular hair approximately bisects it. Then firmly clamp the transit-center. *The telescope will then be in the true meridian.*

3. Bring the telescope back to its normal position in its sleeve, and secure it by the set-screw. Unclamp the telescope-axis and fix the meridian-line by suitable points. In doing this the reflector is unclamped and placed parallel to the line of collimation. In this position it forms no obstruction whatever to the line of sight.

To Determine the Latitude.—1. Place the reflector in proper angular relation to the line of collimation (as in the instructions for determining the meridian), so as to reflect into that line the sun's image when at noon-declination. Rotate the telescope 90° in its sleeve, and secure it by the set-screw.

2. Dip the telescope, and follow the sun until it has attained its greatest altitude. Then set the latitude- or transverse axis level in a horizontal position, in order that the telescope may be returned to the proper latitude-position whenever desired.

3. To read the latitude-angle from the transit-limb, first place the telescope in the vertical plane passing through the target-point T^1, by returning to the same reading of the limb as indicated when the target was first sighted, in the operation of setting the reflector to its declination-position. Still retaining the telescope in its established latitude-position, change the

reflector so as to throw the image of the target-point T^1 into the line of collimation. Now place the telescope in a horizontal plane, rotating it 90°; and then move it horizontally until the target-center is again seen reflected in the line of collimation. (See Figs. 134 and 135.) Then read off the latitude from the transit-limb.

The Properties of Brass Made from Copper Containing Sub-Oxide, with Observations of the Effect of Oxygen on Copper.

BY ERWIN S. SPERRY, BRIDGEPORT, CONN.

(Canadian Meeting, August, 1900.)

I. INTRODUCTION.

THE oxidation of metals melted in contact with air takes place with dissimilar results. Tin, lead or zinc are examples of a class, the oxides of which float on the surface of the melted metal. First a film is produced, which covers the surface; then, if agitation from any cause exposes new metal to the action of the air, additional oxidation takes place, and the film is increased in volume. This change goes on until a considerable quantity of oxide (or "dross," as it is technically called) is formed; depending, of course, upon the duration of the exposure of the metal to the atmosphere. When such metals are poured, the dross may be skimmed off; and clean metal will be left underneath. The removal of such oxides is, therefore, merely a mechanical process. In the case of copper, however, the result is quite different. The sub-oxide of copper (Cu_2O) is readily soluble in molten copper; and therefore, instead of the formation of a film of oxide, to be finally removed as dross, the surface of the metal remains bright and clear, because the oxide has been dissolved as soon as it was produced.

It is customary in the process of copper-refining to leave a small quantity of oxide in the metal, in order to oxidize any traces of bismuth, arsenic or antimony which have not been entirely removed. As a result, these metals exist in the commercial product as oxides, and not as metals, which would form an