AINSWORTH'S MANUAL

for

ENGINEERS

AND

SURVEYORS

Edited by

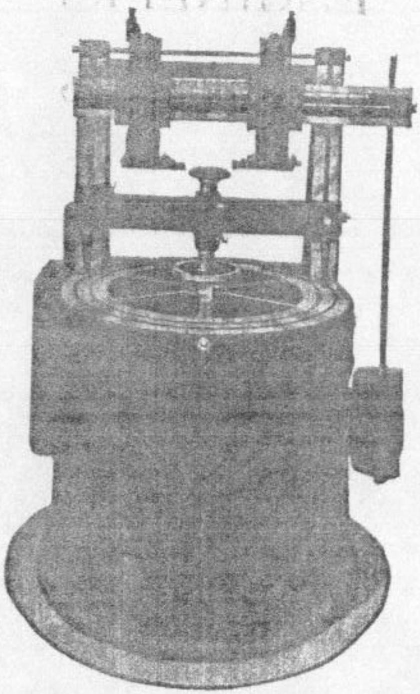
E. E. GRAHAM, M. E.

1911

PRICE TWENTY-FIVE CENTS

WM. AINSWORTH & SONS
DENVER, COLO.
U. S. A.

THE AINSWORTH 30-INCH AUTOMATIC DIVIDING ENGINE



The most accurate circular dividing engine in the world and capable of dividing circles, each division of which is in its theoretical position to within one second of arc.

NOTE.

The Editor acknowledges the incompleteness of this little Manual, but believes that in a measure it fills a want that will best be felt after a year's use, and takes this occasion to solicit criticisms and suggestions regarding its revision, and the addition of such new matter as will render it indispensable to "the man in the field."

The price (25c) covers about one-half the cost of publication and insures the distribution of the "Manual" among live engineers and surveyors whom, we believe, will appreciate its compactness, brevity and lucidity.

Your suggestion as to its further improvement will be appreciated by

E. E. GRAHAM, Editor.

Denver, Colo., U. S. A.
January, 1911.

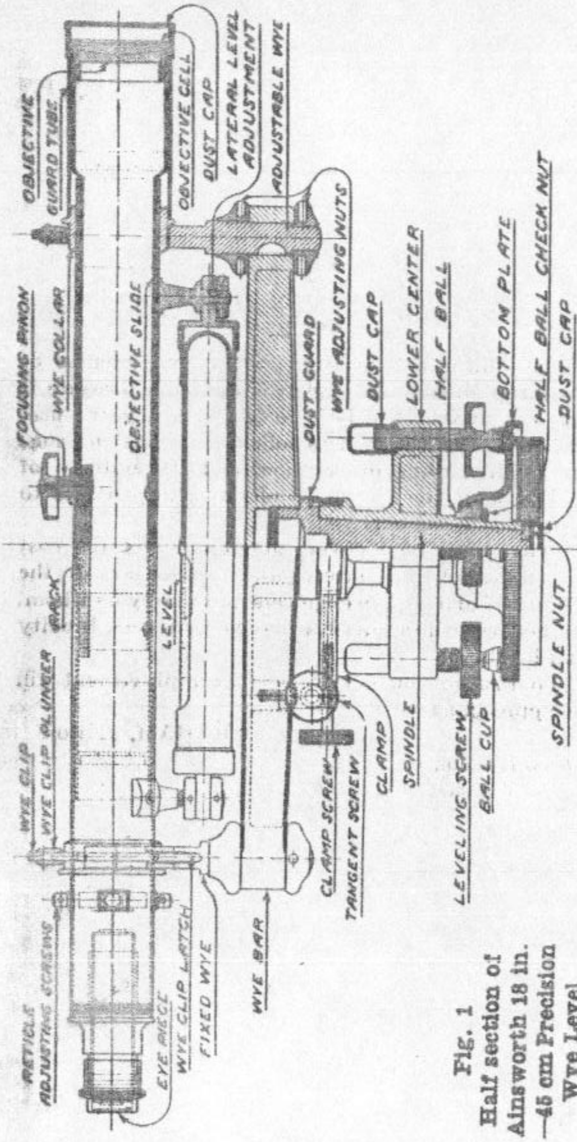
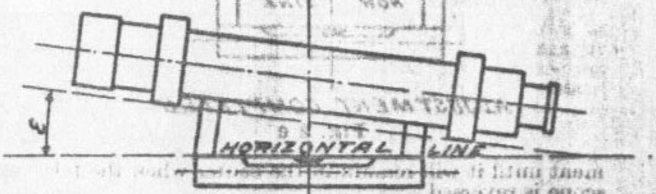


Fig. 1
Half section of Ainsworth 18 in. —45 cm Precision Wye Level

ADJUSTMENT OF INSTRUMENTS

THE Y LEVEL.

Level Adjustment:—Set up the instrument on a firm support where it is protected from the sun and wind. Clamp the spindle, and by means of the

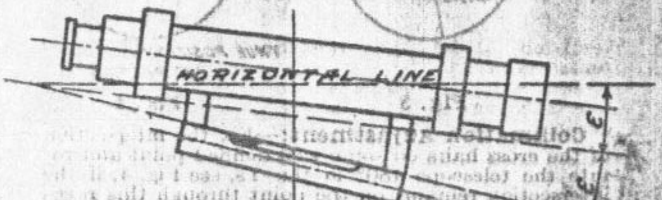


FIRST POSITION

Fig. 2 a

leveling screws, bring the bubble to the center of the tube. Open the Y clips and rotate the telescope slightly in the Ys. If the bubble remains in the center, the axis of the level is in a vertical plane with the axis of the telescope. If, however, it leaves the center, traveling in one direction when the telescope is rotated to the right, and in the opposite direction when rotated to the left, the level should be adjusted by means of the lateral adjusting screws at one end of the tube until it will remain in the center while the telescope is rotated in the Ys 4° or 5° in either direction.

Having completed this adjustment level carefully, see Fig. 2 a, turn the telescope end for end in the



REVERSED POSITION

Fig. 2 b

Ys, see Fig. 2 b, taking care to not jar the instrument in so doing. Return the bubble half way to the center by the adjusting nuts at one end of the tube and the remaining half by the leveling screws, see Fig. 2 c. Reverse the telescope in the Ys, if the bubble is not now in the center repeat the adjust-

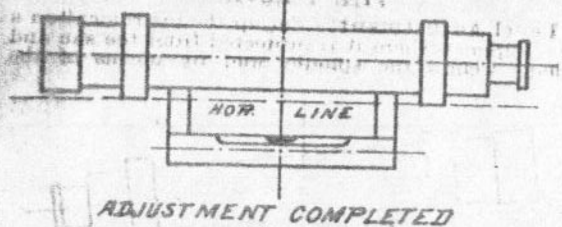


Fig. 2 c

ment until it will remain in the center when the telescope is reversed.

Cross Hair Adjustment:—To adjust the horizontal hair, clamp the telescope in the Ys, fix one end of the hair on some well defined point, move the telescope laterally and if the hair does not follow the point, see Fig. 3, loosen two adjacent reticle adjusting screws and rotate the reticle until the hair is horizontal, tighten the same screws and repeat the test.

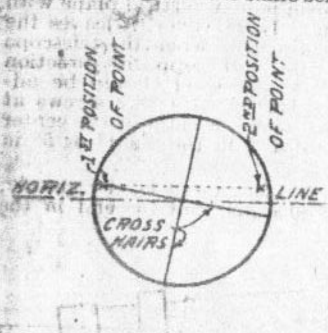


Fig. 3

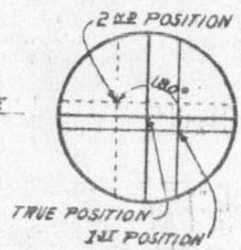


Fig. 4

Collimation Adjustment:—Fix the intersection of the cross hairs on some well defined point and rotate the telescope 180° in the Ys, see Fig. 4; if the intersection remains on the point through this revolution, the line of collimation—optical axis of telescope—is parallel to the axis of the wye collars and consequently to the level.* If the intersection does

* The wye collars are here assumed to be the same diameter. Where they are not the same diameter, adjust like a dumpy level. The collars may be tested for equality of diameter by a striding level or by setting two pegs at equal distances from the instrument, as in the adjustment of the dumpy level, and testing the adjustment on these pegs.

not remain on the point adjust the reticle to correct half the error for each hair and repeat until the intersection will remain on the same point throughout a revolution of the telescope.

In an erecting telescope move the reticle in a direction that would apparently increase the error as the erecting eyepiece inverts the image of the cross hairs.

Objective Slide Adjustment:—* Proceed as for "Collimation Adjustment," using first a nearby point and then a distant point, if the intersection of the cross hairs does not remain on the distant point when the telescope is revolved, correct for one

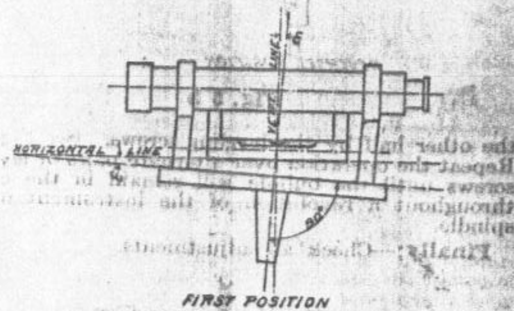


Fig. 5 a

half the error in each direction by means of the screws usually found under a slip ring on the outside of the telescope main tube, adjusting them so as to apparently increase the error. Repeat the operation until the telescope is in collimation at both distances.

Eyepiece Adjustment:—† If, when the foregoing adjustments are completed, the intersection of the cross wires is not in the center of the field of the eyepiece it may be centered by means of the first set of adjusting screws in front of the eyepiece.

Y Adjustment:—Bring the bubble to the center of its tube with the telescope over a pair of leveling screws, see Fig. 5 a, then rotate through 180° on the

* Modern precision instruments are constructed with sufficient accuracy to enable the elimination of this adjustment, but directions are given for the benefit of those using instruments requiring it.

† This is not an essential adjustment, and its elimination in nowise affects the accuracy of the readings. For inverting eyepieces it is always eliminated and frequently also on short erecting eyepieces.

spindle, see Fig. 5 b, return the bubble half way to the center by the adjusting nuts on one of the Ys and

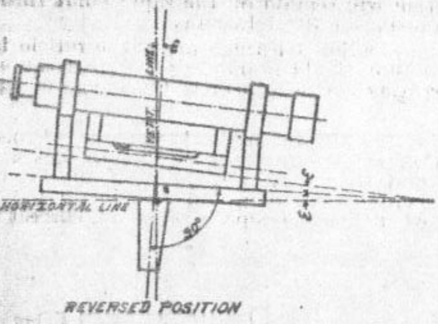


Fig. 5 b

the other half by the leveling screws. See Fig. 5 c. Repeat the operation over alternate pairs of leveling screws until the bubble will remain in the center throughout a revolution of the instrument on its spindle.

Finally;—Check all adjustments.

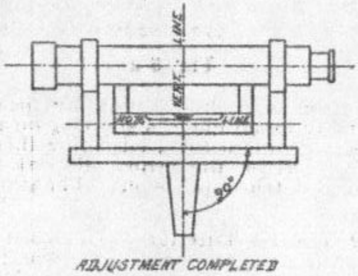


Fig. 5 c

THE DUMPY LEVEL.

Level Adjustment:—If the level tube is provided with adjusting screws, bring the bubble to the center of its tube when the telescope is over a pair of leveling screws, see Fig. 2 a, rotate 180° on the spindle, see Fig. 2 b, return the bubble half way to the center by the adjusting screws and the other half way by the leveling screws, see Fig. 2 c, repeat over alternate leveling screws until the bubble will remain in the centre throughout a revolution of the instrument on its spindle.

Cross Hair Adjustment:—First, adjust horizontal hair. See "Cross Hair Adjustment" under

"Y Level Adjustments," P. 6. Measure equal distances, 150 to 200 ft.—50 to 60 meters, in opposite directions from the instrument and drive pegs. See

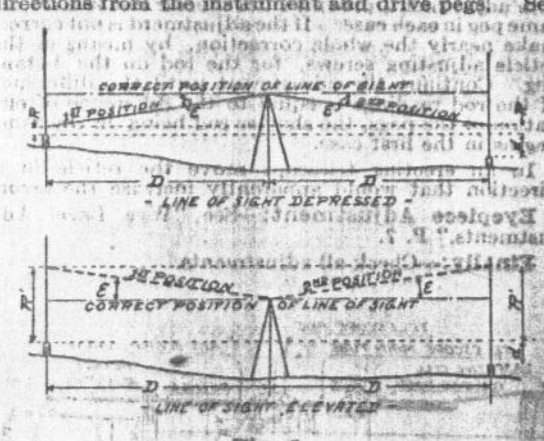


Fig. 6

Fig. 6. Read a rod on each peg, keeping the bubble in the center while making each reading. The difference of the rod readings will be the true difference of elevation of the pegs, whether the instrument is in

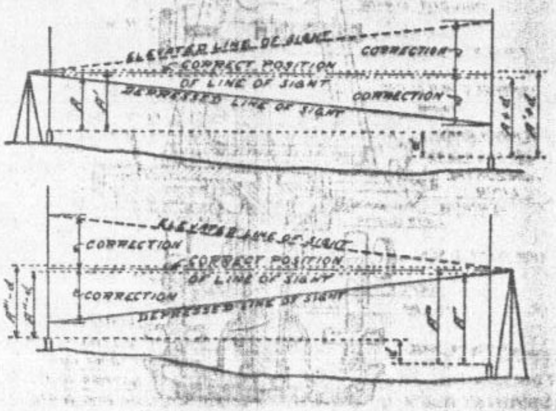


Fig. 7

adjustment or not. Move the instrument to a point a few feet, as short as the instrument will focus, beyond one of the pegs See Fig. 7. Read the rod again on each peg, keeping the bubble in the center.

If the difference between these two readings is the same as it was between the first two, the cross hair is in adjustment, provided the shorter rod was on the same peg in each case. If the adjustment is not correct make nearly the whole correction, by means of the reticle adjusting screws, for the rod on the distant peg. Continue the adjustment until the difference of the rod readings is equal to the difference of elevation of the pegs, the shorter rod being on the same peg as in the first case.

In an erecting telescope move the reticle in a direction that would apparently increase the error.

Eyepiece Adjustment:—See "Wye Level Adjustments," P. 7.

Finally:—Check all adjustments.

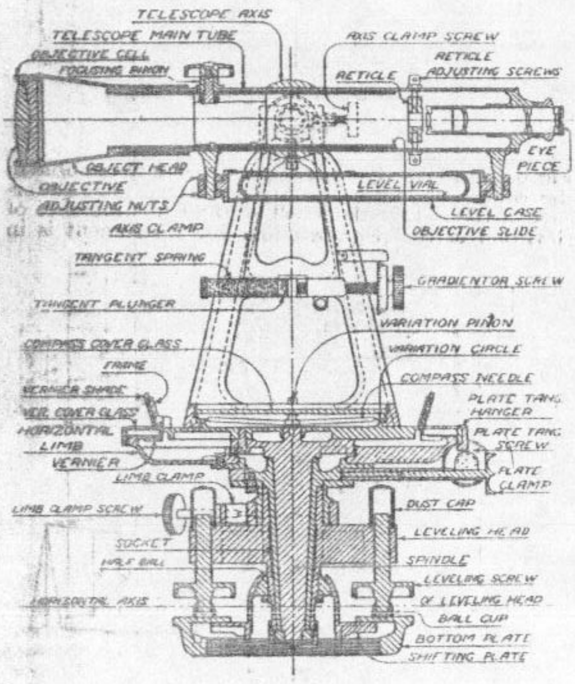


Fig. 8

Cross Section of Ainsworth 6-inch—15-cm. Theodolite

THE TRANSIT.

(Theodolite)*

Plate Level Adjustment:—By means of the leveling screws bring the bubbles of the plate levels to their centers, see Fig. 9 a, then turn the plate

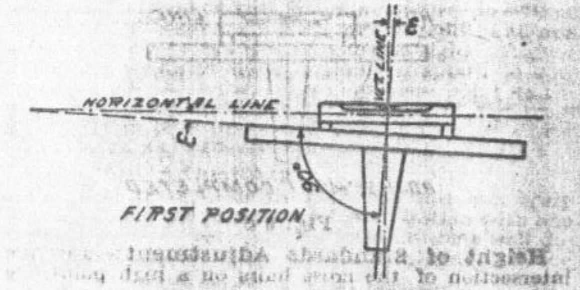


Fig. 9 a

180°. See Fig. 9 b. If the bubbles are now central the adjustment is correct, if not, make half the correction by means of the adjusting screws on the levels

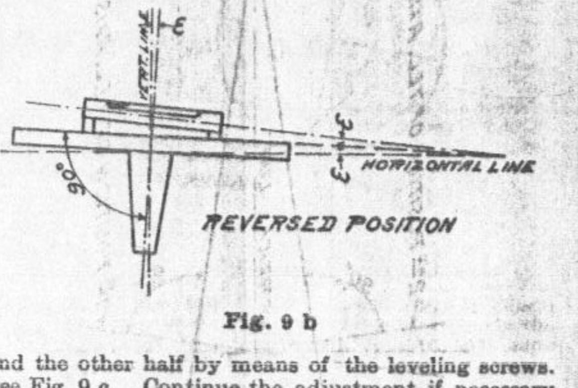


Fig. 9 b

and the other half by means of the leveling screws. See Fig. 9 c. Continue the adjustment if necessary until the bubbles remain in the center when reversed.

* Theodolite: "A surveying instrument for measuring horizontal angles upon a graduated circle. It may also be provided with a vertical circle, and if this is not very much smaller than the horizontal circle, the instrument is called an *altazimuth*.. A small altazimuth with a concentric magnetic compass is called a *surveyor's transit*."—Century dictionary.

The vertical axis will now be truly vertical when the plate level bubbles are central.

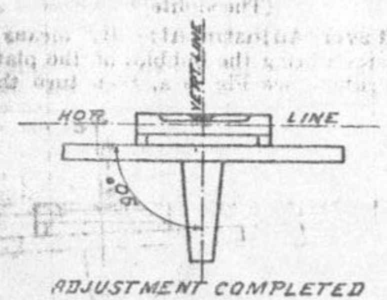


Fig. 9 c

Height of Standards Adjustment:—Fix the intersection of the cross hairs on a high point, see

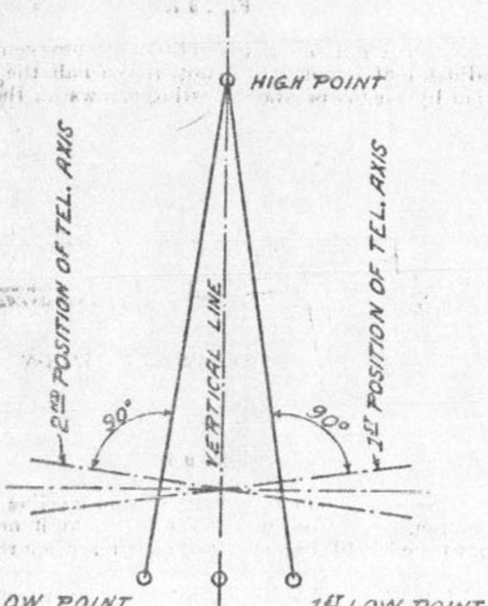


Fig. 10

Fig. 10; the angle of elevation should be about as great as can be sighted over the vernier plate; depress the telescope as low as convenient and set a point at the intersection of the cross hairs. Reverse the telescope in altitude and azimuth, sight the high point and depress the telescope and set a second low point, if the cross hairs do not bisect the first one. If the intersection of the cross hairs falls at the same point as at first the standards are of equal height and need no adjusting. If it falls to the left, it indicates —in an instrument with erecting telescope—*that the left hand standard is high, or the right hand one is low and vice versa if it falls to the right. Adjust the axis bearing in the adjustable standard to correct one half the error; set a new lower point as before and repeat until the intersection of the cross hairs falls on both upper and lower points on direct and reverse sights.

Collimation Adjustment:

Vertical Hair:—To bring the vertical hair truly vertical clamp the plates and lower motion with one extremity of the vertical hair fixed on some well defined point, move the telescope in altitude; if the

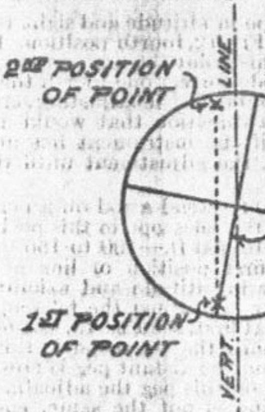


Fig. 11

hair does not follow the point, see Fig. 11, loosen two adjacent reticle adjusting screws and rotate the reticle until the hair is vertical, tighten the same screws and repeat the test.

Now level the instrument and fix the intersection of the cross hairs on a well defined point 300 to 400 ft.—100 to 150 meters, distant, see Fig. 12, first position. With the limb and lower motion clamped, turn the telescope 180° in altitude and fix a similar point about the same distance in the opposite direc-

*If the instrument has an inverting telescope the error will appear in the field to be on the opposite side of the vertical hair from its actual position.

tion, see Fig. 12, second position; now turn the instrument 180° in azimuth until the first point is sighted, see Fig. 12, third position, clamp spindle and

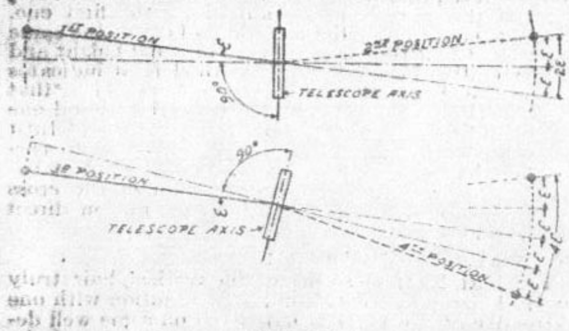


Fig. 12

reverse the telescope in altitude and sight toward the second point. See Fig. 12, fourth position. If the vertical hair falls on this point the adjustment is correct. If it falls to one side correct one-fourth the error by means of the horizontal reticle adjusting screws, moving the reticle in a direction that would apparently increase the error if the instrument has an erecting telescope. Repeat the adjustment until the hair is in collimation.

Horizontal Hair:—Read a rod on a peg near the instrument, clamp the telescope in this position, then read on a peg 300 to 400 ft.—100 to 150 meters distant—see Fig. 13, first position of line of sight, reverse the telescope in altitude and azimuth. With the rod on the near peg adjust the telescope to read the same as it did at first, see Fig. 13, second position of line of sight, clamp the telescope in this position, and if the reading on the distant peg is now the same as the first reading on this peg the adjustment is correct. If the reading is not the same, correct one-half the error with the rod on the distant peg by means of the reticle adjusting screws. Repeat the

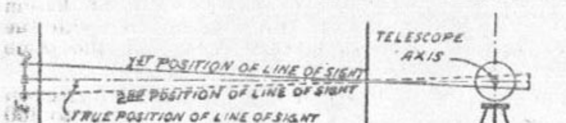


Fig. 13

adjustment until the readings with the telescope direct and reversed agree.

Test the adjustment of both vertical and horizontal hairs to insure against their having been displaced.

Telescope Level Adjustment:—The adjustment of the telescope level is the same as for the dumpy level, see "Level Adjustment, Dumpy Level," P. 8, excepting that the correction is made by means of the level adjusting screws instead of the reticle adjusting screws.

Objective Slide Adjustment:—Not required on most instruments. With the plates and lower motion clamped fix the intersection of the cross hairs on a near point, within a few feet of the instrument, and then on a distant point 500 feet or more—150 meters, or more away, in line with the first point, reverse the telescope in altitude and azimuth, set on the near point, and if upon focusing on the distant point, the intersection of the cross hairs falls on this point, the objective slide is in adjustment. If it does not, correct for one-half the error by means of the slide adjusting screws, which will be found under a slip ring on the outside of the telescope main tube, moving the slide in a direction that apparently increases the error, adjust for collimation, see P. 13-14, under "Transit Adjustments." Repeat the operation until the telescope is in collimation for both distances.

Eyepiece Adjustment:—See eyepiece adjustment under "Y Level Adjustments," P. 7.

Stadia Adjustment:—Most instruments have fixed stadia but where adjustable; level the telescope and sight a rod held at a measured distance of 100 ft.—100 meters—plus the constant, F + c, see Fig. 29, P. 46, and adjust until the stadia hairs intercept exactly 1 foot—meter—on the rod.

In an instrument having fixed stadia it is well to determine the error, if any, in the stadia interval for use in a precise survey.

Vertical Circle Vernier Adjustment:—Level the instrument carefully by means of the telescope level. The vertical circle vernier should read zero when the telescope is level, if it does not, loosen the screws or nuts attaching same to the standard and shift it until the zero on circle and vernier coincide, tighten the vernier and revolve the telescope to see that the circle does not touch the vernier throughout its revolution.

Compass Needle Adjustment:—If either end of the needle dips below the plane of the compass circle balance it by shifting the little coil of brass wire on its south end.

To straighten the needle turn the plate until the N end of the needle reads north, carefully read the S end, turn the plate until the S end of the needle reads north and carefully read the N end. If the N end does not now read the same as the S end did at first, the needle is bent and should be straightened by trial bending until the N and S ends will read alike.

Needle Pivot Adjustment:—If, after straightening the needle the two ends do not read opposite, the pivot is not central and should be centered by bending until the ends will read opposite at any position on the compass circle. If, for any reason, the pivot is removed, it should be tested for eccentricity as above, after replacing.

When the pivot is dull it should be removed and sharpened on a fine oil stone, giving it a rotary motion as it is drawn back and forth. Finish on a razor strop or other close grained leather. The original angle of the point should be preserved as nearly as possible.

ADJUSTMENT OF SOLAR ATTACHMENTS

THE BURT.

(See Fig. 19, P. 35)

Collimation Adjustment:—To bring the optical axes parallel, first detach the declination arm by removing the clamp and tangent screw and the center with its small screws by means of which the arm is attached to the arc. The adjuster, which is a short bar usually furnished with this Solar, is then substituted for the declination arm. Screw the center into place at one end and the clamp screw,—through the hole left by the removal of the tangent screw—into the other, thus securing the adjuster firmly to the arc.

Place the Solar attachment on the instrument and the declination arm on the adjuster, directed toward the Sun and brought into position so that the image of the Sun through the lens is brought precisely between the equatorial lines on the screen. Clamp all motions of the instrument and carefully turn the arm over until it rests upon opposite faces of the rectangular blocks with the Sun's image on the opposite screen; if it remains between the lines as before, the arm is in adjustment, if not, loosen the three small screws holding the screen and move it to correct one-half the error. Bring the image again between the lines, turn the bar as before and repeat the operation until the image will remain between the lines in both positions of the arc, when it will be in proper adjustment and may be replaced on the attachment.

This adjustment is not often required.

Declination Vernier Adjustment:—Set the declination vernier at zero, direct the attachment toward the Sun and bring the Sun's image exactly between the equatorial lines on the plate, clamp all motions of the instrument and revolve the Solar 180° on its polar axis, until the Sun's image appears on the opposite screen. If precisely between the lines, no

adjustment is required; if not, correct one-half the error by means of the declination arm tangent screw and repeat until the image comes precisely between the lines on opposite screens. Clamp the arm and remove the index error by loosening the vernier screws and moving the vernier to coincide with the zero of the declination arc, tighten the screws and this adjustment is complete.

Polar Axis Adjustment:—With the Solar attachment removed* level the instrument carefully by means of the telescope level, until the bubble will remain central during a complete revolution in azimuth of the instrument. Place the Solar upon the Polar axis, bring the declination arm parallel with the telescope, set the vernier at zero and place the adjusting level—usually furnished with the attachment—upon the top of the rectangular blocks. Bring the bubble to the center by means of the declination arm tangent screw, swing the attachment through 180° on its axis, bringing it again parallel with the telescope. If the bubble is not central correct for one-half the error by means of the capstan head adjusting screws under the base of the Polar axis; bring the bubble to the center again by means of the declination arm tangent screw and repeat the operation until the bubble will remain central in direct and reverse positions. Pursue the same course in adjusting the Polar axis in a plane perpendicular to the telescope, until when, with the telescope level, the Solar test level bubble will remain central throughout a complete revolution of the attachment on the Polar axis. This adjustment is then complete.

Hour Circle Adjustment:—With the instrument in the Meridian, see instructions for "Determination of the Meridian with the Solar Attachment," P. 33-35, the index should read apparent time on the hour circle; if it does not, loosen the two flat head screws on top of the hour circle and revolve the circle until, with the image of the Sun within the square on the Solar screen, the index reads apparent time, then tighten the screws and the adjustment will be complete.

THE SAEGMULLER.

(See Fig. 20, P. 36)

Collimation Adjustment:—With the attachment in position on the instrument, level the transit telescope, bring the Solar telescope into the same plane and level by means of the Solar telescope level when the cross hairs of both telescopes should fall on a distant point—more than 5000 ft. away. If they do not, correct the error by means of the Solar reticle adjusting screws. If a nearby point is taken for this

* The center of gravity of the Burt Solar being to one side of the Polar axis, when on the instrument, it throws it out of balance somewhat.

adjustment it is necessary to use two points vertically above one another, a distance equal to the vertical distance between the axes of the two telescopes.

Polar Axis Adjustment:—Proceed as described under the "Polar Axis Adjustment, Burt Solar," using the Solar telescope level instead of the test level as used with the Burt, and the Solar telescope axis tangent motion instead of the declination arc tangent as described.

Hour Circle Adjustment:—See "Hour Circle Adjustment, Burt Solar."

THE SMITH.

(See Fig. 21, P. 37)

Latitude Vernier Adjustment:—Clamp the latitude arc at zero and place the striding level furnished with this attachment upon the telescope. Bring the bubble to the center by turning the latitude tangent screw. Reverse the level, and if the bubble is central the axis is horizontal; if not, adjust the tangent screw to correct one-half the error, the other half being in the level itself. If, when the level is reversed, the bubble occupies a similar position in the opposite direction, the axis is horizontal—the observed error being in the adjustment of the level itself. The vernier will now indicate the index error, which may be corrected by shifting the vernier by means of the vernier adjusting screws.

Declination Arc Adjustment:—Having set off the latitude, observe the Sun on the Meridian, and bring its image accurately between the equatorial wires by means of the declination vernier tangent screw. The difference between the observed and calculated declinations corrected for refraction will be the index error, which may be corrected by loosening the three small screws on top of the arc, and moving the arc to the correct reading.

Planes of the Latitude Arc Adjustment:—The plane of the latitude arc and that of the reflector should be placed by the maker at right angles with the optical axis of the solar telescope, and are not liable to derangement. The vertical planes of the latitude arc and the solar and transit telescopes should also be made parallel; but as this condition is sometimes disturbed in detaching and attaching the apparatus to the standards, the following is the adjustment:

Having completed the adjustments above described, take a Solar observation at say, 9 A. M., and note the error east or west of the Meridian as indicated by the transit telescope directed south. Bring the transit telescope into the Meridian with the tangent screws, which will cause the Sun's image to leave the Equatorial hairs diagonally. Then by means of the small adjusting screws in the Solar frame move the south end of the plate east, if the error was east,

or west, if it was west, until the Sun is accurately between the wires. A Solar observation at 3 P. M. will verify the adjustment; but if the morning and afternoon observations cannot be made to agree, then a portion of the error must be ascribed to the plane of the reflector not being truly at right angles with the line of collimation. The adjustment of the reflector is a delicate operation and should not be attempted in the field. Allowance may be made for this error if small, but if large it should be sent to a competent instrument maker for re-adjustment.

Cross Hair Adjustment:—If the Sun in traversing the field of view should appear to depart from the Equatorial hairs, the correction can be made by loosening the reticle adjusting screws and rotating the cross hair reticle until the Sun appears to follow the Equatorial wires accurately.

Finally; if possible, check all adjustments.

THE SHATTUCK.

(See Figs. 22 and 23, P. 38-39)

Owing to the optical construction of the Shattuck Double Reflecting Solar Attachment no adjustments are required.

TESTS

The following tests should be made, but any adjustments found necessary should not be attempted outside of the factory.

Eccentricity of Centers:—With the lower motion clamped, level the instrument carefully by means of the telescope level, loosen the lower motion and holding the vernier plate as nearly stationary as possible revolve the limb slowly; the telescope level will then show the eccentricity in the centers, the accuracy of the test depending upon the sensitiveness of the level.

When the centers are eccentric, the adjustment of the plate levels and height of standards should be made with the lower motion clamped.

Opposition of Verniers:—Read the two verniers, then bring the zero of the B vernier to the same point on the circle that the zero of the A vernier occupied. If the A vernier now reads the same as the B vernier did in the first position, they are diametrically opposite.

Eccentricity of Graduations:—When the circle is fitted with two verniers, read the angle between the two verniers in various positions on the circle. If these angles are equal, the center of the graduated circle coincides with its centre of revolution. When they vary, the circle is eccentric.* The error in the measurement of an angle due to eccentricity may be

*It is assumed that the graduations are accurate, but by carefully reading and repeating angles, errors can be located in most of the instruments put out at the present time.

eliminated by taking the mean of the angles as read by the two verniers.

When the circle to be tested has but one vernier the instrument should be in adjustment especially in collimation and set up level.

To Test the Limb, carefully fix the intersection of the cross hairs on a well defined point, read the vernier, reverse the telescope in altitude and azimuth, fix the intersection of the cross hairs on the same point and read vernier. The difference between the readings should be 180°. Repeat the test at different points on the limb and if the difference between the direct and reverse readings on any point is not 180° the limb is eccentric.*

To Test the Vertical Circle, the vernier and telescope level should be in exact adjustment and the instrument carefully leveled. With the telescope level, the vernier reading zero, fix the intersection of the cross hairs on a well defined point, reverse the telescope in altitude and azimuth, fix the intersection of the cross hairs on the same point and read the vernier. It should read zero. Make similar tests, reading the telescope direct and reversed, on points at various angles of elevation and depression. If the angle read on any point with the telescope direct is not the same as that read with it reversed, the circle is eccentric.*

Gradienter:—Level the telescope, clamp the gradienter, and read the position of the horizontal hair on a rod 100 ft.—100 meters—from the instrument. Set the micrometer head of the gradienter at zero and turn the screw until 100 divisions of the micrometer head have passed the indicator. The rod reading should now differ by one foot—meter—from the first reading. If it differs by more than one foot—meter—it indicates that the radius of the gradienter arm is too short, if by less it indicates that it is too long. If the gradienter arm is adjustable this is easily corrected.

In using the gradienter the setting should always be made by turning the screw in the same direction—right handed—in order to eliminate the effects of friction and backlash. When the setting requires the screw to be turned left handed, turn it beyond the proper point and then return to the correct position by turning it right handed.

USE AND CARE OF INSTRUMENTS

In adjusting, the instrument should be set up on a firm support where it is protected from the Sun and wind, or make the adjustments on a still and cloudy

* It is assumed that the graduations are accurate, but by carefully reading and repeating angles errors can be located in most of the instruments put out at the present time.

day. The sun shade should be in place on the telescope and the draw tube kept as near the mid-position as possible. Be careful to not disturb the instrument while making an adjustment.

In leveling an instrument, it is convenient to place the level tubes parallel to the line joining a pair of opposite leveling screws. Work the leveling screws slack* until the bubble is nearly central, then screw them up firmly, centering the bubbles at the same time. Heavy pressure is unnecessary and injurious.

All adjusting screws and nuts should be screwed up to a firm bearing. Excessive tightening will not aid an instrument in keeping its adjustment and may damage its parts.

All adjustments should be tested frequently, and after making a number of them they should be retested as a final precaution.

When adjusting the reticle, remember that, in erecting telescopes, the image is reversed by the eyepiece and the adjusting screws must be turned in the direction which will apparently increase the error, while in inverting telescopes, they must be turned in the direction which will apparently decrease the error.

Parallax:—If the cross hairs are not exactly in the plane of the image they will appear to move on the object as the eye is moved about over the sight hole of the eyepiece. To secure accurate results this apparent motion must be carefully removed, which may be done as follows: Adjust the eyepiece until the cross hairs are in sharp focus, then focus the objective until they appear to be fixed on the object and there is no relative motion of cross hairs and object.

In Case of Accident:—Proceed with care, as frequently a transit is damaged more by the treatment it receives after the accident than by the accident itself. The graduated silver circles and verniers in particular are easily injured.†

First:—Note if one or both of the limb verniers are above or below the plane of the limb; this will at

* All Ainsworth instruments have the feet of the leveling screws in a plane passing through the centre of the half ball, see Fig. 8, P. 10, "Horizontal Axis of Leveling Head", allowing perfect freedom of movement in leveling up the instrument and making it impossible for the leveling head to bind in any position.

† A slight accident, if the instrument is made of soft material, may spring the plates, forcing the verniers against the edge of the limb, which may be repaired at moderate expense. If, however, the vernier plate is revolved "to see if it will go around," it will burr up the entire edge of the limb and one or both verniers, necessitating boring out the limb and making a new set of verniers, as they are only suited for a limb of a certain predetermined diameter.

once indicate whether the plates or centers are bent, in event of which clamp the plates together, as it is inadvisable to move the verniers with reference to the limb.

Second:—See if the instrument will revolve freely on the lower motion.

Third:—Note if the vertical arc or circle is out of plane with its vernier. If it is, this will indicate that either the circle or the standards, or both, are sprung, in event of which loosen the vernier screws and move the vernier away from the circle. Now carefully revolve the telescope on its axis, watching the face of the circle to see that it does not strike the standard or guard. If the telescope does not revolve freely it is quite likely that the axis is sprung.

Fourth:—Focus the objective slide to see that it operates freely, examine the objective to see that the lenses have not separated, examine the clamp, tangent and leveling screws to see if they are bent, and the plate and telescope levels to see if they are leaking or broken.

If the instrument appears to be in good condition test all adjustments, see P. 11-16, and for opposition of verniers, eccentricity of graduations and centers, P. 19-20.

The foregoing in part applies to a Wye or Dumpy Level as well.

Cleaning and Oiling:—If any of the working parts of an instrument turn hard or show signs of cutting, they should be examined at once and the cause removed. Dirt, thick oil or lack of oil on spindles, tangent clamps, telescope axes, or objective slide may be responsible. The obvious remedy is a thorough cleaning, using a clean, soft cloth. Before assembling, every particle of dust and dirt should be removed from the spindles, sockets and telescope axes, and a **little** watch or transit oil well distributed on the bearing parts.

Sometimes clamps, owing to the alloys of which they are made, operate better without than with lubrication.

Never touch the graduated edge of a circle or vernier, and when necessary to clean them do it with as little rubbing as possible.

Cutting:—When cutting has started, carefully burnish down the roughened parts with the back of a knife blade as well as possible, clean thoroughly and oil. If cutting continues, the roughened parts may be scraped a little, but very little scraping should be done, however, except by an experienced instrument maker. **Never use emery in any form on a transit or level.** The leveling, clamp and tangent screws should be oiled only when cleaning and then wiped dry.

Cleaning Lenses:—Dust the lenses off with a camel's hair brush, then wipe carefully with a clean,

soft rag to avoid scratching. The use of a little alcohol on the rag will materially assist in the cleaning. Screw the lens cells up firmly to their shoulders, taking care that they occupy their original positions. By marking them before removal they may be readily returned to their correct positions.

The Tripod shoes should be kept tight and well sharpened. The thumb screws holding the legs to the head should be tightened so that the legs will just close by their own weight when raised to the horizontal position and released.

Moisture:—Should moisture find its way into the telescope it should be dried out by removing the eyepiece and standing the instrument in a dry place for a few hours, protecting the inside from dust by a cloth thrown over the open end.

Always carry a waterproof bag or cover when in the field, for the protection of the instrument.

Storing:—Never store an instrument in a damp place or where there is gas or rubber. The silver parts may be blackened by rubber bands or erasers left in the carrying case.

USE OF THE TOP AND SIDE TELESCOPES

Top Telescope:—When using the top telescope to take vertical angles it is necessary to apply a correction to the readings. In Fig. 14, V is the true

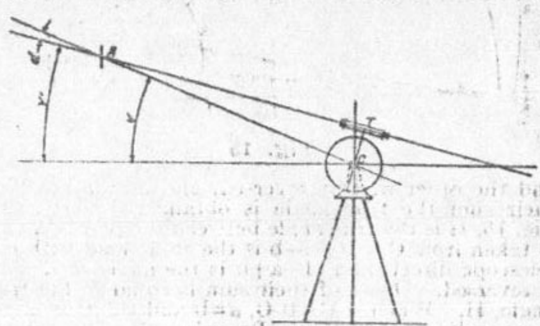


Fig. 14

angle of elevation of A above the centre, C, of the instrument. V′ is the angle read on the vertical circle, when A is sighted through the top telescope. Hence $V = V' + d$, where d = the angle whose sine is $\frac{CT}{AC}$. The algebraic sign of V′ is + for angles of elevation and − for angles of depression; the sign of d is always +. An excellent practical method that eliminates computation is to make a little stick or gauge with a point distant from one end equal to the vertical distance between the axes of the main and top telescopes, and when sighting through the top telescope to sight this point with the end of the gauge on the point that would be sighted by the main telescope if it were used, and held perpendicular to the line of sight. For distances over 100′ and small vertical angles, 15° or less, it is sufficient, except in very accurate work, to set the target at the height of the top telescope from the ground and sight it through the top telescope.

The top telescope being in the same vertical plane as the main telescope, no correction is required when reading horizontal angles.

Side Telescope:—When using the side telescope, to take horizontal angles, it is necessary to apply a similar correction to the readings. However, by making two readings, one with the telescope direct

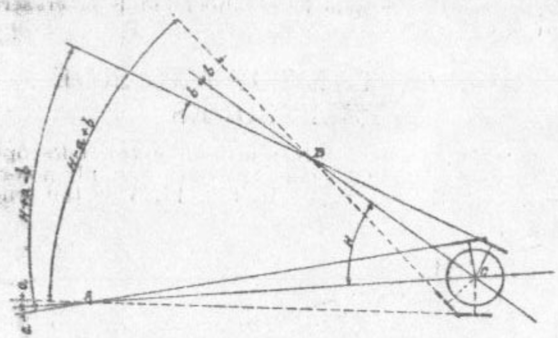


Fig. 15

and the other with it reversed, and taking one-half their sum, the true angle is obtained directly. In Fig. 15, H is the true angle between the points A and B taken from C. H+a−b is the angle read with the telescope direct, and H−a+b is the angle read with it reversed. One-half their sum is equal to the true angle, H. When A C=B C, a=b and the true angle is given by one reading. By using an offset target, the offset being equal to the distance of the side telescope from the centre of the instrument, the true angle will be given by one reading. The rod is held on A and then on B, with the offset perpendicular to the line to C and on the same side of it as the side telescope.

The side telescope being in the same horizontal plane as the main telescope, no correction is necessary when reading vertical angles.

The Interchangeable Telescope:—The advantage of this construction is that it enables the measurement of horizontal angles when used as a top telescope and vertical angles when used as a side telescope, without correction for eccentricity and without adjustment other than to bring it into the respective vertical and horizontal planes of the main telescope by means of the tangent screws when used in the top and side positions.

It can also be used throughout a survey as either a top or side telescope; see foregoing directions.

ASTRONOMICAL TERMS

The Sun is the center of the Solar system, remaining constantly fixed in its position, although often spoken of as in motion around the Earth.

The Earth makes a complete revolution around the Sun in three hundred and sixty-five days, five hours, forty-eight minutes and forty-six seconds.

It also rotates about an imaginary line passing through its center, and termed its axis, once in twenty-three hours, fifty-six minutes and four seconds, mean time, turning from west to east.

The Poles are the extremities of the Earth's axis; that in our own hemisphere, known as the North Pole, if produced indefinitely toward the concave surface of the heavens, would reach a point situated near the Polar star, and called the North Pole of the heavens.

The Equator is an imaginary line passing around the Earth, equi-distant from the Poles, and in a plane at right angles with the axis.

If the plane of the Equator be produced to the heavens, it forms what is termed the Celestial Equator.

The Orbit of the Earth is the path in which it moves in making its yearly revolution. If the plane of this orbit were produced to the heavens, it would form the Ecliptic, or the Sun's apparent path in the heavens.

The Earth's axis is inclined to its orbit at an angle of about 23° 27′, making an angle between the Earth's orbit and its equator, or between the Celestial Equator and the Ecliptic, of the same amount.

The Equinoxes are the two points in which the Ecliptic and the Celestial Equator intersect one another.

The Horizon of a place is the surface which is defined by a plane supposed to pass through the place at right angles with a vertical line, and to bound our vision at the surface of the Earth. The horizon, or a horizontal surface, is determined by the surface of any liquid when at rest, or by the spirit-levels of an instrument.

The Zenith of any place is the point directly overhead, in a line at right angles with the horizon.

The Meridian of any place is a great circle passing through the zenith of a place and the Poles of the Earth.

The Latitude of a place is its distance north or south of the Equator, measured on the Meridian At the Equator the latitude is 0°, at the Poles 90°.

Refraction:—By reason of the atmosphere, the rays of light from the Sun are bent out of their course, so as to make its altitude appear greater than is actually the case.

The amount of refraction varies according to the altitude of the body observed; being zero when it is in the zenith, about one minute when midway from the zenith to the horizon, and almost thirty-four minutes when in the horizon.

The Longitude of a place is its angular distance east or west of a given place taken as the starting point or first Meridian; it is measured on the equator or on any parallel of latitude and usually from Greenwich.

As the Earth makes a complete rotation upon its axis once a day, every point on its surface must pass over three hundred and sixty degrees in twenty-four hours, or fifteen degrees in one hour, and so on in the same ratio. And as the rotation is from west to east, the Sun would come to the Meridian of every place fifteen degrees west of Greenwich just one hour later than the time given in the Ephemeris for apparent noon at that place.

To an observer situated at Denver, Colo., the longitude of which is in time, seven hours, the Sun would come to the Meridian seven hours later than at Greenwich, and thus when it was 12 M. at that place it would be but 5 A. M. in Denver.

TIME.

A Solar Day is the interval of time between two successive upper transits of the Sun across the same Meridian. Solar days are of unequal length. A mean Solar day is the average for a year.

A Sideral Day is the interval of time between two successive upper transits of a fixed star across the same Meridian; it is invariable and is equal to twenty-three hours, fifty-six minutes, four and nine-hundredths seconds of mean Solar time. The Earth makes one complete rotation on its axis in a Sideral day.

Mean Noon:—A clock keeps mean Solar time when it divides a mean Solar day into twenty-four

equal parts or hours. Noon as shown by such a clock is mean noon.

Apparent Noon for any place is the time of the upper transit of the sun across the Meridian of that place; it may occur several minutes earlier or later than mean noon.

Equation of Time:—The column headed "Equation of Time" in the Ephemeris shows the quantity to add to or subtract from mean time to obtain the corresponding apparent time.

Standard Time:—Since November, 1883, in the United States, the mean Solar time of the Meridians 60, 75, 90, 105, and 120 west of Greenwich are adopted as standard time, and are called respectively Colonial, Eastern, Central, Mountain and Pacific time. Each differs from the next in time by one hour. Instead of employing the local mean Solar time, the time used is the mean Solar time at the nearest of the standard Meridians.

Hour Angle:—The number of hours from the meridian.

To Set a Watch to Mean Local Time by the Sun:—Set up the transit and adjust the telescope to the true Meridian, then note the exact time that the centre of the Sun's image crosses the vertical cross hair. This is apparent noon, and at this instant, set the minute hand to as many minutes before 12 as the equation of time for the given day shows is to be added to mean time, or to as many minutes after 12 as it shows is to be subtracted. The correction may be noted in case it is not desired to set the watch.

DECLINATION

The Declination of the Sun is its angular distance north or south of the Celestial Equator; when the Sun is at the Equinoxes, that is, about the 21st of March and the 21st of September of each year, its declination is 0, or it is said to be on the Equator; from these points its declination increases from day to day and from hour to hour, until on the 21st of June and the 21st of December it is 23° 27′ distant from the Equator.

It is the declination which causes the Sun to appear so much higher in summer than in winter, its altitude in the heavens being about 46° 54′ more on the 21st of June than it is on the 21st of December.

The Ephemeris gives the Sun's declination for mean noon at Greenwich for each day in the year. The declination of the Sun at any place for any hour of the day is determined from the Ephemeris as follows:

(1) Divide the longitude of the place (reckoned from Greenwich) by 15 to obtain the corresponding difference of time in hours.

(2) Find the corresponding Greenwich time by adding the difference of time to the mean time at the given place, when west from Greenwich, and subtracting when east.

(3) Multiply the difference for one hour, as found in the table opposite the given day of the year, by the number of hours from noon by Greenwich time.

(4) This product is the change in declination to be applied as indicated in the following expression:

$$\left\{\begin{array}{l}\text{Declination for}\\ \text{given time}\\ \text{and place}\end{array}\right\} = \left\{\begin{array}{l}\text{apparent dec.}\\ \text{for given day}\\ \text{of year}\end{array}\right\} \begin{array}{c}+\\ -\end{array} \left\{\begin{array}{l}\text{change in}\\ \text{declina-}\\ \text{tion.}\end{array}\right.$$

The sign of the last term is + for time after noon when declination is increasing, and for time before noon when declination is decreasing.

The − sign is to be used for time after noon when declination is decreasing and for time before noon when declination is increasing.

An inspection of the Ephemeris will show whether the declination is increasing or decreasing from day to day.

N in the column of apparent declination indicates north, and S indicates south declination.

Example:—Required the declination at 10 A. M., Aug. 10th, 1911, at Denver, Colo., U. S. A., latitude 39° 46′ 31″ north, longitude 105° west.

(1) Dif. of time $= \frac{105}{15} = 7$ hrs.

(2) As Denver is west from Greenwich, add the dif. of time, obtaining 10 A. M., Denver time = 10+7=17 or 5 P. M., Greenwich time.

(3)	Change in dec. for 1 hr.	=43″.32
	Change for 5 hrs.	=43″.32×5=0° 03′ 36″.60
(4)	Sun's apparent dec. at Greenwich, mean noon	=N 15° 49′ 53″.60
	Dec. at 10 A. M., Denver	=N 15° 46′ 17″

The change is subtracted as the time is afternoon and the dec. is decreasing, since the dec. the next day is less.

LATITUDE

Determination of Latitude by Direct Observation of the Sun:—Carefully level the transit a few minutes before apparent noon, and if it is not provided with Solar hairs, bring the horizontal cross hair tangent to the upper limb of the Sun and keep it tangent by the slow motion screw until the Sun

ceases to rise, then read the vertical angle, and from this angle subtract the semi-diameter of the Sun, as given in the Ephemeris for the proper month of the year, also the refraction corresponding to the observed angle, as given on P. 86. The resulting angle will be the true altitude of the Sun's center. Calculate the Sun's declination for noon, apparent time, for place of observation as described above. If the declination is N, **subtract**, but if it is S, **add** it to the true altitude of the Sun. The result is the co-latitude of the place of observation and the lat. = 90° — co. lat.

Note.—In direct Solar observations it is necessary to protect the eye by a darkened glass, which should be used at the eye end of the telescope unless both its surfaces are true and parallel. When the altitude is high, a diagonal eyepiece will be found convenient, or an image of the sun and cross hairs may be formed on a screen, a card or a blank page of a note book held a few inches from the eyepiece. If this method is used no darkener is required. An average of several observations is preferable to a single observation. When more than one observation is made, the alternate ones should be taken with the telescope reversed in order to eliminate instrumental errors. When great accuracy is not essential, standard time may be used in computing the declination. As the difference between standard and local time is seldom more than 30 min. and the greatest hourly change in declination is about one minute of an arc, the maximum error in declination due to using standard time would not be greater than 30″.

Example:—On April 17th, 1910, an observation was made of the Sun to determine the latitude of Denver. The horizontal cross hair was kept tangent to the lower limb of the Sun until it ceased to rise, then the vertical circle reading was 60° 20′ 00″.

Apparent alt. lower limb	=60° 20′ 00″
Refraction for 60° 20′ 00″	=00° 00′ 34″
True alt. lower limb	=60° 19′ 26″
Add Sun's semi-diameter	=00° 15′ 58″
True alt. Sun's centre	=60° 35′ 24″
Subtract declination	=10° 21′ 55″
Co lat.	=50° 13′ 29″
Latitude	=39° 46′ 31″

Latitude may be determined by reference to an accurate map, from which the latitude of a neighboring point may be found and then due allowance made for the distance north or south to the station.

The table, P. 87-88, gives the length, in feet, of one min. (arc) and the number of min. (arc) in a mile for latitude and longitude from 0° to 60° latitude by one degree intervals.

DETERMINATION OF THE MERIDIAN

By Direct Solar Observation:—The best time of day for a Solar observation is from 8 to 10 A. M., and from 2 to 4 P. M. Observations greater than five or less than one hour from noon should not be relied upon.

The transit should be accurately adjusted and carefully leveled. Set the limb at zero when the telescope is directed to some convenient mark, then with the lower motion clamped, point the telescope to the Sun and bring the vertical and horizontal cross hairs tangent to its image, say in the lower left hand quarter, thus ┼; read the vertical circle and the limb. Note the time, quickly reverse the telescope in altitude and azimuth and again bring the cross hairs tangent to the image, but in the opposite quarter, thus ┼; read the vertical circle and the limb. The mean of the vertical circle readings will give the apparent altitude of the center of the Sun. The mean of the readings on the limb will give the angle between the Sun and the selected mark.

Formula A:—Let Z = the angle between the Sun and the Meridian, then its value may be obtained from the equation

$$\cos \tfrac{1}{2}Z = \sqrt{\frac{\sin \tfrac{1}{2}S \times \sin(\tfrac{1}{2}S - \text{co dec.})}{\sin \text{co alt.} \times \sin \text{co lat.}}}$$

where S = co dec. + co alt. + co lat.

Example:—The following notes are of an observation made at Denver at 10 A. M., April 17, 1910. Latitude 39° 46′ 31″.

Telescope	Horizontal Angle	Vertical Angle	Position of Sun's Image
Direct...........	89° 17′ R	+ 50° 14′	┼
Reversed.........	89° 07′ R	+ 51° 07′	┼

Reduction of Notes:—10 A. M., Denver time = 10+7=17 or 5 P. M., Greenwich time.

Change in dec. since noon
Greenwich..........=5×53″.02=+00° 04′ 25″.1
Dec. at noon Greenwich....=N10° 15′ 44″.4
Dec. at 10 A. M. Denver...=N10° 20′ 09″.5
co dec.............= 79° 39′ 50″.5

$$\text{Apparent alt} = \frac{(51° 07′)+(50° 14′)}{2} = 50° 40′ 30″$$

Subtract refraction correction=00° 00′ 49″
True alt..................=50° 39′ 41″
Co alt....................=39° 20′ 19″
Lat.......................=39° 46′ 31″
Co lat....................=50° 13′ 29″

$\tfrac{1}{2}S =$
$\tfrac{1}{2}[(79° 39′ 50″.5) + (39° 20′ 19″) + (50° 13′ 29″)]$
$= 84° 36′ 49″.2$

Substituting in equation for cos ½Z

$$\cos \tfrac{1}{2}Z = \sqrt{\frac{(\sin 84° 36′ 49″.2) \times (\sin 4° 56′ 58″.7)}{(\sin 39° 20′ 19″) \times (\sin 50° 13′ 29″)}}$$

$$\log \cos \tfrac{1}{2}Z = \tfrac{1}{2}\begin{bmatrix} +9.9980780 \\ +8.9359106 \\ -9.8020222 \\ -9.8856776 \end{bmatrix} = 9.6231444$$

½Z=65° 10′ 18″, Z=130° 20′ 36″

Interpretation of Result:—Fig. 16 shows the relative positions of the Sun, the Meridian, and the point of reference.

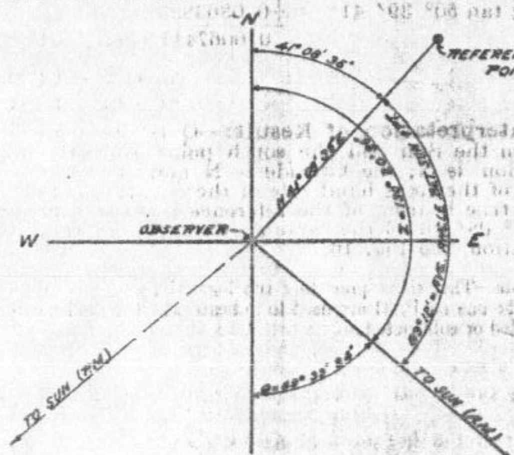


Fig. 16

Before noon Z is to the left of the line to the Sun and to the right after noon.

The true bearing of the reference point is N 41° 08′ 36″ E.

Formula B:—Identical results will be obtained by the use of the following equation and it may be preferred on account of its containing the direct angles instead of the co angles, but it is necessary to pay careful attention to the algebraic signs when it is used.

$$\cos Q = \frac{\sin \text{dec.}}{\cos \text{lat.} \times \cos \text{alt.}} - \tan \text{lat.} \times \tan \text{alt.}$$

The sign of the first term of the right hand side of the equation is **minus** when declination is S; the second term is **plus** where the latitude is S. If the algebraic sign of the result is **plus**, Q is the angle between the Sun and the north point, but if it is **minus**, it is the angle between the Sun and the south point.

Example:—The solution of the above example by this equation is as follows:

$$\cos Q = \left\{ \begin{array}{l} + \dfrac{\sin 10^\circ\ 20'\ 09''.5}{(\cos 39^\circ\ 46'\ 31'') \times (\cos 50^\circ\ 39'\ 41'')} \\ -(\tan 39^\circ\ 46'\ 31'') \times (\tan 50^\circ\ 39'\ 41'') \end{array} \right\}$$

$$\begin{array}{ll} \log \sin 10^\circ\ 20'\ 09''.5 & = +9.2538706 \\ \log \cos 39^\circ\ 46'\ 31'' & = -9.8856775 \\ \log \cos 50^\circ\ 39'\ 41'' & = -9.8020222 \\ \hline & \ 9.5661709 = \log\ 0.368274 \end{array}$$

$$\begin{array}{ll} \log \tan 39^\circ\ 46'\ 31'' & = +9.9203518 \\ \log \tan 50^\circ\ 39'\ 41'' & = +0.0863893 \\ \hline & \ 0.0067411 = \log\ \underline{1.015640} \end{array}$$

$$\cos Q = -.647366$$

$$\therefore Q = 49^\circ\ 39'\ 24''$$

Interpretation of Result:—Q is the angle between the Sun and the south point, since the declination is N, the latitude is N and the algebraic sign of the right hand side of the equation is minus. The true bearing of the reference point is therefore N 41° 08′ 36″ E, the same as obtained by the first equation, see Fig. 16.

Note—The signs preceding the logarithms in this example and the one on P. 31 are used to indicate whether the logarithm is added or subtracted.

WITH THE SOLAR ATTACHMENT.

Let Fig. 17 represent a vertical plane through the axis of the Earth. O is the center of the Earth. P P is the Earth's axis. H H is the intersection of the plane of the horizon, and E E is the intersection of that of the Equator with the vertical plane. The vertical line, Z N, through O defines the zenith above and the nadir below. The dotted lines at either side of E E represent the Sun's declination. A line of sight at O mounted on an axis of revolution coinciding with P P will follow the Sun by simple rotation on this axis, so long as the inclination of the

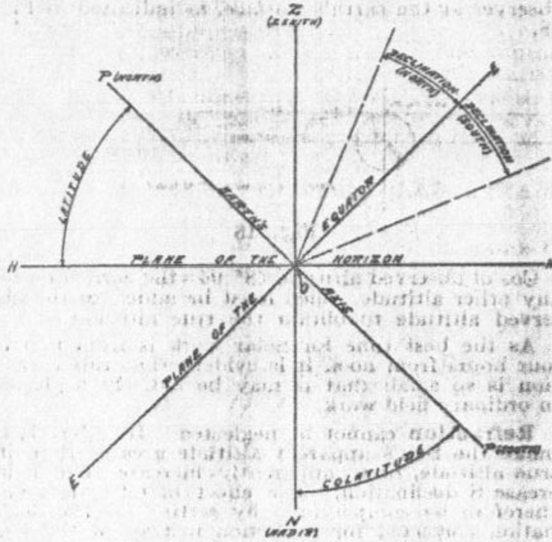


Fig. 17

line of sight to E E equals the Sun's declination. It follows that if the line of sight is inclined to E E at an angle equal to the Sun's declination, and E E is at 90° to the axis of revolution, as before, the Sun can be followed by simple rotation only when the axis of rotation coincides with the Earth's axis P P.

All Solar instruments operate on the above principle; their essential features are:

A vertical axis on which is mounted a Polar axis and a line of sight mounted on the Polar axis. The Polar axis corresponds to P P in Fig. 17. It is so arranged that it may be inclined at an angle to the horizon, equal to the angle the Earth's axis makes with the horizon, or the latitude of the place. The line of sight is so mounted that it may be inclined at an angle with a normal to the Polar axis equal to the Sun's declination. A Solar attachment mounted on a transit converts the latter into a Solar instrument.

Two assumptions were made in the foregoing which are not met with in practice:

1st. That the point of observation was at the center of the earth.

2nd. That there was no refraction.

Solar Parallax:—When the Sun is in the true horizon it is 8".94 below the visible horizon of an observer at the earth's surface, as indicated in Fig. 18.

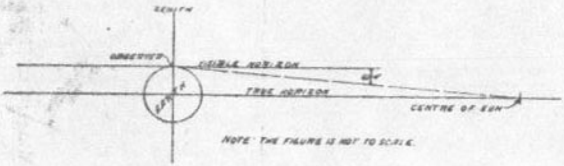


Fig. 18

Cos of observed altitude×8".94 = the correction for any other altitude, which must be added to the observed altitude to obtain the true altitude.

As the best time for Solar work is from two to four hours from noon it is evident that this correction is so small that it may be entirely neglected in ordinary field work.

Refraction cannot be neglected. Its effect is to make the Sun's apparent altitude greater than its true altitude, or to apparently increase N and decrease S declination. The effect of refraction may therefore be compensated by setting off the declination corrected for refraction instead of the true declination. The tables on P. 89-92 show the refraction corrections to be applied to the declination.

A table of declination settings for the hours suitable for observations should be prepared previous to the day's work.

Example:—Declination settings for August 10th, 1911, for Denver, Colo.:

Lat.=39° 46′ 31″

Long.=105° W.

Dif. of time=7 hrs.

8 A. M. Denver time = 8+7=15 or 3 P. M. Greenwich time.

Hourly change in dec. = 43".32.

Dec. at 8 A. M. Denver, to the nearest sec. = (N. 15° 49′ 53".6)—(43".32×3)=(N. 15° 47′ 44″)

By successively deducting 43".32, the dec. for the consecutive hours is obtained as follows:

Time	Declination North	Refrac. Corr.	Setting
8 A. M.	15° 47′ 44″	+55″	15° 48′ 39″
9	15° 47′ 00″	+40″	15° 47′ 40″
10	15° 46′ 17″	+32″	15° 46′ 49″
2 P. M.	15° 43′ 24″	+32″	15° 43′ 56″
3	15° 42′ 40″	+40″	15° 43′ 20″
4	15° 41′ 57″	+55″	15° 42′ 52″

The refraction correction is taken from the tables on P. 89-92, under the nearest given latitude in the column headed by the nearest declination and opposite the hour angle.

Add the correction when dec. is N and subtract when it is S.

When the attachment is fitted with an hour circle, Sun time may be read from it, or by setting it to Sun time, the Sun may be brought into the field by rotation on the vertical axis.

DIFFERENT TYPES OF THE SOLAR ATTACHMENT.

In the following descriptions and diagrams the reference letters are the same as in Fig. 17.

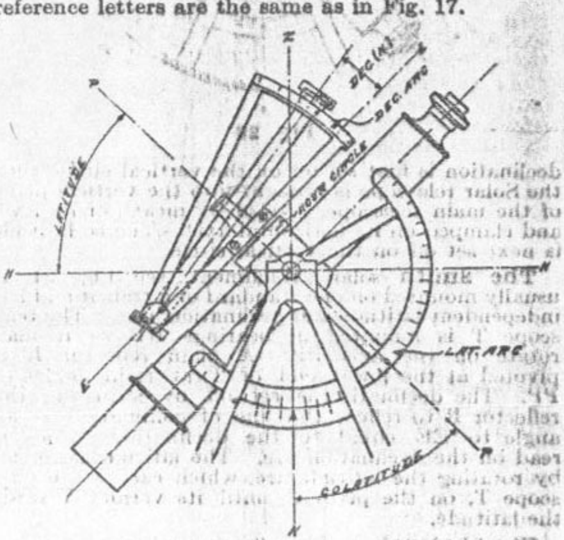


Fig. 19

The Burt solar attachment, see Fig. 19, is mounted on the top of the transit telescope. The colatitude is set off on the vertical circle of the transit and the declination on the declination arc of the attachment. For south declination the attachment is rotated 180° on its Polar axis.

The Saegmuller solar attachment, see Fig. 20, is also mounted above the transit telescope. The

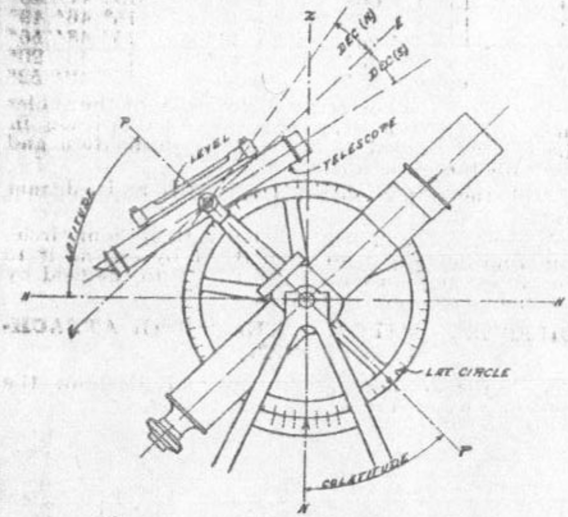


Fig. 20

declination is first set off on the vertical circle, then the Solar telescope is brought into the vertical plane of the main telescope, leveled by means of its level and clamped on its horizontal axis. The co-latitude is next set off on the vertical circle.

The Smith solar attachment, see Fig. 21, is usually mounted on one standard of a transit and has independent latitude and declination arcs. The telescope T is mounted in bearings BB so it may rotate on the axis PP. A plain reflector R is pivoted at the lower end of T at right angles to PP. The declination is set off by adjusting the reflector R to reflect the line of collimation at an angle to EE equal to the declination, which is read on the declination arc. The latitude is set off by rotating the latitude arc, which carries the telescope T, on the pivot C until its vernier V reads the latitude.

The Shattuck double reflecting solar attachment, as made by Wm. Ainsworth & Sons, is shown in Figs. 22 and 23.

Fig. 22 shows how it is attached to a transit in place of the Sun shade, and Fig. 23 is a cross section of the

attachment, showing the double reflection of the ray before entering the objective of the instrument. The attachment consists of a frame AA which revolves about a main axis called the Polar axis, by means of a bearing in the objective cap B. This axis is parallel to the sight line PP of the transit and is provided with a clamp and tangent screw engaging the ring C. The frame AA carries two reflectors, one of which (H) is stationary and the other (I) is mounted on the swinging arm D so that by turning the declination screw E, any suitable angle may be set between the reflectors. The screw E is provided with a clamp G and a slow motion or micrometer nut F having ten divisions, one revolution of which changes the reflected ray ten minutes of arc.

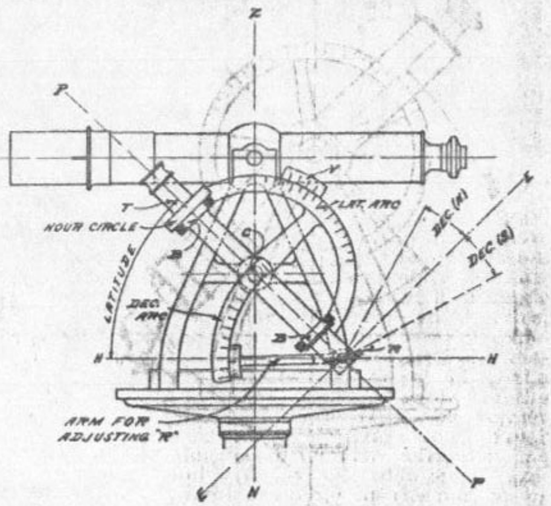


Fig. 21

The effectiveness of the Shattuck double reflecting solar attachment depends upon the optical principle that a ray of light which suffers reflection twice in the same plane, makes, after its second reflection, an angle with its original direction equal to twice the angle between the reflecting surfaces.

By the adaptation of this principle to a Solar attachment, all adjustments for the Polar axis and of the declination and latitude arcs are eliminated. At whatever angle the first reflector is to the incident ray, the deflection of the ray after its second reflection depends solely upon the angle between the mirrors, thus obviating the necessity of making the Polar bearing exactly parallel to the line of collimation

To illustrate this more clearly, suppose, instead of two reflectors, that a single movable mirror is mounted on the frame so that the ray of light is reflected but once before entering the telescope. It then becomes necessary to make the Polar bearings absolutely parallel to the line of collimation, with no lost motion; the draw-tube must be parallel to the sight-line of the telescope, and the cap carrying the Solar must be accurately placed in position, which can not be done within a limit of several minutes error. All of these affect the accuracy of the Polar axis of the Solar.

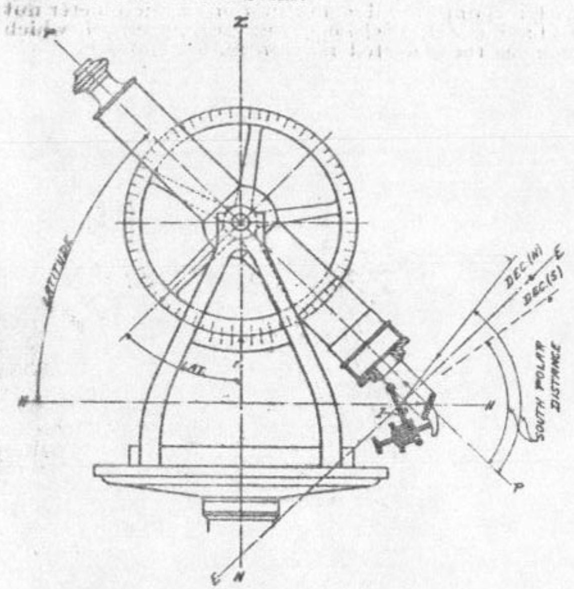


Fig. 22

When a single reflector is used, an error of even one minute in this axis (which mechanically is very accurate) may cause an error of two minutes in the reflector, four minutes in the reflected ray and an error of eight or more minutes in the result.

Though it has been often tried, the principle of the single reflector can never be successfully applied to removable solar attachments, as its use multiplies even the errors to which the ordinary forms of solar attachments are liable.

The introduction of the second mirror obviates all these difficulties and optically makes the Polar axis parallel to the line of collimation, which mechanically it is impossible to do.

It will be seen by referring to Fig. 22 that the mirrors must be so adjusted that an incident ray of light will make an angle with a normal to the reflected ray equal to the Sun's declination. The angle

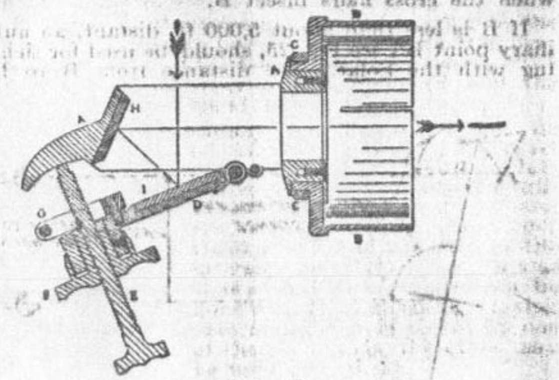


Fig. 23

that the incident ray makes with the reflected ray, produced, is consequently 90° plus the declination, taken algebraically. But 90° plus the declination is equal to the South Polar Distance, hence the mirrors must deflect the incident ray through an angle equal to the South Polar Distance. In practice, the refraction correction is applied to the Polar distance and this corrected, or the apparent Polar distance is the angle of deflection to be set off in the attachment. This setting is made by means of the adjustable mirror, I, as follows: With the vernier plate of the transit set at the apparent South Polar Distance of the Sun corrected for refraction, as above described, and with the telescope level, carefully bisect some prominent point on the horizon or suitable distant object, B Fig. 24.

Fig. 24

Place the cap carrying the Solar attachment in place on the telescope and set the vernier of the horizontal circle at zero, the lower motion remaining clamped. Now, with the telescope still horizontal, bring the reflected image of B into the field of view by turning the declination screw E, Fig. 23, of the Solar, which is then clamped with the clamp G. when the cross hairs bisect B.

If B is less than about 5,000 ft. distant, an auxiliary point B′, see Fig. 25, should be used for sighting with the Solar. The distance from B to B′

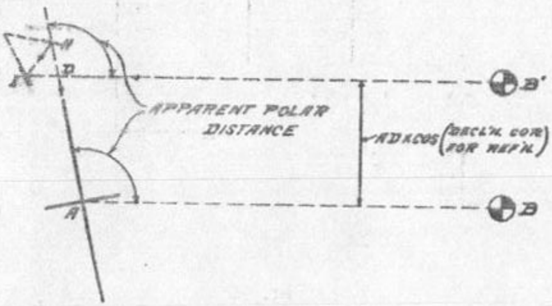


Fig. 25

should be such that the line from A to B is parallel to the line from D to B′. A small hole on the side of the frame of the Solar marks the point D. A D is then easily measured for any instrument and the correct value of B B′ equals A D × cos (declination corrected for refraction). The values of B B′ should be calculated for the various angles of declination and tabulated for ready reference. A D should be measured when B′ is in focus, sighting through the Solar, D B′ being some convenient distance, as 200 feet. When using the tabular values of B B′ thus determined, remember that they are correct only when B′ is at the same distance from D as in determining A D.

The Sun's corrected Polar distance now being set off in the attachment, release the lower clamp of the instrument and depress the objective of the telescope, as shown in Fig. 22* until the vernier of the vertical circle or arc is set at an angle equal to the latitude of the place of observation. Bring the Sun's image to the center of the field by turning the transit upon its vertical axis, using the lower clamp and tangent screw for the

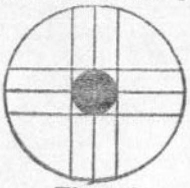


Fig. 26

* In high latitudes and where the diameter of the plates, with reference to the standards, is large, the North Polar Distance must be computed and the telescope elevated.

fine adjustment and the Solar upon its Polar axis. After the Sun's image has been bisected as shown in Fig. 26 the bisection may be successively checked by turning the tangent screw which engages the ring C, Fig. 23.

The axis of the telescope is now parallel to the earth's axis and the instrument is in the Meridian, with the vernier of the horizontal limb at zero. The Solar attachment may now be removed and the azimuth of any desired object taken.

If still greater accuracy be desired, there being no Solar hairs in the telescope as shown in Fig. 26, set off on the vertical limb the **latitude minus the Sun's semidiameter** as given in the Ephemeris, and then bring the **upper limb** or edge of the Sun to the intersection of the cross-hairs as shown in Fig. 27, which can be done with great precision. Having determined the Meridian by one of these methods, the other may be used as a check.

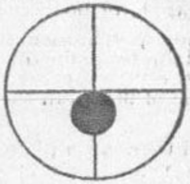


Fig. 27

To use the Solar attachment at subsequent hours during the day, when the declination setting of the previous observation has not been disturbed, correct the former setting by turning the micrometer nut of the declination screw a number of divisions equal to the number of minutes of the Sun's aggregate change in declination and refraction; attach the Solar and proceed as before.

Each division of the micrometer nut equals one minute of arc. Turning the nut forward corresponds to the Sun's change to the North (+), and turning in the opposite direction corresponds to the Sun's change to the South (—), when the telescope is directed toward the South Pole; when directed toward the North Pole the reverse is true.

The refraction correction, being always positive, is added to the South Polar Distance, or subtracted from the North Polar Distance when making observations in the northern hemisphere.

When making observations in the southern hemisphere with the telescope in the ordinary position (Fig. 22) the North Polar Distance is computed and the refraction correction is added to it. The telescope is then directed toward the North Pole. In other respects the operation is the same as in the northern hemisphere.

To save time it is advisable before going into the field to prepare a table for the day, giving the Polar distances of the Sun for every hour suitable for taking observations, similar to the table of declination settings on P. 35.

Vein Tracing:—To trace over a rough or rolling country the apex of a vein which does not stand in a vertical position, requires considerable time in taking measurements and making computations when using an ordinary transit.

By using the Shattuck Solar Attachment, this becomes a very simple operation and is performed as follows:

The dip and strike of the vein are first determined by any convenient means.

Then set the transit over an outcrop of the vein and attach the Solar with the mirror set to deflect the line of collimation through an angle of 90°.

Point the telescope in a direction perpendicular to the plane of the vein, which is done by deflecting an angle of 90° from the strike of the vein, and setting off on the vertical limb an angle of 90° from the dip of the vein.

The Solar revolved on its axis will then cut a plane coincident with the plane of the vein. The line where this plane cuts the surface of the ground is the line of the apex of the vein, which may be traced by simply sighting through the transit and Solar. Its position may be marked where it crosses gulches or hillsides with equal facility.

In case there are two openings at different elevations on the apex of a slanting vein, the strike of the vein may be determined in a similar manner. Place the transit with Solar attached over one of the croppings; depress the telescope to an angle of 90° plus the dip of the vein and direct the telescope toward the foot wall of the vein. Sight through the transit and Solar at the other outcrop, when the vernier reading will be 90° from the strike of the vein.

BY OBSERVATIONS OF POLARIS.

At Elongation:—A few minutes before elongation, set up the transit and center the plumb bob over a tack driven into a stake. Level up very carefully, and keep the vertical cross hair on Polaris, using the tangent screw of the vernier plate, until elongation is reached. This is easily recognized since the azimuth then remains practically constant for several minutes.

When elongation has been reached, depress the telescope and carefully fix a stake on line, reverse the telescope on its axis and rotate the instrument 180° on its vertical axis, fix the vertical hair on Polaris depress the telescope and fix another stake on line, if the vertical hair does not bisect the first one. These two observations must be made before Polaris has appreciably commenced its return motion in azimuth.

When it is necessary to set two stakes,* a third stake midway between them will be in a vertical plane through the plumb line of the transit and Polaris at elongation. By daylight, lay off from this plane the proper azimuth, as given on P. 85. North is to the right, if Polaris was at western, and to the left, if at eastern elongation.

In making this and the following observation it is necessary to illuminate the stakes and the cross hairs. The latter may be accomplished by a suitable lamp, held at one side of the transit, so that sufficient light is reflected into the telescope.

At Culmination:—On account of the great difficulties attending this method, it should be used only when the method of elongation is impracticable.

This method is based on the fact that Polaris is very nearly on the Meridian when it is in the same vertical plane with the star Delta, in the constellation Cassiopeia, or Zeta of the Great Dipper, the star at the bend in the handle. It consists in watching either Delta or Zeta until it comes into the same vertical plane with Polaris and then waiting a known interval of time,† until Polaris is on the Meridian. The vertical cross hair must be placed on Polaris precisely at the end of this interval as the motion, in azimuth, is most rapid at culmination. The telescope is now in the Meridian, which may be marked in any suitable manner.

Limitations:—On account of the haziness of the atmosphere near the horizon, the lower culminations of Zeta and Delta cannot be used below about 38° north latitude; neither can their upper culminations be used north of about 25° and 30° respectively, on account of their being too near the zenith.

Selecting the Star:—The diagram, Fig. 28, shows Delta Cassiopeiae on the Meridian below the Pole at midnight about April 10th. It may therefore be used in the above method for two to three months before and after that date. Likewise Zeta, of the Great Dipper, may be used for two to three months before and after October 10th.

Time of Elongation and Culmination:—Fig 28 shows Polaris near eastern elongation at midnight about July 10th, at western at midnight about January 10th, at upper culmination at midnight about October 10th, and at lower at midnight about April 10th. The approximate time of elongation or culmination for other dates may be determined by noting the position of the line joining Zeta of the Great Dipper and Delta Cassiopeiae. When this

* When the transit is in correct adjustment it will be necessary to set but one stake whose position will correspond with that of the third one, as given above.

† The waiting time for 1911 is 6 min., 27 sec., for Zeta of the Great Dipper and 7 min., 2 sec., for Delta Cassiopeiae.

line is vertical, Polaris is near culmination and when horizontal it is near elongation. Polaris is on the opposite side of the Pole from Zeta of the Great Dipper, thus furnishing a convenient means of dis-

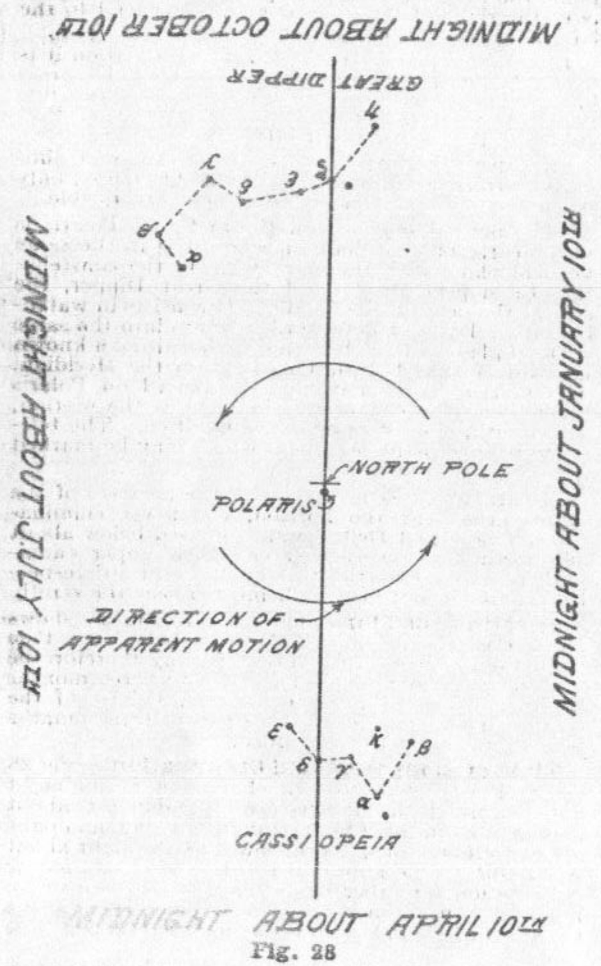


Fig. 28

tinguishing eastern from western elongation and upper from lower culmination. When Zeta is west, Polaris is east of the Pole, and when Zeta is above, Polaris is below the Pole.

BY ANY STAR AT EQUAL ALTITUDES.

In high latitudes neither the Sun nor Polaris give reliable results. The Sun is low and the refraction is uncertain, while, on account of the height of Polaris, the observation is difficult to make and instrumental errors are magnified. In southern latitudes Polaris is not visible at all. Although this method may be used in any latitude, it is particularly applicable under the above conditions.

The Method consists in observing a star when at equal altitudes, east and west of the Meridian. The Meridian will then be half way between these two positions of the star. The star selected should be 30° or more from the Zenith when on the Meridian and, at least, the same distance from the Pole. The observations should be made when the star is three to four hours from the Meridian.

Making the Observation:—To make the first observation; level the transit carefully, direct the telescope to the star, clamp all the motions and fix the intersection of the cross hairs on the star by the slow motion screws, read the star's altitude, unclamp the telescope axis, depress the telescope and fix a point on line.

To make the second observation; re-level the transit carefully, set the telescope at the altitude determined by the first observation, clamp the limb and lower motion when the star comes near to the horizontal hair, keeping the vertical hair on the star by means of the slow motion screw of the vernier plate until it reaches the intersection of the cross hairs, then unclamp the telescope axis, depress the telescope and fix a point on line. A third point set half way between these two will mark the Meridian through the transit.

If the transit has a vertical circle, the error due to the adjustment of the height of standards may be eliminated by making the first observation with the telescope direct and the second with it reversed in altitude and azimuth. In this method, artificial illumination must be used for the cross hairs and for setting the points on line.

STADIA MEASUREMENTS.

Theory:—In Fig. 29 let O represent the object glass of a telescope, i i, the stadia hairs, s s, a stadia

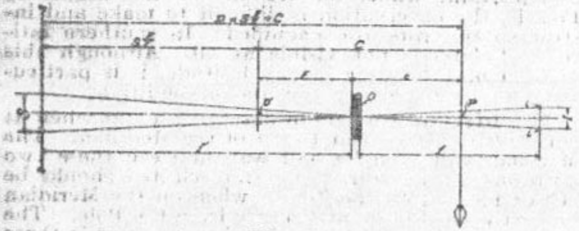


Fig. 29

rod, and P the center of the instrument, then I is the stadia interval and S the rod intercept.

(1) From similar triangles $\frac{S}{f'} = \frac{I}{f}$

(2) From the law of lenses $\frac{1}{f'} + \frac{1}{f} = \frac{1}{F}$

Where F is the principal focal length of the object-glass O.

Substituting in (2) the value of $\frac{1}{f}$ taken from (1),

$$\frac{1}{f'} + \frac{S}{f'I} = \frac{1}{F}$$

(3) Whence $f' = S\frac{F}{I} + F$

By referring to Fig. 29 it will be seen that f′ is the distance of the stadia rod from the **object-glass** and that D is equal to f′+c, where D and c are the distances of the stadia rod and the object-glass respectively from the center of the instrument.

(4) Hence $D = f' + c = S\frac{F}{I} + (F+c)$

When I is made equal to $\frac{1}{100}$ F, as it generally is, $\frac{F}{I} = 100.$

(F+c) is usually considered a constant = C = (the constant of the instrument), although c varies slightly when focusing is accomplished by moving the object-glass.

(5) Equation (4) then reduces to D = 100 S+C

In words, the distance of the stadia rod from the center of the instrument equals one hundred times the rod intercept plus the constant of the instrument.

It should be noted that from O′ the distances are directly proportional to the rod intercept.

Inclined Sights:—The above applies to horizontal sights only, for inclined sights it must be modified as follows: Let Fig. 30 represent diagram-

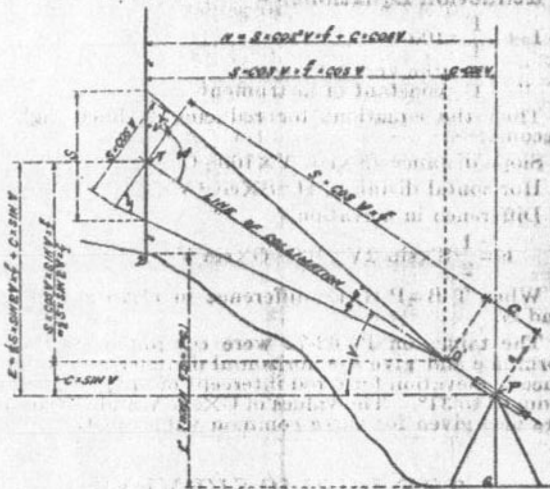


Fig. 30

matically an inclined sight. S is the intercept on the rod, s s, which is held vertically. S×cos V is what it would be if the rod was held at right angles to the line of collimation.* The distance along the line of collimation from O′ to the rod is then

$$S \times \cos V \times \frac{F}{I}$$

The horizontal distance from the center of the instrument to the rod is

$$H = S \times \cos^2 V \times \frac{F}{I} + C \times \cos V.$$

The difference in elevation of O′ and T is

$$S \times \cos V \times \sin V \times \frac{F}{I} = \frac{1}{2} S \times \sin 2V \times \frac{F}{I}$$

T is the point on the rod corresponding to the vertical angle V.

* This is strictly correct only when the angles Y and Z are each equal to 90°. Y is greater, and Z less than 90° by an amount equal to n, the error in one so nearly compensates that of the other that the resulting error may safely be neglected. The use of the half interval when V is large may on this account cause serious error

It follows that the difference in elevation of the center of the instrument and T is

$$E = \frac{1}{2} S \times \sin 2V \times \frac{F}{I} + C \times \sin V$$

Reduction Equations:—

Let $\frac{F}{I} = 100$

" V = the vertical angle

" C = constant of instrument

Then the equations for reducing inclined sights become:—

Slope distance $= S \times \cos V \times 100 + C$

Horizontal distance, $H = S \times \cos^2 V \times 100 + C \times \cos V$

Difference in elevation,

$$E = \frac{1}{2} S \times \sin 2V \times 100 + C \times \sin V$$

When T B = P G, E = difference in elevation of B and G.

The tables on P. 62-72 were computed by these formulae and give the horizontal distance and difference in elevation for a rod intercept of one, for angles from 0° to 31°. The values of C×sin V and C×cos V are also given for three common values of C.

THE PUBLIC SURVEYS

Principal lines are run east and west and north and south from the Initial Point. The east and west line is called the Principal Base and the north and south line the Principal Meridian.

List of Principal Meridians and the Surveys They Control:—

Ohio, 1st P. M. with several Initial Points.

Indiana, 2nd P. M.

Illinois, 2nd, 3d and 4th P. M.

Wisconsin, 4th P. M.

Minnesota, 4th and 5th P. M.

Dakota, 5th and 6th P. M.

Iowa, Missouri and Arkansas, 5th P. M.

Kansas, Nebraska and most of Colorado, 6th P. M.

Michigan, the Michigan Meridian.

Florida, the Tallahassee.

Alabama, the Huntsville and St. Stephens.

Mississippi, the St. Stephens, Choctaw and Washington.

Louisiana, east of Mississippi River the St. Helena and west of the river the Louisiana.

Arizona, the Gila and Salt River.

Utah, the Salt Lake.

Nevada, the Mount Diablo.

Montana, the Montana.

California, the Mount Diablo, San Bernardino and Humboldt.

Oregon and Washington, the Willamette.

Standard Parallels:—At intervals of 24 miles* measured from the Initial Point on the Principal Meridian, Standard Parallels, or Correction Lines are run east and west from the Principal Meridian. They are numbered north and south from the Principal Base, the first one north being the First Standard Parallel North and the first one south the First Standard Parallel South. See Fig. 31.

-DIVISION INTO CHECKS-

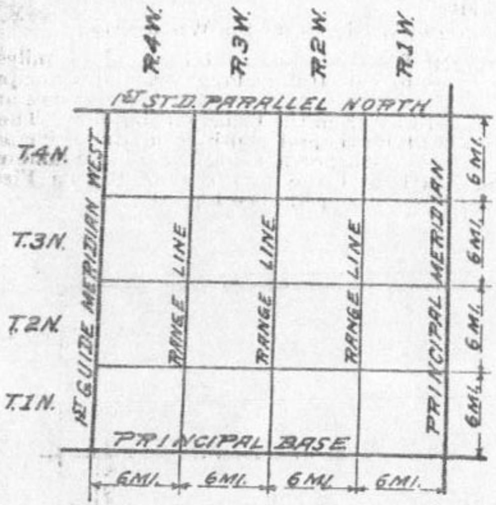
Fig. 31

Guide Meridians:—From the Principal Base and Standard Parallels, Guide Meridians are run north to the next Standard or Base, the starting points of the Guides being at intervals of 24* miles along the line from which they are run. A check is 24 miles north and south by 24 miles east and west on the south side and is bounded by Standards and Guides or Principals. See Fig. 31.

Townships:—The north and south boundaries of Townships, or Township Lines, are true parallels, and are spaced at intervals of 6 miles. The east and west

* In some cases the interval is greater than 24 miles.

boundaries, or Range Lines, are true meridians; they run north from a Base Line or Standard Parallel to the next Standard Parallel. They are placed at intervals of 6 miles along the Base or Standard Line from



-DIVISION OF CHECK INTO TOWNSHIPS-

Fig. 32

which they run. Fig. 32 shows the division of a check into Townships. All lines so far described are either true Meridians or true Parallels.

Subdivision:—Fig. 33 shows the subdivision of a township into sections, the numbering of the sections and the usual method of marking the corner stones of sections. The distances given are in chains. Excess or deficiency is thrown into the north half of the north tier of sections and the west half of the west tier. Section corners inside a township are notched on the south and east edges with as

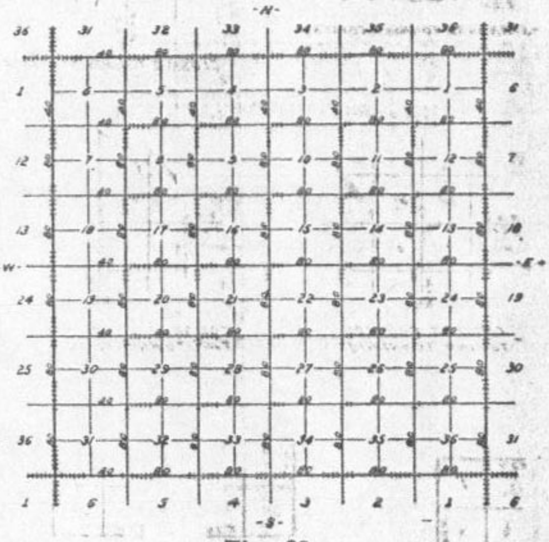


Fig. 33

many notches as they are miles from the south and east boundaries of the township. On township lines the marks are on the edges in the direction of the line, there being as many notches on an edge as it is miles to the township corner it faces. The diagrams in Figs. 34 and 35 show the method of marking Township and Section corners for cases not covered by Fig. 33. In Figs. 33, 34 and 35 the short cross lines indicate the number and position of the notches cut on the stones.

Markings:—In the following Figs. 34 and 35 the marks used for various cases are shown:

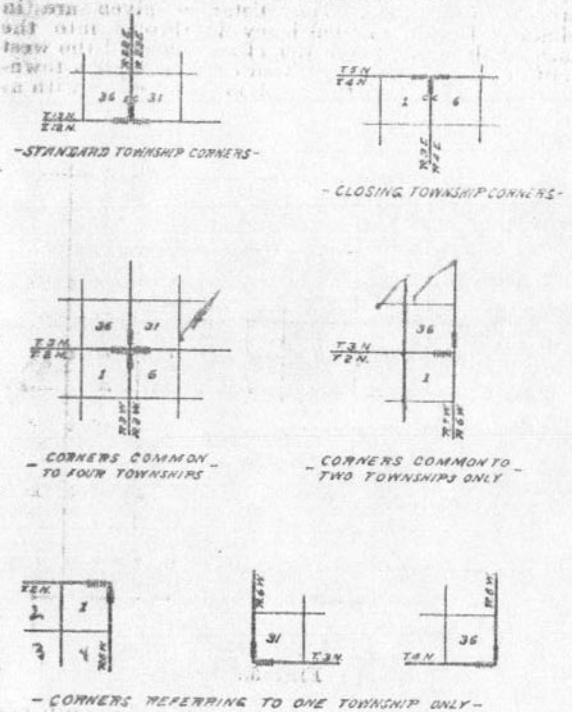


Fig. 34

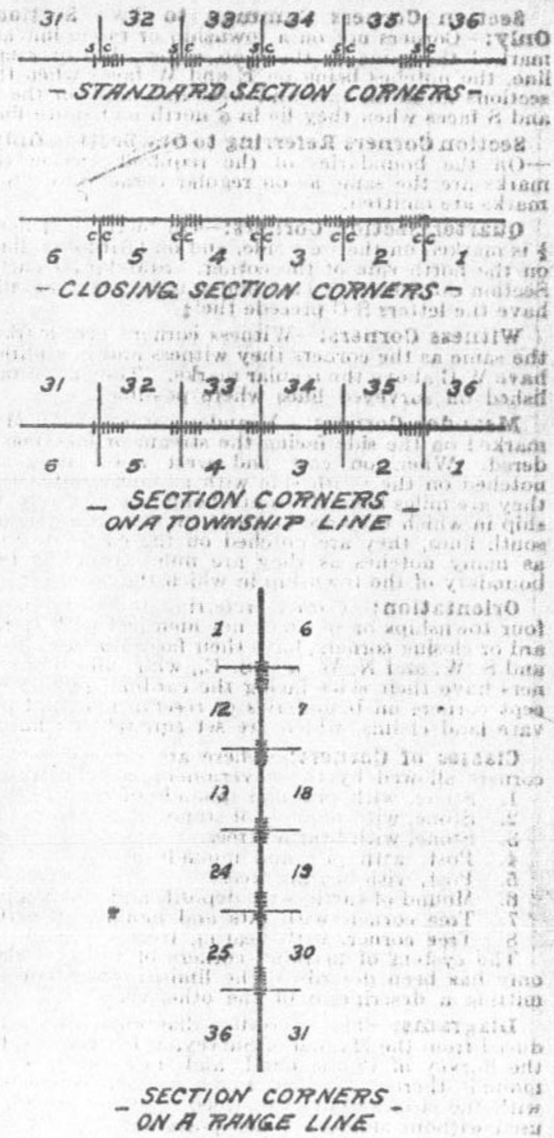


Fig. 35

Section Corners Common to Two Sections Only:—Corners not on a township or range line are marked the same as those on a township or range line, the notches being on E and W faces when the sections lie in an east and west line, and on the N and S faces when they lie in a north and south line.

Section Corners Referring to One Section Only:—On the boundaries of the required section the marks are the same as on regular corners; all other marks are omitted.

Quarter Section Corners:—On meridional lines, ¼ is marked on the west side, and on latitudinal lines on the north side of the corner. Standard Quarter Section Corners, on a base line or a Standard Parallel have the letters S C precede the ¼.

Witness Corners:—Witness corners are marked the same as the corners they witness and in addition have W C above the regular marks. They are established on surveyed lines where possible.

Meander Corners:—Meander corners have M C marked on the side facing the stream or lake meandered. When on east and west lines, they are notched on the south side with as many notches as they are miles from the south boundary of the township in which they are located. When on north and south lines, they are notched on the east side with as many notches as they are miles from the east boundary of the township in which they are located.

Orientation:—Corners referring to one, two, or four townships or sections, not identical with standard or closing corners, have their faces directed N. E. and S. W. and N. W. and S. E., while all other corners have their sides facing the cardinal points; except corners on boundaries of reservations and private land claims, which are set squarely on line.

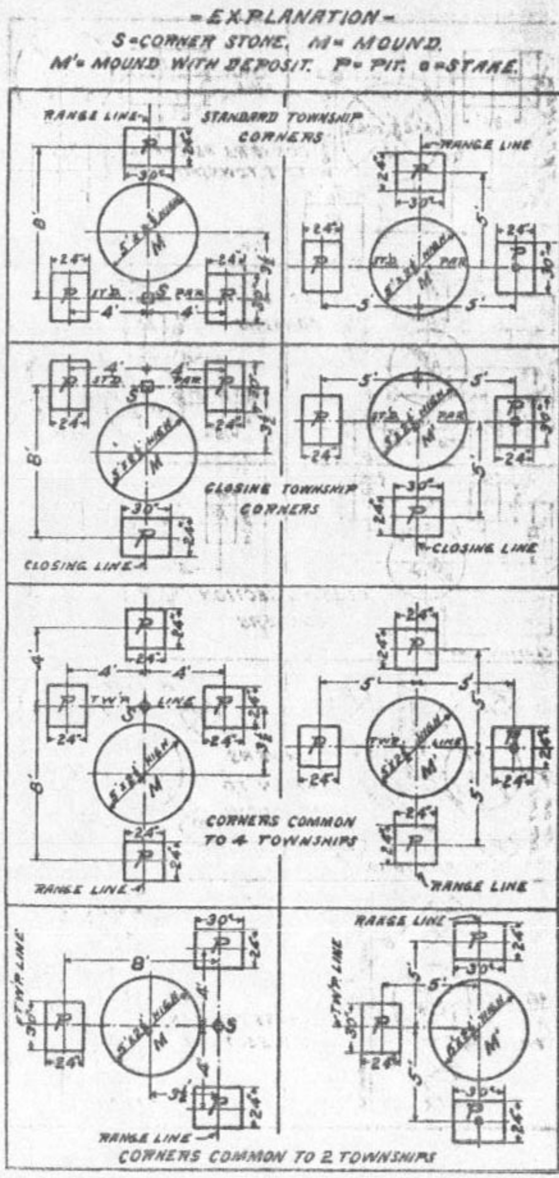
Classes of Corners:—There are eight classes of corners allowed by the government, as follows:

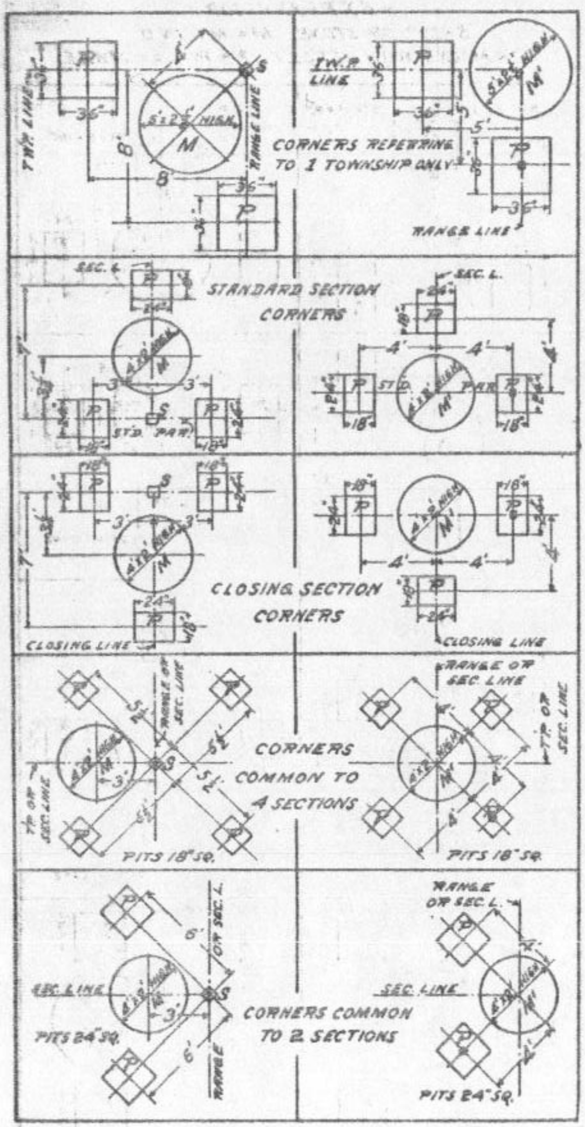
1. Stone, with pits and mounds of earth.
2. Stone, with mounds of stone.
3. Stone, with bearing trees.
4. Post, with pits and mounds of earth.
5. Post, with bearing trees.
6. Mound of earth, with deposit, and stake in pit.
7. Tree corner, with pits and mounds of earth.
8. Tree corner, with bearing trees.

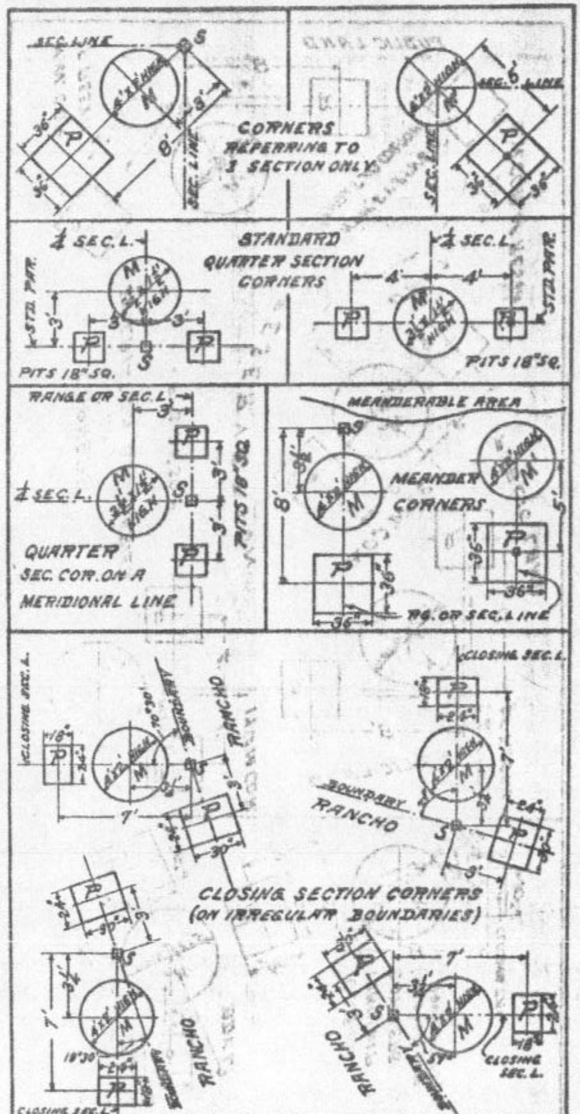
The system of marking corners of the first class only has been described, the limited space not admitting a description of the other classes.

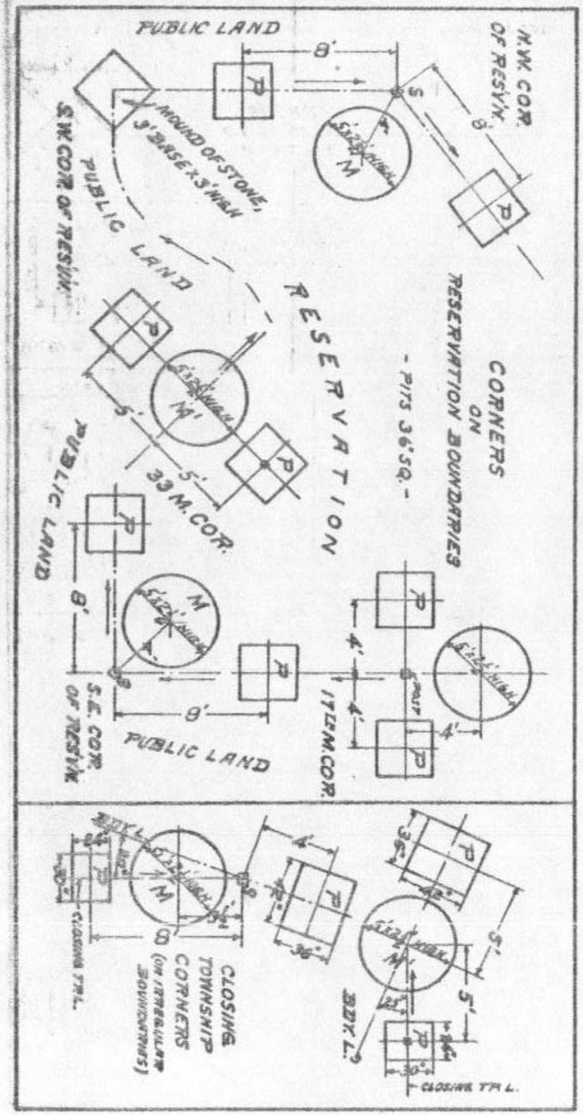
Diagrams:—The following diagrams are reproduced from the Manual of Surveying Instructions for the Survey of Public Lands and show the pits and mounds therein specified to be used in connection with the stones above described, and how they are used without stones. When posts are used for corners they are marked with the proper section, township and range in addition to the regular notches.

WM. AINSWORTH & SONS THE PRECISION FACTORY DENVER, COLO. U. S. A.

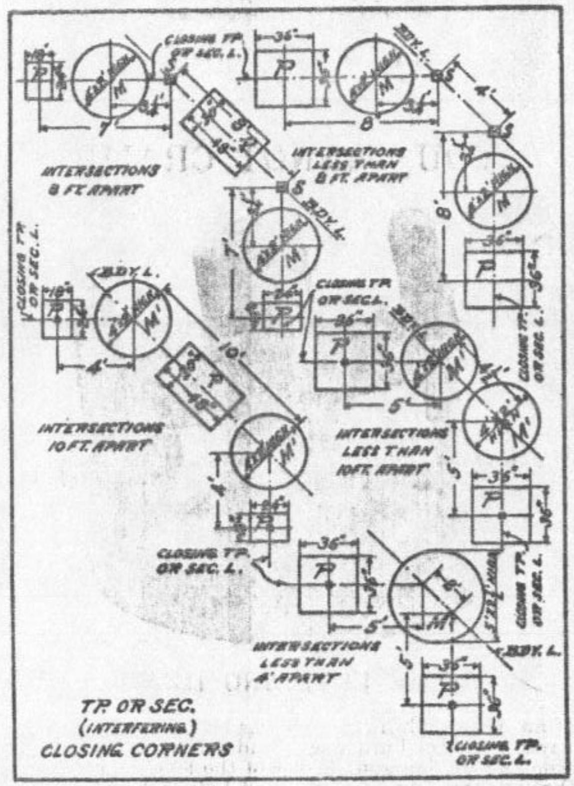



CORNERS REFERRING TO 1 TOWNSHIP ONLY
TWP. LINE
RANGE LINE
STANDARD SECTION CORNERS
SEC. L.
STD. PAR.
CLOSING SECTION CORNERS
CLOSING LINE
CORNERS COMMON TO 4 SECTIONS
RANGE OR SEC. LINE
TP. OR SEC. LINE
PITS 18" SQ.
CORNERS COMMON TO 2 SECTIONS
SEC. LINE
RANGE OR SEC. L.
PITS 24" SQ.


SEC. LINE
CORNERS REFERRING TO 1 SECTION ONLY
STANDARD QUARTER SECTION CORNERS
¼ SEC. L.
STD. PAR.
PITS 18" SQ.
RANGE OR SEC. L.
QUARTER SEC. COR. ON A MERIDIONAL LINE
MEANDERABLE AREA
MEANDER CORNERS
RG. OR SEC. LINE
CLOSING SEC. L.
RANCHO
BOUNDARY
CLOSING SECTION CORNERS (ON IRREGULAR BOUNDARIES)



WM. AINSWORTH & SONS | THE PRECISION FACTORY | DENVER, COLO. U. S. A.

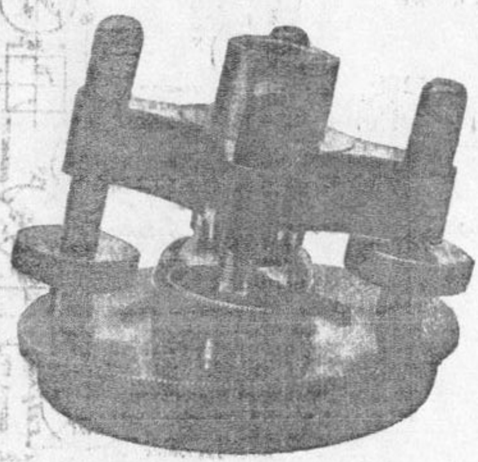


OURS IS AN EDUCATIONAL CAMPAIGN

We believe that the more familiar an engineer is with the instruments he uses the more likely he is to purchase an Ainsworth owing to the evident superiority of the

AINSWORTH PRECISION INSTRUMENTS

YOU CANNOT CRAMP



THE LEVELING HEAD

of an Ainsworth instrument, as all parts are made to hardened steel limit gages and strictly interchangeable and the horizontal axes of the leveling head pass through the centers of the half ball and balls on the ends of the leveling screws. See Fig. 8 P. 10

In other instruments it is necessary to loosen all screws when leveling up and then frequently when almost level you find the head cramped, making it necessary to again loosen the screws before completing the operation.

TABLES

STADIA REDUCTION TABLE

M.	0°		1°		2°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0′	100.00	.00	99.97	1.74	99.88	3.49
2	100.00	.06	99.97	1.80	99.87	3.55
4	100.00	.12	99.97	1.86	99.87	3.60
6	100.00	.17	99.96	1.92	99.87	3.66
8	100.00	.23	99.96	1.98	99.86	3.72
10	100.00	.29	99.96	2.04	99.86	3.78
12	100.00	.35	99.96	2.09	99.85	3.84
14	100.00	.41	99.95	2.15	99.85	3.90
16	100.00	.47	99.95	2.21	99.84	3.95
18	100.00	.52	99.95	2.27	99.84	4.01
20	100.00	.58	99.95	2.33	99.83	4.07
22	100.00	.64	99.94	2.38	99.83	4.13
24	100.00	.70	99.94	2.44	99.82	4.18
26	99.99	.76	99.94	2.50	99.82	4.24
28	99.99	.81	99.93	2.56	99.81	4.30
30	99.99	.87	99.93	2.62	99.81	4.36
32	99.99	.93	99.93	2.67	99.80	4.42
34	99.99	.99	99.93	2.73	99.80	4.48
36	99.99	1.05	99.92	2.79	99.79	4.53
38	99.99	1.11	99.92	2.85	99.79	4.59
40	99.99	1.16	99.92	2.91	99.78	4.65
42	99.99	1.22	99.91	2.97	99.78	4.71
44	99.98	1.28	99.91	3.02	99.77	4.76
46	99.98	1.34	99.90	3.08	99.77	4.82
48	99.98	1.40	99.90	3.14	99.76	4.88
50	99.98	1.45	99.90	3.20	99.76	4.94
52	99.98	1.51	99.89	3.26	99.75	4.99
54	99.98	1.57	99.89	3.31	99.74	5.05
56	99.97	1.63	99.89	3.37	99.74	5.11
58	99.97	1.69	99.88	3.43	99.73	5.17
60	99.97	1.74	99.88	3.49	99.73	5.23
C= .75	.75	.01	.75	.02	.75	.03
C=1.00	1.00	.01	1.00	.03	1.00	.04
C=1.25	1.25	.02	1.25	.03	1.25	.05

STADIA REDUCTION TABLE

M.	3°		4°		5°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0′	99.73	5.23	99.51	6.96	99.24	8.68
2	99.72	5.28	99.51	7.02	99.23	8.74
4	99.71	5.34	99.50	7.07	99.22	8.80
6	99.71	5.40	99.49	7.13	99.21	8.85
8	99.70	5.46	99.48	7.19	99.20	8.91
10	99.69	5.52	99.47	7.25	99.19	8.97
12	99.69	5.57	99.46	7.30	99.18	9.03
14	99.68	5.63	99.46	7.36	99.17	9.08
16	99.68	5.69	99.45	7.42	99.16	9.14
18	99.67	5.75	99.44	7.48	99.15	9.20
20	99.66	5.80	99.43	7.53	99.14	9.25
22	99.66	5.86	99.42	7.59	99.13	9.31
24	99.65	5.92	99.41	7.65	99.11	9.37
26	99.64	5.98	99.40	7.71	99.10	9.43
28	99.63	6.04	99.39	7.76	99.09	9.48
30	99.63	6.09	99.38	7.82	99.08	9.54
32	99.62	6.15	99.38	7.88	99.07	9.60
34	99.62	6.21	99.37	7.94	99.06	9.65
36	99.61	6.27	99.36	7.99	99.05	9.71
38	99.60	6.33	99.35	8.05	99.04	9.77
40	99.59	6.38	99.34	8.11	99.03	9.83
42	99.59	6.44	99.33	8.17	99.01	9.88
44	99.58	6.50	99.32	8.22	99.00	9.94
46	99.57	6.56	99.31	8.28	98.99	10.00
48	99.56	6.61	99.30	8.34	98.98	10.05
50	99.56	6.67	99.29	8.40	98.97	10.11
52	99.55	6.73	99.28	8.45	98.96	10.17
54	99.54	6.78	99.27	8.51	98.94	10.22
56	99.53	6.84	99.26	8.57	98.93	10.28
58	99.52	6.90	99.25	8.63	98.92	10.34
60	99.51	6.96	99.24	8.68	98.91	10.40
C= .75	.75	.05	.75	.06	.75	.07
C=1.00	1.00	.06	1.00	.08	.99	.09
C=1.25	1.25	.08	1.25	.10	1.24	.11

STADIA REDUCTION TABLE

M.	6° Hor. Dist.	6° Diff. Elev.	7° Hor. Dist.	7° Diff. Elev	8° Hor. Dist.	8° Diff. Elev.
0′	98.91	10.40	98.51	12.10	98.06	13.78
2	98.90	10.45	98.50	12.15	98.05	13.84
4	98.88	10.51	98.48	12.21	98.03	13.89
6	98.87	10.57	98.47	12.26	98.01	13.95
8	98.86	10.62	98.46	12.32	98.00	14.01
10	98.85	10.68	98.44	12.38	97.98	14.06
12	98.83	10.74	98.43	12.43	97.97	14.12
14	98.82	10.79	98.41	12.49	97.95	14.17
16	98.81	10.85	98.40	12.55	97.93	14.23
18	98.80	10.91	98.39	12.60	97.92	14.28
20	98.78	10.96	98.37	12.66	97.90	14.34
22	98.77	11.02	98.36	12.72	97.88	14.40
24	98.76	11.08	98.34	12.77	97.87	14.45
26	98.74	11.13	98.33	12.83	97.85	14.51
28	98.73	11.19	98.31	12.88	97.83	14.56
30	98.72	11.25	98.29	12.94	97.82	14.62
32	98.71	11.30	98.28	13.00	97.80	14.67
34	98.69	11.36	98.27	13.05	97.78	14.73
36	98.68	11.42	98.25	13.11	97.76	14.79
38	98.67	11.47	98.24	13.17	97.75	14.84
40	98.65	11.53	98.22	13.22	97.73	14.90
42	98.64	11.59	98.20	13.28	97.71	14.95
44	98.63	11.64	98.19	13.33	97.69	15.01
46	98.61	11.70	98.17	13.39	97.68	15.06
48	98.60	11.76	98.16	13.45	97.66	15.12
50	98.58	11.81	98.14	13.50	97.64	15.17
52	98.57	11.87	98.13	13.56	97.62	15.23
54	98.56	11.93	98.11	13.61	97.61	15.28
56	98.54	11.98	98.10	13.67	97.59	15.34
58	98.53	12.04	98.08	13.73	97.57	15.40
60	98.51	12.10	98.06	13.78	97.55	15.45
C= .75	.75	.08	.74	.10	.74	.11
C=1.00	.99	.11	.99	.13	.99	.15
C=1.25	1.24	.14	1.24	.16	1.23	.18

STADIA REDUCTION TABLE

M.	9° Hor. Dist.	9° Diff. Elev.	10° Hor. Dist.	10° Diff. Elev.	11° Hor. Dist.	11° Diff. Elev.
0′	97.55	15.45	96.98	17.10	96.36	18.73
2	97.53	15.51	96.96	17.16	96.34	18.78
4	97.52	15.56	96.94	17.21	96.32	18.84
6	97.50	15.62	96.92	17.26	96.29	18.89
8	97.48	15.67	96.90	17.32	96.27	18.95
10	97.46	15.73	96.88	17.37	96.25	19.00
12	97.44	15.78	96.86	17.43	96.23	19.05
14	97.43	15.84	96.84	17.48	96.21	19.11
16	97.41	15.89	96.82	17.54	96.18	19.16
18	97.39	15.95	96.80	17.59	96.16	19.21
20	97.37	16.00	96.78	17.65	96.14	19.27
22	97.35	16.06	96.76	17.70	96.12	19.32
24	97.33	16.11	96.74	17.76	96.09	19.38
26	97.31	16.17	96.72	17.81	96.07	19.43
28	97.29	16.22	96.70	17.86	96.05	19.48
30	97.28	16.28	96.68	17.92	96.03	19.54
32	97.26	16.33	96.66	17.97	96.00	19.59
34	97.24	16.39	96.64	18.03	95.98	19.64
36	97.22	16.44	96.62	18.08	95.96	19.70
38	97.20	16.50	96.60	18.14	95.93	19.75
40	97.18	16.55	96.57	18.19	95.91	19.80
42	97.16	16.61	96.55	18.24	95.89	19.86
44	97.14	16.66	96.53	18.30	95.86	19.91
46	97.12	16.72	96.51	18.35	95.84	19.96
48	97.10	16.77	96.49	18.41	95.82	20.02
50	97.08	16.83	96.47	18.46	95.79	20.07
52	97.06	16.88	96.45	18.51	95.77	20.12
54	97.04	16.94	96.42	18.57	95.75	20.18
56	97.02	16.99	96.40	18.62	95.72	20.23
58	97.00	17.05	96.38	18.68	95.70	20.28
60	96.98	17.10	96.36	18.73	95.68	20.34
C= .75	.74	.12	.74	.14	.73	.15
C=1.00	.99	.16	.98	.18	.98	.20
C=1.25	1.23	.21	1.23	.23	1.22	.25

STADIA REDUCTION TABLE

M.	12°		13°		14°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0′	95.68	20.34	94.94	21.92	94.15	23.47
2	95.65	20.39	94.91	21.97	94.12	23.52
4	95.63	20.44	94.89	22.02	94.09	23.58
6	95.61	20.50	94.86	22.08	94.07	23.63
8	95.58	20.55	94.84	22.13	94.04	23.68
10	95.56	20.60	94.81	22.18	94.01	23.73
12	95.53	20.66	94.79	22.23	93.98	23.78
14	95.51	20.71	94.76	22.28	93.95	23.83
16	95.49	20.76	94.73	22.34	93.93	23.88
18	95.46	20.81	94.71	22.39	93.90	23.93
20	95.44	20.87	94.68	22.44	93.87	23.99
22	95.41	20.92	94.66	22.49	93.84	24.04
24	95.39	20.97	94.63	22.54	93.81	24.09
26	95.36	21.03	94.60	22.60	93.79	24.14
28	95.34	21.08	94.58	22.65	93.76	24.10
30	95.32	21.13	94.55	22.70	93.73	24.24
32	95.29	21.18	94.52	22.75	93.70	24.29
34	95.27	21.24	94.50	22.80	93.67	24.34
36	95.24	21.29	94.47	22.85	93.65	24.39
38	95.22	21.34	94.44	22.91	93.62	24.44
40	95.19	21.39	94.42	22.96	93.59	24.49
42	95.17	21.45	94.39	23.01	93.56	24.55
44	95.14	21.50	94.36	23.06	93.53	24.60
46	95.12	21.55	94.34	23.11	93.50	24.65
48	95.09	21.60	94.31	23.16	93.47	24.70
50	95.07	21.66	94.28	23.22	93.45	24.75
52	95.04	21.71	94.26	23.27	93.42	24.80
54	95.02	21.76	94.23	23.32	93.39	24.85
56	94.99	21.81	94.20	23.37	93.36	24.90
58	94.97	21.87	94.17	23.42	93.33	24.95
60	94.94	21.92	94.15	23.47	93.30	25.00
C= .75	.73	.16	.73	.17	.73	.19
C=1.00	.98	.22	.97	.23	.97	.25
C=1.25	1.22	.27	1.21	.20	1.21	.31

STADIA REDUCTION TABLE

M	15°		16°		17°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0′	93.30	25.00	92.40	26.50	91.45	27.96
2	93.27	25.05	92.37	26.55	91.42	28.01
4	93.24	25.10	92.34	26.59	91.39	28.06
6	93.21	25.15	92.31	26.64	91.35	28.10
8	93.18	25.20	92.28	26.69	91.32	28.15
10	93.16	25.25	92.25	26.74	91.29	28.20
12	93.13	25.30	92.22	26.79	91.26	28.25
14	93.10	25.35	92.19	26.84	91.22	28.30
16	93.07	25.40	92.15	26.89	91.19	28.34
18	93.04	25.45	92.12	26.94	91.16	28.39
20	93.01	25.50	92.09	26.99	91.12	28.44
22	92.98	25.55	92.06	27.04	91.09	28.49
24	92.95	25.60	92.03	27.09	91.06	28.54
26	92.92	25.65	92.00	27.13	91.02	28.58
28	92.89	25.70	91.97	27.18	90.99	28.63
30	92.86	25.75	91.93	27.23	90.96	28.68
32	92.83	25.80	91.90	27.28	90.92	28.73
34	92.80	25.85	91.87	27.33	90.89	28.77
36	92.77	25.90	91.84	27.38	90.86	28.82
38	92.74	25.95	91.81	27.43	90.82	28.87
40	92.71	26.00	91.77	27.48	90.79	28.92
42	92.68	26.05	91.74	27.52	90.76	28.96
44	92.65	26.10	91.71	27.57	90.72	29.01
46	92.62	26.15	91.68	27.62	90.69	29.06
48	92.59	26.20	91.65	27.67	90.66	29.11
50	92.56	26.25	91.61	27.72	90.62	29.15
52	92.53	26.30	91.58	27.77	90.59	29.20
54	92.49	26.35	91.55	27.81	90.55	29.25
56	92.46	26.40	91.52	27.86	90.52	29.30
58	92.43	26.45	91.48	27.91	90.48	29.34
60	92.40	26.50	91.45	27.96	90.45	29.39
C= .75	.72	.20	.72	.21	.72	.23
C=1.00	.96	.27	.96	.28	.95	.30
C=1.25	1.20	.34	1.20	.36	1.19	.38

STADIA REDUCTION TABLE

M.	18°		19°		20°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev
0'	90.45	29.39	89.40	30.78	88.30	32.14
2	90.42	29.44	89.36	30.83	88.26	32.18
4	90.38	29.48	89.33	30.87	88.23	32.23
6	90.35	29.53	89.29	30.92	88.19	32.27
8	90.31	29.58	89.26	30.97	88.15	32.32
10	90.28	29.62	89.22	31.01	88.11	32.36
12	90.24	29.67	89.18	31.06	88.08	32.41
14	90.21	29.72	89.15	31.10	88.04	32.45
16	90.18	29.76	89.11	31.15	88.00	32.49
18	90.14	29.81	89.08	31.19	87.96	32.54
20	90.11	29.86	89.04	31.24	87.93	32.58
22	90.07	29.90	89.00	31.28	87.89	32.63
24	90.04	29.95	88.96	31.33	87.85	32.67
26	90.00	30.00	88.93	31.38	87.81	32.72
28	89.97	30.04	88.89	31.42	87.77	32.76
30	89.93	30.09	88.86	31.47	87.74	32.80
32	89.90	30.14	88.82	31.51	87.70	32.85
34	89.86	30.19	88.78	31.56	87.66	32.89
36	89.83	30.23	88.75	31.60	87.62	32.93
38	89.79	30.28	88.71	31.65	87.58	32.98
40	89.76	30.32	88.67	31.69	87.54	33.02
42	89.72	30.37	88.64	31.74	87.51	33.07
44	89.69	30.41	88.60	31.78	87.47	33.11
46	89.65	30.46	88.56	31.83	87.43	33.15
48	89.61	30.51	88.53	31.87	87.39	33.20
50	89.58	30.55	88.49	31.92	87.35	33.24
52	89.54	30.60	88.45	31.96	87.31	33.28
54	89.51	30.65	88.41	32.01	87.27	33.33
56	89.47	30.69	88.38	32.05	87.24	33.37
58	89.44	30.74	88.34	32.09	87.20	33.41
60	89.40	30.78	88.30	32.14	87.16	33.46
C= .75	.71	.24	.71	.25	.70	.26
C=1.00	.95	.32	.94	.33	.94	.35
C=1.25	1.19	.40	1.18	.42	1.17	.44

STADIA REDUCTION TABLE

M.	21°		22°		23°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0'	87.16	33.46	85.97	34.73	84.73	35.97
2	87.12	33.50	85.93	34.77	84.69	36.01
4	87.08	33.54	85.89	34.82	84.65	36.05
6	87.04	33.59	85.85	34.86	84.61	36.09
8	87.00	33.63	85.80	34.90	84.57	36.13
10	86.96	33.67	85.76	34.94	84.52	36.17
12	86.92	33.72	85.72	34.98	84.48	36.21
14	86.88	33.76	85.68	35.02	84.44	36.25
16	86.84	33.80	85.64	35.07	84.40	36.29
18	86.80	33.84	85.60	35.11	84.35	36.33
20	86.77	33.89	85.56	35.15	84.31	36.37
22	86.73	33.93	85.52	35.19	84.27	36.41
24	86.69	33.97	85.48	35.23	84.23	36.45
26	86.65	34.01	85.44	35.27	84.18	36.49
28	86.61	34.06	85.40	35.31	84.14	36.53
30	86.57	34.10	85.36	35.36	84.10	36.57
32	86.53	34.14	85.31	35.40	84.06	36.61
34	86.49	34.18	85.27	35.44	84.01	36.65
36	86.45	34.23	85.23	35.48	83.97	36.69
38	86.41	34.27	85.19	35.52	83.93	36.73
40	86.37	34.31	85.15	35.56	83.89	36.77
42	86.33	34.35	85.11	35.60	83.84	36.80
44	86.29	34.40	85.07	35.64	83.80	36.84
46	86.25	34.44	85.02	35.68	83.76	36.88
48	86.21	34.48	84.98	35.72	83.72	36.92
50	86.17	34.52	84.94	35.76	83.67	36.96
52	86.13	34.57	84.90	35.80	83.63	37 00
54	86.09	34.61	84.86	35.85	83.59	37.04
56	86.05	34.65	84.82	35.89	83.54	37.08
58	86.01	34.69	84.77	35.93	83.50	37.12
60	85.97	34.73	84.73	35.97	83.46	37.16
C= .75	.70	.27	.69	.29	.69	.30
C=1.00	.93	.37	.92	.38	.92	.40
C=1.25	1.16	.46	1.15	.48	1.15	.50

STADIA REDUCTION TABLE

M.	24°		25°		26°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0′	83.46	37.16	82.14	38.30	80.78	39.40
2	83.41	37.20	82.09	38.34	80.74	39.44
4	83.37	37.23	82.05	38.38	80.69	39.47
6	83.33	37.27	82.01	38.41	80.65	39.51
8	83.28	37.31	81.96	38.45	80.60	39.54
10	83.24	37.35	81.92	38.49	80.55	39.58
12	83.20	37.39	81.87	38.53	80.51	39.61
14	83.15	37.43	81.83	38.56	80.46	39.65
16	83.11	37.47	81.78	38.60	80.41	39.69
18	83.07	37.51	81.74	38.64	80.37	39.72
20	83.02	37.54	81.69	38.67	80.32	39.76
22	82.98	37.58	81.65	38.71	80.28	39.79
24	82.93	37.62	81.60	38.75	80.23	39.83
26	82.89	37.66	81.56	38.78	80.18	39.86
28	82.85	37.70	81.51	38.82	80.14	39.90
30	82.80	37.74	81.47	38.86	80.09	39.93
32	82.76	37.77	81.42	38.89	80.04	39.97
34	82.72	37.81	81.38	38.93	80.00	40.00
36	82.67	37.85	81.33	38.97	79.95	40.04
38	82.63	37.89	81.28	39.00	79.90	40.07
40	82.58	37.93	81.24	39.04	79.86	40.11
42	82.54	37.96	81.19	39.08	79.81	40.14
44	82.49	38.00	81.15	39.11	79.76	40.18
46	82.45	38.04	81.10	39.15	79.72	40.21
48	82.41	38.08	81.06	39.18	79.67	40.24
50	82.36	38.11	81.01	39.22	79.62	40.28
52	82.32	38.15	80.97	39.26	79.58	40.31
54	82.27	38.19	80.92	39.29	79.53	40.35
56	82.23	38.23	80.87	39.33	79.48	40.38
58	82.18	38.26	80.83	39.36	79.44	40.42
60	82.14	38.30	80.78	39.40	79.39	40.45
C= .75	.68	.31	.68	.32	.67	.33
C=1.00	.91	.41	.90	.43	.89	.45
C=1.25	1.14	.52	1.13	.54	1.12	.56

STADIA REDUCTION TABLE

M.	27°		28°		29°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0′	79.39	40.45	77.96	41.45	76.50	42.40
2	79.34	40.49	77.91	41.48	76.45	42.43
4	79.30	40.52	77.86	41.52	76.40	42.46
6	79.25	40.55	77.81	41.55	76.35	42 49
8	79.20	40.59	77.77	41.58	76.30	42.53
10	79.15	40.62	77.72	41.61	76.25	42.56
12	79.11	40.66	77.67	41.65	76.20	42.59
14	79.06	40.69	77.62	41.68	76.15	42.62
16	79.01	40.72	77.57	41.71	76.10	42.65
18	78.96	40.76	77.52	41.74	76.05	42.68
20	78.92	40.79	77.48	41.77	76.00	42.71
22	78.87	40,82	77.42	41.81	75.95	42.74
24	78.82	40.86	77.38	41.84	75.90	42.77
26	78.77	40.89	77.33	41.87	75.85	42.80
28	78.73	40.92	77.28	41.90	75.80	42.83
30	78.68	40.96	77.23	41.93	75.75	42.86
32	78.63	40.99	77.18	41.97	75.70	42.89
34	78.58	41.02	77.13	42.00	75 65	42.92
36	78.54	41.06	77.09	42.03	75.60	42.95
38	78.49	41.09	77.04	42.06	75.55	42.98
40	78.44	41.12	76.99	42.09	75.50	43.01
42	78.39	41.16	76.94	42.12	75.45	43.04
44	78.34	41.19	76.89	42.15	75.40	43.07
46	78.30	41.22	76.84	42.19	75.35	43.10
48	78.25	41.26	76.79	42.22	75.30	43.13
50	78.20	41.29	76.74	42.25	75.25	43.16
52	78.15	41.32	76.69	42.28	75.20	43.18
54	78.10	41.35	76.64	42.31	75.15	43.21
56	78.06	41.39	76.59	42.34	75.10	43.24
58	78.01	41.42	76.55	42.37	75.05	43.27
60	77.96	41.45	76.50	42.40	75.00	43.30
C= .75	.66	.35	.66	.36	.65	.37
C=1.00	.89	.46	.88	.48	.87	.49
C=1.25	1.11	.58	1.10	.60	1.09	.62

STADIA REDUCTION TABLE

M.	30° Hor. Dist.	30° Diff. Elev.
0′	75.00	43.30
2	74.95	43.33
4	74.90	43.36
6	74.85	43.39
8	74.80	43.42
10	74.75	43.45
12	74.70	43.47
14	74.65	43.50
16	74.60	43.53
18	74.55	43.56
20	74.49	43.59
22	74.44	43.62
24	74.39	43.65
26	74.34	43.67
28	74.29	43.70
30	74.24	43.73
32	74.19	43.76
34	74.14	43.79
36	74.09	43.82
38	74.04	43.84
40	73.99	43.87
42	73.93	43.90
44	73.88	43.93
46	73.83	43.95
48	73.78	43.98
50	73.73	44.01
52	73.68	44.04
54	73.63	44.07
56	73.58	44.09
58	73.52	44.12
60	73.47	44.15
C= .75	.65	38
C=1.00	.86	.51
C=1.25	1.08	.64

WM. AINSWORTH & SONS THE PRECISION FACTORY DENVER, COLO. U. S. A.

AT GREENWICH MEAN NOON
JANUARY, 1911

Day of Week	Day of Month	Sun's Semi-Diameter 16′ 17″ Sun's Apparent Declination °	′	″	Diff. for 1 Hr. ″	Equation of Time to be Subtracted from Mean Time m	s
Sun.	1	S.23	4	39.5	+11.46	3	19.35
Mon.	2	22	59	50.7	12.61	3	47.89
Tues.	3	22	54	34.4	13.75	4	16.10
Wed.	4	22	48	50.7	+14.89	4	43.94
Thur.	5	22	42	39.8	16.02	5	11.38
Frid.	6	22	36	1.9	17.14	5	38.38
Sat.	7	22	28	57.2	+18.25	6	4.91
Sun.	8	22	21	25.8	19.36	6	30.95
Mon.	9	22	13	28.1	20.45	6	56.48
Tues.	10	22	5	4.2	+21.53	7	21.45
Wed.	11	21	56	14.5	22.60	7	45.84
Thur.	12	21	46	59.2	23.66	8	9.64
Frid.	13	21	37	18.7	+24.71	8	32.83
Sat.	14	21	27	13.1	25.75	8	55.39
Sun.	15	21	16	42.8	26.78	9	17.31
Mon.	16	21	5	48.0	+27.79	9	38.58
Tues.	17	20	54	28.9	28.79	9	59.18
Wed.	18	20	42	46.0	29.78	10	19.09
Thur.	19	20	30	39.5	+30.76	10	38.31
Frid.	20	20	18	9.7	31.72	10	56.81
Sat.	21	20	5	17.0	32.67	11	14.59
Sun.	22	19	52	1.8	+33.60	11	31.63
Mon.	23	19	38	24.2	34.52	11	47.93
Tues.	24	19	24	24.8	35.43	12	3.48
Wed.	25	19	10	3.8	+36.32	12	18.25
Thur.	26	18	55	21.7	37.19	12	32.24
Frid.	27	18	40	18.8	38.05	12	45.44
Sat.	28	18	24	55.5	+38.89	12	57.84
Sun	29	18	9	12.2	39.71	13	9.44
Mon.	30	17	53	9.2	40.52	13	20.23
Tues.	31	17	36	47.1	41.31	13	30.20
Wed.	32	S.17	20	6.2	+42.09	13	39.34

Note—The sign + prefixed to the hourly change of declination indicates that south declinations are decreasing.

AT GREENWICH MEAN NOON

FEBRUARY, 1911

Day of Week	Day of Month	Sun's Semi-Diameter 16′ 13″ — Sun's Apparent Declination °	′	″	Diff. for 1 Hr. ″	Equation of Time to be Subtracted from Mean Time m	s
Wed.	1	S. 17	20	6.2	+42.09	13	39.34
Thur.	2	17	3	6.9	42.84	13	47.65
Frid.	3	16	45	49.7	43.58	13	55.12
Sat.	4	16	28	15.0	+44.30	14	1.75
Sun.	5	16	10	23.2	45.00	14	7.55
Mon.	6	15	52	14.8	45.69	14	12.52
Tues.	7	15	33	50.2	+46.36	14	16.65
Wed.	8	15	15	9.7	47.01	14	19.96
Thur.	9	14	56	13.9	47.64	14	22.46
Frid.	10	14	37	3.1	+48.26	14	24.15
Sat.	11	14	17	37.8	48.85	14	25.05
Sun.	12	13	57	58.3	49.43	14	25.16
Mon.	13	13	38	5.0	+50.00	14	24.50
Tues.	14	13	17	58.4	50.55	14	23.08
Wed.	15	12	57	38.8	51.08	14	20.92
Thur.	16	12	37	6.7	+51.60	14	18.03
Frid.	17	12	16	22.4	52.10	14	14.43
Sat.	18	11	55	26.3	52.58	14	10.13
Sun.	19	11	34	18.7	+53.04	14	5.15
Mon.	20	11	13	0.2	53.49	13	59.50
Tues.	21	10	51	31.1	53.93	13	53.19
Wed.	22	10	29	51.7	+54.35	13	46.25
Thur.	23	10	8	2.5	54.75	13	38.68
Frid.	24	9	46	4.0	55.13	13	30.50
Sat.	25	9	23	56.5	+55.49	13	21.73
Sun.	26	9	1	40.5	55.84	13	12.38
Mon.	27	8	39	16.3	56.17	13	2.46
Tues.	28	8	16	44.4	56.48	12	51.98
Wed.	29	S. 7	54	5.3	+56.78	12	40.96

Note—The sign + prefixed to the hourly change of declination indicates that south declinations are decreasing.

AT GREENWICH MEAN NOON

MARCH, 1911

Day of Week	Day of Month	Sun's Semi-Diameter 16′ 06″ — Sun's Apparent Declination °	′	″	Diff. for 1 Hr. ″	Equation of Time to be Subtracted from Mean Time m	s
Wed.	1	S. 7	54	5.3	+56.78	12	40.96
Thur.	2	7	31	19.2	57.06	12	29.41
Frid.	3	7	8	26.6	57.32	12	17.35
Sat.	4	6	45	28.0	+57.56	12	4.79
Sun.	5	6	22	23.8	57.78	11	51.75
Mon.	6	5	59	14.4	57.99	11	38.24
Tues.	7	5	36	0.3	+58.18	11	24.27
Wed.	8	5	12	41.8	58.35	11	9.88
Thur.	9	4	49	19.4	58.51	10	55.08
Frid.	10	4	25	53.3	+58.66	10	39.90
Sat.	11	4	2	24.0	58.78	10	24.35
Sun.	12	3	38	51.8	58.89	10	8.45
Mon.	13	3	15	17.1	+58.99	9	52.22
Tues.	14	2	51	40.3	59.07	9	35.70
Wed.	15	2	28	1.6	59.14	9	18.91
Thur.	16	2	4	21.4	+59.20	9	1.88
Frid.	17	1	40	40.1	59.24	8	44.62
Sat.	18	1	16	58.0	59.27	8	27.16
Sun.	19	0	53	15.4	+59.28	8	9.51
Mon.	20	0	29	32.8	59.27	7	51.71
Tues.	21	S. 0	5	50.4	59.25	7	33.77
Wed.	22	N. 0	17	51.4	+59.22	7	15.72
Thur.	23	0	41	32.2	59.17	6	57.57
Frid.	24	1	5	11.6	59.11	6	39.35
Sat.	25	1	28	49.4	+59.03	6	21.08
Sun.	26	1	52	25.2	58.94	6	2.78
Mon.	27	2	15	58.6	58.84	5	44.46
Tues.	28	2	39	29.3	+58.72	5	26.15
Wed.	29	3	2	56.9	58.58	5	7.86
Thur.	30	3	26	20.9	58.42	4	49.61
Frid.	31	3	49	41.0	58.25	4	31.42
Sat.	32	N. 4	12	56.8	+58.06	4	13.29

Note—The sign + prefixed to the hourly change of declination indicates that south declinations are decreasing or north declinations increasing.

AT GREENWICH MEAN NOON
APRIL, 1911

Sun's Semi-Diameter 15′ 58″

Day of Week	Day of Month	Sun's Apparent Declination °	′	″	Diff. for 1 Hr. ″	Equation of Time to be Subtracted from / Added to Mean Time m	s
Sat.	1	N. 4	12	56.8	+58.06	4	13.29
Sun.	2	4	36	7.9	57.86	3	55.24
Mon.	3	4	59	14.0	57.64	3	37.29
Tues.	4	5	22	14.6	+57.41	3	19.45
Wed.	5	5	45	9.5	57.16	3	1.74
Thur.	6	6	7	58.2	56.90	2	44.19
Frid.	7	6	30	40.5	+56.62	2	26.80
Sat.	8	6	53	15.9	56.33	2	9.60
Sun.	9	7	15	44.2	56.02	1	52.61
Mon.	10	7	38	5.0	+55.70	1	35.84
Tues.	11	8	0	17.9	55.37	1	19.32
Wed.	12	8	22	22.7	55.03	1	3.07
Thur.	13	8	44	19.2	+54.67	0	47.11
Frid.	14	9	6	7.0	54.30	0	31.45
Sat.	15	9	27	45.7	53.92	0	16.12
Sun.	16	9	49	15.0	+53.52	0	1.13
Mon.	17	10	10	34.7	53.11	0	13.50
Tues.	18	10	31	44.4	52.69	0	27.74
Wed.	19	10	52	43.7	+52.25	0	41.59
Thur.	20	11	13	32.4	51.80	0	55.02
Frid.	21	11	34	10.2	51.34	1	8.01
Sat.	22	11	54	36.7	+50.86	1	20.57
Sun.	23	12	14	51.6	50.37	1	32.68
Mon.	24	12	34	54.5	49.87	1	44.32
Tues.	25	12	54	45.2	+49.35	1	55.48
Wed.	26	13	14	23.2	48.82	2	6.15
Thur.	27	13	33	48.3	48.27	2	16.33
Frid.	28	13	53	0.0	+47.71	2	26.00
Sat.	29	14	11	58.0	47.13	2	35.16
Sun.	30	14	30	42.0	46.54	2	43.81
Mon.	31	N. 14	49	11.7	+45.93	2	51.94

Note—The sign + prefixed to the hourly change of declination indicates that north declinations are increasing.

AT GREENWICH MEAN NOON
MAY, 1911

Sun's Semi-Diameter 15′ 51″

Day of Week	Day of Month	Sun's Apparent Declination °	′	″	Diff. for 1 Hr. ″	Equation of Time to be Added to Mean Time m	s
Mon.	1	N. 14	49	11.7	+45.93	2	51.94
Tues.	2	15	7	26.6	45.31	2	59.55
Wed.	3	15	25	26.4	44.68	3	6.64
Thur.	4	15	43	10.9	+44.03	3	13.20
Frid.	5	16	0	39.6	43.37	3	19.23
Sat.	6	16	17	52.3	42.69	3	24.72
Sun.	7	16	34	48.6	+42.00	3	29.67
Mon.	8	16	51	28.3	41.30	3	34.07
Tues.	9	17	7	51.1	40.59	3	37.92
Wed.	10	17	23	56.7	+39.87	3	41.21
Thur.	11	17	39	44.9	39.14	3	43.94
Frid.	12	17	55	15.3	38.40	3	46.09
Sat.	13	18	10	27.7	+37.64	3	47.67
Sun.	14	18	25	21.9	36.87	3	48.67
Mon.	15	18	39	57.5	36.09	3	49.10
Tues.	16	18	54	14.3	+35.30	3	48.95
Wed.	17	19	8	12.0	34.50	3	48.23
Thur.	18	19	21	50.4	33.69	3	46.93
Frid.	19	19	35	9.2	+32.87	3	45.06
Sat.	20	19	48	8.2	32.04	3	42.61
Sun.	21	20	0	47.0	31.20	3	39.60
Mon.	22	20	13	5.5	+30.34	3	36.02
Tues.	23	20	25	3.3	29.47	3	31.88
Wed.	24	20	36	40.2	28.60	3	27.20
Thur.	25	20	47	56.0	+27.71	3	21.99
Frid.	26	20	58	50.4	26.82	3	16.26
Sat.	27	21	9	23.1	25.91	3	10.02
Sun.	28	21	19	33.9	+24.99	3	3.30
Mon.	29	21	29	22.5	24.06	2	56.11
Tues.	30	21	38	48.8	23.13	2	48.46
Wed.	31	21	47	52.6	22.18	2	40.37
Thur.	32	N. 21	56	33.6	+21.23	2	31.87

Note—The sign + prefixed to the hourly change of declination indicates that north declinations are increasing.

AT GREENWICH MEAN NOON
JUNE, 1911

Day of Week	Day of Month	Sun's Semi-Diameter 15′ 46″ — Sun's Apparent Declination °	′	″	Diff. for 1 Hr. ″	Equation of Time to be Added to Subtracted from Mean Time m	s
Thur.	1	N. 21	56	33.6	+21.23	2	31.87
Frid.	2	22	4	51.7	20.27	2	22.97
Sat.	3	22	12	46.6	19.30	2	13.69
Sun.	4	22	20	18.2	+18.33	2	4.05
Mon.	5	22	27	26.3	17.35	1	54.07
Tues.	6	22	34	10.7	16.36	1	43.77
Wed.	7	22	40	31.4	+15.37	1	33.15
Thur.	8	22	46	28.3	14.37	1	22.24
Frid.	9	22	52	1.3	13.37	1	11.06
Sat.	10	22	57	10.2	+12.37	0	59.61
Sun.	11	23	1	54.9	11.36	0	47.92
Mon.	12	23	6	15.4	10.35	0	36.00
Tues.	13	23	10	11.5	+ 9.33	0	23.88
Wed.	14	23	13	43.2	8.31	0	11.57
Thur.	15	23	16	50.3	7.29	0	0.91
Frid.	16	23	19	32.9	+ 6.26	0	13.54
Sat.	17	23	21	50.9	5.23	0	26.30
Sun.	18	23	23	44.2	4.20	0	39.17
Mon.	19	23	25	12.7	+ 3.17	0	52.12
Tues.	20	23	26	16.5	2.14	1	5.13
Wed.	21	23	26	55.5	1.11	1	18.19
Thur.	22	23	27	9.6	+ 0.07	1	31.27
Frid.	23	23	26	59.0	— 0.96	1	44.34
Sat.	24	23	26	23.6	1.99	1	57.38
Sun.	25	23	25	23.3	— 3.03	2	10.36
Mon.	26	23	23	58.3	4.06	2	23.25
Tues.	27	23	22	8.5	5.09	2	36.01
Wed.	28	23	19	54.1	— 6.12	2	48.62
Thur.	29	23	17	15.0	7.14	3	1.06
Frid.	30	23	14	11.3	8.16	3	13.29
Sat.	31	N. 23	10	43.2	— 9.18	3	25.29

Note—The sign + prefixed to the hourly change of declination indicates that north declinations are increasing; the sign — indicates that north declinations are decreasing.

AT GREENWICH MEAN NOON
JULY, 1911

Day of Week	Day of Month	Sun's Semi-Diameter 15′ 46″ — Sun's Apparent Declination °	′	″	Diff. for 1 Hr. ″	Equation of Time to be Subtracted from Mean Time m	s
Sat.	1	N. 23	10	43.2	— 9.18	3	25.29
Sun.	2	23	6	50.7	10.19	3	37.03
Mon.	3	23	2	34.0	11.20	3	48.50
Tues.	4	22	57	58.1	—12.20	3	59.67
Wed.	5	22	52	48.3	13.20	4	10.52
Thur.	6	22	47	19.6	14.19	4	21.04
Frid.	7	22	41	27.2	—15.18	4	31.20
Sat.	8	22	35	11.2	16.16	4	40.99
Sun.	9	22	28	31.7	17.13	4	50.39
Mon.	10	22	21	29.0	—18.10	4	59.40
Tues.	11	22	14	3.2	19.05	5	7.99
Wed.	12	22	6	14.5	20.00	5	16.15
Thur.	13	21	58	3.0	—20.95	5	23.88
Frid.	14	21	49	29.0	21.88	5	31.15
Sat.	15	21	40	32.6	22.81	5	37.96
Sun.	16	21	31	14.0	—23.73	5	44.29
Mon.	17	21	21	33.4	24.65	5	50.13
Tues.	18	21	11	31.0	25.55	5	55.48
Wed.	19	21	1	7.0	—26.45	6	0.33
Thur.	20	20	50	21.6	27.33	6	4.66
Frid.	21	20	39	15.0	28.21	6	8.47
Sat.	22	20	27	47.5	—29.08	6	11.74
Sun.	23	20	15	59.4	29.93	6	14.46
Mon.	24	20	3	50.8	30.78	6	16.62
Tues.	25	19	51	22.0	—31.61	6	18.21
Wed.	26	19	38	33.4	32.44	6	19.22
Thur.	27	19	25	25.1	33.25	6	19.63
Frid.	28	19	11	57.5	—34.05	6	19.43
Sat.	29	18	58	10.8	34.84	6	18.62
Sun.	30	18	44	5.4	35.61	6	17.19
Mon.	31	18	29	41.6	36.37	6	15.14
Tues.	32	N. 18	14	59.6	—37.12	6	12.46

Note—The sign — prefixed to the hourly change of declination indicates that north declinations are decreasing.

AT GREENWICH MEAN NOON
AUGUST, 1911

Day of Week	Day of Month	Sun's Semi-Diameter 15′ 50″				Equation of Time to be Subtracted from Mean Time	
		Sun's Apparent Declination			Diff. for 1 Hr.		
		°	′	″	″	m	s
Tues.	1	N. 18	14	59.6	—37.12	6	12.46
Wed.	2	17	59	59.8	37.86	6	9.16
Thur.	3	17	44	42.4	38.59	6	5.24
Frid.	4	17	29	7.7	—39.30	6	0.70
Sat.	5	17	13	16.1	40.00	5	55.54
Sun.	6	16	57	7.8	40.69	5	49.77
Mon.	7	16	40	43.1	—41.37	5	43.39
Tues.	8	16	24	2.3	42.03	5	36.40
Wed.	9	16	7	5.7	42.68	5	28.82
Thur.	10	15	49	53.6	—43.32	5	20.66
Frid.	11	15	32	26.3	43.95	5	11.92
Sat.	12	15	14	44.1	44.57	5	2.62
Sun.	13	14	56	47.2	—45.17	4	52.76
Mon.	14	14	38	36.0	45.76	4	42.36
Tues.	15	14	20	10.7	46.34	4	31.43
Wed.	16	14	1	31.6	—46.91	4	19.99
Thur.	17	13	42	39.0	47.47	4	8.03
Frid.	18	13	23	33.2	48.01	3	55.57
Sat.	19	13	4	14.6	—48.54	3	42.62
Sun.	20	12	44	43.4	49.06	3	29.18
Mon.	21	12	24	59.9	49.56	3	15.27
Tues.	22	12	5	4.5	—50.05	3	0.90
Wed.	23	11	44	57.5	50.53	2	46.08
Thur.	24	11	24	39.3	50.99	2	30.82
Frid.	25	11	4	10.3	—51.43	2	15.12
Sat.	26	10	43	30.7	51.86	1	59.00
Sun.	27	10	22	40.9	52.28	1	42.46
Mon.	28	10	1	41.2	—52.68	1	25.51
Tues.	29	9	40	32.1	53.07	1	8.16
Wed.	30	9	19	13.9	53.45	0	50.44
Thur.	31	8	57	46.8	53.81	0	32.37
Frid.	32	N. 8	36	11.2	—54.16	0	13.95

Note—The sign — prefixed to the hourly change of declination indicates that north declinations are decreasing.

AT GREENWICH MEAN NOON
SEPTEMBER, 1911

Day of Week	Day of Month	Sun's Semi-Diameter 15′ 57″				Equation of Time to be Subtracted from / Added to Mean Time	
		Sun's Apparent Declination			Diff. for 1 Hr.		
		°	′	″	″	m	s
Frid.	1	N. 8	36	11.2	—54.16	0	13.95
Sat.	2	8	14	27.5	54.49	0	4.80
Sun.	3	7	52	35.9	54.81	0	23.86
Mon.	4	7	30	36.8	—55.12	0	43.21
Tues.	5	7	8	30.4	55.41	1	2.83
Wed.	6	6	46	17.1	55.69	1	22.70
Thur.	7	6	23	57.3	—55.96	1	42.81
Frid.	8	6	1	31.2	56.22	2	3.12
Sat.	9	5	38	59.1	56.46	2	23.62
Sun.	10	5	16	21.3	—56.69	2	44.29
Mon.	11	4	53	38.1	56.91	3	5.10
Tues.	12	4	30	49.9	57.11	3	26.03
Wed.	13	4	7	56.9	—57.31	3	47.05
Thur.	14	3	44	59.3	57.49	4	8.15
Frid.	15	3	21	57.5	57.66	4	29.31
Sat.	16	2	58	51.9	—57.81	4	50.51
Sun.	17	2	35	42.8	57.95	5	11.73
Mon.	18	2	12	30.5	58.07	5	32.94
Tues.	19	1	49	15.4	—58.18	5	54.13
Wed.	20	1	25	57.8	58.28	6	15.28
Thur.	21	1	2	38.0	58.36	6	36.37
Frid.	22	0	39	16.4	—58.43	6	57.39
Sat.	23	N. 0	15	53.5	58.48	7	18.33
Sun.	24	S. 0	7	30.4	58.51	7	39.17
Mon.	25	0	30	55.0	—58.53	7	59.89
Tues.	26	0	54	19.8	58.53	8	20.46
Wed.	27	1	17	44.5	58.52	8	40.88
Thur.	28	1	41	8.8	—58.50	9	1.12
Frid.	29	2	4	32.3	58.46	9	21.16
Sat.	30	2	27	54.6	58.40	9	40.99
Sun.	31	S. 2	51	15.4	—58.33	10	0.58

Note—The sign — prefixed to the hourly change of declination indicates that north declinations are decreasing; south declinations increasing.

AT GREENWICH MEAN NOON
OCTOBER, 1911

Day of Week	Day of Month	Sun's Semi-Diameter 16′ 05″ — Sun's Apparent Declination				Diff. for 1 Hr.	Equation of Time to be Added to Mean Time	
			°	′	″	″	m	s
Sun.	1	S.	2	51	15.4	—58.33	10	0.58
Mon.	2		3	14	34.3	58.24	10	19.92
Tues.	3		3	37	50.9	58.14	10	38.98
Wed.	4		4	1	5.0	—58.03	10	57.74
Thur.	5		4	24	16.1	57.90	11	16.18
Frid.	6		4	47	24.0	57.76	11	34.28
Sat.	7		5	10	28.3	—57.60	11	52.00
Sun.	8		5	33	28.6	57.43	12	9.33
Mon.	9		5	56	24.7	57.24	12	26.26
Tues.	10		6	19	16.2	—57.04	12	42.75
Wed.	11		6	42	2.8	56.83	12	58.78
Thur.	12		7	4	44.1	56.60	13	14.32
Frid.	13		7	27	19.7	—56.36	13	29.36
Sat.	14		7	49	49.4	56.10	13	43.88
Sun.	15		8	12	12.8	55.83	13	57.85
Mon.	16		8	34	29.4	—55.54	14	11.25
Tues.	17		8	56	38.8	55.24	14	24.08
Wed.	18		9	18	40.7	54.92	14	36.31
Thur.	19		9	40	34.7	—54.58	14	47.92
Frid.	20		10	2	20.3	54.22	14	58.91
Sat.	21		10	23	57.2	53.85	15	9.27
Sun.	22		10	45	24.9	—53.46	15	18.98
Mon.	23		11	6	42.9	53.05	15	28.02
Tues.	24		11	27	50.9	52.62	15	36.39
Wed.	25		11	48	48.5	—52.17	15	44.07
Thur.	26		12	9	35.2	51.71	15	51.06
Frid.	27		12	30	10.5	51.23	15	57.34
Sat.	28		12	50	34.1	—50.73	16	2.90
Sun.	29		13	10	45.7	50.22	16	7.73
Mon.	30		13	30	44.8	49.69	16	11.82
Tues.	31		13	50	30.9	49.15	16	15.15
Wed.	32	S.	14	10	3.7	—48.59	16	17.71

Note—The sign — prefixed to the hourly change of declination indicates that south declinations are increasing.

AT GREENWICH MEAN NOON
NOVEMBER, 1911

Day of Week	Day of Month	Sun's Semi-Diameter 16′ 12″ — Sun's Apparent Declination				Diff. for 1 Hr.	Equation of Time to be Added to Mean Time	
			°	′	″	″	m	s
Wed.	1	S.	14	10	3.7	—48.59	16	17.71
Thur.	2		14	29	22.8	48.01	16	19.49
Frid.	3		14	48	27.8	47.41	16	20.49
Sat.	4		15	7	18.3	—46.80	16	20.70
Sun.	5		15	25	53.9	46.17	16	20.10
Mon.	6		15	44	14.2	45.52	16	18.69
Tues.	7		16	2	18.9	—44.86	16	16.44
Wed.	8		16	20	7.6	44.18	16	13.35
Thur.	9		16	37	39.9	43.49	16	9.42
Frid.	10		16	54	55.4	—42.79	16	4.63
Sat.	11		17	11	53.8	42.07	15	58.98
Sun.	12		17	28	34.6	41.33	15	52.47
Mon.	13		17	44	57.4	—40.57	15	45.08
Tues.	14		18	1	1.8	39.80	15	36.82
Wed.	15		18	16	47.5	39.01	15	27.68
Thur.	16		18	32	14.1	—38.20	15	17.68
Frid.	17		18	47	21.1	37.38	15	6.83
Sat.	18		19	2	8.1	36.54	14	55.12
Sun.	19		19	16	34.7	—35.68	14	42.57
Mon.	20		19	30	40.4	34.80	14	29.19
Tues.	21		19	44	25.0	33.91	14	14.99
Wed.	22		19	57	48.0	—33.00	13	59.98
Thur.	23		20	10	49.1	32.08	13	44.16
Frid.	24		20	23	27.8	31.14	13	27.56
Sat.	25		20	35	43.9	—30.19	13	10.20
Sun.	26		20	47	37.0	29.22	12	52.09
Mon.	27		20	59	6.7	28.24	12	33.24
Tues.	28		21	10	12.6	—27.25	12	13.67
Wed.	29		21	20	54.5	26.24	11	53.41
Thur.	30		21	31	12.2	25.22	11	32.47
Frid.	31	S.	21	41	5.3	—24.19	11	10.87

Note—The sign — prefixed to the hourly change of declination indicates that south declinations are increasing.

AT GREENWICH MEAN NOON
DECEMBER, 1911

Day of Week	Day of Month	Sun's Semi-Diameter 16′ 17″ — Sun's Apparent Declination °	′	″	Diff. for 1 Hr. ″	Equation of Time to be Added to / Subtracted from Mean Time m	s
Frid.	1	S. 21	41	5.3	—24.19	11	10.87
Sat.	2	21	50	33.4	23.15	10	48.62
Sun.	3	21	59	36.4	22.10	10	25.74
Mon.	4	22	8	14.0	—21.04	10	2.26
Tues.	5	22	16	26.0	19.96	9	38.20
Wed.	6	22	24	12.0	18.87	9	13.57
Thur.	7	22	31	31.9	—17.78	8	48.39
Frid.	8	22	38	25.4	16.68	8	22.68
Sat.	9	22	44	52.4	15.57	7	56.47
Sun.	10	22	50	52.7	—14.45	7	29.77
Mon.	11	22	56	26.0	13.32	7	2.62
Tues.	12	23	1	32.1	12.19	6	35.04
Wed.	13	23	6	10.9	—11.05	6	7.06
Thur.	14	23	10	22.3	9.90	5	38.72
Frid.	15	23	14	6.0	8.74	5	10.04
Sat.	16	23	17	21.9	— 7.58	4	41.06
Sun.	17	23	20	9.9	6.41	4	11.82
Mon.	18	23	22	29.8	5.24	3	42.35
Tues.	19	23	24	21.6	— 4.07	3	12.69
Wed.	20	23	25	45.2	2.89	2	42.88
Thur.	21	23	26	40.5	1.72	2	12.95
Frid.	22	23	27	7.5	— 0.54	1	42.94
Sat.	23	23	27	6.2	+ 0.64	1	12.89
Sun.	24	23	26	36.6	1.82	0	42.84
Mon.	25	23	25	38.7	+ 3.00	0	12.83
Tues.	26	23	24	12.4	4.18	0	17.11
Wed.	27	23	22	17.9	5.36	0	46.94
Thur.	28	23	19	55.2	+ 6.53	1	16.63
Frid.	29	23	17	4.4	7.70	1	46.13
Sat.	30	23	13	45.5	8.87	2	15.42
Sun.	31	23	9	58.8	10.03	2	44.47
Mon.	32	S. 23	5	44.3	+11.18	3	13.24

Note—The sign — prefixed to the hourly change of declination indicates that south declinations are increasing; the sign + indicates that south declinations are decreasing.

AZIMUTH OF POLARIS WHEN AT ELONGATION.
For the Year 1911.

Latitude	Azimuth	Latitude	Azimuth
25°	1° 17′.4	40°	1° 31′.6
26°	1° 18′.0	41°	1° 32′.9
27°	1° 19′.1	42°	1° 34′.2
28°	1° 19′.4	43°	1° 35′.9
29°	1° 20′.2	44°	1° 37′.5
30°	1° 21′.0	45°	1° 39′.2
31°	1° 21′.8	46°	1° 41′.0
32°	1° 22′.7	47°	1° 42′.8
33°	1° 23′.6	48°	1° 44′.8
34°	1° 24′.6	49°	1° 46′.9
35°	1° 25′.6	50°	1° 49′.1
36°	1° 26′.7	51°	1° 51′.5
37°	1° 27′.8	52°	1° 53′.9
38°	1° 29′.0	53°	1° 56′.6
39°	1° 30′.2	54°	1° 59′.3

The above table is based on the average Polar distance for the year. It has a maximum error of about 0° 00′ 60″. When greater accuracy is required the following table may be used which gives the average Polar distance for each month. It has a maximum error of about 0° 00′ 06″. The azimuth at elongation is determined by the equation.

$$\text{sin azimuth} = \frac{\text{sin Polar distance}}{\text{cos lat}}$$

AVERAGE POLAR DISTANCE OF POLARIS.
For the Year 1911.

Month	Polar Distance	Month	Polar Distance
Jan..........	1° 09′ 49″	July..........	1° 10′ 19″
Feb..........	1° 09′ 51″	Aug..........	1° 10′ 13″
Mar..........	1° 09′ 57″	Sept..........	1° 10′ 04″
April..........	1° 10′ 06″	Oct..........	1° 09′ 53″
May..........	1° 10′ 14″	Nov..........	1° 09′ 41″
June..........	1° 10′ 19″	Dec..........	1° 09′ 32″

FIXED STARS—1911.

Star	Apparent Declination	Mag-nitude	Right Ascension
	° ′ ″		h m s
α Tauri (*Aldebaran*)	+16 19 51	1.0	4 30 48
β Orionis (*Rigel*)	− 8 18 13	0.3	5 10 15
α Orionis (*Var.*)	+ 7 23 28	0.9	5 50 21
α Canis Majoris (*Sirius*)	−16 35 36	1.4	6 41 13
α Canis Min. (*Procyon*)	+ 5 27 12	0.5	7 34 38
α Lionis (*Regulus*)	+12 24 09	1.3	10 03 38
α Virginis (*Spica*)	−10 41 49	1.1	13 20 30
α Bootis (*Arcturus*)	+19 38 43	0.2	14 11 36
α Scorpii (*Antares*)	−26 14 06	1.2	16 23 56
α Aquilae (*Altair*)	+ 8 37 57	0.9	19 46 26

Observations on fixed stars for the Meridian or latitude are made with the Solar attachment in exactly the same manner as on the Sun. There being no appreciable hourly change in the declination of the fixed stars, the refraction correction for the proper hour angle is applied directly to the apparent declination given above.

MEAN REFRACTION

(To be Subtracted from Observed Altitude, in Direct Solar Observations). Barometer 30 Inches; Thermometer 50° Fahrenheit.

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

ERRORS IN AZIMUTH FOR 1 MIN. ERROR IN DECLINATION OR LATITUDE.

Hour Angle	For 1 Min. Error in Declination			For 1 Min. Error in Latitude		
	Lat. 30°	Lat. 40°	Lat. 50°	Lat. 30°	Lat. 40°	Lat. 50°
h m	Min.	Min.	Min.	Min.	Min.	Min.
0 30	8.85	10.00	12.90	8.77	9.92	11.80
1 00	4.46	5.05	6.01	4.33	4.87	5.80
2 00	2.31	2.61	3.11	2.00	2.26	2.70
3 00	1.63	1.85	2.20	1.15	1.30	1.56
4 00	1.34	1.51	1.80	0.67	0.75	0.90
5 00	1.20	1.35	1.61	0.31	0.35	0.37
6 00	1.15	1.30	1.56	0.00	0.00	0.00

By the use of the above table the amount of the azimuth error, resulting from the use of erroneous declination or latitude at the different hours of the day, may be determined.

If the South Polar Distance used be **too great,** the observed Meridian falls to the **right** of the **true south point** in the **forenoon** and to the **left** in the **afternoon** and **vice versa** if too small.

If the **latitude** used be **too great,** the observed Meridian falls to the **left** of the **true south point** in the **forenoon,** and to the **right** in the **afternoon** and **vice versa** if too small.

TABLE SHOWING FEET PER MIN. (ARC) AND MIN. (ARC) PER MILE OF LATITUDE AND LONGITUDE.

Latitude	Length of 1 Min. in Feet		No. of Min. in 1 Mile	
	Latitude	Longitude	Latitude	Longitude
0°	6045	6087	.8734	.8674
1°	6045	6085	.8734	.8677
2°	6045	6083	.8734	.8679
3°	6045	6078	.8734	.8687
4°	6045	6071	.8734	.8697
5°	6045	6063	.8734	.8708
6°	6045	6053	.8734	.8722
7°	6046	6041	.8733	.8740
8°	6046	6027	.8733	.8760
9°	6046	6012	.8733	.8782
10°	6047	5994	.8731	.8808
11°	6047	5975	.8731	.8836
12°	6048	5954	.8730	.8867
13°	6048	5931	.8730	8902
14°	6049	5907	.8728	.8938
15°	6049	5880	.8728	.8979

TABLE SHOWING FEET PER MIN. (ARC) AND MIN. (ARC) PER MILE OF LATITUDE AND LONGITUDE.—Continued.

Latitude	Length of 1 Min. in Feet		No. of Min. in 1 Mile	
	Latitude	Longitude	Latitude	Longitude
16°	6050	5852	.8727	.9022
17°	6050	5822	.8727	.9069
18°	6051	5790	.8725	.9119
19°	6052	5757	.8724	.9171
20°	6052	5721	.8724	.9229
21°	6053	5684	.8722	.9280
22°	6054	5646	.8721	.9351
23°	6054	5605	.8721	.9420
24°	6055	5563	.8720	.9491
25°	6056	5519	.8718	.9566
26°	6057	5474	.8717	.9645
27°	6058	5427	.8715	.9729
28°	6059	5378	.8714	.9817
29°	6060	5327	.8712	.9911
30°	6061	5275	.8711	1.0009
31°	6061	5222	.8711	1.0111
32°	6062	5166	.8709	1.0220
33°	6063	5109	.8708	1.0334
34°	6064	5051	.8707	1.0453
35°	6065	4991	.8705	1.0579
36°	6066	4930	.8704	1.0709
37°	6067	4867	.8702	1.0848
38°	6068	4802	.8701	1.0995
39°	6070	4736	.8698	1.1148
40°	6071	4669	.8697	1.1308
41°	6072	4600	.8695	1.1478
42°	6073	4530	.8694	1.1655
43°	6074	4458	.8692	1.1846
44°	6075	4385	.8691	1.2040
45°	6076	4311	.8689	1.2247
46°	6077	4235	.8688	1.2467
47°	6078	4158	.8687	1.2698
48°	6079	4080	.8685	1.2941
49°	6080	4001	.8684	1.3196
50°	6081	3920	.8682	1.3469
51°	6082	3838	.8681	1.3757
52°	6084	3755	.8678	1.4061
53°	6085	3671	.8677	1.4383
54°	6086	3586	.8675	1.4723
55°	6087	3499	.8674	1.5090
56°	6088	3413	.8672	1.5470
57°	6089	3323	.8671	1.5888
58°	6090	3233	.8669	1.6331
59°	6091	3142	.8668	1.6804
60°	6092	3051	.8667	1.7305

WM. AINSWORTH & SONS — THE PRECISION FACTORY — DENVER, COLO. U. S. A.

TABLE OF MEAN REFRACTIONS IN DECLINATION

TO BE USED WITH THE SOLAR ATTACHMENT ONLY.

Apply to the Declination as Found in the Ephemeris.

HOUR ANGLE.	DECLINATIONS.								
	For Latitude 2° 30′.								
	+20°	+15°	+10°	+5°	0°	−5°	−10°	−15°	−20°
0 h.	−18″	−12″	−07″	−02″	+02″	07″	12″	18″	23″
2	−18	−12	−07	−02	+02	07	12	18	23
3	−17	−11	−06	−01	+03	08	13	19	25
4	−15	−10	−05	0	+05	10	15	21	27
5	−10	−05	0	+05	10	15	20	26	32
	For Latitude 5°.								
0 h.	−15″	−10″	−05″	0″	+05″	10″	15″	20″	27″
2	−15	−10	−05	0	+05	10	15	20	27
3	−13	−08	−03	+02	07	12	17	23	29
4	−10	−05	0	+05	10	15	20	27	33
5	−05	0	+05	10	15	20	27	32	40
	For Latitude 7° 30′.								
0 h.	−13″	−08″	−02″	+02″	08″	13″	18″	24″	29″
2	−12	−07	−01	+03	09	14	19	25	31
3	−10	−05	0	+05	10	15	20	26	32
4	−05	0	+05	10	15	20	26	33	39
5	+07	12	17	23	29	36	43	51	1′01″
	For Latitude 10°.								
0 h.	−10″	−05″	0″	+05″	10″	15″	20″	26″	32″
2	−07	−03	+02	07	12	17	22	28	34
3	−03	0	+03	08	13	19	25	31	38
4	0	05	10	15	20	26	32	39	46
5	+15	20	26	32	39	46	55	1′06″	1′19″
	For Latitude 12° 30′.								
0 h.	−08″	−02″	+02″	8″	13″	18″	24″	30″	36″
2	−06	00	+05	10	15	20	26	32	39
3	+02	07	12	17	23	29	36	43	51
4	04	09	14	20	25	31	40	48	55
5	21	27	33	40	48	57	1′08″	1′28″	1′41″
	For Latitude 15°.								
0 h.	−05″	0″	+05″	10″	15″	21″	27″	33″	40″
2	−03	+02	07	12	18	23	29	35	43
3	+01	05	11	16	22	28	34	41	49
4	08	12	19	24	30	37	44	53	1′04
5	29	34	41	49	59	1′10	1′24	1′43	2 03
	For Latitude 17° 30′.								
0 h.	−02″	+02″	08″	13″	18″	24″	30″	36″	44″
2	0	05	10	15	21	27	33	40	48
3	+02	10	15	21	27	33	40	48	57
4	13	18	23	29	35	43	51	1′01	1′13
5	34	41	49	58	1′10	1′23	1′41	2 06	2 42

TABLE OF MEAN REFRACTIONS IN DECLINATION

HOUR ANGLE	DECLINATIONS.								
	For Latitude 20°.								
	+20°	+15°	+10°	+5°	0°	−5°	−10°	−15°	−20°
0 h.	0″	05″	10″	15″	21″	27″	33″	40″	48″
2	03	07	13	18	24	30	36	44	53
3	06	13	18	24	30	36	44	52	1′02
4	17	22	28	35	42	50	1′00	1′11	1 26
5	39	47	57	1′07	1′20	1′37	2 00	2 32	3 25
	For Latitude 22° 30′.								
0 h.	02″	08″	13″	18″	24″	30″	36″	44″	52″
2	06	11	15	21	27	33	40	48	57
3	11	15	21	27	33	40	48	57	1′08
4	20	26	32	39	46	56	1′07	1′19	1 37
5	45	53	1′03	1′16	1′31	1′52	2 21	3 07	4 28
	For Latitude 25°.								
0 h.	05″	10″	15″	21″	27″	33″	40″	48″	57″
2	08	14	19	25	31	38	46	54	1′05
3	12	18	24	30	37	44	53	1′04	1 18
4	23	29	35	45	53	1′03	1′16	1 31	1 52
5	49	59	1′10	1′24	1′52	2 07	2 44	3 46	5 43
	For Latitude 27° 30′.								
0 h.	08″	13″	18″	24″	30″	36″	44″	52″	1′02″
2	11	16	22	28	34	41	49	1′00	1 10
3	17	22	28	35	42	50	1′00	1 11	1 26
4	28	35	42	50	1′00	1′11	1 26	1 43	2 09
5	54	1′05	1′18	1′34	1 54	2 24	3 11	4 38	6 15
	For Latitude 30°.								
0 h.	10″	15″	21″	27″	33″	40″	48″	57″	1′08″
2	14	19	25	31	38	46	54	1′05	1 18
3	20	26	32	39	47	55	1′06	1 19	1 36
4	32	39	46	52	1′06	1′19	1 35	1 57	2 29
5	1′00	1′10	1′24	1′38	2 07	2 44	3 46	5 43	13 06
	For Latitude 32° 30′.								
0 h.	13″	18″	24″	30″	36″	44″	52″	1′02″	1′14
2	17	22	28	35	42	50	1 00	1 11	1 26
3	23	29	35	43	51	1′01	1 13	1 28	1 47
4	35	43	51	1′01	1′13	1 27	1 46	2 13	2 54
5	1′08	1′15	1′31	1 53	2 30	3 05	4 25	7 36	
	For Latitude 35°.								
0 h.	15″	21″	27″	33″	40″	48″	57″	1′08″	1′21″
2	20	25	32	38	46	55	1 06	1 18	1 35
3	26	33	39	47	56	1′07	1 21	1 38	2 00
4	39	47	56	1′07	1′30	1 36	1 59	2 32	3 25
5	1′07	1′20	1′38	2 00	2 34	3 29	5 14	10 16	
	For Latitude 37° 30′.								
0 h.	18″	24″	30″	36″	44″	52″	1′02″	1′14″	1′29″
2	22	28	35	42	50	1′00	1 12	1 26	1 45
3	29	36	43	53	1′02	1 14	1 29	1 49	2 16
4	43	51	1′01	1′13	1 27	1 49	2 14	2 51	4 05
5	1′11	1′26	1 54	2 10	2 49	3 55	6 15	14 58	
	For Latitude 40°.								
0 h.	21″	27″	33″	40″	48″	57″	1′08″	1′21″	1′39″
2	25	32	39	46	52	1′06	1 19	1 35	1 57
3	33	40	48	57	1′08	1 21	1 38	2 02	2 36
4	47	55	1′06	1′19	1 36	1 58	2 30	3 21	4 59
5	1′15	1′31	1 51	2 20	3 05	4 25	7 34	25 18	

TABLE OF MEAN REFRACTIONS IN DECLINATION

HOUR ANGLE	DECLINATIONS.								
	For Latitude 42° 30′.								
	+20°	+15°	+10°	+5°	0°	−5°	−10°	−15°	−20°
0 h.	24″	30″	36″	44″	52″	1′02″	1′14″	1′29″	1′49″
2	28	35	39	50	1′00	1 12	1 26	1 45	2 11
3	36	43	53	1′02	1 18	1 29	1 49	2 17	2 59
4	50	1′00	1′11	1 25	1 44	2 10	2 49	3 55	6 16
5	1′19	1 36	1 58	2 30	3 22	5 00	9 24		
	For Latitude 45°.								
0 h.	27″	33″	40″	48″	57″	1′08″	1′21″	1′39″	2′02″
2	32	39	46	58	1′06	1 19	1 35	1 57	2 29
3	40	47	56	1.07	1 21	1 38	2 00	2 34	3 29
4	54	1′04	1′16	1 33	1 54	2 24	3 11	4 38	8 15
5	1′23	1 41	2 05	2 41	3 40	5 40	12 02		
	For Latitude 47° 30′.								
0 h.	30″	36″	44″	52″	1′03″	1′14″	1′29″	1′49″	2′19″
2	35	42	50	1′00	1 12	1 26	1 45	2 01	2 51
3	43	51	1′01	1 13	1 28	1 47	2 15	2 56	4 08
4	56	1′09	1 23	1 40	2 05	2 40	3 39	5 37	11 18
5	1′27	1 46	2 12	2 52	4 01	6 30	16 19		
	For Latitude 50°.								
0 h.	33″	40″	48″	57″	1′08″	1′21″	1′39″	2′02″	2′38″
2	38	46	55	1′06	1 18	1 35	1 57	2 28	3 19
3	47	56	1′06	1 19	1 36	2 29	2 31	3 28	5 02
4	1′03	1′14	1 29	1 48	2 16	2 58	4 18	6 59	19 47
5	1 30	1 51	2 19	3 04	4 22	7 28	24 10		
	For Latitude 52° 30′.								
0 h.	36″	44″	52″	1′02″	1′14″	1′29″	1′49″	2′18″	3′06″
2	43	50	59	1 11	1 26	1 42	2 28	2 49	3 55
3	50	1′00	1′11	1 26	1 45	2 11	2 51	3 58	6 22
4	1′05	1 18	1 35	2 10	2 28	3 19	4 33	6 42	
5	1 34	1 56	2 27	3 16	4 47	6 52			
	For Latitude 55°.								
0 h.	40″	48″	57″	1′08″	1′21″	1′39″	2′02″	2′36″	3′32″
2	46	55	1′05	1 18	1 34	1 56	2 30	3 15	4 47
3	55	1′06	1 19	1 35	1 58	2 30	3 21	4 58	9 19
4	1′10	1 23	1 42	2 06	2 43	3 44	5 49	12 41	
5	1 37	2 01	2 34	3 28	5 15	10 18			
	For Latitude 57° 30′.								
0 h.	44″	52″	1′02″	1′14″	1′29″	1′49″	2′18″	3′06″	4′37″
2	50	59	1 11	1 25	1 43	2 09	2 47	3 51	6 04
3	58	1′10	1 24	1 42	2 07	2 43	3 45	5 50	12 47
4	1′11	1 25	1 43	2 10	2 50	3 55	6 14	24 49	
5	1 41	2 06	2 42	3 42	5 46	12 26			
	For Latitude 60°.								
0 h.	48″	57″	1′08″	1′21″	1′39″	2′02″	2′36″	3′33″	5′29″
2	54	1′04	1 17	1 33	1 54	2 24	3 13	4 38	8 15
3	1′03	1 15	1 30	1 51	2 20	3 04	4 24	7 31	24 44
4	1 18	1 34	1 56	2 28	3 18	4 50	8 56		
5	1 45	2 11	2 50	3 57	6 21	15 33			
	For Latitude 62° 30′.								
0 h.	52″	1′02″	1′14″	1′29″	1′50″	2′18″	3′00″	4′17″	7′13″
2	58	1 09	1 23	1 41	2 06	2 48	3 44	5 50	12 44
3	1′07″	1 23	1 38	2 01	2 35	3 30	5 16	10 34	
4	1 23	1 40	2 05	2 40	3 40	5 57	11 50		
5	1 48	2 17	2 59	4 14	7 03				

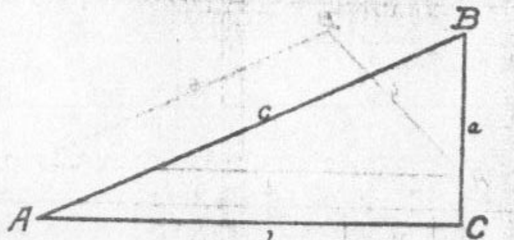
TABLE OF MEAN REFRACTIONS IN DECLINATION

HOUR ANGLE.	DECLINATIONS.								
	For Latitude 65°.								
	+20°	+15°	+10°	+5°	0°	−5°	−10°	−15°	−20°
0 h.	57"	1'08"	1'21"	1'39"	2'02"	2'36"	3'33"	5'23"	10'51"
2	1'08"	1 16	1 31	1 52	2 21	3 07	4 28	7 44	
3	1 12	1 27	1 46	2 12	2 32	4 02	6 33		
4	1 27	1 47	2 13	2 54	4 05	6 40			
5	1 59	2 22	3 08	4 20	7 52				
	For Latitude 67° 30'.								
0 h.	1'02"	1'14"	1'29"	1'50"	2'18"	3'00"	4'17"	7'13"	
2	1 08	1 22	1 40	2 05	2 39	3 37	5 32	11 28	
3	1 17	1 34	1 55	2 26	3 14	4 44	8 34		
4	1 32	1 58	2 23	3 14	4 35	8 05			
5	1 56	2 28	3 17	4 40	8 31				
	For Latitude 70°.								
0 h.	1'08"	1'21"	1'39"	2'02"	2'36"	3'33"	5'23"	10'51"	
2	1 14	1 29	1 50	2 18	3 00	4 17	7 18		
3	1 23	1 48	2 05	2 41	3 41	5 59	12 15		
4	1 37	2 09	2 34	3 28	5 20	10 12			
5	2 02	2 32	3 27	5 11	10 05				

OUR AIM.

It will be our constant effort to elevate the art of instrument making from the European methods so closely followed by American manufacturers in the past to a plane corresponding to the American watch-making industry—which is unequaled by any industry in the world for systematic accuracy, factory methods and results—and make it better for our having entered the field.

TRIGONOMETRIC FUNCTIONS.



In the right angled triangle let the angles be designated by A, B, and C and the sides opposite these angles by a, b and c respectively. We then have:

(1) $\sin A = \frac{a}{c} = \cos B$

(2) $\cos A = \frac{b}{c} = \sin B$

(3) $\tan A = \frac{a}{b} = \cot B$

(4) $\cot A = \frac{b}{a} = \tan B$

(5) $\sec A = \frac{c}{b} = \operatorname{cosec} B$

(6) $\operatorname{cosec} A = \frac{c}{a} = \sec B$

(7) $\operatorname{vers} A = \frac{c-b}{c} = \operatorname{covers} B$

(8) $\operatorname{covers} A = \frac{c-a}{c} = \operatorname{versin} B$

(9) $a = c \sin A = c \cos B = b \tan A = b \cot B = \sqrt{(c+b)(c-b)}$

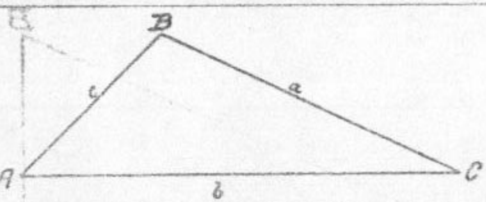
(10) $b = c \cos A = c \sin B = a \cot A = a \tan B = \sqrt{(c+a)(c-a)}$

(11) $c = \frac{a}{\sin A} = \frac{a}{\cos B} = \frac{b}{\cos A} = \frac{b}{\sin B} = \sqrt{a^2+b^2}$

(12) $C = 90° = A + B$

(13) $\text{area} = \frac{ab}{2}$

SOLUTION OF OBLIQUE TRIANGLES.



Given	Required	FORMULAE
A, B, a	C	$C=180°-(A+B)$ ....(1)
	b	$b=\sin B \dfrac{a}{\sin A}$ ....(2)
	c	$c=\sin C \dfrac{a}{\sin A}$ ....(3)
A, a, b	B	$\sin B=\dfrac{\sin A}{a} b$ ....(4)
	C	C use (1)
	c	c use (3)
A, b, c	a	$a=\sqrt{b^2+c^2-2bc \cos A}$ ....(5)
	B	B use (4)
	C	C use (1)
	area	$area=\frac{1}{2} bc \sin A$ ....(6)
a, b, c		Let $s=\frac{1}{2}(a+b+c)$
	A	$\sin \frac{1}{2} A=\sqrt{\dfrac{(s-b)(s-c)}{bc}}$ (7)
	B	B use (4)
	C	C use (1)
	area	$area=\sqrt{s(s-a)(s-b)(s-c)}$ (8)

TRIGONOMETRIC FORMULAE.

$\sin^2 A+\cos^2 A=1$

$\sin A=2 \sin \frac{1}{2} A \times \cos \frac{1}{2} A$

$\cos A=2 \cos^2 \frac{1}{2} A-1=1-2 \sin^2 \frac{1}{2} A$

$$\tan A=\frac{1-\cos 2A}{\sin 2A}=\frac{\sin A}{\cos A}$$

$$\sin \tfrac{1}{2} A=\sqrt{\frac{1-\cos A}{2}}$$

$$\cos \tfrac{1}{2} A=\sqrt{\frac{1+\cos A}{2}}$$

$$\tan \tfrac{1}{2} A=\frac{1-\cos A}{\sin A}$$

$\sin 2A=2 \sin A \cos A$

$\cos 2A=\cos^2 A-\sin^2 A=2 \cos^2 A-1$

$$\tan 2A=\frac{2 \tan A}{1-\tan^2 A}$$

$\sin (A\pm B)=\sin A \cos B\pm\sin B \cos A$

$\cos (A\pm B)=\cos A \cos B\mp\sin A \sin B$

$\sin A+\sin B=2 \sin \frac{1}{2}(A+B) \cos \frac{1}{2}(A-B)$

$\sin A-\sin B=2\cos \frac{1}{2}(A+B) \sin \frac{1}{2}(A-B)$

$\cos A+\cos B=2 \cos \frac{1}{2}(A+B) \cos \frac{1}{2}(A-B)$

$\cos B-\cos A=2 \sin \frac{1}{2}(A+B) \sin \frac{1}{2}(A-B)$

$$\tan A+\tan B=\frac{\sin (A+B)}{\cos A \cos B}$$

$$\tan A-\tan B=\frac{\sin (A-B)}{\cos A \cos B}$$

$\sin (A\pm 90°)=\pm\cos A$

$\cos (A\pm 90°)=\mp\sin A$

$\sin (A\pm 180°)=\sin A$

$\cos (A\pm 180°)=\cos A$

MENSURATION

PLANE SURFACES.

Quadrilateral:—A four sided plane figure.

Parallelogram:—A quadrilateral with opposite sides parallel (Square, Rectangle, Rhombus, Rhomboid).

Area = Base × Altitude.

Trapezium:—A quadrilateral with unequal sides.

Area = Product of either diagonal × Half the sum of the perpendiculars from this diagonal to the opposite angles.

Trapezoid:—A quadrilateral with only one pair of opposite sides parallel.

Area =
Product of the sum of the two parallel sides × Half the perpendicular distance between them.

Triangle:—A three sided plane figure.

Area = Product of the base × Half the altitude.
= Half the product of two sides × The sine of the included angle.

$$= \sqrt{\tfrac{1}{2}S \times (\tfrac{1}{2}S - a)\ (\tfrac{1}{2}S - b)\ (\tfrac{1}{2}S - c)}$$

Where a, b, c = The three sides and $S = a + b + c$.

Polygon:—A plane figure having three or more sides.

Area, Divide into triangles and find the sum of the areas of these triangles.

Irregular Figures:—Divide the figure into a suitable number of parts by parallel lines equally spaced; to half the sum of the two end lines add all the other lines, divide this sum by one less than the number of lines and multiply by the length to obtain the area.

Circle:—

Area = .7854 × (Diameter)² = 3.1416 × (Radius)²

Circumference = 3.1416 × Diameter
= 2 × 3.1416 × Radius.

$$\text{Length of an arc} = \frac{\text{Circumference}}{360} \times \text{Number of degrees in the arc.}$$

Ellipse:—

Area = .7854 × Product of its axes.

$$\text{Circumference (approximate)} = 3.1416 \times \sqrt{\frac{D^2 + d^2}{2}}$$

Where D and d are the two axes.

SOLID BODIES.

Prism or Cylinder:—

Volume = Area of one end × Perpendicular distance to the other end. (This rule applies to all prisms whether right or oblique, regular or irregular.)

Frustrum of Prism:—

$$\text{Volume} = \frac{\left(\begin{array}{c}\text{Sum of lengths}\\ \text{of parallel edges}\end{array}\right)}{\left(\begin{array}{c}\text{Number of}\\ \text{parallel edges}\end{array}\right)} \times \left\{\begin{array}{c}\text{Area of cross sec-}\\ \text{tion perpendicular}\\ \text{to the parallel edges}\end{array}\right\}$$

This rule applies to prisms whose cross section, perpendicular to the parallel edges, is a triangle, parallelogram, or regular polygon.

Pyramid or Cone:—

Volume = Area of base × One-third the altitude.

Frustrum of Pyramid or Cone:—

$$\text{Volume} = \frac{\text{Altitude}}{3} \times \left\{\begin{array}{l} + \sqrt{\text{Area of top} \times \text{Area of base}}\\ + \text{Area of top} + \text{Area of base}\end{array}\right\}$$

Wedge:—A wedge is a solid bounded by five planes; a parallelogram base, two triangular ends, and two trapezoids or parallelograms meeting in an edge. The altitude is the perpendicular distance from the edge to the plane of the base. The length of the base is parallel to the edge.

Volume =

$$\left(\begin{array}{l} +2 \times \text{Length of base}\\ + \text{Length of edge}\end{array}\right) \times \frac{\text{Altitude} \times \text{Width of base}}{6}$$

Sphere:—

$$\text{Volume} = \frac{(\text{Diameter})^3 \times 3.1416}{6}$$

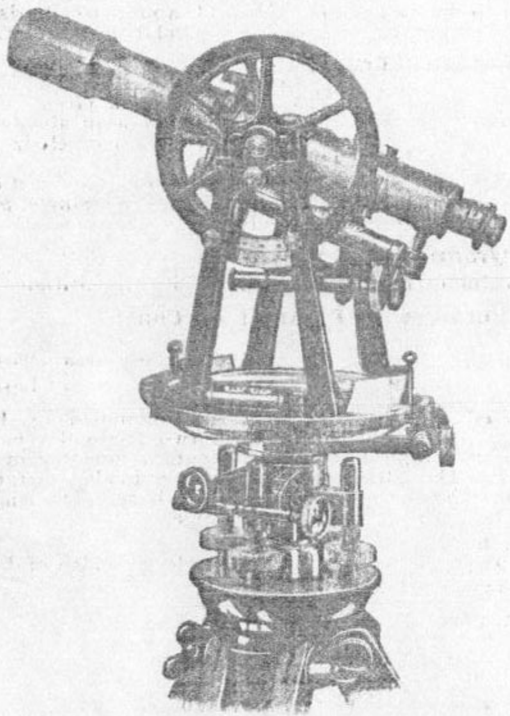
Surface = (Diameter)² × 3.1416.

Prismoid:—A solid having two parallel plane figures for its ends, and it may be composed of any combination of prisms, cylinders, wedges, pyramids, or cones or frustrums of the same, whose bases and apices lie in the end planes.

$$\text{Volume} = \frac{h}{6} \times (A + 4M + B)$$

Where A and B = Areas of the ends, M = Middle area and h = Perpendicular distance between the parallel ends.

AINSWORTH



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Weight 10 lbs.—4.5 Kilos.
Code word, **Babal.**

The most popular instrument for general work on the surface or underground.

Has 10-inch—25 cm., 22 power telescope, 4½-inch—11.5 cm. vertical circle, gradienter, 3½-inch—78 cm. compass with variation plate and extension or split leg tripod.

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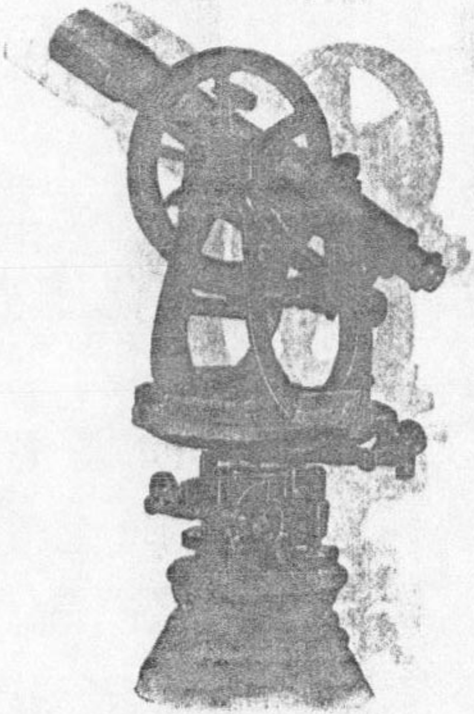
Catalog BX-O shows our complete line, send for it.

AINSWORTH



TYPE BX THEODOLITE.

5-inch—12.7 cm. limb.
Weight 10¼ lbs.—4.6 Kilos.
Code word, **Bulge.**

A type that is rapidly gaining in favor owing to its rigidity and stability of adjustment. Has 2½-inch—6.4 cm. compass with variation plate in center of standard.

Price **$260.00**

Send for catalog BX-O showing our complete line of transits and theodolites.

AINSWORTH

TYPE BZ THEODOLITE

With Interchangeable Auxiliary Telescope.

5-inch—12.7 cm. limb.

Weight 12 lbs.—5.5 Kilos.

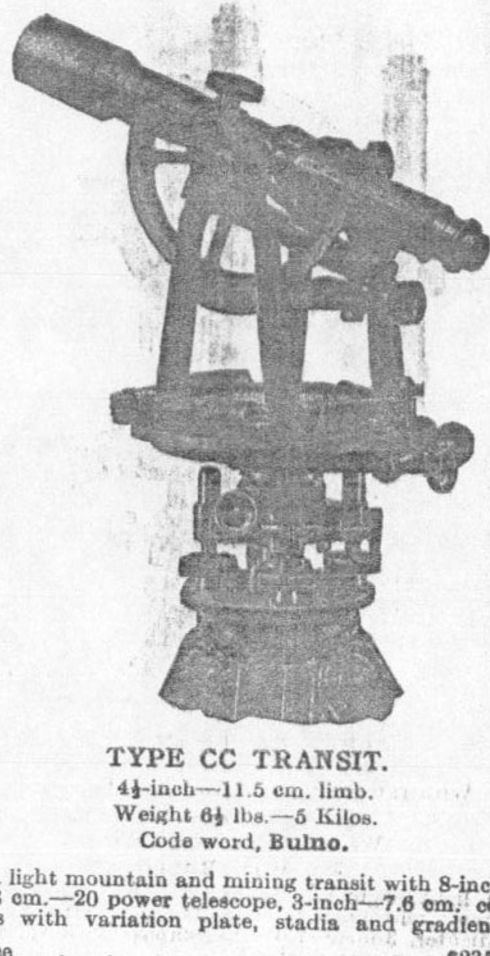
Code Word, **Bulax.**

Has 10-inch—25 cm. main telescope and 8-inch—20 cm. auxiliary telescope; 5-inch—12.7 cm. vertical circle, gradienter; 2½-inch—6.4 cm. compass with variation plate and extension tripod.

Price, as shown $325.00

Send for Catalog BX-O.

AINSWORTH



TYPE CC TRANSIT.

4½-inch—11.5 cm. limb.

Weight 6½ lbs.—5 Kilos.

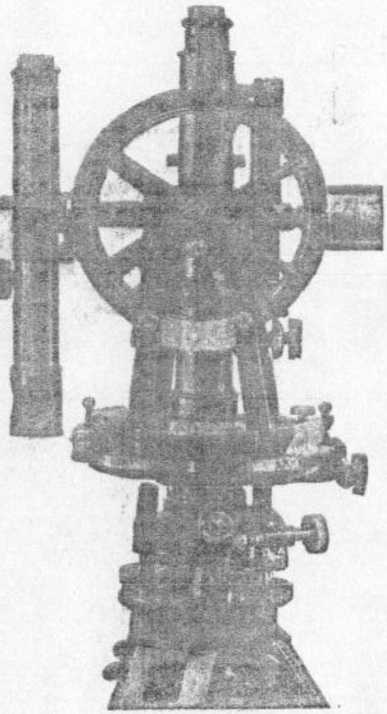
Code word, Bulno.

A light mountain and mining transit with 8-inch—20.3 cm.—20 power telescope, 3-inch—7.6 cm. compass with variation plate, stadia and gradienter.

Price $235.00

Fully described in catalogue BX-O.

AINSWORTH



TYPE CF TRANSIT

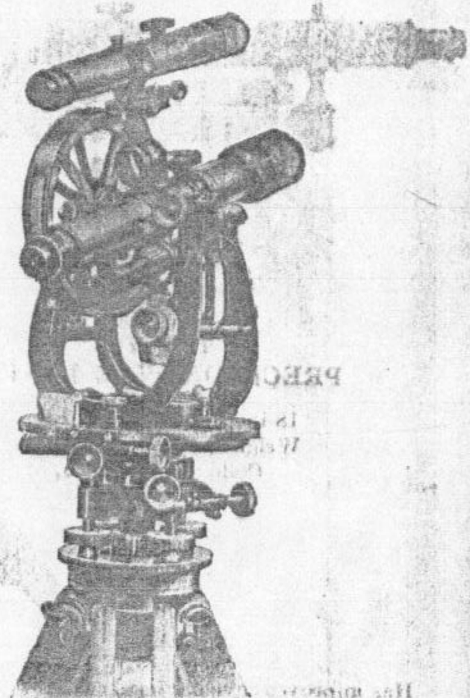
With Interchangeable Auxiliary Telescope.
4½-inch—11.5 cm. limb.
Weight 8½ lbs.—3.8 Kilos.
Code Word, **Bunch.**

A light weight mining transit with 8-inch—20 cm., 20 power telescopes; 4½-inch—11.5 cm. vertical circle, gradienter, 3-inch—7.6 cm. compass with variation plate and extension tripod.

Price $305.00

Fully described in Catalog BX-O.

AINSWORTH



TYPE CZ THEODOLITE.

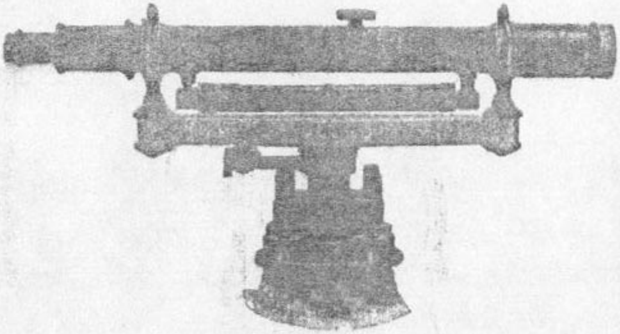
With Interchangeable Auxiliary Telescope.
4½-inch—11.5 cm. limb.
Weight 9 lbs.—4 Kilos.
Code word, Bumeg.

A precision mining theodolite with 8-inch—20 cm. telescopes, 2¼-inch—5.8 cm. compass with variation plate and edge graduation on vertical circle.

Price, with equipment shown $340.00

Fully described in catalogue BX-O.

AINSWORTH



Type YC
PRECISION WYE LEVEL.

18-inch—45 cm. telescope.
Weight 10 lbs.—4.5 Kilos.
Code word, **Becko.**

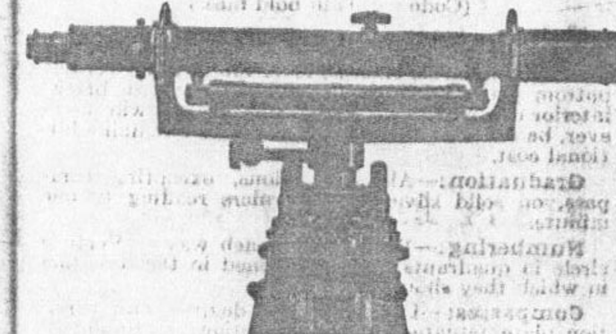
Has improved leveling head and dust protection for objective, and eyepiece slide tubes, and for clamp and spindle.

The wye clips are held by improved latches and a fibre tipped spring plunger holds the wye collar firmly in position in the wyes.

Price.................................... $140.00

Fully described in catalog BX-O.

AINSWORTH

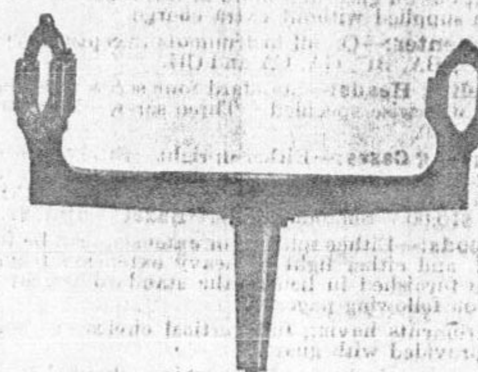


TYPE YF RAILROAD WYE LEVEL.

Code Word, **Beclo.**

For specifications see preceding page.

In this type the spindle, bar and wyes are in one piece and the wye adjustment is made by means of adjusting studs in one of the wyes.



It is a strictly high grade instrument at a moderate price.

Price **$110.00**

Send for Calatog BX-O.

SPECIFICATIONS

Standard Transits and Theodolites

(Code words in bold face.)

Finish:—Standard; Telescope, vertical circle, limb, shifting center, tangent and leveling screws, lacquered; standards, clamps, level tubes, lower center, bottom plate, tripod head, and circle guard, black; interior of compass silvered. Instruments will, however, be furnished in any finish desired at small additional cost.

Graduation:—All graduations, excepting compass, on solid silver with verniers reading to one minute.

Numbering:—Limbs 0-360 each way. Vertical circle in quadrants, figures inclined in the direction in which they should be read.

Compasses:—Divided in half degrees with variation plate actuated by pinion motion; continuous if desired. With black face—**Bamox**—to order.

Telescopes:—Erecting unless inverting—**Babox**—is ordered, for which there is no extra charge.

Cross Hairs:—Spider web unless platinum—**Balup**—is ordered.

Levels:—Both telescope and plate levels have graduations on glass and more or less sensitive levels will be supplied without extra charge.

Gradienter:—On all instruments excepting types AA, AU, BA, BU, GA, CA and CU.

Leveling Heads:—Standard four screw furnished unless otherwise specified. Three screw—**Bamco**—extra, $5.00.

Carrying Cases:—Either upright—**Burly**—or flat—**Burab**—carrying cases furnished, the former, unless otherwise specified. Leather covers—**Baski**—extra, $10.00. Shoulder straps—**Basel**—extra, $2.00

Tripods:—Either split leg or extension can be furnished, and either light or heavy extension tripods can be furnished in lieu of the standard weight as listed on following pages.

Instruments having full vertical circles are regularly provided with guards.

Aluminum instruments weighing about half as much as the regular bronze instruments can be furnished on short notice at 10 per cent. increased cost.

WYE LEVELS

The foregoing in part applies to Wye Levels but with the following exceptions:

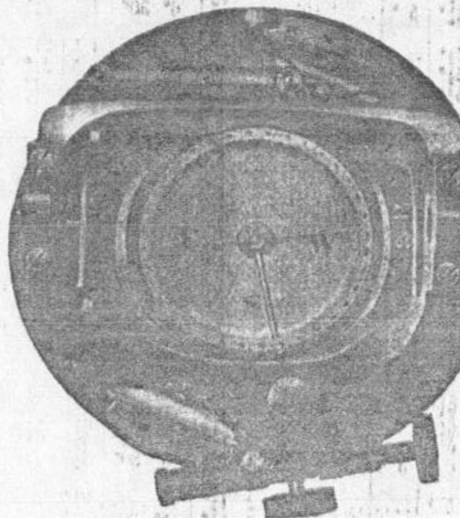
Finish:—Telescope, and on type YF, bar and wyes, cloth finished; eyepiece, object slide, dust

guard, wyes, level, clamp, lower center, bottom plate and tripod head, black; wye clips, bar, tangent and leveling screws, lacquered.

Carrying Cases:—For type YC, mahogany with telescope packed separately to protect wye collars; for type YF, poplar, with instrument packed with telescope in wyes and provided with the usual accessories.

Tripods:—Split leg, furnished with type YC, solid leg with type YF. Heavy, 10 lbs., extension tripods can be furnished with either instrument.

PLAN OF VERNIER PLATE



AINSWORTH THEODOLITE

Telescope removed.

Showing position of plate levels—one of them hidden by the standard—tangent, variation pinon, needle lifter and relative size of compass.

This construction permits the placing of the transverse level entirely on the plate which is not possible on the usual double standard construction with verniers at 30 degrees with telescope.

STANDARD INSTRUMENTS

TRANSITS

Type	Limb	Vert. Circle	Vert. Arc	Telescope	Power	Aperature	Tel. Level	Graduation*	Compass	Plate Levels	Graduation*
AA	6½"	....	....	12"	25	1¼"	......		4½"	2¾"	75"
AC	6½"	....	3"	12"	25	1¼"	6"	30"	4½"	2¾"	75"
AD	6½"	5"	....	12"	25	1¼"	6"	30"	4½"	2¾"	75"
AE	6½"	5"	....	12"	25	1¼"	6"	30"	4½"	2¾"	75"
GA	5½"	....	....	10"	22	1¼"	......		4"	2¼"	90"
GC	5½"	....	2¼"	10"	22	1¼"	5"	30"	4"	2¼"	90"
GD	5½"	5"	....	10"	22	1¼"	5"	30"	4"	2¼"	90"
GE	5½"	5"	....	10"	22	1¼"	5"	30"	4"	2¼"	90"
BA	5"	....	....	10"	22	1¼"	......		3½"	2¼"	90"
BC	5"	....	2¼"	10"	22	1¼"	5"	30"	3½"	2¼"	90"
BD	5"	4½"	....	10"	22	1¼"	5"	30"	3½"	2¼"	90"
BE	5"	4½"	....	10"	22	1¼"	5"	30"	3½"	2¼"	90"
BF	5"	4½"	....	10"	22	1¼"	5"	30"	3½"	2¼"	90"
CC	4½"	....	2¼"	8"	20	1⅛"	4"	30"	3"	2"	100"
CD	4½"	4½"	....	8"	20	1⅛"	4"	30"	3"	2"	100"
CE	4½"	4½"	....	8"	20	1⅛"	4"	30"	3"	2"	100"
CF	4½"	4½"	....	8"	20	1⅛"	4"	30"	3"	2"	100"

THEODOLITES

Type	Limb	Vert. Circle	Vert. Arc	Telescope	Power	Aperature	Tel. Level	Graduation*	Compass	Plate Levels	Graduation*
AU	6½"	....	....	12"	25	1¼"	......		3½"	2¾"	75"
AW	6½"	....	3"	12"	25	1¼"	6"	30"	3½"	2¾"	75"
AX	6½"	5"	....	12"	25	1¼"	6"	30"	3½"	2¾"	75"
AY	6½"	5"	....	12"	25	1¼"	6"	30"	3½"	2¾"	75"
BU	5"	....	....	10"	22	1¼"	......		2½"	2¼"	90"
BW	5"	....	2¼"	10"	22	1¼"	5"	30"	2½"	2¼"	90"
BX	5"	5"	....	10"	22	1¼"	5"	30"	2½"	2¼"	90"
BY	5"	5"	....	10"	22	1¼"	5"	30"	2½"	2¼"	90"
BZ	5"	5"	....	10"	22	1¼"	5"	30"	2½"	2¼"	90"
CW	4½"	....	2¼"	8"	20	1⅛"	4"	30"	2¼"	2"	100"
CX	4½"	4½"	....	8"	20	1⅛"	4"	30"	2¼"	2"	100"
CY	4½"	4½"	....	8"	20	1⅛"	4"	30"	2¼"	2"	100"
CZ	4½"	4½"	....	8"	20	1⅛"	4"	30"	2¼"	2"	100"

WYE LEVELS

Type	Limb	Vert. Circle	Vert. Arc	Telescope	Power	Aperature	Tel. Level	Graduation*	Compass	Plate Levels	Graduation*
YC	....	....	....	18"	35	1⅝"	8"	20"	....	....	
YF	....	....	....	18"	35	1⅝"	8"	20"	....	....	

* In seconds of arc per 1-10 inch division.

STANDARD INSTRUMENTS

TRANSITS

‡Aux. Telescope	Power	Weight Inst.†	Tripod	Weight†	Carry. Case Wt	Code Word	Price	Type
....		13½	Split	7	11	**Boabe**	$215	AA
....		14	Split	7	11	**Boadi**	255	AC
....		14	Split	7	11	**Boafe**	265	AD
8"	20	15½	Ext.	10	11	**Boagi**	305	AE
....		11	Split	7	10	**Bogas**	210	GA
....		11½	Split	7	10	**Bogit**	250	GC
....		11½	Split	7	10	**Bogoz**	260	GD
8"	20	13	Ext.	9	10	**Boggy**	300	GE
....		9½	Split	9	8	**Babex**	200	BA
....		10	Ext.	9	8	**Babil**	240	BC
....		10	Ext.	9	8	**Babb**	250	BD
8"	20	11½	Ext.	9	8	**Bunel**	290	BE
8"‡	20	12	Ext.	9	8	**Babor**	310	BF
....		6¼	Ext.	6½	6	**Bulno**	235	CC
....		6½	Ext.	6½	6	**Bulor**	245	CD
8"	20	7½	Ext.	6½	6	**Bump**	285	CE
8"‡	20	7¾	Ext.	6½	6	**Bunch**	305	CF

THEODOLITES

‡Aux. Telescope	Power	Weight Inst.†	Tripod	Weight†	Carry. Case Wt	Code Word	Price	Type
....		14¼	Split	7	11	**Boaha**	$225	AU
....		14¾	Split	7	11	**Boaji**	265	AW
....		14¾	Split	7	11	**Boaky**	275	AX
8"	20	16¼	Ext.	10	11	**Boalo**	315	AY
....		10	Split	7	8	**Bugbe**	210	BU
....		10½	Ext.	9	8	**Bugle**	250	BW
....		10½	Ext.	9	8	**Bulge**	260	BX
8"	20	12	Ext.	9	8	**Buled**	300	BY
8"‡	20	12½	Ext.	9	8	**Bulax**	325	BZ
....		6¾	Ext.	6½	6	**Bulin**	250	CW
....		6¾	Ext.	6½	6	**Budge**	260	CX
8"	20	8	Ext.	6½	6	**Bulky**	300	CY
8"‡	20	8¼	Ext.	6½	6	**Bumeg**	325	CZ

WYE LEVELS

‡Aux. Telescope	Power	Weight Inst.†	Tripod	Weight†	Carry. Case Wt	Code Word	Price	Type
....		10	Split	7	8½	**Becko**	$140	YC
....		9¾	Solid	10	6	**Becam**	110	YF

† In pounds. ‡Interchangeable, top or side.

EXTRAS AND ATTACHMENTS

(Code words in bold face.)

Only standard instruments as listed on preceding pages are carried in stock, but the following extras and attachments can be furnished on new instruments at the prices below with but little delay.

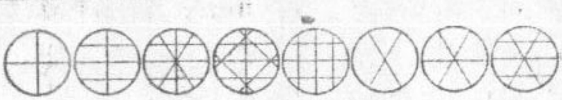
Graduation:—Regular, reading to one minute.

30 sec. limb	**Badge**	$10.00
20 sec. limb	**Badle**	15.00
10 sec. limb	**Badam**	20.00
30 sec. vert. circle	**Bafie**	10.00
Edge Grad., vert. circle	**Bafou**	10.00
Limb numbered { 0-90 each way inside; 0-360 clockwise outside }	**Bagey**	
Limb numbered { 0-90 each way inside; 0-360 counter clockwise outside }	**Bagoz**	

Levels:—Regular, 30 seconds telescope; 75-100 seconds plate. Wye Levels, 20 seconds. Graduations on glass.

8″ 10 sec.	**Bedew**	$ 5.00
8″ 10 sec. reversion	**Bedse**	15.00
8″ 20 sec. reversion	**Beeto**	12.00
6″ 30 sec. reversion	**Baine**	10.00
6″ 20 sec.	**Bakox**	3.00
6″ 20 sec. reversion	**Bakin**	10.00
5″ 30 sec. reversion	**Bairn**	10.00
5″ 20 sec.	**Bacon**	3.00
4″ 30 sec. reversion	**Bacoz**	10.00
4″ 20 sec. reversion	**Balog**	10.00
4″ 20 sec.	**Baier**	3.00
3″ 30 sec. latitude	**Baker**	10.00
3″ 30 sec. striding	**Balan**	12.00
3″ 30 sec. level on vertical circle guard	**Bacam**	5.00
60 sec. plate	**Bajab**	......
90 sec. plate	**Bajer**	......
120 sec. plate	**Bajoe**	......

Reticles:—Regular, Transits No. 37, Levels, No. 36, Spider Web. Platinum wires and other arrangements to order.



36 37 37a 37b 37c 37d 37e 37f

No. 37 Cross and stadia hairs	**Bales**	$ 3.00
No. 37a Cross, diagonal and stadia hairs	**Balor**	3.00
No. 37b Cross, stadia and solar hairs	**Balos**	5.00

EXTRAS AND ATTACHMENTS
(Continued)

No. 37c Cross, horizontal and vertical stadia hairs	**Balag**	$5.00
No. 37d 60° Cross hairs	**Balex**	....
No. 37e 60° Cross and horizontal hairs	**Balle**	....
No. 37f 60° Cross, horizontal and stadia hairs	**Balor**	3.00
Adjustable stadia	**Balut**	7.00
Fixed disappearing stadia	**Balke**	6.00
Adjustable disappearing stadia	**Balad**	8.00

Auxiliary Telescopes:—Top or side; erecting furnished unless inverting—**Babox**—is ordered.

Telescope Axis ends threaded with caps	**Balon**	$ 3.00
Axis for interchangeable telescope	**Balmy**	20.00
10″ 22 power, 1½″ aperature	**Balso**	40.00
8″ 20 power, 1¼″ aperature	**Banit**	35.00
6″ 20 power, 1¼″ aperature, inverting only	**Banta**	30.00

(The latter used as a top telescope will transit on type B and larger instruments.)

Solar Attachments:—Attached to new instruments, otherwise $10.00 extra for the Burt and Saegmuller and $4.00 for the Davis solar screen.

Burt	**Barke**	$50.00
Improved Saegmuller	**Barex**	55.00
Shattuck	**Barba**	30.00
Davis Solar Screen	**Barac**	6.00
Diagonal, prismatic, eyepiece, with colored glass	**Baron**	8.00
Colored glass in eyepiece shutter	**Barry**	1.00

Miscellaneous:—

Reading glass for vertical circle vernier	**Bagat**	$ 5.00
Reading glasses for opposite verniers	**Bagbi**	8.00
Reading glasses for limb verniers	**Balif**	10.00
Double opposite verniers on adjustable guard for vertical circle	**Bacar**	10.00
Double opposite verniers with 3″ 30 sec. level on adjustable guard	**Bacam**	15.00
Adjustable vertical circle vernier	**Bacco**	5.00
Adjustable vertical circle vernier with tangent motion	**Bacox**	15.00
Reversible telescope axis	**Batis**	5.00
Reflectors for illuminating cross wires	**Basal**	4.00
Transit waterproof cover	**Basul**	1.00

EXTRAS AND ATTACHMENTS
(Continued)

Level waterproof cover	Begot	$ 1.00
Bottle of transit oil	Bason	.25
Leather cover for carrying case	Baski	10.00
Shoulder straps for leather case	Basel	2.00
Canvas cover for carrying case	Baton	4.00
Leather extension tripod cover	Batab	10.00
Canvas extension tripod cover	Batus	4.00

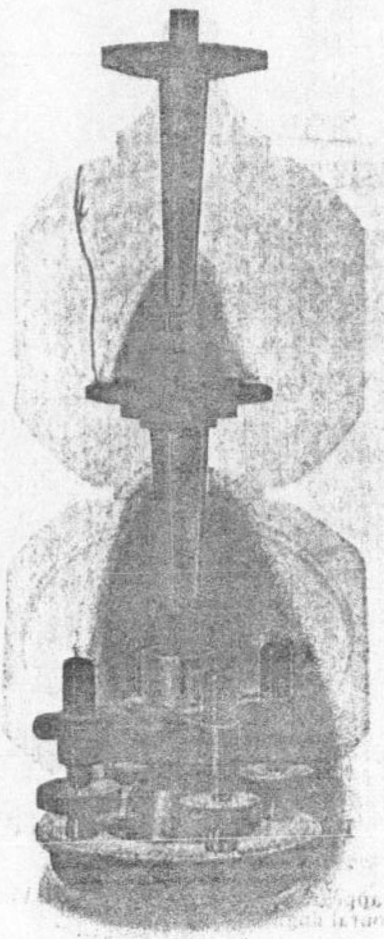
Tripods:—See weights under standard instruments.

Solid leg	Bayor	......
Split leg where solid leg is specified	Bayar	2.00
Extension where solid or split leg is specified	Bayen	6.00
Heavier extension tripod than listed with instrument	Bayte	......
Lighter extension tripod than listed with instrument	Bayum	......

AINSWORTH
TYPE BZ THEODOLITE

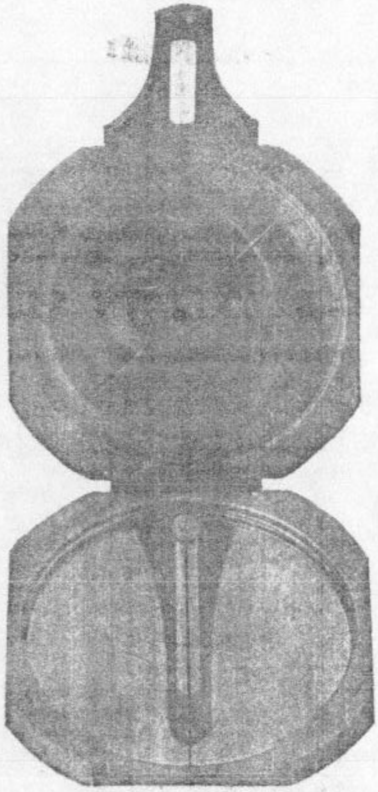
With Saegmuller type solar mounted high enough to clear a full vertical circle and which also serves as an auxiliary telescope.

THE CENTERS



of Ainsworth instruments are of liberal dimension and made of the hardest bronze and bell metal alloys with ample provision for refitting in case of accident.

THE BRUNTON



PAT. POCKET TRANSIT

Code word, **Brunt.**

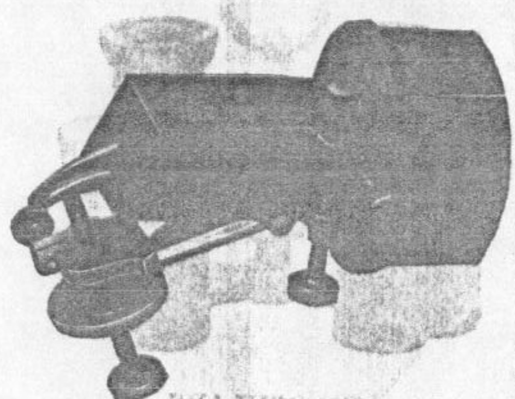
As it appears to the operator when taking courses or horizontal angles.

Price $25.00

OVER 5,500 IN USE

Fully described in bulletin B-O.

THE SHATTUCK DOUBLE REFLECTING



SOLAR ATTACHMENT.

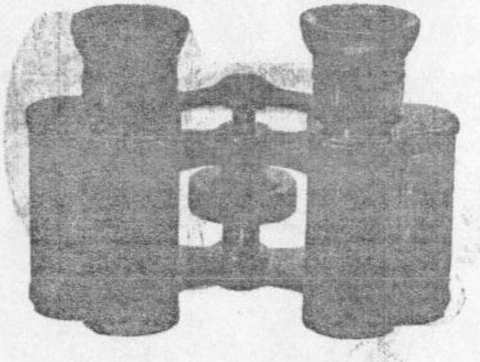
Code word, **Barba.**

This Solar is one of the most convenient, accurate and reliable Solar attachments made, overcoming by its optical construction the Polar axis adjustment so necessary for the accurate operation of all other Solar attachments.

Price, attached $30.00

See description under "Solar Attachments."

AINSWORTH PRECISION PRISM



BINOCULARS.

Power 8X.
Field at 1000 yards (meters), 90 yards (meters).
Weight 15 oz.—460 Grms.
Code word, **Bindo.**

Of the highest grade mechanically and optically. Made in 6, 8 and 10 power and furnished with black leather case with sling strap.

Price $35.00

Fully described in Bulletin H-O.

POCKET MILITARY AND SURVEYING ANEROIDS

Bulletin E-O.

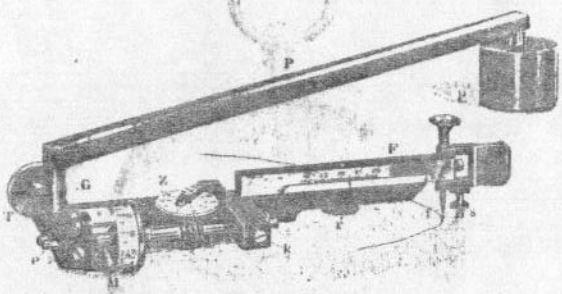
Shows the largest line of pocket military and surveying aneroids carried by anyone in America. Send for it,

We carry a complete line of

COMPASSES, CLINOMETERS, TAPES, BOOKS, RODS AND FIELD SUPPLIES,

And will be glad to receive your orders.

PRECISION



COMPENSATING PLANIMETERS TYPE A

Code Word, **Bogey.**

For the accurate measurement of irregular plane figures the planimeter offers a mechanical means of the highest precision and eliminates all complicated calculation.

It is simply necessary to trace the outline of the area to be measured when the reading of the dials indicates the inclosed area.

Made in two types. Type A, as above, in leatherette case.

Price $20.00

TELEGRAPH CODE

Cable Address, **"Ainsworth, Denver."** A B C (4th ed.) Western Union and Lieber's Codes Used.

Note:—In a cablegram any two of our code words may be combined to form a ten-letter word, which will be charged as one word only. **Aaronabate,** what is the price of, how soon can you ship. In telegrams, code words are limited to five letters.

What is the price of	**Aaron**
How soon can you ship	**Abate**
Can you ship immediately	**Abase**
What is the shipping weight	**Abrod**
Shall we ship immediately or hold for shipment with	**Acond**
We can ship immediately	**Acide**
Do not ship until you hear from us further	**Ackme**
Will ship as soon as possible	**Adore**
We have shipped	**Arial**
Telegraph cost of repairs upon receipt of instrument	**Arona**
Are awaiting your instructions	**Affab**
Repair immediately	**Afect**
Repair immediately and return by express	**Aflic**
Shipped as per your instructions	**Afray**
Telegraph reply to our letter of	**Afrit**
Send by mail	**Afrix**
Send by registered mail	**Agile**
Send by mail, special delivery	**Aimed**
Ship by——express	**Alarm**
Ship by——freight	**Alden**
Have you shipped	**Alert**
We can ship——days after receipt of order	**Alone**
We can positively ship inside of ——days and will ship sooner is possible	**Altar**
Trace shipment of——	**Altit**
Shipping instructions will follow by mail	**Amaze**
When can you ship our order of	**Abeam**
Awaiting receipt of enclosure from	**Algon**
Hold for shipment with	**Abord**
Prepare for shipment by express	**Alcat**
Prepare for shipment by freight	**Allty**
Prepare for export shipment	**Altig**
Duplicate last order	**Addam**

REPAIRING.

We have every facility for the repair and adjustment of engineering instruments and solicit your work.

INSTRUCTIONS.

When shipping instruments for repairs pack in a box about 4 inches larger each way than the carrying case, filling the space with excelsior, papers or waste to cushion the instrument. Mark box:

DELICATE INSTRUMENTS

HANDLE WITH CARE

THIS SIDE UP

For

WM. AINSWORTH & SONS

THE PRECISION FACTORY

DENVER, COLORADO

U. S. A.

and ship, charges prepaid, at the same time notifying us of shipment by mail.

Upon receipt of same, unless otherwise instructed, will send estimate covering cost of repairs and await your instructions before proceeding with the work.

1911

	S	M	T	W	T	F	S		S	M	T	W	T	F	S
January	1	2	3	4	5	6	7	July	...	...	...	...	...	...	1
	8	9	10	11	12	13	14		2	3	4	5	6	7	8
	15	16	17	18	19	20	21		9	10	11	12	13	14	15
	22	23	24	25	26	27	28		16	17	18	19	20	21	22
	29	30	31	...	...	...	...		23	24	25	26	27	28	29
	...	...	...	...	...	...	...		30	31	...	...	...	...	...
February	...	...	...	1	2	3	4	August	...	...	1	2	3	4	5
	5	6	7	8	9	10	11		6	7	8	9	10	11	12
	12	13	14	15	16	17	18		13	14	15	16	17	18	19
	19	20	21	22	23	24	25		20	21	22	23	24	25	26
	26	27	28	...	...	...	...		27	28	29	30	31	...	...
	...	...	...	...	...	...	...		...	...	...	...	...	...	...
March	...	...	...	1	2	3	4	September	...	...	...	...	...	1	2
	5	6	7	8	9	10	11		3	4	5	6	7	8	9
	12	13	14	15	16	17	18		10	11	12	13	14	15	16
	19	20	21	22	23	24	25		17	18	19	20	21	22	23
	26	27	28	29	30	31	...		24	25	26	27	28	29	30
	...	...	...	...	...	...	...		...	...	...	...	...	...	...
April	...	...	...	...	...	...	1	October	1	2	3	4	5	6	7
	2	3	4	5	6	7	8		8	9	10	11	12	13	14
	9	10	11	12	13	14	15		15	16	17	18	19	20	21
	16	17	18	19	20	21	22		22	23	24	25	26	27	28
	23	24	25	26	27	28	29		29	30	31	...	...	...	...
	30	...	...	...	...	...	...		...	...	...	...	...	...	...
May	...	1	2	3	4	5	6	November	...	...	...	1	2	3	4
	7	8	9	10	11	12	13		5	6	7	8	9	10	11
	14	15	16	17	18	19	20		12	13	14	15	16	17	18
	21	22	23	24	25	26	27		19	20	21	22	23	24	25
	28	29	30	31	...	...	...		26	27	28	29	30	...	...
	...	...	...	...	...	...	...		...	...	...	...	...	...	...
June	...	...	...	...	1	2	3	December	...	...	...	...	...	1	2
	4	5	6	7	8	9	10		3	4	5	6	7	8	9
	11	12	13	14	15	16	17		10	11	12	13	14	15	16
	18	19	20	21	22	23	24		17	18	19	20	21	22	23
	25	26	27	28	29	30	...		24	25	26	27	28	29	30
	...	...	...	...	...	...	...		31	...	...	...	...	...	...

WM. AINSWORTH & SONS | THE PRECISION FACTORY | DENVER, COLO. U. S. A.

1912

January

S	M	T	W	T	F	S
...	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	...	...	...
...	...	...	...	...	...	...

February

S	M	T	W	T	F	S
...	...	...	...	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	...	...
...	...	...	...	...	...	...

March

S	M	T	W	T	F	S
...	...	...	...	...	1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31	...	...	...	...	...	...

April

S	M	T	W	T	F	S
...	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	...	...	...	...
...	...	...	...	...	...	...

May

S	M	T	W	T	F	S
...	...	...	1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	...
...	...	...	...	...	...	...

June

S	M	T	W	T	F	S
...	...	...	...	...	...	1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	...	...	...	...	...	...

July

S	M	T	W	T	F	S
...	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	...	...	...
...	...	...	...	...	...	...

August

S	M	T	W	T	F	S
...	...	...	...	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31
...	...	...	...	...	...	...

September

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	...	...	...	...	...
...	...	...	...	...	...	...

October

S	M	T	W	T	F	S
...	...	1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31	...	...
...	...	...	...	...	...	...

November

S	M	T	W	T	F	S
...	...	...	...	...	1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
...	...	...	...	...	...	...

December

S	M	T	W	T	F	S
1	[illegible]	3	4	5	6	7
8	[illegible]	10	11	12	13	14
15	[illegible]	17	18	19	20	21
22	[illegible]	24	25	26	27	28
29	[illegible]	31	...	...	...	...
...	[illegible]	...	...	...	...	...