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ATTACHMENT FOR SURVEYING INSTRUMENTS.

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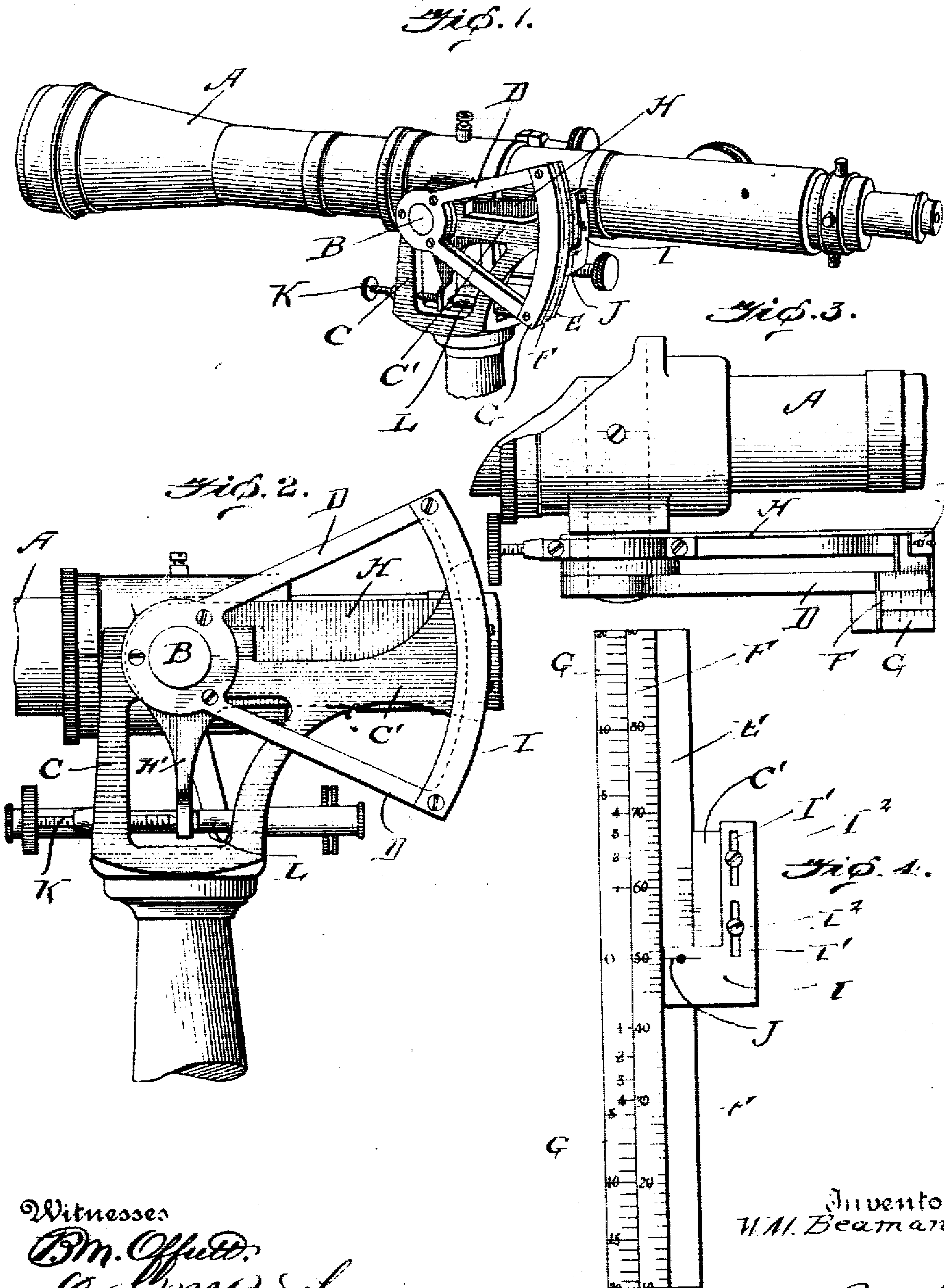

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ATTACHMENT FOR SURVEYING INSTRUMENTS.

No. 816,422. Specification of Letters Patent. Patented March 27, 1906.

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To all whom it may concern:

Be it known that I, WILLIAM M. BEAMAN, a citizen of the United States, residing at Washington, in the District of Columbia, have invented a new and useful Attachment for Surveying Instruments, of which the following is a specification.

This invention relates to surveying instruments carrying a vertical arc and stadia-wires, and more particularly to those intended for determining differences in elevation and reduced distances between the instrument and a stadia-rod.

The object of my invention is to provide an attachment for a surveying instrument whereby differences in elevation can be quickly and accurately determined without either the measurement of an angle, the use of a vernier, the use of a table or chart, and with only very slight computation.

Another object of this invention is to provide an attachment by means of which not only the differences in elevation are determined, but also the true distance reduced to horizontal with the same ease and accuracy as before referred to; and a still further object is to provide an attachment which can be used in connection with any of the well-known forms of surveying instruments and one which can be attached to the vertical arc or which can be made to replace said vertical arc.

With these objects in view my invention consists, broadly, in the employment of an arc graduated according to a law of natural sines, said arc being movable with the telescope, and an adjustable index adapted for use in connection with the graduated arc, but movable independent thereof.

The invention consists also in the employment of an arc graduated according to a law of natural cosines and arranged beside the arc graduated according to a law of natural sines and an adjustable index common to both graduated arcs.

The invention consists also in certain details of construction hereinafter fully described, and pointed out in the claims.

In the drawings forming a part of this specification, Figure 1 is a perspective view of a surveying-telescope provided with my attachment. Fig. 2 is a detail side elevation. Fig. 3 is a detail top plan view, and Fig. 4 is an enlarged view of the scales and adjustable index.

Referring to the drawings, A indicates a telescope of the usual or any approved type, said telescope being supported upon a horizontal axis B, resting on standards C, one of which is extended horizontally, as shown at C'. This extension or arm ordinarily serves as a support for the vernier; but I also employ it as a point of attachment for the adjustable index-plate hereinafter referred to.

Rigidly attached to the axis B are the arms D, supporting the ordinary graduated arc E, to which are secured the arcs F and G. It will be understood that the arc E is not used in my method and is not at all essential to my invention. The graduated arcs F and G may be made in a single piece or separately and attached to the ends of the arms D. Another arm H is hinged loosely on the axis B and carries at its outer end a plate I, carrying the index-line J. This plate I is slotted vertically, as shown at I', through which screws I^2 pass into the end of the extension C'. The lower end of the plate I, which carries the index-line J, is made sufficiently broad to extend over next to the graduated scale F, as most clearly shown in Figs. 1, 3, and 4. The arm H has a depending finger H', against which bears an adjusting-screw K, working through the standards C, and a spring-pressed rod L holds the finger always in contact with the end of the screw, so that by adjusting the screw the plate I can be moved up or down for the purpose of raising or lowering the index-line J.

It will be understood that the movement of the index-plate I is dependent entirely upon the screw K and is independent of any movement of telescope and arcs.

In looking through a telescope fitted with fixed stadia-wires and at a vertical stadia-rod whose face is divided into any number of equal divisions we see the stadia-wires projected upon the rod. The theory of the measurement of distances by the stadia method is that the space subtended on the rod by these wires is exactly proportional to the distance of the rod from the telescope.

It is customary to divide the stadia-rod into units of some convenient length and fractions thereof and then to set the stadia-wires at such a fixed distance apart that when one unit is subtended by them on the rod the rod is one hundred units in distance from the telescope. Now if the line of sight is horizontal the observed stadia distance is the true distance, (certain minor corrections are here ignored;) but if this line is inclined to the horizontal the observed distance must be corrected according to the degree of inclination as shown by the measurement of a vertical angle. Also if the line of sight is horizontal the projection of the middle horizontal wire (placed midway between the stadia-wires) on the rod indicates the difference in elevation; but, again, if this line is inclined to the horizontal we can compute the difference in elevation from the data, observed distance, and measured vertical angle by well-known formulæ. To facilitate these operations, various tables, charts, diagrams, and slide-rules have in the past been devised. They all involve the measurement of a vertical angle, including the reading of a vernier, the entering of a table or diagram, and the subsequent performance of either a tiresome computation or the acceptance of only an approximate result, due to an awkward interpolation.

Briefly stated, my invention is used as follows: (It is assumed that the observed distance has been read in the usual manner and that the rod has been held vertically.) When telescope is level, an adjustable index is set at the zero-point of a new-vertical-arc scale. When the telescope is turned toward the rod, (the new arc carrying F and G moving rigidly with it, while the index J remains stationary,) I do not make an exact setting at any definite point on the rod, but instead set the nearest arc-graduation exactly opposite the index and then note the arc and rod readings. There are two independent scales side by side on the same face of the new vertical arc. First, the numbers on the elevation-scale F next the index (always small and whole and never fractional) are so placed in angular value that when that number indicated by the scale-reading is multiplied by the observed distance, expressed in subtended units, it gives the exact difference in elevation between the instrument and that point on the rod which is now behind the middle wire. Second, if it is desirable to reduce the observed distance to true horizontal distance, then apply such correction to it as is indicated by the reading of the reduction-scale G opposite the same index J just used. The correction is expressed on the scale in percentage to be subtracted from observed distance, each subtended unit on rod being here regarded as representing one hundred units of distance. Scale F is for determining differences in elevation. The zero-point is marked "50" instead of "0," so that the scale as read (always an even division and never estimated between) will show and the notes will afterward prove the sign of the angular value represented. The graduations run outward in either direction from the zero-point or the "50" graduation and for the same number of divisions on either side from "50" are graduated at equal distances from said zero-point. The numbering here runs from about "10," which represents a minus angular value of 26° 33.9′, to about "90," which represents a plus angular value of 26° 33.9′. The scale is read in the usual way—as, *e. g.*, 54, 62, 47, &c. The angular range as here shown could be made less or greater, or a different zero-numeral than "50" could obviously be used without departing from the spirit of my invention.

The graduations follow a law of natural sines and are computed from the formula

$$h = \frac{1}{2} S \text{ sine } 2\,a, \text{ (based on vertical rod,)}$$

where h equals difference in elevation, s equals observed stadia distance, a equals vertical angle or inclination of the telescope to the horizontal.

Now in order that the various pointings of the telescope on the rod shall give whole-number multiples ranging from one to forty plus, and similarly one to forty minus, which when multiplied by the observed stadia distance (units on rod subtended between the fixed stadia-wires) will give at once the difference in elevation, forty computations have been made with the above formula, as follows: Such angular values have been found as will make $\frac{1}{2}$ sine $2\,a = 1, 2, 3$, &c., respectively—*e. g.*, when a equals 5° 46.1 $\frac{1}{2}$ sine $2\,a = 0.1$—but as the observed stadia distance is usually read as so many units subtended on rod this is multiplied by one hundred to get actual distance, so we multiply above result by one hundred, thus $0.1 \times 100 = 10$—*i. e.*, when telescope is inclined 5° 46.1′ to horizontal the arc reading is "10," $(60 - 50 = 10,)$ which means that ten times the numbers of units subtended on the rod between the stadia-wires is the difference in elevation, subject to final correction for height on rod sighted. Therefore to get the multiple to be used in the computation I subtract fifty from the arc setting as read, and the algebraic result is the multiple with appropriate sign. Thus $54 - 50 = +4$, $44 - 50 = -6$.

In the angular value cited above 5° 46.1′, which gives a multiple of ten, the tenth graduation above "50" and the tenth graduation below "50" are each placed 5° 46.1′ in angular distance on either side of the zero-point, but are marked "60" and "40," respectively. It is thus that the reading of a vernier and the consequent determination of a vertical angle is made unnecessary, for the reason that the fractional part of a division, apparently necessary, but really to be avoided, is read as so many units of height on the rod, as indicated by the height of the middle wire (stadia-wires being disregarded) counting up from the ground as zero.

Scale G is for determining correction necessary to reduce observed distance to horizontal on account of line of sight being inclined to horizontal. The zero-point is marked "0" and is exactly opposite the "50" (or zero-point) of scale F. On scale G the graduations are numbered consecutively and outwardly from "0" in either direction (up and down) and are placed in such angular positions as will indicate even percentages of correction. The same index is used to read both scales. When telescope is finally set with the rod in the field of view and index falling exactly opposite some graduation of scale F, as previously explained, I then note the reading of the index by estimation on scale G. If nearest reading, *e. g.*, is "4," then reduce observed distance by four per cent. For a more exact value, if desired, the nearest tenth of a per cent. can be easily read by estimation of tenths.

The graduations follow a law of natural cosines, and the angular position for each graduation is computed from the formula

$$d = s \cos^2 a, \text{ (based on vertical rod,)}$$

where d equals true horizontal distance, s equals observed stadia distance, a equals vertical angle or inclination of telescope to the horizontal.

To facilitate the slight computation necessary in determining differences in elevation, I have devised a special form of notes, which follow the general form of those used in differential leveling. The following will serve as a sample:

Arc reading.		Distance.	Rod and product.	D. E.	Elevation.
B. S.	F. S.				
					100.0 ground at rod.
56		7.3	+8.4		
			−43.8	−35.4	64.6 H. I.
	51	6.7	−7.1		
			+26.8	+19.7	84.3 grd.
46		4.8	+9.2		
			+19.2	+28.4	112.7 H. I.

Under column of "Distance," "7.3," "6.7," and "4.8" are units subtended on rod by stadia-wires and represent seven hundred and thirty, six hundred and seventy, and four hundred and eighty units of distance, respectively. Under column of "Rod and product," "8.4," "7.1," and "9.2" are units on rod between its base and middle wire—*i. e.*, the final rod readings—when arc reading is taken. A complete note entry for the first backsight is "56 7.3 8.4," which means that $+6 \times 7.3 = +43.8$ is D. E. between instrument and that point on rod which is 8.4 above ground. The proper signs for final rod readings and for products are:

Final rod reading.	Product.
For B. S. +	Opposite sign to that indicated by arc reading.
For F. S. −	Same sign as that indicated by arc reading.

Take rod readings and products by pairs and add algebraically, *e. g.*, $+8.4 - 43.8 = -35.4$, which applied algebraically to starting-point 100.0 gives 64.6.

It is to be noted that in most surveying instruments the vertical arc is placed on the side of the telescope, where the graduations are on a scale which is in a vertical plane parallel to the telescope. In the drawings herewith, however, the graduations are on the side of the arc facing the eyepiece of the telescope, simply for convenience in reading.

My invention is as attachable in the one position as in the other, the only differences being in the mechanical arrangements of the various parts.

In either case the principles involved and the methods of use as above described and the claims made below are of identical application.

Having thus fully described my invention, what I claim as new, and desire to secure by Letters Patent, is—

1. In a surveying instrument, a telescope provided with stadia-wires, and an arc connected to the telescope and movable therewith and a movable index arranged in combination with the said telescope and arc, said arc being graduated according to a law of natural sines, whereby a single reading of the instrument used in connection with a stadia-rod will be sufficient to determine the difference in elevation between the instrument and rod.

2. In a surveying instrument the combination with the telescope having an ordinary arc connected thereto and movable therewith, of a supplemental arc, connected to the first-mentioned arc, said supplemental arc being graduated according to a law of natural sines, and an index movable independent of the telescope, said index extending across the first-mentioned arc and resting against the supplemental arc for the purpose specified.

3. In a surveying instrument a telescope having an ordinary arc, a supplemental arc, having graduations adjacent both edges, one set of graduations being according to a law of natural sines, and the other set of graduations being according to a law of natural cosines, and a movable index extending across the ordinary arc and resting flush with the supplemental arc for the purpose specified.

4. In a surveying instrument, a telescope, a vertical arc and a movable index, said arc being graduated outwardly from a zero-point

near its middle and similarly on either side of said zero-point, said graduations following a certain law of natural sines, said arc having such selected positions computed from said law as will give when placed on the arc, even whole-number multiples, which for certain positions of the telescope, indicating such graduations, will, when multiplied by observed rod distance, give the difference in elevation between the instrument and the rod, whereby further computation is avoided, as described.

5. In a surveying instrument, a telescope provided with a vertical arc, and a movable index, said arc being graduated outwardly from a zero-point, near its middle and similarly on either side of said zero-point, said graduations following a certain law of natural cosines, said arc having such selected angular positions computed from said law as will give when placed on the arc, even whole-number percentages whereby for any setting of the telescope, can be read by estimation, the percentage of correction, to be subtracted from the observed stadia distance, in order to obtain the true horizontal distance.

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