GURLEY MANUAL

AMERICAN
ENGINEERS AND SURVEYORS
INSTRUMENTS

FORTY-EIGHTH EDITION

A MANUAL
OF THE PRINCIPAL
INSTRUMENTS
USED IN
AMERICAN ENGINEERING AND SURVEYING

MANUFACTURED BY

W. & L. E. GURLEY

TROY, N. Y., U. S. A.

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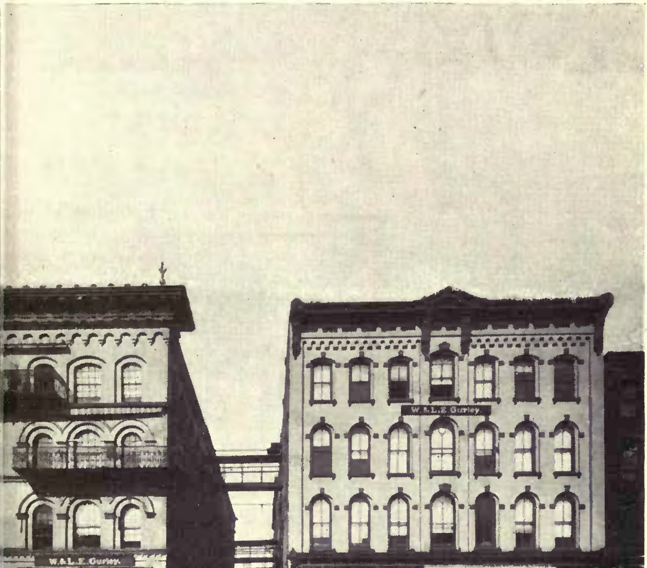

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GURLEY'S MANUAL is primarily a book of instructions in the adjustment and use of field instruments.

Simplicity of expression is sought and no attempt is made at treatises which are more properly to be found in technical publications.

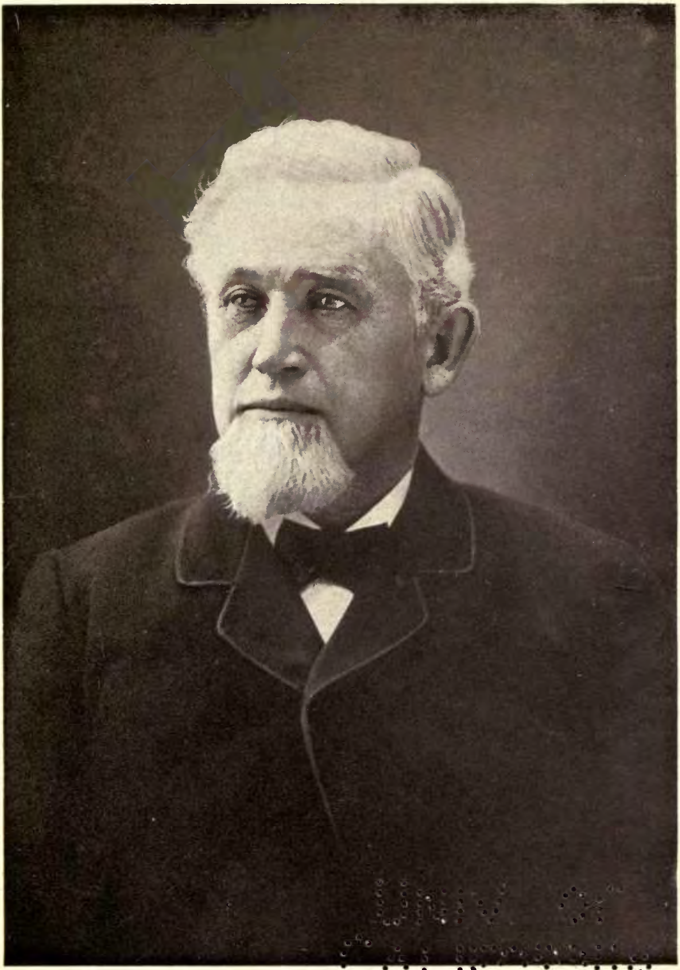
PREFACE

IN presenting this edition of our Manual we offer the engineering profession many new field instruments, new features and refinements, resulting from continuous effort and study for a period of seventy-five years. The House of W. & L. E. Gurley is the largest as well as the oldest American manufacturer of engineering instruments and our line is the most desirable and also the most complete of its kind in the world.

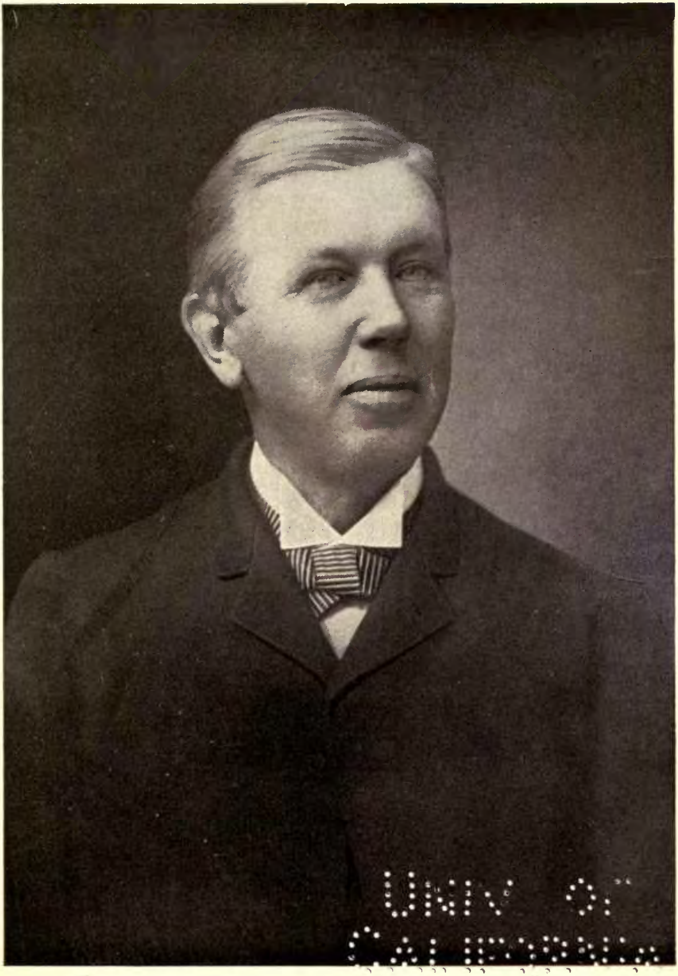
The merit of any article is fully determined by its ability to stand the test of time, and the service given by Gurley Instruments for three-quarters of a century proves that they possess those characteristics which qualify them for the most exacting demands of modern engineering practice.

In our zeal for offering only the best we have looked beyond the vision of commercialism and our entire organization takes great pride in our finished products as they leave our hands to fulfill their mission of locating, developing and conserving the resources of nature and the upbuilding of those projects which tend to the welfare and comfort of mankind.

W. & L. E. Gurley.



William Gurley



Lewis E. Gurley

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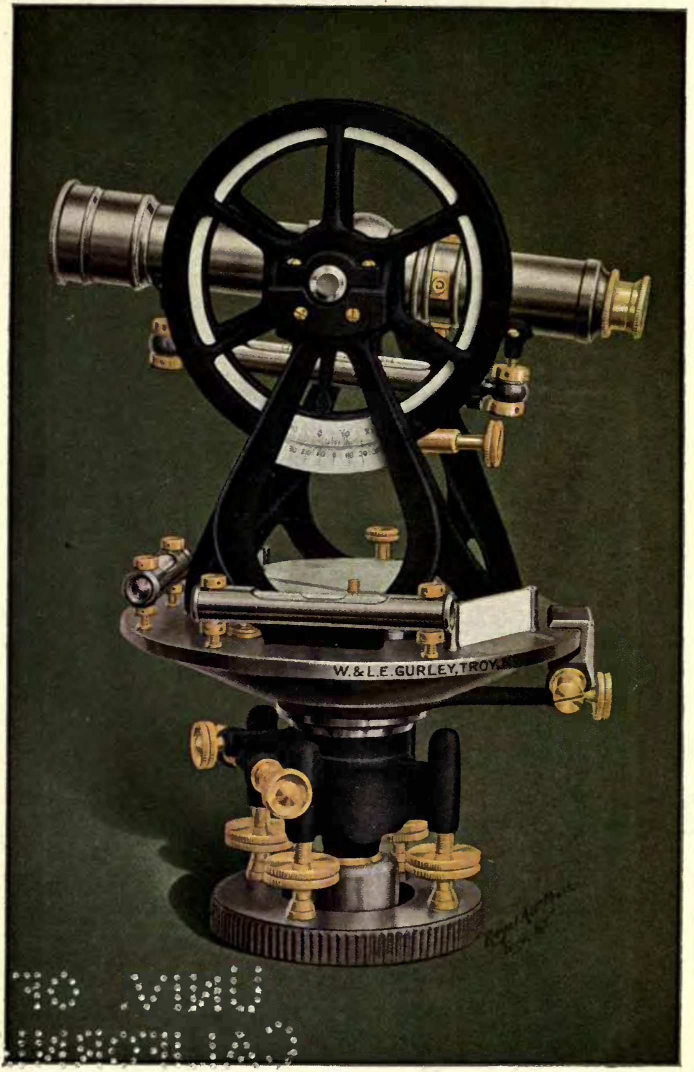

Gurley Precise Mountain Transit

TRANSITS

CONSTRUCTION OF TRANSITS

THE TRANSIT is by far the most important and indispensable instrument of an engineers' outfit. With it the engineer can read and lay off both horizontal and vertical angles, determine a level line or the difference in elevation between two points, read distances by means of the stadia, measure grades and distances with the gradienter and determine the meridian by the compass, by direct observation, or by the solar attachment.

The distinguishing features of Gurley Transits as developed after many years of study and experience, are their simplicity of construction, ease of manipulation, and accuracy and permanence of adjustments, which are all made without undue strain on any part.

The essential parts, which may be seen in the illustrations, and in section in Figure 1, are the telescope with its axis, the standards, the circular plates with their attachments, the sockets upon which the plates revolve, the leveling head, and the tripod upon which the whole instrument stands.

TELESCOPE. The different parts of the telescope are shown in Fig. 1. An achromatic lens (H) at the enlarged end of a sliding cylinder mounted near each end, in bearings (I) of hard babbitt metal, is moved out or in to bring the focus of the rays of light from the object viewed to an inverted image in the plane of the cross wires (J) to be there magnified by an eyepiece (T-W), and restored to its natural position.

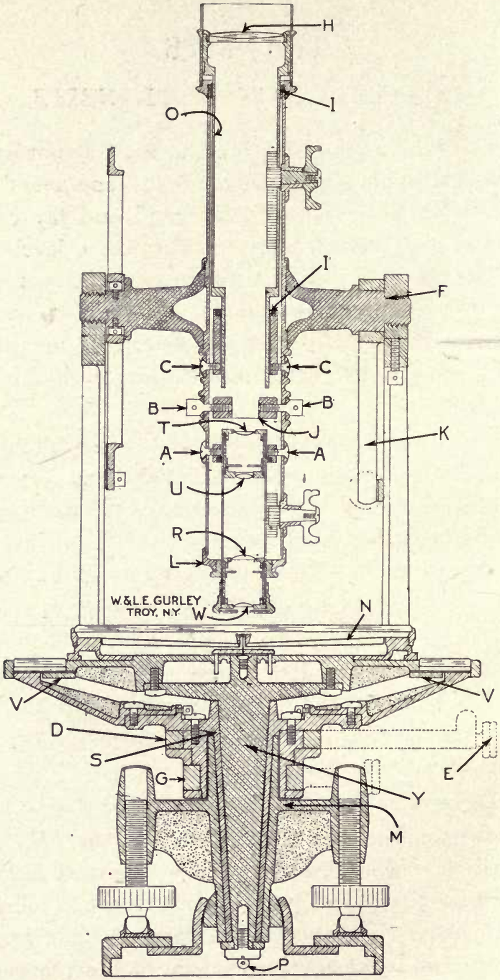

Fig. 1

Cross Section of Transit

The telescope is secured to an axis having multi-grooved bearings (F) fitted in the standards, allowing the telescope to transit at both ends.

The various sizes of telescopes, made to suit the instruments on which they are to be used, are of the best quality. They must be free from chromatic and spherical aberration and of as high a magnifying power as is consistent with good illumination and sharp definition, or resolving power.

The lenses, however good, must be so accurately mounted that the optical axes of all of them will be in one straight line. This imaginary line, called the line of collimation must be at right angles to the axis of revolution for all positions of the focusing slide.

OPTICAL AXIS. The intersection of the cross wires forms a point which, when adjusted, enables the observer to fix the telescope upon an object with precision. The process of bringing the intersection of the wires into the optical axis is called the adjustment of the line of collimation.

One of the babbitt bearings (I, Fig. 1) of the objective slide is supported in a ring and can be adjusted with the screws (C C).

The adjustment of the objective slide, which is described on pages 74 and 75, keeps the line of collimation in adjustment through the whole range of the slide without placing any strain on the slide or bearings. This adjustment, which is one of the distinctive features of Gurley telescopes, permits the alignment of both wires with equal accuracy, which is impossible without it. The slide adjustment is always made in the process of manufacture, and needs no attention from the engineer, unless the instrument is severely injured.

The slides are now made to focus at any distance from four and one-half feet to infinity.

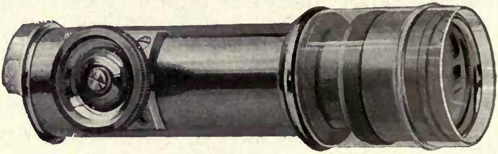

FIG. 2

NO. 154 SHOWING DUST GUARD FOR OBJECTIVE

DUST GUARD (No. 154) for the objective slide, is placed on all our Transit Telescopes. A velvet band effectually prevents any particle of dust or foreign substance from interfering with the perfect action of the slide. It also helps protect the objective slide from injury.

CENTER POINT. To facilitate the setting of the transit precisely under a given point, we make in the top of the ball of the telescope axis and directly over the center of the instrument, a small conical hole or center point.

EYEPIECE. Four lenses, (T, U, R, W,) form a compound microscope that focuses on the image at the cross wires and conveys the magnified image to the eye, in an erect or natural position. Sometimes an eyepiece of but two lenses is used. While this absorbs less light and therefore gives a more distinct image, it presents to the eye an inverted image of the object viewed. American engineers usually prefer the erect image.

The centering of the eyepiece is effected after the wires have been adjusted, by moving the ring and babbitt bearing with the screws, AA, shown on the outside of the tube, until the intersection of the wires is brought into the center of the field of view.

Magnifying Power. The apparent size of an object viewed through the telescope is as many times greater than the image which the naked eye sees, as the number which expresses its magnifying power. A telescope which magnifies twenty times, increases the visual angle in this same proportion, and therefore diminishes the apparent distance of the object to one-twentieth of the actual distance. In other words, it will show an object two hundred feet distant, the same size as if it were only ten feet from the naked eye.

It is often supposed that the greater the power of a telescope the better it is; but beyond a certain limit, this is not true. As only a given amount of light can enter the objective, the more the object is magnified the less clear and bright will it appear. A power of from sixteen to twenty-six diameters in the telescopes of transits gives the best results for regular use.

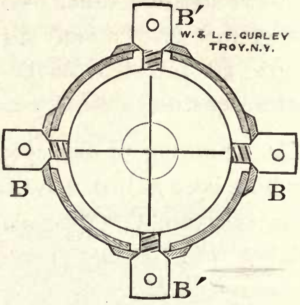

Fig. 3

Platinum Cross Wires. The cross wires in Gurley telescopes are filaments of platinum, mounted on the face of a heavy brass ring which will always retain its shape. They are placed at right angles with each other, so as to divide the field of view into quadrants, and are adjusted in the line of collimation by means of the four capstan head screws, BB and B′B′, Figure 3.

For special cases they can be mounted in many other forms.

The advantages of platinum over spider web have long been conceded. It is smooth, opaque and unaffected by moisture. The desirability of non-transparent wire is manifested when sighting against the sun or when observing a lamp as in mine work. We are successfully drawing wire to one fifty-thousandth of an inch in diameter. For transits we use wire one ten-thousandth of an inch in diameter, selected according to the degree it is to be magnified.

Unless otherwise specified we supply *fixed* stadia wires with most of our instruments as they are preferred by the majority of engineers because they cannot be thrown out of adjustment accidentally.

However, when requested, we will substitute adjustable stadia wires which are necessary if the user wishes to change his unit of measurement from feet to chains (1 : 100 -1 : 66). In all cases where the ratio is 1 : 100 the interval between the stadia wires need not be changed as the ratio 1:100 is good for one foot to one hundred feet, one meter to one hundred meters or one vara to one hundred varas.

DISAPPEARING STADIA WIRES. The Stadia Wires are usually arranged in the same focal plane with the cross wires so that they may be seen at the same time. When desired, however, they may be placed so that they are out of focus when the cross wires are visible; and conversely when the stadia wires are in focus, the cross wires are invisible. Some engineers like this method, but it has the disadvantage that changing the focus from stadia wires to cross wires or vice versa, necessitates a change of the objective focus. For this reason, the majority of engineers prefer the regular system; that is, with all the wires in one focal plane. This arrangement of the wires also enables them to observe, by means of the vertical cross wire, whether the rod is being held plumb.

BEAMAN STADIA ARC. The Beaman Stadia Arc, described on page 90, which is made exclusively by W. & L. E. Gurley, avoids the use of all stadia computations in inclined sights. It can be attached to any Gurley transit or telescopic alidade having a vertical limb four inches in diameter or larger.

The Standards. The axis on which the telescope revolves, or transits, is supported in a most substantial manner. The original design of the standards has been much improved by adopting an angular section and enlarging the bases so that two strong screws in each base may firmly secure them to the ribbed plate. Such standards are supplied with our Light Mountain and Reconnoissance Transits.

Fig. 4
One Piece Truss Standard
Patented July 25, 1916

A new design (patented), as here shown, was recently introduced by us and represents the greatest advance in instrument construction. It is stronger and more rigid than any other form of standard. Cast of the toughest bronze, in one piece, and with angle cross section, it provides the greatest rigidity with the least possible weight. The principle of diagonal cross bracing is used here and the supporting members are carried as far up on the legs as is possible without interfering with the use of the instrument. The base is wide, and its attachment to the top plate by eight large screws allows the development of the full strength of the deeply ribbed plate for support and reinforcement, making the whole structure mechanically one piece for withstanding stress. The finish of the standard is a beautiful and very durable morocco, applied directly to the surface of the casting, which thus retains its skin intact. The internal stresses of the metal are relieved by a process of artificial aging in which the metal assumes its permanent set without any loss of its tenacity or rigidity. The bearings for the axis are of perfect circles in cross-section, but instead of being plain cylinders, they have V threads of zero lead. They are always ground into place to insure a perfect fit. This form of ground multi-shoulders, as illustrated at F, Fig. 1, adds rigidity to the standards and automatically prevents any looseness or lateral motion, regardless of any possible wear through long use.

On the right hand bearing of the standard there is an adjustable block whereby the axis may be made truly horizontal or at right angles to the vertical spindle.

THE AXIS CLAMP AND TANGENT, which is regularly supplied on all transits, consists of an arm, K, Fig. 1, one end of which encircles the telescope axis, and can be clamped to it. The other end is held between the tangent screw on one side and the tangent slide and spring on the other. These are supported from the standards. When clamped the telescope may be tilted slowly by means of the tangent screw; when unclamped, it may be revolved freely in either direction.

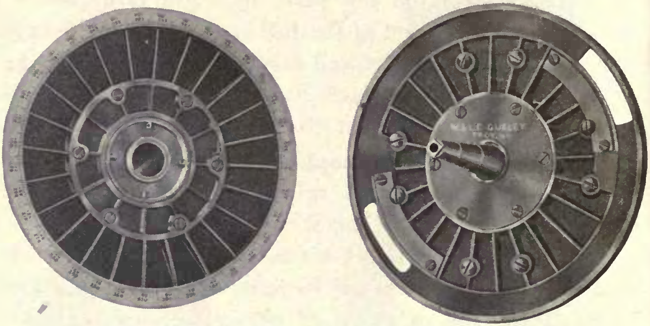

Fig. 5

Radially Ribbed and Dished Limb and Plate, and Tapered Centers

The Main Plate. By a system of deep ribbing, the top plate has been materially stiffened without adding to its weight, and the liability of warping with age has been reduced. It carries the standards supporting the telescope, the compass box with its movement for magnetic declination, the verniers for the horizontal limb, two levels at right angles to each other, and the support for the tangent screw for movement about the vertical axis. Note Fig. 10 that the longitudinal plate level is of extra length, providing a more precise check when measuring vertical angles than is possible with a short level.

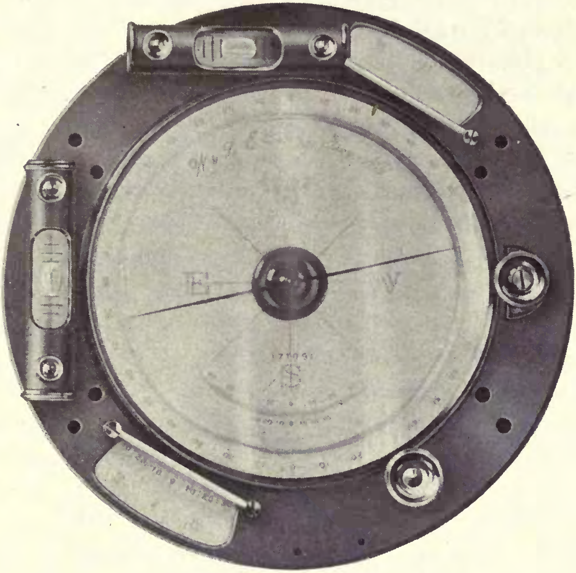

Fig. 6

Top Plate of the Light Mountain Transit, showing location of verniers, levels, variation arc pinion, and needle lifter screw

The Compass Circle is silvered, graduated and figured 0 to 90 each way. The graduations of this circle, on Transits Nos. 6-A to 18-A, are half degrees and the declination arc reads by vernier to one minute.

On Transits Nos. 25-A to 32-A the compass circle is graduated to whole degrees and the declination arc reads by vernier to five minutes. The declination arcs are movable by a pinion.

The Compass Box containing the needle is covered by a glass to exclude moisture and air. These covers on all Gurley transits are made of specially selected plate glass, beveled on the edge and set flush with the bezel ring, thus facilitating the removal of moisture from the top of the glass and affording an unobstructed observation of the compass face.

The Magnetic Needle, made of special magnet steel, has a cap in which is inserted a polished jewel center and this, resting upon the hardened and polished point of the center pin, allows the needle to play freely and settle in the magnetic meridian.

The needle has on its South end (North end for Southern hemisphere) a coil of wire, easily moved to adjust the balance of the needle against dipping. The needles are balanced as nearly as possible for the location to which they are to be shipped, so that only a slight adjustment should be necessary. A screw passing through the upper plate moves a concealed lever by which the needle button is raised against the setting, thus lifting the needle from the pin so as to check its vibration, or to hold it up against the glass when not in use, avoiding unnecessary wear of the jewel center and the pivot.

The test of the delicacy of a magnetic needle is the number of horizontal vibrations which it will make in a certain arc before coming to rest. Most surveyors desire also a quivering motion in the needle. This quality, which is manifested more in a horizontal than in a vertical needle, depends upon the close coincidence of the point of suspension with the center of gravity of the needle, and merely serves to show that the cap is unobstructed.

Plate Levels. The two plate levels, mounted on brass posts or studs, are at right angles to each other so as to level the plate in all directions. The position of the levels, near the edge of the plate, makes them accessible for adjustment and permits the use of longer and consequently more accurate levels than if placed inside the compass box. These levels are held firmly in place by the capstan nuts above and below each end. They cannot possibly be jarred out of position. Their adjustment is made by turning the capstan head nuts at either end. The glass vials used in the levels of all Gurley transits are ground on their inner surface to give the bubble an even motion and the required degree of sensitiveness.

Horizontal Limb. All cast metal parts, but more particularly the casting of the limbs, should be thoroughly aged. A fresh casting will shrink and warp like a piece of wood, but, of course, to a lesser degree.

We machine the limbs, apply the sterling silver, and then completely season them before putting them through the final operations of finishing and graduating. To secure the utmost accuracy and to avoid any possibility of molecular changes, the limbs are finished and the figures engraved before the graduating is done, which is the last process before they are placed in their respective instruments.

The form of the limb has been considerably changed by a greater dishing, which adds to the rigidity and allows deeper ribbing.

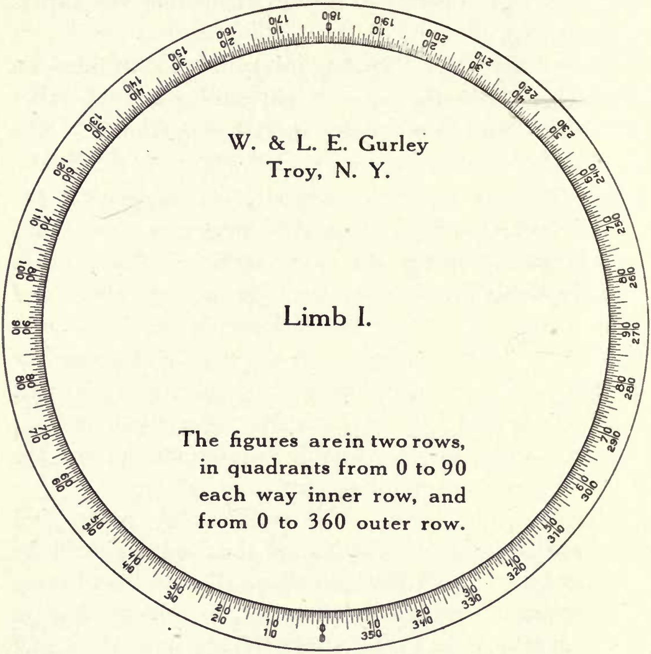

FIG. 7

The graduations, cut on sterling silver, are usually to half degrees, reading by vernier to one minute. If desired, they may be cut to thirds, quarters or sixths of a degree, with verniers reading to thirty, twenty, fifteen or ten seconds, but at an additional cost. This is known as the sexagesimal system.

If desired, one or both verniers may be graduated to read to one-hundredth or one-fiftieth of a degree.

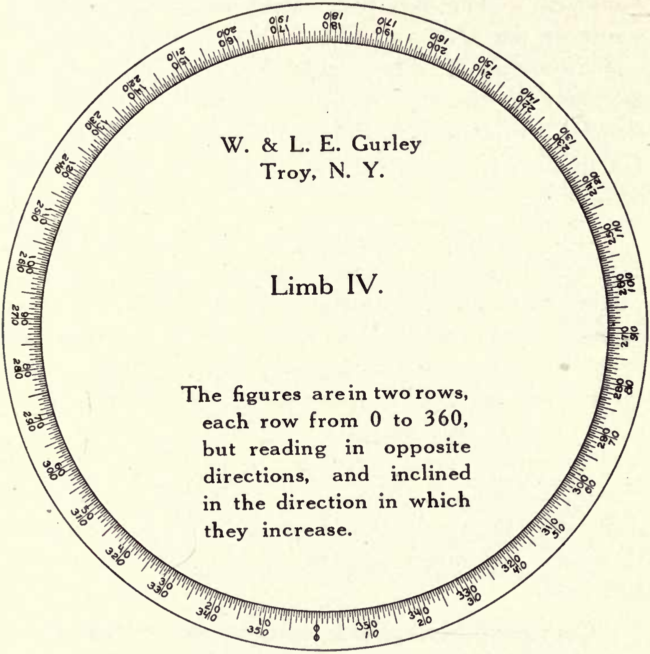

Fig. 8

Another form is to graduate the limb to one hundred grads to the quadrant, the vernier reading to one one-hundredth of a grad. This is called the centesimal system.

In artillery practice, the mil is used because of its convenience in the rapid calculation of small angles in fire control. For this purpose the mil is taken to be 1/6400 of a circumference.

LIMB FIGURING. Various methods of figuring are employed. The two forms most commonly used are shown on pages 36 and 37. Limb I has two rows, the inner row figured in quadrants as a compass circle and the outer row from 0 continuous to 360°, reading clockwise. Limb IV has two rows of figures, each 0 to 360, but in opposite directions and inclined in the direction of increase.

THE VERNIERS. As shown at V in the sectional cut, Fig. 1, the horizontal verniers are attached to the main plates and revolve within the horizontal limb, with their surfaces flush and so close that there is no apparent parallax. They are placed thirty degrees to the left of the line of sight and can be easily read without change of position by the observer. They are covered with selected plate glass carefully cemented to exclude moisture and dust. The upper surface of the glass is flush with the plate, thus they are easy to clean and there are no frames or rims to cast shadows or collect dust.

The use of two opposite verniers give the means of cross checking the graduations and the perfection with which they are centered. Thus the accuracy of the angle readings is indicated.

ONE GRADUATION IS ADDED to each end of the vernier to enable the last numbered division to be more easily read but this has only the practical use indicated and is not considered in calculating the smallest reading of the vernier. With the exception of the extra graduation mentioned above, the number of spaces on the vernier at one side of the zero graduation is equal to the number of parts into which the smallest division on the limb is to be divided.

TO FIND THE SMALLEST READING OF THE VERNIER, divide the value of the smallest space on the limb by the number of parts into which this space is to be divided, the resulting quotient is the smallest reading of the vernier. Thus in Fig. 9 we have a vertical limb graduated into half degrees or thirty minute spaces, the vernier is shown between the standard legs and is divided into thirty parts either side of the zero; the vernier therefore reads to one thirtieth of a graduation or a single minute.

TO READ THE TRANSIT VERNIER. Note the position of the zero on the limb and read to the nearest whole space the position of the zero of the vernier with respect to it. Reading in the direction of increasing limb figures, count the graduations on the vernier from zero to the one which coincides with a graduation on the limb. The sum of these two readings will be the reading required.

Divisions should be counted in the direction of increasing limb figures.

For example, in Fig. 9, the vernier zero reads between 5° and $5\frac{1}{2}^\circ$. Counting the vernier divisions to the left, it is seen that the 16th line coincides with a line of the arc. The correct reading is therefore $5^\circ\ 16'$.

Had the vernier zero read between $5\frac{1}{2}^\circ$ and 6°, the vernier reading would have been added to $5\frac{1}{2}^\circ$ and the result would have been $5^\circ\ 46'$.

REFLECTORS. Reflectors of white opaque celluloid, or of glass if preferred, are placed back of the horizontal verniers to reflect a white light and to eliminate glare.

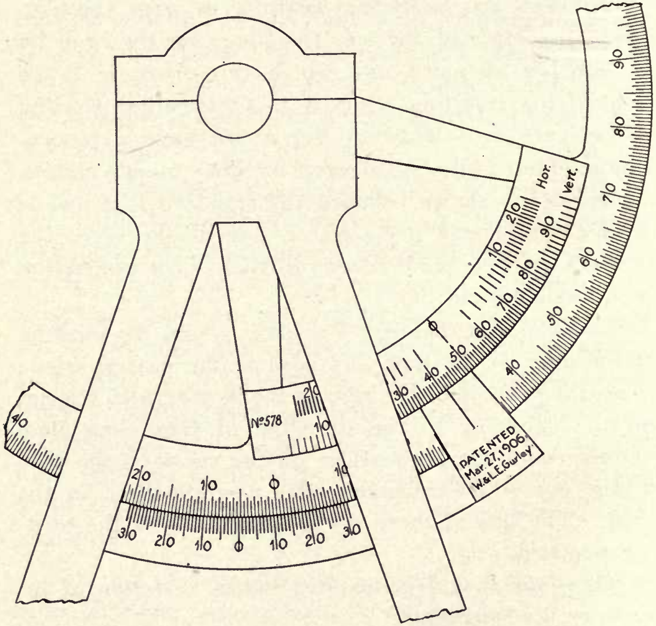

FIG. 9

NO. 149 BEAMAN STADIA ARC,

ATTACHED TO THE VERTICAL ARC OF A TRANSIT

THE LIMB CLAMP AND TANGENT. The tangent hanger, fastened to the edge of the main plate, carries the tangent screw and nut on one side, and opposed to them the tangent spring, slide, and barrel. The spring is made large enough to give practically the same force throughout the length of its travel.

The limb clamp, D, Fig, 1, is a heavy ring and arm which is fitted on the socket so as to turn freely. The clamp screw, E, pushing against a plunger, operates to clamp the ring firmly around the socket without tending to turn it. The arm of the clamp is held between the tangent screw and spring.

When the clamp screw, E, is loosened, the plate may be freely turned to any desired position for setting the verniers or sighting the telescope. When the clamp screw is turned lightly against the plunger, the plate is held firmly in position with reference to the limb; and it may be given a very slow motion by turning the tangent screw.

Because of the special form of Gurley clamps, only a very light pressure of the clamp screw is necessary to make them hold. The heads of the clamp screws are therefore made small to prevent unnecessary force being applied to the screw and clamp.

THE SOCKETS. The sockets are compound. The interior spindle Y, Fig. 1, attached to the main plate — carrying it and its attachments — turns in the intermediate socket S to which the limb is attached. When clamped, this socket turns in the socket of the leveling head, governed by a second clamp and tangent movement with opposing spring.

The sockets or centers are constructed with the greatest care, are of carefully chosen composition and are made of different degrees of hardness to eliminate friction and wear. They are truly concentric, are of substantial diameter and length and are designed to provide maximum stability in the most vital parts of the instrument.

THE LEVELING HEAD. The outer socket has four ribbed arms that bear the nuts for the leveling screws. At its lower end there is a hemispherical nut fitting in a corresponding cup in the shifting center, which is the center of movement when leveling. The leveling screws are nicely fitted with long bearings in the nuts and are protected from dust by covers. The lower ends of the screws rest in cup bearings fitted with fiber bushings to eliminate friction. The cups avoid marring the plate when shifting the instrument from side to side on the tripod. To prevent cramping, the centers of the lower ends of the leveling screws are in line with the center of the hemispherical nut, even when the leveling head is tilted far to one side.

SHIFTING CENTER. The base plate is in two parts. The outer part is threaded to screw on the metal head of the tripod and the inner part encircles the hemispherical nut of the leveling head. When the leveling screws are loosened the whole instrument can be moved so that the plummet may be precisely suspended over a desired point. The action of the leveling screws on the base plate as the instrument is leveled serves as a clamp, thus preventing any inadvertant shift after it is once set.

THE TRIPOD. The tripod has a head of bronze with three strong tenons to receive the wooden legs, the upper ends of which are pressed firmly on each side of the tenon by a bolt and wing nut, which can be tightened by hand and thus kept firm. The lower end of each leg has a metal shoe with hardened point, securely fastened to the wood. There are four styles of legs — the solid round leg, the split leg, the extension leg and jointed extension leg.

For illustrations and descriptions see pages 238 to 242.

INVITATION TO VISIT OUR FACTORY

The extent of our business makes it impracticable for us to personally interview but a small number of our customers; therefore, we extend a cordial invitation to all of our friends to call on us whenever it is convenient to do so. It is our desire to become better acquainted and to more fully express our appreciation of the co-operation and good will which have so largely contributed to the success of our efforts.

DISTINCTIVE FEATURES OF GURLEY TRANSITS

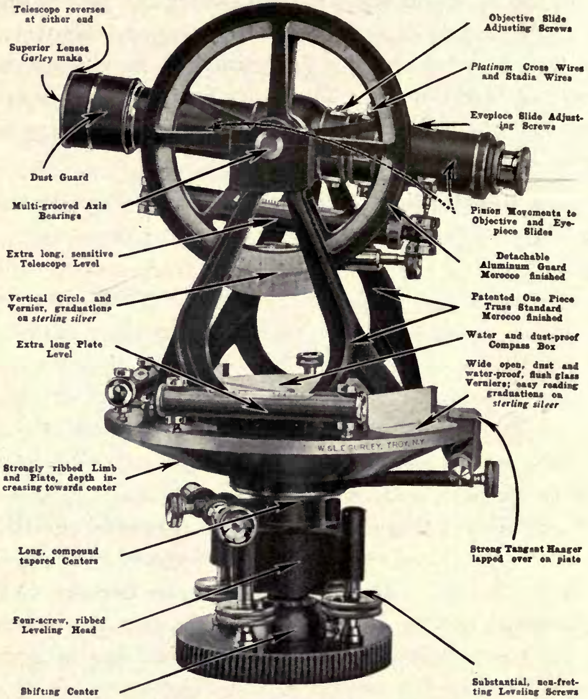

FIG. 10

NO. 27-A PRECISE TRANSIT

SELECTION OF TRANSITS

Variety of Models. As we make various models and sizes, it is possible to select an instrument which will suit every individual requirement. The difference in prices does not indicate a difference in quality, as we make only one grade. The price is based on the actual cost of manufacture and, in each instance, it is the lowest for which a high grade and fully warranted instrument can be made.

The Gurley Precise Transits with patented One Piece Truss Standard and other new features represent the last word in design and construction and, as their name implies, they are adapted for work which demands the highest degree of accuracy and refinement.

They are made in four sizes; the largest size is No. 18-A, Hell Gate Model; medium size, Nos. 6-A to 10-A and 10-A-3; the Light Mountain size, Nos. 25-A to 32-A; and the Explorers size, Nos. 20-A to 24-A.

HELL GATE BRIDGE ERECTION CONTROLLED BY A GURLEY PRECISE TRANSIT

THE BRIDGE OF THE NEW YORK CONNECTING RAILROAD over the East River at Hell Gate stands as one of the most notable achievements in bridge engineering in recent years. It is a steel arch of 970 feet span and carries four tracks.

The rapid tidal currents of the river and the necessity of maintaining a free passage for navigation during the construction made the use of false work impossible. The arch was built from the two abutments simultaneously and its successful completion demanded that the ends of the two halves should meet in mid-stream with extreme exactness. This necessitated instrument control of the very highest precision.

The engineers who had this work in charge selected a Gurley Precise Transit and staked their engineering reputation on this choice. Their confidence in the instrument was justified when the cantilever members met within one-quarter of an inch of their predetermined position.

Long base lines lateral to the structure were laid out on both shores. Concrete piers were built at the triangulation points, each pier having a permanent base for the Gurley Precise Transit which governed the work.

Vertical and horizontal angles to 10 seconds were taken to panel points as erection proceeded, the exact

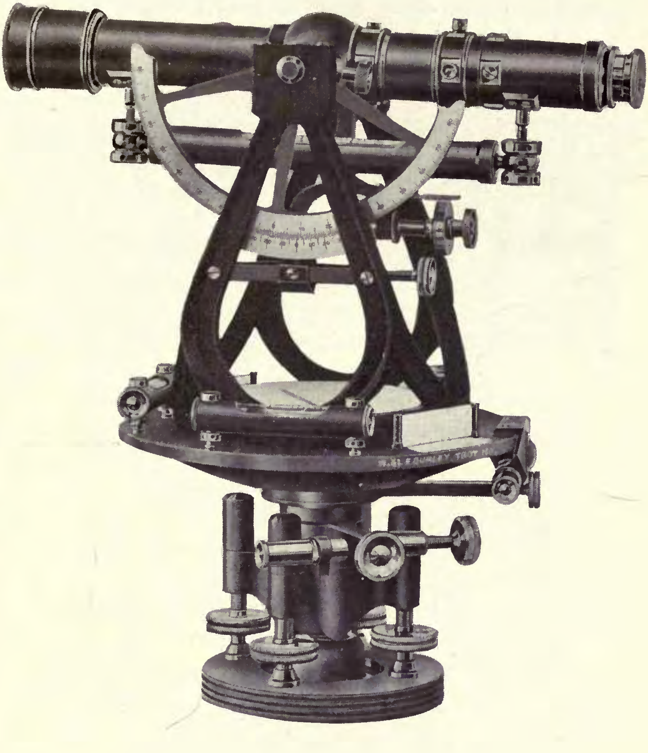

FIG. 11

No. 10-A PRECISE TRANSIT

position of each point being accurately determined and checked by observations from several stations.

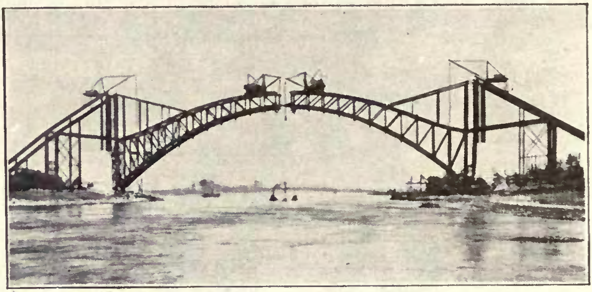

FIG. 12

VIEW OF HELL GATE BRIDGE DURING CONSTRUCTION

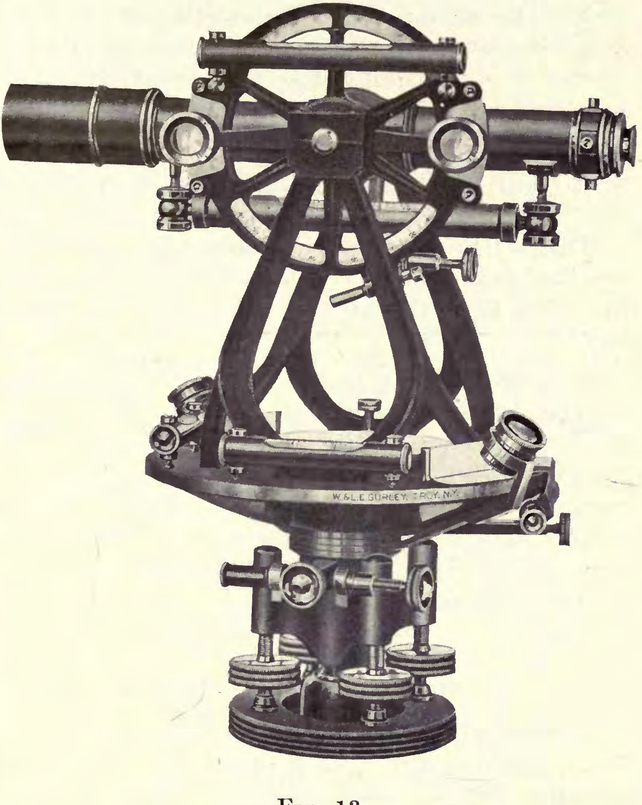

Fig. 13

No. 18-A Precise Transit, Hell Gate Model

Precise Transit, Hell Gate Model

This transit is of the Gurley One Piece Truss Standard construction and represents our supreme efforts. It is the result of seventy-five years experience in designing and building engineering instruments. It embodies all of the desirable qualities of our regular model Precise Transits and has the added advantages of the special features as shown in Fig. 13.

Thus it is adapted for triangulation, bridge building, municipal engineering, etc., and for all classes of work demanding the highest degree of accuracy and refinement.

Both the horizontal and the vertical limbs are graduated to 10 minutes and each reads by two opposite double verniers to 10 seconds. A rigid frame or guard protects the vertical circle and supports a long sensitive level which controls the zeros of the double opposite verniers, also supported by the frame. Microscopes suspended over each vernier facilitates the reading of the fine graduations. The telescope has an inverting eyepiece.

Medium Size Precise Transits

Transits with a 6.25″ horizontal limb are listed as Nos. 6-A, 7-A, 8-A, 9-A, 10-A and 10-A-3, the numbers indicating different combinations of attachments, such as level on telescope, vertical circle or arc, and gradienter. The limb is graduated on sterling silver and reads by two opposite double verniers to single minutes. Finer graduations can be supplied at additional cost.

The telescope is eleven inches long, erecting, and has a power of 26 diameters. The compass needle is $3\frac{1}{2}$ inches long and has an arc for setting off the magnetic declination. The instruments, without tripod, weigh from 15.5 to 16.5 pounds.

Numbers 25-A, 26-A, 27-A, 28-A, 29-A, 30-A and 32-A apply to transits having a 5.65″ horizontal limb. The telescopes have erecting eyepieces, a power of 20 diameters and are supported by our new One Piece Truss Standard. They are equipped with a three inch needle and weigh but eleven to thirteen pounds.

Transits Nos. 25, 26, 27, 28, 29 and 30 also have a 5.65″ horizontal limb. They are like Nos. 25-A to 32-A except that the telescope is supported by two separate standards and the compass needle is four inches long.

Detailed specifications of all transits are given in a bulletin in the back of this Manual.

The Gurley Three Screw Leveling Head, as shown in Fig. 14, is of a design which gives the utmost rigidity without being cumbersome and provides a shifting center of liberal movement.

Spiral springs are not used in the construction of this head which can be immovably clamped before angle reading is started. Our instrument need not be detached from the tripod when being carried between stations.

The three screw leveling head is *made only to order.* It can be furnished with any new Gurley Transit, if desired, at an extra cost.

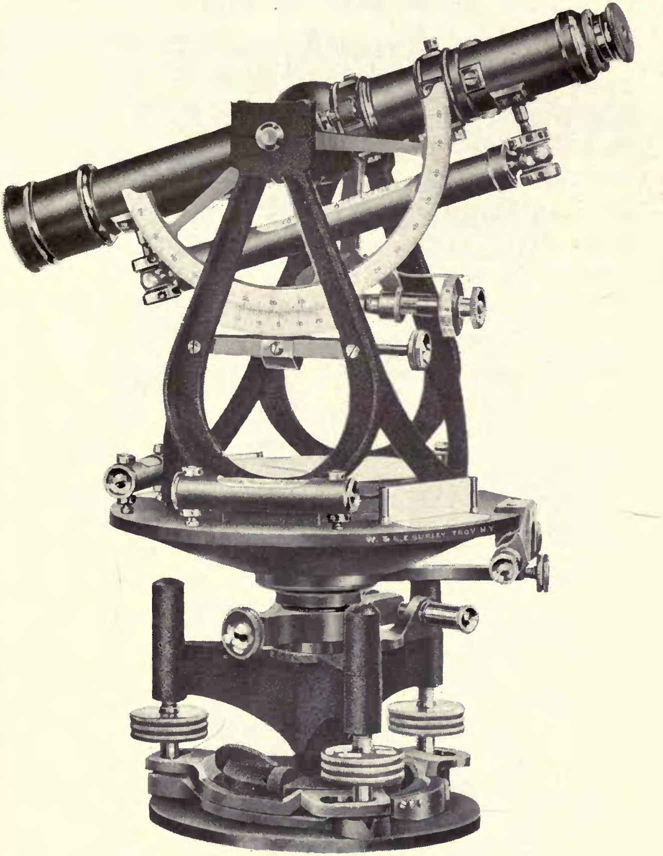

FIG. 14

No. 10-A-3 PRECISE TRANSIT

WITH THREE-SCREW LEVELING HEAD

Light Mountain Transits

The Gurley Light Mountain Transit. Its high grade construction and light weight have made this the most popular Gurley Transit, and in fact it is the ideal transit for all-around work. Although especially adapted for Mine and Mountain Surveys, it is used for Municipal, Highway and Railway Engineering as well as for Bridge and General Construction, Solar Observations and Forest Surveys. It is *the best known transit in America* and we stake our reputation on the results obtained from its use. It can be improved only by substituting in place of the two separate standards, our patented One Piece Truss Standard.

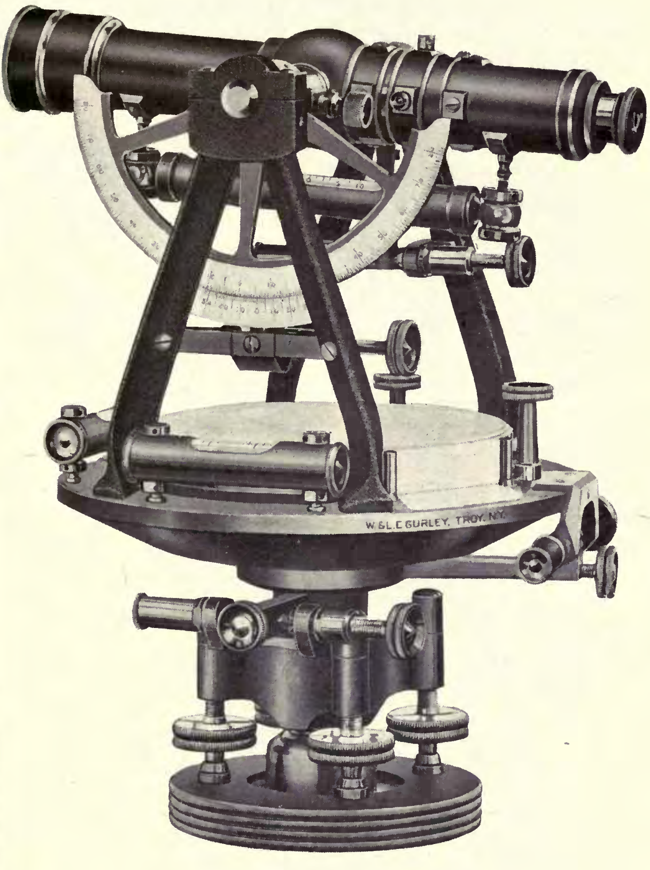

FIG. 15

NO. 28 LIGHT MOUNTAIN TRANSIT

The Best Known Transit in America

The Gurley Explorers Precise Transit. This is the smallest and lightest Gurley transit but it is equal in quality and similar in construction to our Precise Light Mountain Transit and therefore can be used for work of a high degree of accuracy.

As its name implies, it is designed for engineers working in a new or undeveloped country and also for those whose work is scattered and who are obliged to travel constantly. It is also used with great success by Mining Engineers who prefer or require a smaller and lighter instrument than the Light Mountain pattern. When placed in its leather-covered case it can be packed in a twenty-four inch dress suit case, together with its special jointed extension tripod. An Explorers Level, described on page 196, and an Explorers Alidade, described on page 249, can be included, in the suitcase, if desired.

Explorers Precise Transit

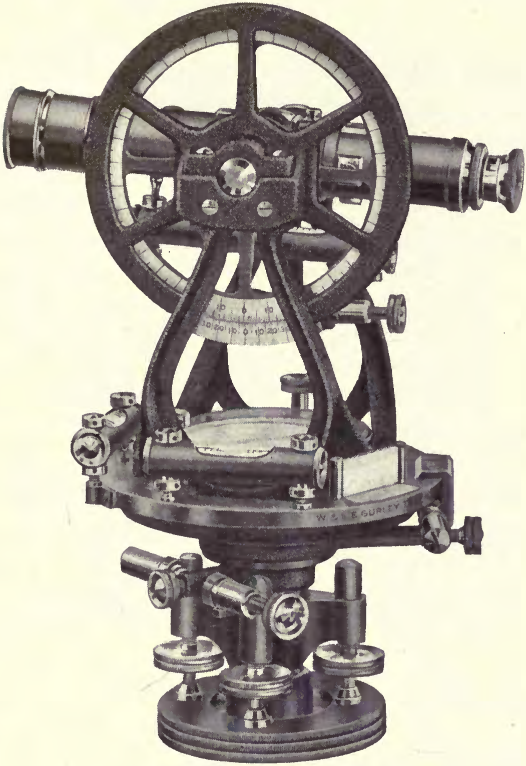

Fig. 16

No. 20-A Explorers Precise Transit

The smallest and lightest Gurley Transit

Fig. 17

Explorers Transit with its special jointed extension tripod, canvas carrying case, and leather covered wooden box

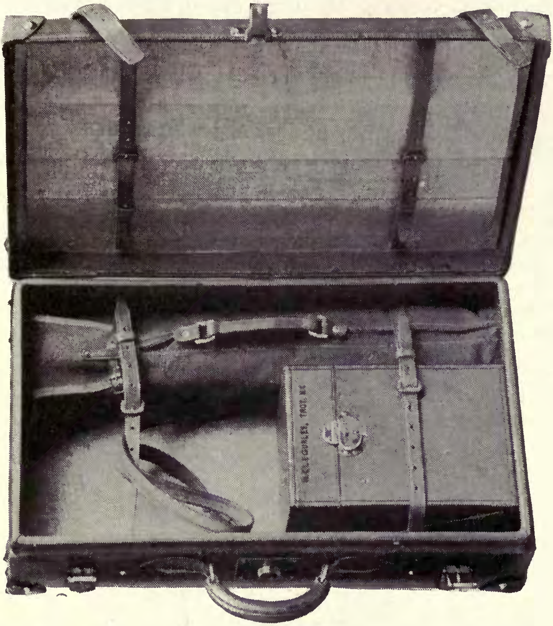

Fig. 18

Explorers Transit, with its special tripod, packed in a dress suit case 24 inches long

RECONNOISSANCE TRANSIT

The Gurley Reconnoissance Transit meets the demand for a very light instrument for rapid work. Constructed like our Mountain Transits, with long centers and with ribbed leveling head, limb and main plate, and made with the same care as our larger and more expensive patterns, it is recommended as reliable for a great variety of work.

Its accuracy, its convenience in carrying, and its proved ability to stand up satisfactorily under severe use, have made this transit especially popular with Surveyors, Contractors, Road Engineers, Architects and Builders.

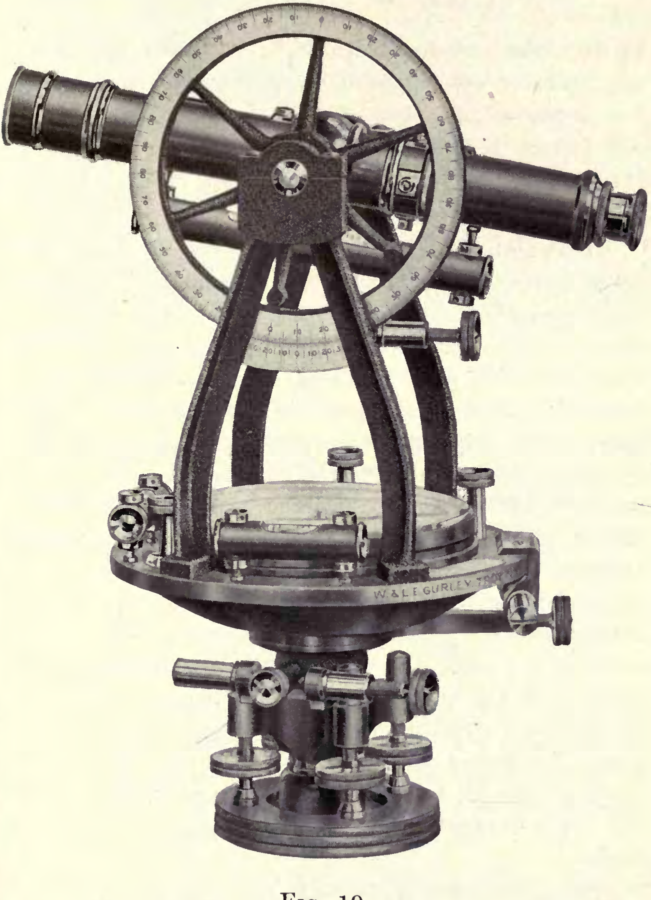

Fig. 19

No. 102 Reconnoissance Transit

CARE OF THE TRANSIT

TOO much emphasis cannot be laid upon the importance of care in handling and transporting instruments of precision. Every instrument as it leaves our factory is properly lubricated and adjusted ready for use. It will remain so for a long time, if treated as an instrument of precision.

Handling the instrument. Extreme care must be taken at all times to prevent the instrument from receiving shocks which may throw it out of adjustment. When shipped for any distance the instrument case should be enclosed in an outer packing box and carefully surrounded with some shock absorbing material. If anything dusty, as excelsior, is used, the case should first be wrapped in paper with the edges pasted to keep out the dirt. When not in use, the instrument should be placed in its case. When carrying the instrument mounted on the tripod, through brush, or through doors of a building or similar places, the tripod should be carried under the arm and not over the shoulder, thus avoiding the possibility of accidently striking the instrument. When setting up the instrument, the tripod should not be set too high, as it may be easily tipped over. Particular care should be given to this feature when setting the tripod on steps or on a hillside where one leg is generally shortened and placed at a high angle.

In handling the instrument, care should be taken to grip it at such points that no strain will be put on any of the adjustments. The Gurley method of packing transits prevents any lateral strain from being placed upon the spindle, sockets, or standards. To remove the transit from the box, first lift out the packing pieces from the ends of the telescope axis, grasp the tops of the standards with both hands, or the telescope axis with one hand, and lift the instrument out of the box. To place upon the tripod, unscrew the leveling head clamp, lift the instrument and with the fingers under the limb or body and the thumbs on the top plate, set upon the tripod. Retain the grasp with one hand and with the other, screw the bottom plate on the tripod head.

The transit may also be lifted from the box by turning the telescope to a vertical position, reaching down into the box and grasping it under the limb as described above. This method has the advantage that the transit may be placed directly upon the tripod without changing the hands. It should never be lifted by taking hold of the standards except as described above, nor should it be lifted or carried by means of the leveling head, leveling screws or bottom plate, when not on the tripod, without being steadied near the top.

Before attempting to turn the transit in either of the sockets, be sure that at least one of the clamp screws has been loosened. Turn the transit by means of the lower part of the standards, the plate or the tangent attachments, but not by the telescope.

In tightening clamp screws it is necessary only to screw them home lightly, as the design of Gurley clamps makes them grip very firmly. If too much force is applied to the clamp screw, the thread will be strained and worn unnecessarily.

All bearing surfaces are made as nearly frictionless as possible and therefore need very little lubrication. If it does become necessary to lubricate a thread or bearing, only the best grade of watch oil should be used and only a very small amount of that. A thin film of light oil is all that most of the fitted surfaces will admit. Oil should be carefully wiped from exposed parts, as it will cause dust to adhere.

CLEANING THE INSTRUMENT. So far as possible, all outside cleaning or dusting of instruments should be done with a soft camel hair brush. Care should be taken not to rub the lacquer from the finished surfaces, as the exposed metal will readily tarnish. Alcohol, or similar solvents should never be used on the instruments.

In cleaning the lenses, first remove the dust with a soft brush and then wipe lightly with a soft, dry cloth, free from lint. Rubbing the lenses dry sometimes causes small particles to stick to them, and, in this case, blowing the breath on the glass will furnish sufficient moisture so that they may be rubbed off easily. If any liquid is brought into contact with the lenses, it is liable to penetrate the mounting and give bad results.

Do not rub the silver upon which the graduations are cut, as this will make bright spots, which cause difficult reading.

Particular care must be taken to prevent anything from coming into contact with the graduated edge, not even rubbing this with a soft cloth. As this is solid silver, it is soft and easily damaged. If necessary to clean the limb, dampen a soft cloth, dip it in powdered charcoal, and rub lightly over the silver, being careful not to rub over the graduated edge.

DISMOUNTING THE INSTRUMENT. In case of damage to the instrument, it should, if possible, be returned to the maker for repairs. If absolutely necessary, however, to take the instrument apart, it should be done in some place which is free from dust; never out in the open where dirt may be blown into the working parts as they are being assembled.

REMOVING THE OBJECTIVE LENS. Unscrew the dust guard on the end of the main tube and then unscrew the small ring in the end of the slide head. This brings with it the complete lens in its setting. The objective consists of two lenses held together by two metal rings. The former are marked on the edge with a cross so that they may be put back together in the same relative position. It is always necessary to check all adjustments of the telescope after the objective lens has been loosened or removed.

REMOVING THE EYE PIECE. If there is an eye piece pinion, first take out the two screws holding it to the telescope and pull the pinion straight out from the tube. Take out the eye piece centering screws, A A, Fig. I, unscrew the eye end ring, L, and withdraw the eye piece from the tube. The eye piece lenses may be separately cleaned, and, *if put back as found,* no adjustments will have been destroyed.

Cross Wire Diaphragm. If necessary to replace a cross wire in the field, the eye piece must first be removed, as described above. With the telescope in a horizontal position, first take out two side adjusting screws, B B, Fig. I, and by means of the remaining screws turn the diaphragm through an angle of 90°, so that the edge points toward the end of the telescope. Place a small stick or pencil in the screw hole in the side of the diaphragm, take out the remaining screws and pull out the diaphragm. If the diaphragm has adjustable stadia wires the stadia screws must first be loosened.

Compass Needle. The closed top over the compass may be removed by unscrewing the bezel ring from right to left. When replacing the needle on its center, it should be lowered very gently into position to prevent damage to the finely polished point.

The Objective Slide. Take out the four screws from the pinion strap, pull the pinion straight out from the tube, and the slide may be withdrawn from the telescope.

Level Vials. Take the levels from the plate, or the telescope, and remove the ends. These screw on for the larger sizes, but simply push in the vial tube, for the smaller sizes. Soak the plaster of paris with water, scrape or cut it out, and push out the old vial. If the new vial fits loosely, it should be fixed in place with slips of paper before being plastered. Take care that the crowning side of the vial, which is graduated, is placed uppermost and see that the sealed tip will not be touched when the end of the case is replaced. If plaster of paris is not available, beeswax or some other heavy wax may be used temporarily to hold the vial, but, as this softens on a warm day, it should replaced by plaster of paris at the first opportunity. The sealed tip should be left uncovered.

TO SEPARATE THE PLATES. Unscrew the tangent barrel, taking care that the tangent slide and spring do not drop out. Take the small screws from the tangent hanger and remove the latter from the plate.

If the lower plate or limb is to be removed, the lower tangent barrel with slide and spring should be removed from the leveling head tangent.

Remove the cap (if there is one) from the bottom of the spindle, take out the large screw and washer, and the plate may then be removed from the sockets.

The most extreme care must be used in replacing the sockets and spindles to see that not the slightest particle of lint or dust gets into the bearing. To lubricate these surfaces, rub a small amount of the very best watch oil on a clean cloth free from lint, and rub over the surfaces to be lubricated. A heavy oil will separate these bearings so far that proper adjustment cannot be maintained.

THE REPAIRS. Attention is again called to the fact that a damaged instrument should not be repaired in the field. If any parts have been injured the best way is to return the whole instrument to us for proper repairs. Such repairs can be made with less trouble and less cost if no attempt has been made to dismount the instrument in the field to determine the extent of the damage.

USE OF THE TRANSIT

THE instrument should be set up firmly, the tripod legs being pressed into the ground only so far as is necessary to give sufficient support. The legs should be spread apart far enough so that the transit cannot be easily knocked over. The height of the instrument should be adjusted for convenient sighting by the operator. The plate should then be carefully leveled, as described hereinafter under level adjustments. For precise work the final leveling of the plates should be made with the telescope level, placing it in turn over the two pairs of opposite leveling screws. In reversing the level, one half of the correction should be made with the axis tangent and the other half with the leveling screws, the same as in the adjustment for plate levels.

With the telescope pointed toward the sky, or out of focus, turn the eye piece pinion or the spiral until the cross wires appear distinct, then the objective should be focused until the object is seen, clear and well defined, and the wires appear to be fastened to its surface.

If the objective is properly focused so that the plane of the image coincides with the plane of the cross wires, the latter will not appear to move on the object when the eye is moved up and down in front of the eyepiece.

When the horizontal angles are to be measured the zeros of the verniers and limb should be in line with the upper motion. Clamped in this position, the telescope should be sighted on a distant point by means of the lower or leveling head motion. After this has been done and with the lower motion clamped, loosen the upper motion on limb clamp and the angles turned may be read directly from the verniers without making any subtractions.

When the compass is to be used, set the variation arc to the proper magnetic declination by means of the pinion on the plate. The value of magnetic variation for any given locality can be obtained from the publications of the U. S. Geological Survey, Washington, D. C.

If the needle does not hang level when at rest, remove it from the pivot and slide the small brass wire, which is on the South end (in the Northern hemisphere), in the proper direction to obtain a balance.

STADIA SURVEYING

The increasing popularity of the stadia for the determination of distances and differences in elevation is due to its widening field of application, together with a better appreciation of its reliability through a clearer understanding of the principles involved.

So much has been written regarding the theory of the stadia and so little as to its practice, that there is need of a condensed statement of the most approved procedure in stadia work.

The instrumental outfit embraces any mounted telescope fitted with stadia wires and a vertical arc or circle, and while any leveling rod may serve for occasional stadia work, a regular stadia rod of some approved type should be used for good work, and must be used for satisfactory results at distances exceeding 400 feet. In all cases, simplicity rather than multiplicity of subdivision is a prime requisite.

STADIA CONSTANT. The use of the stadia when measuring short distances with great accuracy, compels the use of the so called "Stadia Constant." The wires are generally adjusted to read one foot on the rod at a distance of one hundred feet from a point in front of the telescope objective equal to the focal length of the lens (f), Fig. 20. Since measurements are taken from the center of the instrument, it is therefore necessary to add to the stadia reading, the distance C, from the center of the axis to the shoulder of the objective setting when focused at the distance to be measured, plus the distance F, from the objective lens to the plane of the stadia wires, when the instrument is focused at a distant object (not less than 1000 feet) which gives the focal length of the lens. The sum of these two distances (F + C), is the Stadia Constant, which must be added to all stadia measurements regardless of the distance measured. This constant is carefully measured in the factory for each instrument, and its value is marked on a card placed in the instrument box.

For example, in our eleven inch telescope, such as are used with the larger transits, C equals about 5.6 inches and F, about 8.2 inches; and C + F is equal to about 1.15 feet. For the Mountain Transit telescopes, C equals 4 inches and F, 5.4 inches, and C + F equals about 0.783 foot.

The reason for the use of this constant will be seen by reference to Figure 20.

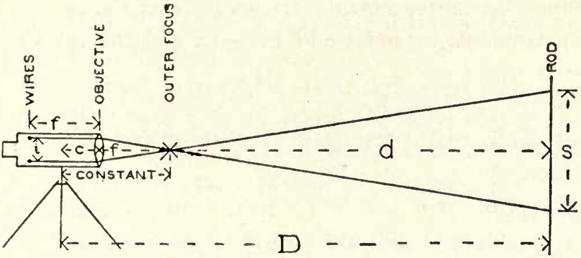

FIG. 20

With the telescope focused upon the rod:

Let i = interval between the stadia wires

c = distance from center of transit to objective lens

f = focal length of objective lens

s = reading on the rod, or space intercepted on rod by stadia wires

Outer focus = a point in front of the lens and F distance from it

d = distance from the outer focus to the rod

From the definition of focal length, those rays of light passing through the outer focus are refracted by the lens to parallel paths. Those which pass through this point and intercept the stadia wires are i distance apart at the lens.

Then from similar triangles

(1) $d/s = f/i$, or $d = f/i\ s$

since f/i is a constant for any given instrument, we may represent it by K

(2) and $d = Ks$

Since the measurements are made from the center of the instrument, we must add F + C, and the total distance is

$$D = Ks + (F + C)$$

(F + C) is called the Stadia Constant and K is made 100 feet.

Therefore, if f + c = 1.2 feet, a subsequent reading of 540 feet would indicate a distance of 541.2 feet from plumb line to rod.

The undue consideration of this very small f + c constant has too often caused the relative neglect of a far more important one, and we wish here to emphasize the latter.

It is either the necessity for extreme accuracy in adjusting the stadia wires to give the desired proportion of 1 to 100, or, in the case of measurements calling for greatest precision, the necessity for determining the stadia interval or factor, i. e., K.

$K = f/i = d/s = 100 \pm$

This factor should be a mean result of rod readings at steel-taped distances of say 400 and 700 feet from a point f + c in front of the center of the instrument. E. g., observed readings of 395.2 and 693.0 feet would give (dividing by 400 and 700) proportions of 98.8 and 99.0 to 1, respectively, and a corresponding mean interval factor of 101.11 (100 divided by the mean proportion 98.9), which, multiplied by subsequent field readings, would bring the observed distances up to the correct ones. Thus, if f + c = 1.2 feet, an observed distance of 230 feet could be treated as follows: (230 ×

1.0111) + 1.2 = 233.75 feet true distance from center of instrument to rod.

In practice, however, a small reduction table can be quickly prepared to give these corrected distances for every 10 feet up to 100, then each 100 feet up to 1,000, etc. This table may include or exclude the f + c constant.

Stadia wires are sometimes set so that the reading indicates the exact figure including the stadia constant for some one distance, and the slight error for other distances is disregarded.

STADIA WORK WITH INCLINED SIGHTS. If the telescopic line of sight is inclined to the horizontal, the distance as read from the rod must be corrected according to the vertical angle indicated by that pointing. The same data, vertical angle and observed distance at that pointing are used to compute difference in elevation between instrument and rod. The rod should be held vertical, which makes the operations simpler and in general more accurate.

To facilitate both these operations various stadia tables, diagrams and slide rules have been devised. They are all based upon the well known stadia formulae, which, for practical purposes, may be expressed as:

$$d = s \cos^2 v + (f + c) \cos v \qquad (1)$$

$$h = s \tfrac{1}{2} \sin 2v + (f + c) \sin v \qquad (2)$$

where

s = observed stadia distance
v = measured vertical angle
d = required distance from center of instrument to rod
h = required difference of elevation between instrument and point sighted on rod.

Stadia diagrams or charts give the difference in elevation and also the reduced horizontal distance, graphically, at a point in the chart which is found at the intersection of two lines, one representing the measured angle and the other the observed distance.

Stadia slide rules involve setting the slide to correspond to the angle and then reading off, opposite the denoted distance, the desired results. We furnish with each instrument having stadia wires, but no Beaman Stadia Arc, a celluloid circular slide rule known as the Cox Stadia Computer.

THE BEAMAN STADIA ARC affords a rapid and exact mechanical solution of these functions without the necessity of the measurement of the usual vertical angle and without recourse to either tables, charts or slide rules, and with but trifling computation. This practical and inexpensive patented attachment for transits and alidades is controlled by us and is described on pages 90 to 96.

SUGGESTIONS FOR STADIA WORK. The accuracy of all stadia work is directly proportional to the ease, care and accuracy with which the observed stadia distance has been read. If either focus is poor, if the rod is indistinct by reason of too great distance or other cause, or if the rod is not held plumb, the observed distance is uncertain, and, therefore, good results cannot be expected.

The greater the vertical angle, the greater the error due to the rod not being held plumb.

Secure such a focus on wires as will give no apparent displacement of object when stadia wires are in sharp focus for the observer and when objective is focused on object and eye is moved up and down in front of eyepiece; i. e., see that there is no parallax.

The instrumental adjustments to be made are for collimation and level tube.

When the air is unsteady or "boiling," remember that the greatest refraction in the line of sight occurs in the lower air stratum. Therefore, at these times avoid so far as possible reading a distance in which the lower wire is nearer the ground than two or three feet.

For refined work, determine the stadia factor, K, under such conditions as will approximate those to be expected in field practice. The mid-forenoon or afternoon is preferable to midday.

For elevation work with inclined sights, note the necessity for extreme accuracy in the observed distance when the vertical angle is large, and the necessity for a carefully determined angular value when the distance is great.

THE GRADIENTER ATTACHMENT No. 150, which may be used to advantage in all stadia work is fully described on pages 96 to 100.

TO ADJUST THE TRANSIT

EACH Gurley instrument leaves the factory in complete adjustment, but some adjustments are liable to derangement by accident or careless use. We describe particularly those which are most likely to need attention.

The principal adjustments of the transit are the,

Plate Levels
Line of Collimation
Standards
Objective Slide
Vertical Circle Vernier
Level on Telescope

TO ADJUST THE PLATE LEVELS. Set the instrument upon its tripod as nearly level as may be, and having unclamped the plates, bring the two levels above, and on a line with, the two opposite leveling screws, and, turning both in or out, as may be needed, bring the bubble of the level directly over the screws exactly to the middle of the opening. Without moving the instrument, proceed in the same manner to bring the other bubble to the middle. The level first corrected may now be thrown a little out; if so, bring it in again, and when both are in place, turn the instrument half way around. If the bubbles are both in the middle they need no correction; but if not, turn the nuts at the end of the levels with the adjusting pin, until the bubbles are moved over half the error. Bring the bubbles again into the middle by the leveling screws, and repeat the operation until the bubbles will remain in the middle during a complete revolution of the instrument. The leveling screws should be kept free at first, gradually tightening them as final adjustment is approached.

TO ADJUST THE LINE OF COLLIMATION. This adjustment is to bring the cross wires into such a position that the instrument, when placed at the middle of a straight line, will, by the transit of the telescope, cut the extremities of the line. Having leveled the instrument, determine if the vertical wire is plumb, by focusing on a defined point and observing if the wire remains on that point when the telescope is elevated or depressed. If not, loosen the cross wire screws, BB, see Fig. 1, and by their heads turn the ring until correct. The openings in the telescope tube are slightly larger than the screws, so that when the latter are loosened the ring can be rotated a short distance in either direction.

Direct the intersection of the cross wires on an object two or three hundred feet distant. Set the clamps, and transit to an object about the same distance in the opposite direction. Unclamp, turn the plates half way around, and direct again to the first object; then transit to the second object. If it strikes the same place, the adjustment is correct. If not, the space which intervenes between the points bisected in the two observations will be double the deviation from a true straight line, since the error is the result of two observations.

In the diagram, Fig. 21, let A represent the center of the instrument, and B C the imaginary straight line, upon the extremities of which the line of collimation is to be adjusted. B represents the object first selected, and D the point which the wires bisected when the telescope was reversed.

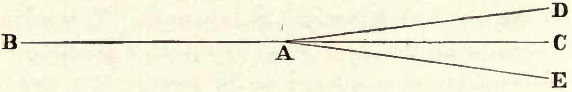

FIG. 21

When the instrument is turned half around, and the telescope again directed to B, and once more reversed, the wires will bisect an object, E, situated as far to one side of the true line as the point, D, is on the other side. The space, D E, is therefore the sum of two deviations of the wires from a true straight line, and the error is made apparent.

In order to correct this, use the two capstan head screws BB, Fig. 1, on the sides of the telescope, these being the ones which affect the position of the vertical wire. It must be kept in mind that the eyepiece apparently inverts the position of the wires, and therefore, in loosening one of the screws and tightening the other on the opposite side, the operator must proceed as if to increase the error observed.

The wires being adjusted, their intersection may now be brought into the center of the field of view by moving the screws, A A, which are slackened and tightened in pairs, the movement being now direct, until the wires are seen in their proper position.

The position of the line of collimation depends upon the relative position of the objective and the cross wires, so that the eyepiece may, as in the case just described, be moved in any direction, or even removed and a new one substituted, without at all deranging the adjustment of the wires.

TO ADJUST THE STANDARDS. In order that the point of intersection of the wires may trace a vertical line as the telescope is elevated or depressed, it is necessary that the standards of the telescope should be of precisely the same height. That is the center line of the horizontal axis must lie in a plane perpendicular to the center line of the spindle. To ascertain this, and make the correction, if needed, proceed as follows:

Having the line of collimation properly adjusted, set up the instrument in a position where points of observation can be selected, giving a long range in a vertical direction, such as the apex and base of a lofty spire.

Level the instrument, direct the telescope to the top of the object, and clamp to the spindle; then bring the telescope down until the wires bisect some well defined point at the base. Turn the instrument half around, reverse the telescope and direct to the lower point, clamp to the spindle, and raise the telescope to the highest point. If the wires bisect it, the vertical adjustment is effected; if they are thrown to either side, this proves that the standard opposite to that side is the highest, the apparent error being double that actually due to this cause. To correct it, we make one of the bearings of the axis movable, so that by turning a screw underneath this sliding piece, as well as the screws which fasten the cap of the standard, the adjustment is made with precision. If the standards adjustment is altered, it is necessary to again adjust the line of collimation.

Besides the three adjustments described, which are all that the surveyor will ordinarily be required to make, there are other adjustments of the transit which may sometimes be necessary.

To Adjust the Objective Slide. In case of accident or injury, it may be necessary to adjust the objective slide, and this should be done as follows. First make sure that the vertical wire is as nearly plumb as it is possible to make it. Having set up and leveled the instrument, the line of collimation being adjusted for objects from three hundred to five hundred feet distant, clamp the plates, and fix the vertical cross wire upon an object as distant as may be distinctly seen. Without disturbing the instrument, move out the objective so as to bring the vertical wire upon an object as near as the range of the telescope will allow. Having this object clearly in mind, loosen the upper clamp, turn the instrument half way around, reverse the telescope, clamp the instrument, and with the tangent screw bring the vertical wire again upon the near object; then draw in the objective until the distant object first sighted upon is brought into distinct vision. If the vertical wire strikes the same line as at first, the slide is correct for both near and remote objects, and, being itself straight, is correct for all distances.

But if there is an error, proceed as follows: With a screw driver turn the two screws, CC, Fig. 1, on the opposite sides of the telescope, loosening one and tightening the other, so as to apparently increase the error, making, by estimation, one half the correction required. Then go over the usual adjustment of the line of collimation, and, having completed it, repeat the operation above described, first sighting upon the distant object, then upon a near one in line, then reversing, making corrections, etc., until the adjustment is complete.

This adjustment is a distinctive feature of Gurley transits and furnishes the only way in which the line of collimation can be correct for all distances.

TO ADJUST THE VERTICAL CIRCLE VERNIER. Having the instrument firmly set up and carefully leveled by means of the telescope level, bring into line the zeros of the circle and vernier, and with the telescope find some well defined point, from one hundred to five hundred feet distant, which is cut by the horizontal wire. Turn the instrument half way around, transit the telescope, and fixing the wire upon the same point as before, observe if the zeros are again in line. If not, loosen the capstan head screws which fasten the vernier, and move the zero of the vernier over half the error; bring the zeros again into coincidence, and proceed exactly as before, until the error is entirely corrected.

In most cases the error is slight and may be best removed by putting the zeros in line and making the adjustment by the horizontal wire, moving it by the vertical capstan head screws until the vertical circle will reverse on the same point.

TO ADJUST THE LEVEL ON TELESCOPE. When the vernier of the vertical circle is adjusted and is at zero, the line of collimation is level and the bubble may be brought into the middle of its run by the capstan head nuts.

Another method is as follows: First level the instrument carefully, using the telescope level and with the clamp and tangent movement to the axis make the telescope as nearly horizontal as may be, by the eye. Then, having previously adjusted the line of collimation, drive a stake at a convenient distance, say from one hundred to three hundred feet, and note the height cut by the horizontal wire upon a staff set at the top of the stake.

Fix another stake in the opposite direction and at the same distance from the instrument, and without disturbing the telescope turn the instrument upon its spindle, set the staff upon the stake, and drive the stake into the ground until the same height is indicated as in the first observation. The tops of the two stakes will then be in the same horizontal line, however much the telescope may be out of level.

Remove the instrument from fifty to one hundred feet to one side of either of the stakes and in line with both. Again level the instrument, clamp the telescope as nearly horizontal as possible, and note the heights indicated upon the staff placed first upon the nearest and then upon the most distant stake. If both agree, the telescope is level. If they do not agree, with the tangent screw move the wire over nearly the whole error, as shown at the distant stake, and repeat the operation just described. Proceed thus until the horizontal wire will indicate the same height at both stakes, when the telescope will be truly horizontal. Taking care not to disturb the position of the telescope, bring the bubble into the middle by the leveling nuts at the end of the tube, when the adjustment will be complete.

REPAIRS. When an instrument becomes worn from service or is injured by a fall or accident of any kind, it is, of course, necessary to have it repaired and refitted before anyone can adjust it.

An instrument in need of repairs should be sent directly to us, as our facilities enable us to do the work economically and promptly. Always place the instrument in its own case, wrap with paper, then enclose in an outside packing case, at least an inch larger in all its dimensions and fill the space between the two with paper wadding, hay or shavings.

ATTACHMENTS FOR TRANSITS

IN the use of the transit it is generally found advisable to add one or more attachments to the telescope. All Gurley transits and their attachments are made to standard sizes, so that one or more of these useful accessories can be fitted to the instrument at any time.

When any of these attachments are desired, either for our instruments or those of other makers, the instrument must be sent to us. Occasionally they can be added by a skillful mechanic nearer the customer, but this is generally more expensive and less satisfactory.

The principal attachments for the transit are described on the following pages, and are:

VERTICAL CIRCLE (see pages 85 to 87).

GUARD FOR VERTICAL CIRCLE (see page 85).

VERTICAL ARC (see page 88).

LEVEL ON TELESCOPE (see page 89).

BEAMAN STADIA ARC (see pages 90 to 96).

GRADIENTER, COMBINED WITH CLAMP AND TANGENT (see pages 96 to 100).

DETACHABLE TELESCOPES FOR VERTICAL SIGHTING (see pages 101 and 102).

REFLECTOR FOR ILLUMINATING THE CROSS WIRES (see page 103).

DIAGONAL PRISM FOR EYEPIECE OF TELESCOPE (see page 103).

PLUMMET LAMP (see page 104).

ATTACHED MAGNIFIERS TO HORIZONTAL OR VERTICAL LIMB (see page 106).

BURT SOLAR ATTACHMENT TO TELESCOPE (see pages 114 to 136).

SOLAR SCREEN (see page 106).

TELESCOPIC SOLAR ATTACHMENT (see pages 136 to 144).

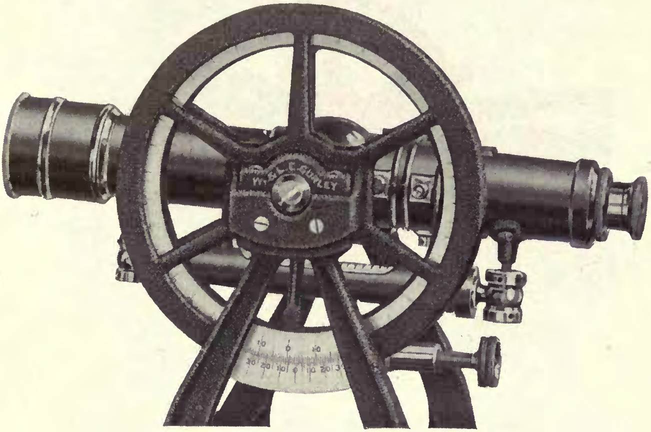

Fig. 22

No. 136 Vertical Circle, with
No. 141 Aluminum Guard

The Vertical Circle. Vertical Circle, No. 136, is graduated on sterling silver and figured in quadrants 0 to 90 each way. We make three sizes, four inches, four and one-half inches and five inches in diameter, all reading by one fixed vernier to single minutes.

There is an adjustment on the hub by which the graduations are as accurately and permanently centered as those of the horizontal limb.

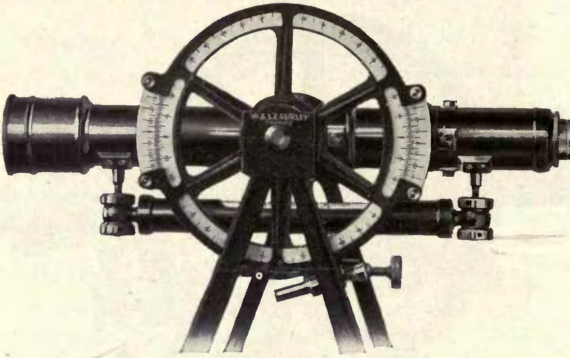

FIG. 23

NO. 138 VERTICAL CIRCLE, WITH TWO OPPOSITE DOUBLE VERNIERS, AND GUARD

The four inch and five inch vertical circle may be arranged as shown in No. 138, to be read by two opposite double verniers to one minute. The verniers are supported on a ribbed frame or guard in such a manner that the circle is concentric with the frame, and the verniers read accurately in any position of the circle.

The frame is arranged with an adjusting screw, to bring the verniers into exact adjustment with the level on the telescope.

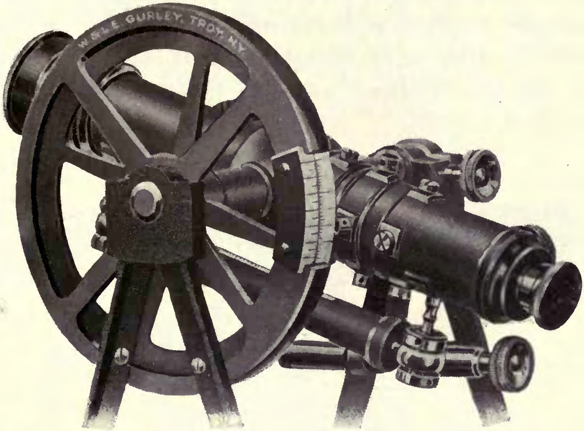

Fig. 24

No. 139 Vertical Circle, 4.5 inches diameter, with graduations on edge or rim, protected by a metal guard. Circle graduated to half degrees, with vernier reading to 1 minute.

If desired the vertical circle can be graduated on the edge or rim, so that the vernier is visible in front of the observer without a change of position. As on No. 138 the vernier is attached to the guard, instead of to the standard. The adjustment is made in the same manner as it is on the regular pattern, No. 136.

Guard for Vertical Circle. All transits having a vertical circle should be equipped with a guard, to protect the graduated edge of the circle. We make an improved guard, shown in No.141, Fig. 22, of aluminum, morocco finished, mounted on the standard concentric with the circle and attached so that it can be removed or put in place without affecting the adjustment of the circle.

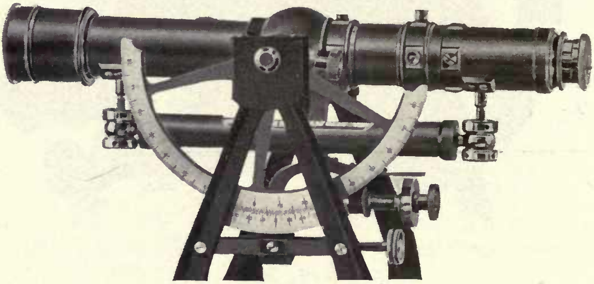

FIG. 25

NOS. 139-A, 139-B AND 140 VERTICAL ARCS

VERTICAL ARC. The Vertical Arc is made in three sizes, of two, two and one-half, and three inches radius. It is graduated on sterling silver and reads by vernier to one minute. The vernier is swung from the axis and is movable by a tangent screw.

The arc is less liable to damage than the full circle. It was first introduced to allow the Burt Solar Attachment to reverse. On Gurley Transits the arc is movable around its bearing on the axis, and it may be clamped at approximate zero when the telescope is level and the vernier brought to exact coincidence of zero, by a tangent screw that moves the vernier only. This Gurley feature prevents any damage to the arc when the telescope is used in the reversed position. Any vertical angle can then be read directly on the arc. This arc can be readily attached to any transit of our manufacture.

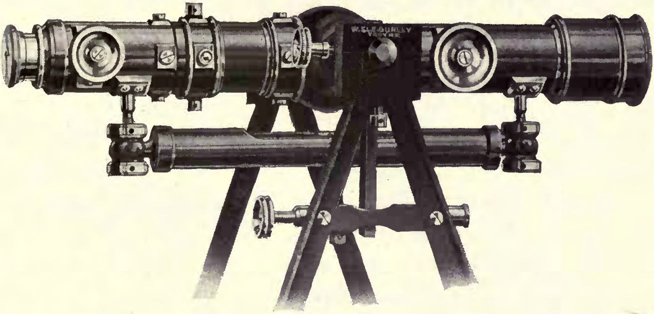

FIG. 26
NO. 145 LEVEL ON TELESCOPE

LEVEL ON TELESCOPE. The Level on Telescope, No. 145, consists of a brass tube about six and one-half inches long, each end of which is held between two capstan nuts connected with a screw or stem attached to the under side of the telescope tube.

The vial enclosed in the tube is a little over five inches long and half an inch in diameter, and is ground on its inner surface so as to insure an even movement of the bubble, the length of which is measured by a scale etched on the glass. The scale is graduated to two millimeters.

When required we supply a tube with a double opening, and a Reversion Level Vial, No. 146, that can be used either side up with equal facility.

Special attention is called to the Gurley feature of having the level vial as nearly as practicable the full length of the telescope. This gives increased accuracy in leveling operations.

To adjust the level on telescope, see method described on page 81.

SIGHTS ON TELESCOPE AND ON STANDARDS. For convenience in observation, we occasionally place a pair of small sights, No. 157, on the telescopes of our transits. These sights have folding joints, that they may lie close to the telescope when not in use. Sights, No. 158, may also be placed on the standards at an angle of ninety degrees with the telescope, for use in offsetting.

BEAMAN STADIA ARC

THE Beaman Stadia Arc is manufactured only by W. & L. E. Gurley, was devised and patented by W. M. Beaman, a topographer in the United States Geological Survey, and is now extensively used by that bureau in its topographical surveys. In 1906 we introduced it on our transits and alidades, and because this arc furnishes engineers with a rapid and exact mechanical solution of the stadia problem, the use of the stadia in surveying has been popularized to an appreciable extent.

By the use of this arc precise differences in elevation, and reduced horizontal distances can be determined with great rapidity, and without the intricate calculation heretofore necessary.

The arc is attached to the vertical limb of the transit Fig. 9, or alidade Figs. 97 and 98, and carries two scales having coincident zero points, marked 0 and 50 respectively, either scale being read by an index common to both. The scale graduations are so spaced and figured as to give simple multiples of the rod interval.

The Beaman Stadia Arc can also be used for metric measurements, as the graduations are based on a ratio of 1 to 100, which is 1 foot to 100 feet, or 1 meter to 100 meters. The stadia constant should be transposed to meters, however, when this unit is used.

Advantages of the Beaman Stadia Arc

1. The use of stadia tables, slide rules, or diagrams is entirely obviated.
2. There is no vernier or similar contrivance to be read.
3. Final results are obtained in less than one-third the time required by ordinary methods.
4. The accuracy of results is identical with formulae or table computations, regardless of the angle or distance.
5. The simplicity of the process practically eliminates the chances of error incidental to the use of other methods.

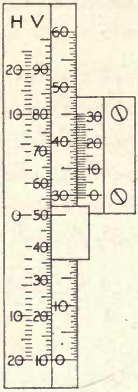

FIG. 27
GRADUATIONS OF BEAMAN STADIA ARC

The Beaman Stadia Arc can be supplied with any new transit or telescopic alidade of our manufacture having a vertical limb of either a one vernier vertical circle, a two vernier circle, or a vertical arc. This attachment can also be fitted to any old Gurley transit or telescopic alidade, but the additional cost of alterations and readjusting can only be determined upon examination of the instrument, which must be in our hands for this purpose.

For view of the graduations of the Beaman Stadia Arc as applied to telescopic alidades, see Fig. 27.

To obtain difference in elevation between instrument and rod the scale marked Vert. is used. This scale indicates multiples of the rod interval, for determining differences in elevation between instrument and rod. The zero point of this scale is marked 50, so a scale reading less than 50 indicates that the telescope is depressed, while a reading greater than 50 shows that the telescope is elevated.

A unique feature of the use of the multiple scale is that only such inclinations of the telescope need be used as will give a whole number vertical scale reading, while the fractional part of the elevation is shown by the rod reading.

To obtain the desired multiple, therefore, sight anywhere on the rod, it does not matter where, so that a whole number reading is obtained on the multiple scale.

Subtract 50 from this scale reading and use the algebraic remainder; e. g., if the Vert. scale reads 56, the multiple is $56 - 50 = +6$. If this scale reads 47, the multiple is $47 - 50 = -3$.

Example: Suppose the observed subtended stadia reading on the rod to be 6.40 (640 ft.), and to obtain a whole number for the scale reading, the telescope is inclined so that the multiple scale reads 33, at which setting the middle wire reads 7.30 on the rod.

Then the desired multiple equals

$$33 - 50 = -17$$

$$\text{and} -17 \times 6.40 = -108.8$$

Difference in elevation between instrument and base of rod is then,

$$-7.30 - 108.8 = -116.1 \text{ ft.}$$

The negative sign indicates that the point where the rod was held is lower than the instrument.

For accurate work at the higher angles it is also necessary to add to the difference in elevation the correction for the stadia constant, $f + c$. This correction is $(f + c)$ sin vertical angle.

THE TRUE HORIZONTAL DISTANCE is found by means of the scale marked "Hor.", which gives at the same pointing a direct reading of the percentage of correction (always subtractive) necessary to reduce the observed stadia reading (in feet subtended) to the true horizontal distance.

Example: At the above setting the reduction scale would read 3, or 3%.

3% of 640 ft. = 19.2 ft.

640—19.2 = 620.8 ft., the true horizontal distance.

If the accuracy desired requires the use of the stadia constant, $(f + c)$ *cos vert. angle* should be added to the horizontal distance as determined above.

A FORM OF NOTES FOR USE WITH BEAMAN STADIA ARC

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To facilitate the slight computation necessary to determine differences in elevation, a special form of notes has been devised for use with this attachment.

Stadia Arc Reading		Distance	Product	Rod Correction	Difference of Elevation	Elevation	Station
B. S.	F. S.						
						654.7	B. M.
54		4.2	— 16.8	+ 8.2	— 8.6	646.1	H. I.
	48	6.3	— 12.6	— 4.9	—17.5	628.6	T. P.
44		9.2	+ 55.2	+ 4.3	+59.5	688.1	H. I.
	57	15.8	+110.6	—13.8	+96.8	784.9	T. P.
50		8.4		+ 6.7	+ 6.7	791.6	H. I.
	50	5.6		— 9.8	— 9.8	781.8	T. P.

The Beaman Arc reading is placed under the appropriate heading, B. S. or F. S., in the above table. All sights are to be regarded as foresights, except those taken to determine the H. I. Thus, after a B. S. has been taken to determine the H. I., all intermediate rod stations, whether taken before the rod reaches the instrument or after the rod goes ahead, are to be entered as foresights.

The distance is recorded as 4.2, 6.3, etc., meaning 420 feet, 630 feet, etc.

The column headed "Product" is for the multiple times the distance; for example $4 \times 4.2 = 16.8$; 4 being the multiple for a stadia arc setting of 54.

The column headed "Rod Correction" is for the final reading of the middle wire on the rod.

The signs to be affixed to the "Product" and to the "Rod Correction" are determined according to whether the observation is a B. S. or a F. S., by following a rule of universal application, namely:

	Product	Rod Correction
B. S.	Opposite sign to that indicated by arc reading...	+
F. S.	Same sign as that indicated by arc reading......	—

A stadia arc reading of 54 indicates +; therefore, here the sign of the "Product" is — for a B. S., and + for a F. S.

Note that the sign of the "Rod Correction" is the same as in leveling.

When the line of sight is level, the stadia reading is 50, and hence the multiple is 0, which gives a "Product"

0. The only entry is, therefore, the "Rod Correction," or the final rod reading, whose sign follows the above rule.

Take the "Product" and the "Rod Correction" by pairs, and add algebraically; e. g., —16.8 + 8.2 = —8.6, the "Difference of Elevation." This, applied algebraically to the last known elevation, gives the elevation desired.

GRADIENTER

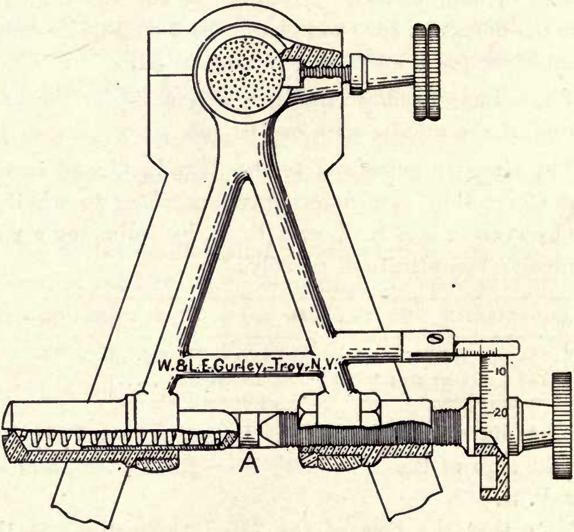


FIG. 28

NO. 150, GRADIENTER

THE GRADIENTER

THIS attachment is a modification of the tangent screw attached to the horizontal axis of the telescope, and is used in measuring small vertical angles in terms of their tangents. It is useful in measuring distances, establishing grades, and similar work.

It consists of a screw accurately cut to a determined number of threads which, passing through an eccentric sleeve nut on one side of the arm, presses against the small stud, A, fixed to the inside of the right-hand standard. A drum having a rim of sterling silver is adjustably centered on the micrometer screw. This drum is graduated into 100 equal parts and a short arm carries a small scale, graduated to read complete turns of the micrometer screw, which serves as an index to the micrometer drum. Pressing against the opposite side of the stud is an enclosed spiral spring which maintains a positive movement of the Gradienter screw.

USE OF THE GRADIENTER

The Gradienter can be used for the determination of vertical angles less than 6° from the horizontal and also for the determination of horizontal distances, without reading the vernier on the vertical circle.

DETERMINING DIFFERENCES IN ELEVATION. The initial reading for each determination should be taken when the graduated edge of the drum is near the zero mark on the index bar.

For a depression angle, the center cross-hair of the telescope is placed on the H. I. point of the rod and the reading of the micrometer is noted, using the nearest even division for general work and nearest one half division for close work. (The reading need not be zero, but may be any number from 0 to 100.) The micrometer is then turned until the instrument is level, the whole turns of the drum (each equal to 100 divisions) being counted or noted on the scale as the screw is revolved. When the level bubble is centered, the reading of the micrometer is noted, and the difference between the two readings, plus 100 for each whole turn of the screw determines the angle. For example, if the initial reading is 20 and is followed by two turns of the screw and a final reading of 32, the angle is equal to 212 divisions. As the screw is so cut that one complete turn intercepts one foot on a rod held 100 feet away, the difference in elevation is 2.12, times the distance divided by 100. As the distances are measured from the center of the instrument there is no stadia constant.

For an angle of elevation the procedure is the same, except that the instrument is first leveled, the initial reading on the micrometer taken, and the telescope is then turned upward to the H. I. point on the rod.

DISTANCE MEASUREMENTS. Under ordinary conditions, for shots up to 1500 feet in length, the usual method of reading the stadia interval on the rod will probably be preferred but for the occasional long shots that are unavoidable in a traverse, and for work in hazy weather, the gradienter determination of distance is much more accurate and is easier to read.

To determine the distance, the zero of the micrometer drum is set opposite a division of the scale. Using the center cross-wire set the target near the bottom of a rod held on the point, the distance to which is desired. Read the target setting. Rotate the drum one complete turn and again set the target. Read the second target setting. The number of hundredths of a foot difference between the two target settings will be the distance in feet.

As it is desirable to read as great an intercept on the rod as possible, it is sometimes necessary to read more than one complete turn of the micrometer screw. In general the distance equals the rod intercept in feet divided by the number of turns of the micrometer drum, the quotient multiplied by one hundred. For example:

Drum reading	2.85	Rod reading	0.246
Drum reading	4.63	Rod reading	13.128
Turn of Drum =	1.78	Rod intercept	12.882

$$\text{Distance} = \frac{12.882}{1.78} \times 100 = 723.7 \text{ feet.}$$

Where this measurement is made on a heavy slope, the correct horizontal distance is obtained by using stadia reduction methods.

The original setting of the drum should be such that the screw can be rotated in a right hand direction.

ESTABLISHING GRADES. One of the most important uses of the Gradienter is in establishing grades in surveying connected with railroads, streets, highways, sewers, canals, irrigation ditches, etc. The procedure is as follows: First, level the instrument: Bring the telescope level to its center by the clamp and the gradienter screws; keeping the telescope level, the graduated head may be turned on its shaft until its zero is brought to the edge of the scale; then turn off as many spaces on the head as there are hundredths of feet to the hundred in the grade to be established.

To avoid the possibility of error, observations should be taken by turning the screw always in the clock wise direction for the same series of observations.

The Gradienter drum and the index are graduated on sterling silver; thus the graduations are even, distinct and permanent. The entire attachment is of such construction and workmanship that it can be depended upon for accurate work.

See illustrations of Transit No. 10-A, Fig. 11, and Transit No. 10-A-3, Fig. 14.

ADJUSTMENT OF THE GRADIENTER

In the Gurley Gradienter attachment the value of the screw thread is such that a complete revolution of the screw will move the horizontal cross wire of the telescope over a space of one foot on a rod held at a distance of 100 feet. If the screw is turned through fifty spaces on its graduated head, the wire will pass over fifty one-hundredths, or one-half foot on the rod, and so on in the same proportion. The same ratio applies to metric measurements, 1 meter to 100 meters.

If this condition does not obtain, loosen the hexagonal nuts and turn the eccentric to the right or left thus lengthening or shortening the arm until the ratio is as required.

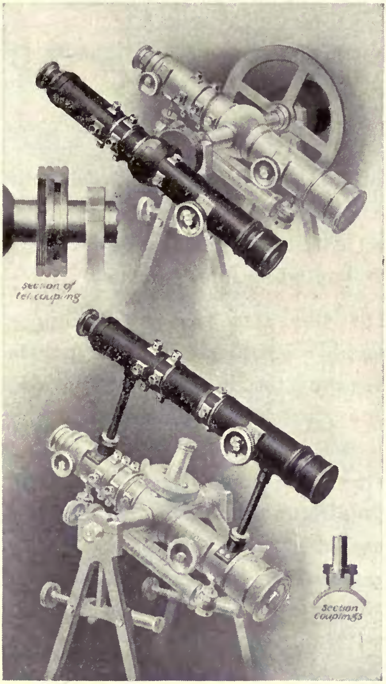


FIG. 29

NOS. 160 AND 161 DETACHABLE SIDE AND RIDING TELESCOPES, FOR VERTICAL SIGHTING IN MINE SURVEYING

DETACHABLE TELESCOPES FOR VERTICAL SIGHTING IN MINE SURVEYING

A convenient arrangement for sighting up or down a vertical shaft is shown in No. 160, in which an extra telescope is fitted with a flange and disk connecting it with the axis, so as to make it precisely parallel with the main telescope. A counterpoise, as shown, is fitted to the other end of the axis, and both telescope and counterpoise can be detached and placed in the transit box when not in use.

In No. 161, the extra telescope is connected with the main telescope by coupling nuts, which fasten it directly over the center of the instrument and allow its ready removal and replacement without disturbing its adjustments. In both arrangements the extra telescope is adjusted to the main telescope of the transit so that the lines of collimation of both are parallel and in the same plane, horizontal in No. 160 and vertical in No. 161; and in both, the extra telescope swings over the outside of the transit plates. The diagonal prism, No. 168, is often used with the extra telescope for greater convenience in sighting.

REFLECTORS FOR ILLUMINATING CROSS WIRES. Nos. 165 and 166, are elliptical pieces of silver inclined at an angle of forty-five degrees with the ring, which is fitted to the objective end of the telescope. The opening of the reflector allows the use of the telescope, while a light held near the inner surface illuminates the cross wires. No. 165 is for transits and No. 166 is for levels.

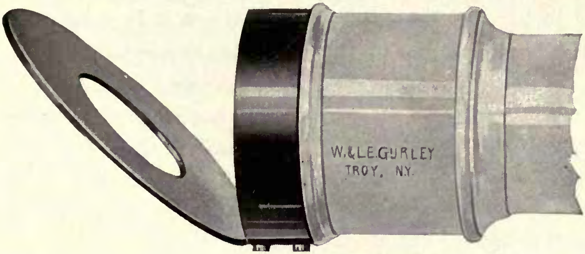


FIG. 30

NOS. 165 AND 166 CROSS WIRE ILLUMINATING REFLECTORS

THE DIAGONAL PRISM, No. 168, is used when it is necessary to observe greater vertical angles than can be taken with the ordinary telescope. It consists of a prism attached to the cap of the eyepiece by means of which the image of the object is reflected through a right angle to the eye. When the telescope is directed to the sun, a slide containing colored glass is moved over the opening to eliminate the glare.

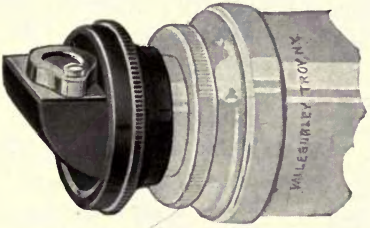


FIG. 31

NO. 168 DIAGONAL PRISM

The circular plate to which the prism is attached is made to turn in the cap, so that, when it is substituted for the ordinary cap of the eyepiece, the opening of the prism can be easily adjusted to the position of the eye. Observations can be taken with the prism up to an angle of sixty degrees elevation.

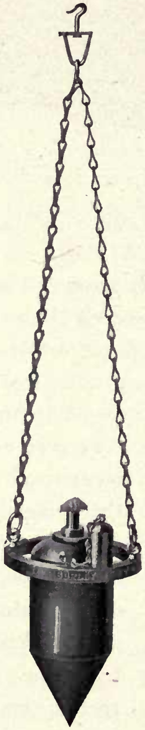


FIG. 32

NO. 170 PLUMMET LAMP

THE PLUMMET LAMP, No. 170, is a large plummet, of which the upper part is hollow to contain oil. It has a tube with a wick, and an extinguisher.

It is hung in gimbals by chains with a hook, and so always assumes a vertical position, and when suspended from the shifting center of a leveling head it can be easily adjusted over a given point.

These lamps are packed in a wooden case, furnished with a strap to sling over the shoulders. The weight of each lamp is about one and one-quarter pounds, and either one, two, or three may be packed in a single box.

PATENTED LATITUDE LEVEL, No. 193, is used for recovering the latitude on a solar transit without referring to the vertical arc, and also for setting the telescope at any desired angle in running grades and similar work.

It consists of a level connected by a short conical socket with the end of the telescope axis, to which it is clamped by a milled head screw, and made adjustable by a tangent screw and spring on the enlarged end of the tube. When the clamp screw is released the level turns vertically upon the axis, and can thus be set at any angle with the telescope, the final adjustment being made by its tangent screw.

The latitude being set off upon the vertical arc as usual, the level is clamped and brought into the middle, as above described.

The telescope may then be released and used in running lines, until it is desired to recover the latitude again. This is easily and accurately done without referring to the vertical arc.

The use of the attachment in running any desired grade is readily understood.

Patented latitude level, No. 193, together with an adjusting level, No. 196, and an adjusting bar, No. 197, are furnished without extra charge with any new transit having a Burt Solar Attachment.

Fig. 33
No. 180
ATTACHED MAGNIFIER

Attached Magnifiers or Microscopes are frequently used over the verniers of the horizontal or vertical limb, and are held by a universal three-jointed arm, which allows the lens to be placed over any point of the vernier. The magnifier for the "A" vernier can also be used for reading the vernier of the vertical limb (any style having one vernier.)

Attached microscopes, Nos. 181 and 182, can be supplied if desired. See No. 18-A Piecise Transit, page 49.

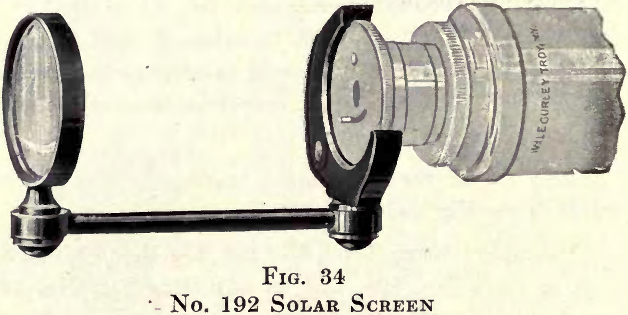


Fig. 34
No. 192 Solar Screen

Solar Screen. If desired, we furnish a Solar Screen arranged to clamp to the eyepiece end of the telescope, and detachable at will. On this screen the image of the sun and cross wires can be readily observed, a greater focusing movement of the eyepiece, however, being required.

ASTRONOMICAL TERMS

IN the following pages we define the terms employed in the use and adjustment of the Solar Attachment, which may be helpful to one not familiar with solar instruments. (See Fig. 35).

Sun. The sun is the fixed center of the solar system, although for convenience it is often spoken of as in motion around the earth.

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, termed its axis, once in twenty-three hours, fifty-six minutes, and four seconds, mean time, turning from west to east.

Poles. The poles are the extremities of the axis. That in our hemisphere, known as the north pole, if produced indefinitely toward the heavens, would reach a point near the polar star, called the north pole of the heavens.

Equator. The equator is an imaginary line passing around the earth, equidistant from the poles, and in a plane at right angles with the axis. If the plane of the equator were produced to the heavens, it would form what is called the celestial equator.

Orbit. The orbit of the earth is the path in which it moves in 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 of the same degree between the earth's orbit and its equator or between the celestial equator and the ecliptic.

EQUINOXES. The equinoxes are the two points at which the ecliptic and the celestial equator intersect one another.

DECLINATION OF THE SUN. The declination of the sun is its angular distance north or south of the celestial equator. When the sun is at the equinoxes, 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 gradually increases, 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.

HORIZON. The horizon of a place is the visible boundary of a plane, tangent to the earth at that place, or at right angles to a vertical line. The horizon, or a horizontal surface, is determined by the surface of a liquid at rest, or by the spirit levels of an instrument.

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

MERIDIAN. The meridian circle of a place is a great circle passing through the zenith of that place and the poles of the earth.

The meridian, or true north and south line, is the line determined by the intersection of the plane of the meridian circle with the plane of the horizon.

MERIDIAN ALTITUDE. The meridian altitude of the sun is its angular elevation above the horizon when passing the meridian of the place, and is equal to the co-latitude plus the declination.

LATITUDE. The latitude of a place is its angular distance north or south of the equator, measured on the meridian. At the equator the latitude is 0°, and at the poles 90°. The co-latitude of a place is its angular distance from the nearest pole, and is equal to 90° minus the latitude.

LONGITUDE. 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.

In the Nautical Almanac, which is commonly used with a solar instrument, the longitude of the principal places in the United States is reckoned from Greenwich, England, and expressed both in degrees and hours.

ZENITH DISTANCE. The zenith distance of any heavenly body is its angular distance north or south of the zenith of a place, measured when the body is on the meridian. The zenith distance of the north pole is equal to the co-latitude.

Suppose a person to be on the equator at the time of an equinox; the sun, when on the meridian, would be in the zenith of the place, and the poles of the earth would lie in a horizontal line.

Disregarding, for the present, the declination of the sun, let us suppose that the person travels toward the north pole. As he passes to the north, the sun will descend from the zenith, and the pole will rise from the horizon in the same proportion, until when he arrives at the north pole of the earth the sun will have declined to the horizon, and the pole of the heavens will have reached the zenith.

The altitude of the pole at any place, or the distance of the sun from the zenith, would, in the case supposed, give the observer the latitude of that place.

If we now take into account the sun's declination, it will increase or diminish its meridian altitude, according as it passes north or south of the equator; but the declination of the sun at any time being known, its zenith distance, and therefore the latitude of the place, can be readily ascertained by an observation made when the sun is on the meridian. It is by this method that we obtain the latitude of any place by the Solar Attachment.

Time. A solar day is the interval of time between the departure of the sun from the meridian of a place and its succeeding return to the same position. The length of the solar day, by reason of the inclination of the earth's axis, is constantly changing.

Mean Solar Day. In order to have a uniform measure of time, we have recourse to what is termed a mean solar day, the length of which is equal to the mean or average of all the solar days in a year.

MEAN SOLAR TIME. The time thus given is called mean solar time, and is the same at any instant for all points on the same meridian, differing, however, at points on different meridians.

STANDARD TIME. Since November, 1883, in the United States, the mean solar times of the meridians 60°, 75°, 90°, and 120° west of Greenwich are adopted as standard time, and are called respectively Colonial, Eastern, Central, Mountain, and Pacific time. The time of each place differs from that of the next 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.

At Troy, N. Y., the longitude is 73° 40′ west, or four hours, fifty-four minutes and forty seconds; hence the mean solar time is five minutes and twenty seconds more than the standard time. At Minneapolis the longitude is six hours, twelve minutes and fifty-seven seconds; hence the mean solar time is twelve minutes and fifty-seven seconds less than standard time, since the city is west of the meridian.

EQUATION OF TIME. The sun is sometimes faster and sometimes slower than the clock, the difference being called the equation of time. It gives the difference between the solar day and the mean solar day.

APPARENT NOON. The moment when the sun is on the meridian of any place is called apparent noon, and this being ascertained, we can, by adding the equation of time for the given day to, or subtracting it from, apparent noon, according as the sun is slow or fast, obtain the time of mean noon, which, converted to standard time, is used to set the watch.

DIFFERENCE OF LONGITUDE. As the earth makes a complete rotation upon its axis once a day, every point on its surface must pass through three hundred and sixty degrees in twenty-four hours, or fifteen degrees in one hour, and so on in the same ratio. As the rotation is 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 Greenwich.

To an observer at Troy, N. Y., the longitude of which is, in time, four hours, fifty-four minutes, forty seconds, the sun would come to the meridian nearly five hours later than at Greenwich, and thus, when it is 12 M. at that place it is only about 7 A. M. in Troy.

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 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 proper allowance to be made for refraction in setting off the declination is fully explained on pages 125 to 131.

EFFECT OF REFRACTION. If the latitude and declination of the sun were both zero, the position of the sun at noon would be at the zenith and there would be no refraction. At any other latitude, declination or hour, the apparent position of the sun would be lower and refraction must be taken into account.

Again, the angles which the equatorial lines of the Solar Attachments make with the horizontal are continually changing, as the declination arm is made to follow the course of the sun during an entire day. Thus in the morning and evening the equatorial lines are more or less inclined to the horizon, while at noon they are parallel with it. It follows that the excess of refraction at morning and evening is in some measure balanced by the fact that the position of the sun's image with reference to the equatorial lines is then less affected by it, on account of the greater inclination of the lines to the horizon.

BURT SOLAR ATTACHMENT

THE solar attachment is essentially the solar apparatus of William A. Burt, placed upon the cross bar of the ordinary transit. A disk one and one-half inches in diameter, having a short, round pivot projecting above its upper surface, is screwed to the telescope axis. Upon this pivot rests the enlarged base of the polar axis, which is firmly connected with the disk by four capstan head screws passing from the under side of the disk into the base. These screws serve to adjust the polar axis, as will be explained hereinafter.

HOUR CIRCLE. The hour circle surrounding the base of the polar axis is easily movable about it, and can be fastened at any point desired by two flat head screws above. It is graduated to five minutes of time, is figured from I to XII, and is read by an index fixed to the declination arc and moving with it. A hollow cone or socket, fitting the polar axis and made to move upon it, or to be clamped at any point desired by a milled head screw on top, furnishes by its arms below a firm support for the declination arc, which is fastened to it.

DECLINATION ARC. The declination arc has a radius of five inches, is graduated to quarter degrees, and reads by vernier to single minutes. The declination arc has the usual lenses and silver plate on the two opposite blocks, also a clamp and tangent movement, as shown in the illustration. The arc of the declination limb is turned on its axis and one or the other solar lens is used, as the sun is north or south of the equator. The illustration shows its position when the sun is north.

Latitude Arc. The latitude is set off by means of a large vertical limb figured from the center each way in two rows, from 0 to 80 degrees and from 90 to 10 degrees, the first series being intended for reading vertical angles, and the second series for setting off the

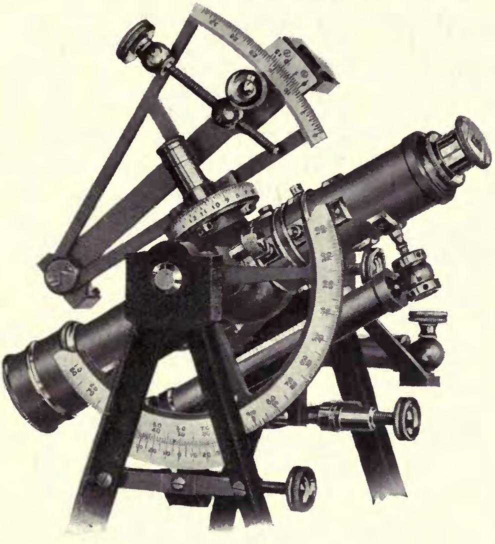


Fig. 35

No. 190 Burt Solar Attachment

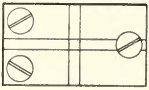
latitude. The vernier of the vertical limb is made movable by the tangent screw so attached that its zero and that of the limb are readily made to coincide when, in adjusting the limb to the level of the telescope, the arc is clamped to the axis.

The usual tangent movement to the telescope axis serves to incline the telescope to the proper angle, as described. A level on the under side of the telescope, with ground and graduated vial is indispensable in the use of the solar attachment. The arcs, verniers, and hour circle are all graduated on sterling silver.

EXPLANATION OF THE BURT SOLAR ATTACHMENT. When the telescope is set horizontal by its spirit level, the hour circle will be in the plane of the horizon, (see Fig. 36), the polar axis will point to the zenith, and the zeros of the vertical arc and its vernier will coincide. If we incline the telescope, directed north, the polar axis will descend from the direction of the zenith. The sun's polar distance, or the co-latitude of the place, can be laid off on the vertical arc—the latitude itself being found by subtracting this amount from 90 degrees, or by reading the inner row of figures, which amounts to the same thing.

When the sun passes above or below the equator, its declination, or angular distance from it, as given in the Ephemeris, can be set off upon the declination arc, and its image brought into position as before.

In order to do this, however, it is necessary not only that the latitude and declination be correctly set off upon their respective arcs, but also that the instrument be moved in azimuth until the polar axis points to the pole of the heavens, or, in other words, is placed in the plane of the meridian. Thus the position of the sun's image will indicate not only the latitude of the place, the declination of the sun for the given hour, and the apparent time, but it will also determine the meridian, or true north and south line passing through the place where the observation is made.



The interval between two equatorial lines, as well as between the hour lines on the silvered blocks, is just sufficient to include the circular image of the sun, as formed by the solar lens on the opposite end of the revolving arm.

Declination. Allowance for declination: Let us now suppose the observation made when the sun has passed the equinoctial point, and when its position is affected by declination.

By referring to the Ephemeris, and setting off on the arc the declination for the given day and hour, we are still able to determine its position with the same certainty as if it remained on the equator.

When the solar attachment is accurately adjusted and the transit plates precisely horizontal, the latitude of the place and the declination of the sun for the given day and hour being set off on their respective arcs, and the instrument set approximately north by the magnetic needle, the image of the sun cannot be brought between the equatorial lines until the polar axis is placed in the plane of the meridian of the place, or in a position parallel with the axis of the earth. The slightest deviation from this position will cause the image to pass above or below the lines, and thus the error will be detected.

From the position of the sun in the solar system we thus obtain a direction absolutely unchangeable, from which to run lines and measure horizontal angles.

This simple principle is not only the basis of the construction of solar instruments, but it is the sole cause of their superiority over instruments having only the magnetic needle. For in an instrument having a magnetic needle, the accuracy of the horizontal angles indicated, and therefore of all the observations made, depends upon the delicacy of the needle and the constancy with which it assumes a certain direction, called the magnetic meridian.

Advantages of the Burt Solar Attachment. The attachment can be added to the telescope of any good transit at a comparatively small expense, thus enabling the surveyor to establish the true meridian, to determine the correct latitude, and to obtain true time approximately.

Its adaptation to the purposes of illustration and instruction in practical astronomy in colleges and schools will occur to every teacher; and it furnishes for the surveyor a long sought and much needed instrument.

When not in use the attachment should be removed from the telescope and packed in the instrument box, and the thin shield put on the polar axis and kept in its place by the screw and washer of the socket.

It is evident that all transits to which the solar attachment is to be added should have a horizontal limb and verniers, and should be furnished with a level on telescope, clamp and tangent to telescope axis, and a vertical arc and vernier. They should also have a movable compass circle to set off the magnetic declination, and should be leveled by leveling screws. They must

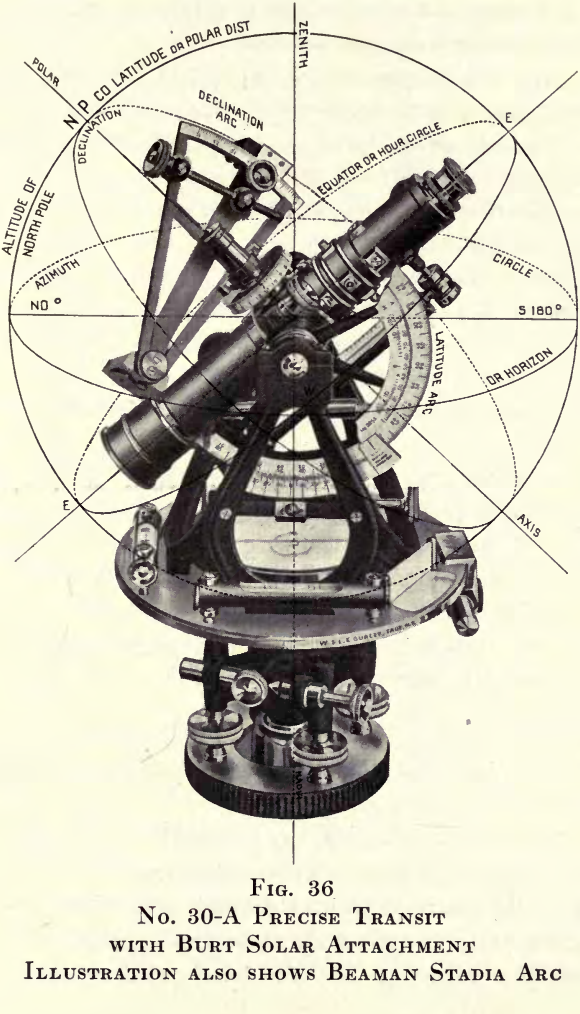


Fig. 36
No. 30-A Precise Transit
with Burt Solar Attachment
Illustration also shows Beaman Stadia Arc

be in perfect order, especially in respect to the sockets, before correct work can be done.

CARE OF THE BURT SOLAR ATTACHMENT. The Solar Attachment can be used with satisfactory results only on a transit which is in good repair and adjustment. The errors arising from defects either in worn or damaged bearings or imperfect adjustment have a direct effect on the Solar Attachment.

The principal sources of error in the transit are found in damaged plates or centers, loose centers, or irregular or loose bearings of the telescopic axis. The latter is the most frequent, and effects the setting of the latitude by describing an elipse instead of a true arc.

The transit must be kept clean at all times, the polar axis covered with the shield provided for the purpose when the Solar is not in use, and the tapered bearing and seat, as well as the socket of the Attachment, thoroughly cleaned with a soft cloth before using.

By taking the precautions mentioned and barring accidents, the Solar will remain in perfect order and adjustment indefinitely.

TO ADJUST THE BURT SOLAR ATTACHMENT

To adjust the Burt Solar Attachment, proceed as follows:

SOLAR LENSES AND LINES. Detach the declination arm by taking off the clamp and tangent screws, and remove the center by which the arm is pivoted on the arc.

Substitute for the declination arm upon the attachment the adjusting bar furnished with every solar instrument. The center of the declination arm fitting into the hole at one end of the bar, and the bar being further secured to the attachment by the clamp screw passing through the hole in the declination arc left by the removal of the tangent screw, into the threaded hole at the other end of the adjusting bar, thus forms a support upon which the declination arm can be adjusted.

Place the declination arm on the adjuster, turn one end to the sun, and bring it into such a position that the image of the sun is made to appear precisely between the equatorial lines on the opposite plate.

Carefully turn the arm over, until it rests upon the adjuster by the opposite faces of the rectangular blocks, and again observe the sun's image. If it remains between the lines as before, the arm is in adjustment. If not, loosen the three small screws and move the silver plate under their heads until one half the error in the position of the sun's image is removed.

Bring the image again between the lines, and repeat the operation as above on both ends of the arm, until the image will remain between the lines of the plate in both positions of the arm, when it will be in proper adjustment, and the arm may be replaced in its former position on the attachment. This adjustment is very rarely needed in our instruments, the lenses being cemented in their cells and the plates securely fastened.

TO ADJUST THE VERNIER OF THE DECLINATION ARC. Set the vernier at zero, and raise or lower the telescope until the sun's image appears exactly between the equatorial lines.

Having the telescope axis clamped, carefully revolve the arm until the image appears on the other plate. If precisely between the lines, the adjustment is complete. If not, move the declination arm by its tangent screw until the image will come precisely between the lines on the two opposite plates. Clamp the arm and remove the index error by loosening two screws that fasten the vernier; place the zeros of the vernier and limb in exact coincidence, tighten the screws, and the adjustment is complete.

TO ADJUST THE POLAR AXIS. Level the instrument carefully by the long level of the telescope, using the tangent movement of the telescope axis in connection with the leveling screws, until the bubble will remain in the middle during a complete revolution of the instrument upon its axis.

Place the solar attachment upon the axis and see that it moves easily around it. Bring the declination arm into the same vertical plane with the telescope, place the Adjusting Level, No. 196, upon the top of the rectangular blocks, and bring the bubble of the level into the middle by the tangent screw of the declination arc.

Fig. 37

No. 196 Striding or Adjusting Level

Turn the arc half way around, bringing it again parallel with the telescope, and note the position of the level. If in the middle, the polar axis is vertical in that direction. If not in the middle, correct one half the error by the capstan head adjusting screws under the base of the polar axis, moving each screw of the pair the same amount, but in an opposite direction. Bring the level to the middle again by the tangent screw of the declination arc, and repeat the operation as before, until the bubble will remain in the middle when the adjusting level is reversed.

Pursue the same course in adjusting the arc in the second position, or over the telescope axis, and when completed the level will remain in the middle during an entire revolution of the arc, showing that the polar axis is at right angles with the level under the telescope, or truly vertical.

As this is by far the most delicate and important adjustment of the solar attachment, it should be made with the greatest care, the bubble being kept precisely in the middle and frequently inspected in the course of the adjustment.

The adjusting level itself can be easily corrected, if necessary, by the screw at one end, when reversed upon a plane surface, exactly as a mason's level is adjusted.

TO ADJUST THE HOUR ARC. Whenever the instrument is set in the meridian, as will be hereafter described, the index of the hour arc should read apparent time. If not, loosen the two flat head screws on the top of the hour circle, and with the hand turn the circle around until the proper reading is indicated, fasten the screws again, and the adjustment will be complete.

TO USE THE BURT SOLAR ATTACHMENT

1. Compute the sun's declination for the day and the hours when observations are to be made, as shown in the examples on pages 132 to 134.

2. Set the declination arc for the hour as computed.

3. Carefully level the transit, using the long telescope level for precision.

4. Set the latitude of the place on the vertical circle or arc, and the zeros of the horizontal limb and south vernier in coincidence. All motions are now clamped.

Release the lower socket motion and turn the transit until the sun's image is precisely between the horizontal lines, using the lower tangent screw.

The instrument will then be in the true meridian, and an angle read by the verniers is the angle from the meridian.

NOTE 1. During north declination, or between the months of March and September, the graduated arc end of the Solar Attachment is pointed toward the sun. During the other one-half of the year, the opposite end is toward the sun.

NOTE 2. The greater the care exercised in setting the declination and latitude and the leveling of the instrument, the better will be the results obtained.

Observations may be made with the telescope pointed north, objective end depressed; again with the telescope pointed south, eye end depressed; or again with the telescope reversed and the attachment on the other side—two other observations. Thus with four distinct observations, the mean may be taken and any errors of adjustment eliminated.

REFRACTION IN DECLINATION. The Table of Refractions on pages 127 to 131 is calculated for latitudes between $2\frac{1}{2}^\circ$ and 70°, at intervals of $2\frac{1}{2}^\circ$, that being as near as is required.

The declination ranges from 0° to 20° both north and south, the $+$ declinations being north and the $-$

south, and is given for every 5°, that being sufficiently near for all practical purposes. The hour angle in the first column indicates the distance of the sun from the meridian in hours, the refraction given for 0 hours being that which affects the observed declination of the sun when on the meridian, commonly known as meridional refraction. The refraction for the hour just before or after noon is so nearly that of the meridian that it may be called and allowed as the same.

When the table is used, it must be remembered that when the declination is north the algebraic sign in the table is plus, when it is south the algebraic sign is minus, and the declination is always added algebraically. It will be noticed that the refraction in south, or —, declination increases very rapidly as the sun nears the horizon, showing that observations should not be taken with the sun when it is south of the equator, less than one hour from the horizon.

THE SOLAR EPHEMERIS is published annually. It is an abridgment of the Nautical Almanac, issued by the United States Government, and contains a Table of Mean Refractions in Declination and Tables of Times of Elongation, Culmination and Azimuths of Polaris. It can be conveniently carried in the vest pocket. A copy will be sent postpaid to any engineer or surveyor, upon request.

TABLE OF MEAN REFRACTIONS IN DECLINATION

To apply on the declination arc of the Solar Attachment of either compasses or transits.

Computed by Edward W. Arms, C. E., for W. & L. E. Gurley, Troy, N. Y.

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	32
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	32	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	—05	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″	08″	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′23	1′41

TABLE OF MEAN REFRACTIONS IN DECLINATION

HOUR ANGLE	DECLINATIONS								
	For Latitude 15°								
	+20°	+15°	+10°	+5°	0°	—5°	—10°	—15°	—20°
0 h.	—05″	0″	+05″	10″	15″	21″	27″	33″	40″
2	—03	+02	07	12	18	23	29	36	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 08
	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
	For Latitude 20°								
0 h.	0″	05″	10″	15″	21″	27″	33″	40″	48″
2	03	07	13	18	24	30	36	44	52
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′42	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	3[illegible]	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	8 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′42	2 07	2 44	3 46	3 43	13 06

TABLE OF MEAN REFRACTIONS IN DECLINATION

HOUR ANGLE	DECLINATIONS								
	+20°	+15°	+10°	+5°	0°	—5°	—10°	—15°	—20°
	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′03	1′15	1′31	1 53	2 20	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′05	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′20	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	52	1′02	1 14	1 29	1 49	2 16
4	43	51	1′01	1′13	1 27	1 49	2 14	2 54	4 05
5	1′11	1′26	1 44	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	
	For Latitude 42° 30′								
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	52	1′02	1 13	1 29	1 49	2 17	2 59
4	50	1′00	1′11	1 26	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	52	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′02″	1′14″	1′29″	1′49″	2′18″
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		

TABLE OF MEAN REFRACTIONS IN DECLINATION

HOUR ANGLE	DECLINATIONS								
	For Latitude 50°								
	+20°	+15°	+10°	+5°	0°	—5°	—10°	—15°	—20°
0 h.	33″	40″	48″	57″	1′08″	1′21″	1′39″	2′02″	2′36″
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	1 58	2 31	3 23	5 02
4	1′02	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′05″
2	43	50	59	1 11	1 26	1 42	2 23	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 53	8 42	
5	1 34	1 56	2 27	3 16	4 47	8 52			
	For Latitude 55°								
0 h.	40″	48″	57″	1′08″	1′21″	1′39″	2′02″	2′36″	3′33″
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 44	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′05″	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	20 24	
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′23″
2	54	1′04	1 17	1 33	1 54	2 24	3 12	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 53		
5	1 45	2 11	2 50	3 57	6 21	15 32			
	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 43	3 44	5 50	12 44
3	1′07	1 23	1 38	2 01	2 35	3 30	5 16	10 24	
4	1 23	1 40	2 05	2 40	3 40	5 37	11 50		
5	1 48	2 17	2 59	4 14	7 03				
	For Latitude 65°								
0 h.	57″	1′08″	1′21″	1′39″	2′02″	2′36″	3′33″	5′23″	10′51″
2	1′03	1 16	1 31	1 52	2 21	3 07	4 28	7 44	
3	1 12	1 27	1 46	2 12	2 52	4 02	6 33		
4	1 27	1 47	2 13	2 54	4 05	6 40			
5	1 52	2 22	3 08	4 30	7 52				

Table of Mean Refractions in Declination

Hour Angle	Declinations								
	For Latitude 67° 30′								
	+20°	+15°	+10°	+5°	0°	—5°	—10°	—15°	—20°
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 03	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 53	2 23	3 14	4 35	8 05			
5	1 56	2 28	3 17	4 40	8 51				
	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 13		
3	1 23	1 43	2 05	2 41	3 41	5 59	12 15		
4	1 37	2 00	2 34	3 28	5 20	10 12			
5	2 02	2 33	3 27	5 11	10 05				

TO COMPUTE THE DECLINATION OF THE SUN

Suppose the corrected declination is desired for the different hours of May 15, 1919, at Troy, N. Y. The latitude is 42° 44′. The longitude is practically five hours; so that the declination given in the Ephemeris for apparent noon of that day at Greenwich would be that for 7 A. M. at Troy, or five hours earlier. Note carefully the algebraic signs. The declination is North or plus. Its hourly difference is plus. The refraction always is plus. Hence we use the algebraic sum:

+18° 40′ 44″.3	is the tabular declination for	7 A. M.
+36″.0	difference for one hour	
+18° 41′ 20″.3	+ ref. (4 hrs.) 55″ = 18° 42′ 15″	8 A. M.
+36″.0		
+18° 41′ 56″.3	+ ref. (3 hrs.) 39″ = 18° 42′ 35″	9 A. M.
+36″.0		
+18° 42′ 32″.3	+ ref. (2 hrs.) 30″ = 18° 43′ 02″	10 A. M.
+36″.0		
+18° 43′ 08″.3	+ ref. (1 hr.) 26″ = 18° 43′ 34″	11 A. M.
+36″.0		
+18° 43′ 44″.3	+ ref. (0 hrs.) 26″ = 18° 44′ 10″	12 Noon
+36″.0		
+18° 44′ 20″.3	+ ref. (1 hr.) 26° = 18° 44′ 46″	1 P. M.
+36″.0		
+18° 44′ 56″.3	+ ref. (2 hrs.) 30″ = 18° 45′ 26″	2 P. M.
+36″.0		
+18° 45′ 32″.3	+ ref. (3 hrs.) 39″ = 18° 46′ 11″	3 P. M.
+36″.0		
+18° 46′ 08″.3	+ ref. (4 hrs.) 55″ = 18° 47′ 03″	4 P. M.
+36″.0		
+18° 46′ 44″.3	+ ref. (5 hrs.) 1′26″ = 18° 48′ 10″	5 P. M.

Again, suppose the corrected declination is desired for the different hours of October 20th, 1921, at Troy, N. Y. Now the declination and hourly difference are both minus and the refraction is plus.

—10° 03′ 29″.2	the tabular declination for	7 A. M.
—54″.2	difference for one hour	
—10° 04′ 23″.4	+ ref. (4 hrs.) 2′49″ = 10° 01′ 34″	8 A. M.
—54″.2		
—10° 05′ 17″.6	+ ref. (3 hrs.) 1′49″ = 10° 03′ 29″	9 A. M.
—54″.2		
—10° 06′ 11″.8	+ ref. (2 hrs.) 1′26″ = 10° 04′ 46″	10 A. M.
—54″.2		
—10° 07′ 06″.0	+ ref. (1 hr.) 1′14″ = 10° 05′ 52″	11 A. M.
—54″.2		
—10° 08′ 00″.2	+ ref. (0 hr.) 1′14″ = 10° 06′ 46″	12 Noon
—54″.2		
—10° 08′ 54″.4	+ ref. (1 hr.) 1′14″ = 10° 07′ 40″	1 P. M.
—54″.2		
—10° 09′ 48″.6	+ ref. (2 hrs.) 1′26″ = 10° 08′ 23″	2 P. M.
—54″.2		
—10° 10′ 42″.8	+ ref. (3 hrs.) 1′49″ = 10° 08′ 54″	3 P. M.
—54″.2		
—10° 11′ 37″.0	+ ref. (4 hrs.) 2′49″ = 10° 08′ 48″	4 P. M.

It will be found that the use of the table, as illustrated above, will not only relieve the surveyor of the perplexity which hitherto attended the subject of refractions, but will also enable him to secure more accurate results than by some other methods commonly given.

The calculation of the declination for the different hours of the day should, of course, be made and noted before the surveyor begins his work, that he may lay off the change from hour to hour, from a table prepared as before described.

TO FIND THE LATITUDE

Level the instrument very carefully, using the telescope level, until the bubble will remain in the middle during a complete revolution of the instrument, the tangent movement of the telescope being used in connection with the leveling screws, and the axis of the telescope being clamped.

Clamp the vertical arc, so that its zero and the zero of its vernier coincide as near as may be, and bring them into exact line by the tangent screw of the vernier.

Set off on the proper arc the declination of the sun for apparent noon of the given day, corrected for the meridional refraction. Note the equation of time, and fifteen or twenty minutes before noon direct the telescope to the north and lower the objective end until the sun's image can be brought nearly into position between the equatorial lines, by moving the instrument upon its spindle and the declination arc from side to side.

The declination arc being brought directly in line with the telescope, clamp the axis, and with the tangent screw of the telescope axis bring the image precisely between the lines, following the sun's motion as the image runs below the lower equatorial line, or, in other words, as long as the sun continues to rise in the heavens.

When the sun reaches the meridian the image will remain stationary in altitude for an instant, and will then begin to rise on the plate.

The moment the image ceases to run below is apparent noon, when the index of the hour arc should indicate XII, and the latitude be determined by the reading of the vertical arc.

The angle through which the polar axis has moved in the operation just described is measured from the zenith instead of the horizon, so that the angle read on the vertical limb is the complement of the latitude, or is the co-latitude.

The latitude itself is readily found by subtracting this angle from 90°. Thus at Troy the reading of the limb being found as above directed to be 47° 16′, the latitude will be 90°—47° 16′ = 42° 44′. The latitude may also be read direct by referring to the inner row of figures on the arc, beginning with 90 in the middle and reading to 10 on either side.

TIME FOR USING THE SOLAR

While the solar attachment can be used with advantage at all seasons of the year, the most favorable time is the summer, when the declination is north and the days are long and more generally fair. It is best not to take the sun at morning and evening when it is within half an hour of the horizon, nor at noon for about the same interval before and after it passes the meridian.

In favorable weather surveys can be made more rapidly than with the needle instrument, there being no time consumed in waiting for the needle to settle, or in avoiding the errors due to local attraction.

When the sun is obscured the lines can be run by the needle alone, it being always kept with the sun, or at 0 on its arc, thus indicating the direction of the true meridian. The sun, however, must be regarded as the most reliable guide, and should, if possible, be taken at every station.

GURLEY TELESCOPIC SOLAR ATTACHMENT

When a continued series of solar observations are to be made, it is often desirable that the main telescope of the transit be used without disturbing the solar apparatus.

The new Gurley Telescopic Solar Attachment meets such requirement, as the main telescope of the transit may be used independently and solar observations taken with no change in settings other than the hourly change in declination. The instrument is so designed that its adjustments can be accomplished with ease and precision in the field.

As shown in the illustration on page 138, the sun is viewed through an auxiliary telescope, a reflector being placed in front of the objective that brings the sun's reflected image to the cross wires.

The solar telescope is mounted on a horizontal axis which is supported by a vertical triangular base fastened to the right hand standard. The solar telescope can be moved about its horizontal axis and if the latitude is laid off on the latitude arc, the solar telescope will coincide with the polar axis.

The declination arm tilts the mirror at the objective end of the solar telescope, the angle being read on the arc attached to its side. Both the latitude arc and the declination arm have clamp and tangent movements for convenience in setting.

Having set the main telescope in the meridian and adjusted the mirror to the proper declination, the course of the sun is followed by rotating the solar telescope in collar bearings about its own axis; an hour circle surrounding the solar telescope indicates the apparent time.

The Gurley Telescopic Solar adds but little weight and when furnished in connection with a Gurley Precise Mountain Transit, with One Piece Truss Standard, is the standard instrument for public land surveys and similar work requiring exceptionally accurate results.

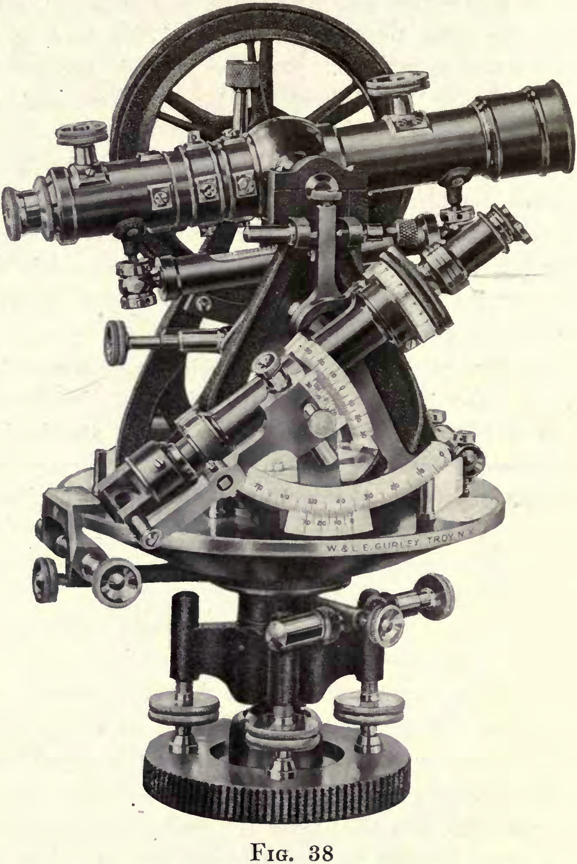


Fig. 38

No. 32-A Precise Transit with telescopic solar attachment, U. S. General Land Office and U. S. Forest Service model

TO ADJUST THE GURLEY TELESCOPIC SOLAR ATTACHMENT

TRANSIT ADJUSTMENT. Care should be taken to see that the main transit is adjusted for plate levels, collimation and telescope level before attempting to adjust Solar.

FOCUSING SOLAR. The eyepiece of the solar telescope is focused on the crosswires by rotating the knurled ring nearest the eye. The objective is focused by pulling out on the tube which holds the eyepiece.

EQUATORIAL WIRES PARALLEL TO THE AXIS OF THE REFLECTOR. Set for approximate latitude declination and hour angle, orient to approximate meridian and view the reflected image of the sun. Turn the telescope back and forth in hour angle, that is, in its collar bearings, and the image should follow the wires from side to side. If it does not, unscrew the cover ring just back of the knurled head, loosen the cross wire screws and turn the diaphragm. If sun is not visible any other well defined distant point may be used.

COLLIMATION OF THE SOLAR TELESCOPE. Unclamp the vernier arm of the declination arc and swing the mirror parallel to the line of sight, thus giving a direct view through the auxiliary telescope. Sight on some distant point and revolve the telescope in its collar bearings 180 degrees, adjusting the cross wires as for the Wye Level. The first adjustment should always be checked after adjusting the collimation.

POLAR AXIS AT RIGHT ANGLES TO LATITUDE AXIS. Transit on fore and back sights, the same as for collimating the main telescope. If any adjustment is necessary, make it by means of the three screws which are in the short arm on the upper end of the latitude arc. The middle screw pulls the eye end closer to the transit; the outside screws oppose the center screw and push the eye end farther away.

LATITUDE AXIS PARALLEL TO TRANSIT AXIS. Carefully level the transit and make the solar telescope cut the same line as the main telescope when sighted at some distant object. Make any necessary adjustment by means of the capstan nuts holding the lower corner of the triangular base to the standard.

Make the auxiliary telescope trace the same vertical line as the main telescope, adjusting by means of the capstan nuts at the upper corner of the triangular base, if necessary. It will be necessary to alter the focus of the solar telescope to make this test. This test is similar to that for the adjustment of the standards of the main telescope.

ZERO OF LATITUDE ARC. Level the main telescope and make both telescopes agree on a distant object. If the latitude vernier does not read zero, loosen the two screws at the back of the vernier and correct it. It is necessary that the main telescope level be adjusted parallel to the line of collimation.

ZERO OF DECLINATION ARC. Turn the mirror back into position and set the declination arm to read zero. Through the auxiliary telescope observe the reflected image of some prominent and distant horizontal object. Reverse the telescope on the latitude axis and view the same object. If the wires do not cut the same point, make the adjustment for one half the error, by means of the two small abutting screws in the middle of the declination arm, operating against the short arm attached to the axis of the mirror. This may also be checked by a noon reading on the sun, other adjustments having been made.

Hour Circle. When the instrument is pointed in the meridian, the hour circle should read apparent time. A screw in the rim of the hour circle on the side opposite the zero hour can be loosened and any necessary correction made by turning the graduated circle to the proper position.

DIRECT OBSERVATION ON THE SUN

With a transit having both vertical and horizontal limbs, direct observations may be taken on the sun to find the meridian. The best time is about three hours before or after noon. A colored or smoked glass darkener will be necessary over the eyepiece to protect the eye. The observations to be taken are those of the altitude of the sun and its horizontal angle from a fixed point, at the same instant. It is best to take a number of these, say three or five, so as to check; and if the telescope is reversed and another set taken, the mean of the two sets will eliminate many inaccuracies. It is also an advantage to use the lower limb of the sun in the morning and the upper limb in the afternoon, it being easier to judge the tangency of image and cross wires. Allowance is then made for the semi-diameter of the sun, which varies from 15¾ to 16¼ minutes.

It will be sufficiently close to have the vertical wire bisect the sun, but the altitude must be taken with care. The transit must be accurately leveled and adjusted.

To reduce the observations there are many forms, all deduced from the same formula. The form much favored is $\tan^2 \frac{1}{2} A = \frac{\sin [S-(90°-\text{alt.})] \,.\, \sin [S-(90°-\text{lat.})]}{\sin S \,.\, \sin [S-(90°-\text{dec.})]}$

REDUCTION FORMULA. In which "A" is the azimuth of the sun or horizontal distance from the meridian, and "S" is one half the sum of (90°— altitude, corrected for refraction) + (90°— latitude) + (90°— declination). Note the sign of the declination. When the declination is South this term would be 90°—(—declination) = 90° + declination.

EXAMPLE. Place, Troy, N. Y. Time, 3h. 30m. P. M., March 31, 1917.

The horizontal angle from a fixed point to sun's center . . . . 241° 46′
Observed altitude of upper limb of sun . . . 30° 31′ 10″
Obs. alt.—refraction 1′ 40″—semi-diameter 16′= alt. of sun's center . . . . 30° 13′ 30″
Declination for day and hour . . . . 4° 02′ 58″
Latitude . . . . 42° 44′
90°—alt. = 59° 46′ 30″, 90°—dec. = 85° 57′ 02″, 90°—lat. = 47° 16′, 2 S = 192° 59′ 32″ S = 96° 29′ 46″

log. sin [S—(90°—alt.)] = 9.77664
log. sin [S—(90°—lat.)] = 9.87923

9.65587

log. sin S = ... 9.99720
log. sin [S—(90°—dec.)] = 9.26251

9.25971

log. tan² ½ A = 0.39616
log. tan ½ A = 0.19808

½ A = 57° 38′ 06″ and A = 115° 16′ 12″ west of North.

If in the morning would be east of North.

Apply this to the horizontal angle from the fixed point to the sun and we have 357° 02′ 12″, which is the reading of the horizontal limb when the telescope is pointed North. Set this reading off on the limb and the telescope will be in the plane of the meridian.

TABLE OF MEAN REFRACTIONS DUE TO ALTITUDE BAROMETER 30″, THERMOMETER 50° F

Apparent Altitude	Mean Ref.	Apparent Altitude	Mean Ref.	Apparent Altitude	Mean Ref.	Apparent Altitude	Mean Ref.
5°	9′ 46″	10°	5′ 16″	20°	2′ 37″	50°	0′ 48″
6°	8′ 23″	12°	4′ 25″	25°	2′ 03″	60°	0′ 33″
7°	7′ 20″	14°	3′ 47″	30°	1′ 40″	70°	0′ 21″
8°	6′ 30″	16°	3′ 19″	35°	1′ 22″	80°	0′ 10″
9°	5′ 49″	18°	2′ 56″	40°	1′ 09″	90°	0′ 0″

TABLE OF SEMI-DIAMETERS OF THE SUN

Jan. 1, 16′ 18″	April 1, 16′ 02″	July 1, 15′ 46″	Oct. 1, 16′ 01″
Feb. 1, 16′ 16″	May 1, 15′ 54″	Aug. 1, 15′ 48″	Nov. 1, 16′ 09″
Mar. 1, 16′ 10″	June 1, 15′ 48″	Sept. 1, 15′ 53″	Dec. 1, 16′ 15″

COMPASSES

THE Surveyors Compass is used considerably for farm surveys, for subdividing land, for retracing old lines, which were run originally with a magnetic needle, for exploration and for other similar work.

It consists of a magnetic needle swinging in a graduated compass circle mounted on a plate, to the ends of which two slotted standards or sight vanes are attached in line with the zeros of the graduations. There are two levels to show when the plates are horizontal, and a socket on which the instrument can be turned to bring the sights into line with the object sought. The spindle on which this socket turns terminates in a ball and socket joint to enable the plates to be leveled.

The Surveyors Compass has a romantic history as it is associated with the early settlement of our country. In 1748 George Washington, at the age of 16, took up the practice of surveying, and the compass of today is a development of the instrument used by him for land surveys in Virginia. Gurley Compasses were first used in 1845 and the accuracy of their service is testified by records which are on file in county seats throughout the country.

VERNIER COMPASS

THE superiority of the Vernier Compass over the Plain Compass consists in its adaptation to retracing the lines of an old survey and to the surveys of the United States public lands, in which the lines are based on a true meridian.

MAGNETIC NEEDLE. A bar of special magnet steel being saturated with a magnetic charge is suspended on a cup shaped jewel that rests on the fine point of the center pin or pivot, about which it turns with practically no friction so that it may assume its position in the magnetic meridian. The ends are pointed and swing close to the graduated circle from which the angular bearing is read.

MAGNETIC DECLINATION. It is well known that the magnetic needle deviates more or less to the east or west of a true meridian, or north and south line. This deviation, which is called the magnetic declination, is not constant, but increases or decreases to a very sensible degree. Thus, at London the needle pointed 11° east in 1580. This diminished until 1658 when it was zero, or the needle stood exactly north and south. The declination continued westerly until 1812, when the bearing was 24° west. This has been gradually decreasing until in 1916, it was about 15° west. Thus a compass bearing at London changed from 11° east to 24° west, or a total of 35°, from 1580 to 1812. The annual change was not uniform but varied from 0 to 14 minutes of arc.

The time periods taken for the needle to change from extreme eastern to extreme western declination vary with the locality. At St. Johns, Newfoundland, the period was about 180 years; at Trenton, N. J., 130 years and at Houston, Texas, 50 years*. At present the annual change is about zero in the middle west, four minutes on the Pacific Coast and six minutes in New Hampshire.

For this reason, in running over lines from field notes of some years standing, the surveyor is obliged to make an allowance, both perplexing and uncertain, in the bearing of every line. It was to obviate this difficulty that the Vernier Compass was devised.

TO SET OFF THE DECLINATION. It will be seen that the surveyor having the Vernier Compass can, by moving the vernier to either side, and with it, of course, the compass circle attached, set the compass to any declination.

He therefore places his instrument on some well defined line of the old survey, and turns the pinion until the needle of his compass indicates the same bearing as that given in the field notes of the original survey. Then, clamping the vernier, he can run all the other lines from the old field notes without further alteration.

**From a speech at the Centennial Celebration of the N. S. C. & G. S., made by Doctor Louis A. Bauer, Director of the Department of Terrestrial Magnetism of the Carnegie Institute, at Washington, D. C.*

The reading of the vernier on the limb in such a case would show the change of declination of the two different periods.

The magnetic declination at any place being known, a true meridian, or north and south line, may be run by moving the vernier to either side, as the declination is east or west, until the arc passed over on the limb is equal to the angle of declination, and then turning the compass until the needle is made to cut the zeros on the graduated circle. The line of sights will then give the direction of the true meridian of the place.

Such a change in the position of the vernier is necessary in surveying the United States public lands, which surveys are always run from the true meridian.

THE LINE OF NO DECLINATION, or the line upon which the needle will indicate a true north and south direction, is situated in the United States nearly in an imaginary line drawn from the middle of Lake Superior to Savannah, Ga.

A magnetic needle placed east of this line has a declination to the west, and when placed west of the line the declination is to the east; and in both cases it increases as the needle is carried farther from the line of no declination.

Thus, in Minnesota, the declination is from eight to eleven degrees to the east, while in Maine it is from fifteen to nineteen degrees to the west. At Troy, in the year 1919, the declination was about 12° 33′ to the west, and is increasing now in the same direction about 5.6 minutes annually.

Diurnal Variation. The magnetic declination does not remain constant through an entire day, but reaches its farthest point east about 8 o'clock A. M., and its farthest point west about 2 o'clock P. M.

Conditions of temperature, magnetic storms and other causes at times affect the needle. Our own experiments show that different needles observed at the same time and under the same conditions differ in their direction, but show nearly the same daily change.

Needle Lifter. Underneath the main plate is a needle lifting screw which, by moving a concealed spring, raises the needle from the pivot, and thus prevents injury to the jewelled center as well as the blunting of the point during transportation or while carrying the instrument in the field.

When the compass is not in use, it is the practice of many surveyors to let down the needle upon the point of the center pin, and allow it to assume its position in the magnetic meridian, so as to retain its polarity. After the needle has settled it should be raised against the glass for the reasons stated above.

Plate Levels. The spirit levels are placed at right angles with each other so as to level the plate in all directions, and are balanced upon a pivot under the middle of the tube, so as to be adjustable by a screw driver.

Outkeeper. A small dial plate, having an index, turned by a milled head underneath, is used with this compass to keep tally in chaining. The dial is figured from 0 to 16, the index being moved one notch for every chain run.

BRASS COVER. A brass cover is fitted over the glass of the compass, and serves to protect it from accident, as well as to prevent electric disturbance.

SIGHTS. The sights, or sight vanes, have fine slits cut through nearly their whole length, terminated at intervals by circular apertures, through which the object

FIG. 39

No. 226 VERNIER COMPASS

sighted upon is more readily found. Sometimes a horse hair or wire is substituted for half the slit, and placed alternately with it on opposite sights.

The telescopic sight is often used with the Vernier Compass, and its adjustments and use are described on pages 158 to 165.

TANGENT SCALE. The edges of the north sight of our compasses are graduated to half degrees for angles of elevation and depression respectively, which are read from corresponding peep sights on the south vane.

The maximum angle which can be read is 23 degrees.

BALL SPINDLE. The compass is fitted to a spindle made slightly conical, and having on its lower end a ball turned perfectly spherical, and confined in a socket by a pressure so light that the ball can be moved in any direction in leveling the compass. The ball is placed either in the brass head of the staff, or better, in the compass tripod.

A leveling adopter, shown on page 158, is often used for more convenient leveling of the compass.

THE STAFF MOUNTINGS consist of the brass head already mentioned, and a pointed steel shoe. The staff, to which the mountings should be securely fastened, may be procured from any wheelwright, or provided by the surveyor himself.

CLAMP SCREW. In the side of the hollow socket of the compass is a screw by which the instrument may be clamped to the spindle in any position.

SPRING CATCH. Besides the clamp screw there is fitted to the socket of our Vernier Compass No. 226, a spring catch, which, as soon as the instrument is set upon its spindle, slips into a groove, and thus removes all danger of the instrument falling from the spindle while being carried.

USE OF THE COMPASS

In using the compass, the surveyor should keep the south end toward his person, and read the bearings from the north end of the needle. The E and W letters on the face of the compass are transposed because the needle represents a fixed line, about which the compass box is revolved in directing the sight to the object observed. In sighting a point situated NW, the needle will point E of the line of sight, but it will correctly *read* NW in accordance with the line actually sighted, because the East quadrant is marked West.

The compass circle being graduated to half degrees, a little practice will enable the surveyor to read the bearings to quarter degrees or even less, estimating with his eye the space bisected by the point of the needle; and as this is as close as the traverse table is usually calculated, it is the general practice.

ANGLES OF ELEVATION. Having leveled the compass, bring the south end toward the person, place the eye at the little button, or peep sight, on the right side of the south sight, and with the hand hold a card on the front surface of the north sight, so that its top edge will be at right angles with the graduated edge and coincide with the zero mark. Then, sighting over the top of the card, note upon a flagstaff, held near the compass, the height cut by the line of sight, move the staff up the elevation and carry the card along the sight until the line of sight again cuts the same height on the staff. Read off the degrees and half degrees passed over by the card, and this will be the angle required.

Angles of Depression. Proceed in the same manner, using the eyepiece and graduations on the opposite side of the sight, and reading from the top of the sight.

New and Old Surveys. When the compass is to be used in making new surveys, the vernier should be set at zero and clamped by the nut on the plate.

In surveying old lines, the change of the magnetic declination should be ascertained by setting the compass on some well defined line of the tract, and making the bearing agree with that of the old survey, by moving the circle as already described. The circle can then be clamped, and the old lines retraced from the bearings given by the original surveyor.

Electricity. Caution should be exercised in handling the compass, that the glass face does not become charged with electricity excited by the friction of cloth, silk, or the hand, so as to attract the needle to its under surface. Should the glass become so charged, however, the electricity may be removed by breathing upon it, or by touching different parts of its surface with the moistened finger. Ignorance of this apparently trifling matter has caused the inexperienced surveyor much annoyance.

COMPASS ADJUSTMENTS

TO ADJUST THE PLATE LEVELS. Bring the level bubbles into the middle by the pressure of the hand on different parts of the plate, and turn the compass half way around. If the bubbles run to the end of the tubes, it indicates that those ends are the highest. Lower them by loosening the screws under the lowest ends and tightening those under the highest ends until, by estimation, the error is half removed. Level the plate again, and repeat the first operation until the bubbles will remain in the middle during an entire revolution of the compass.

TO ADJUST THE SIGHTS. The sights may next be tested by observing through the slits a hair or thread, made exactly vertical by a plummet. Should the hair appear on the side of the slit, the sight must be adjusted by filing its under surface on the side which seems the highest.

TO ADJUST THE NEEDLE. Having the eye nearly in the same plane with the graduated rim of the compass circle, with a splinter of wood or an iron wire bring one end of the needle in line with any prominent graduation of the circle, as the zero or the ninety degree mark, and notice if the other end corresponds with the degree on the opposite side. If it does not, use the small brass wrench furnished with our compasses, and bend the center pin about one eighth of an inch below the point, until the ends of the needle are brought into line with the opposite degrees.

Then, holding the needle in the same position, turn the compass half way around, and note whether it now cuts opposite degrees. If not, correct half the error by bending the needle, and the remainder by bending the center pin. The operation should be repeated until perfect reversion is secured in the first position.

This being obtained, it may be tried on another quarter of the circle. If any error is there manifested, the correction must be made in the center pin only, the needle having been already straightened by the previous operation.

When again made to cut, it should be tried on the other quarters of the circle, and corrections made in the same manner until the error is entirely removed, and the needle will reverse in every point of the graduated surface.

REPAIRS TO THE COMPASS

To enable the surveyor to make such repairs as are possible without recourse to an instrument maker, we add a few simple directions.

NEEDLE. The magnetic needle is the most vexatious and troublesome part of a surveyor's instrument, and its imperfect working is almost invariably due to a roughened or scratched jewel or to a dulled center pin, or to both, and rarely to loss of magnetism.

Injuries to the jewel and center pin are generally caused by allowing the needle to swing on the pin when the instrument is transported or when it is carried in the field from one station to another. If the needle is sufficiently raised by means of the needle lifting screw so that there is no contact between the jewel and the center pin, the most frequent cause of injuries will be avoided.

A wire is coiled on the south end of the needle, and may be moved back and forth to counterbalance the varying magnetic dip at the north end, as a needle which is perfectly balanced in one locality is frequently out of balance in a different latitude.

It may sometimes happen that the needle has lost its polarity and must be remagnetized. To do this, proceed as follows: Unscrew the bezel ring that holds the glass face, and remove the needle. Pass each end of the needle from middle to extremity with a gentle pressure over the magnetic pole of a permanent magnet, describing before each pass a circle of about six inches radius, to which the surface of the pole is tangent, drawing the needle toward the body, and taking care that the north and the south ends are applied to the opposite poles of the magnet.

Should the needle be returned in a path near the magnetic pole, the magnetism induced by the contact of the needle with the magnet, in the pass just described, would be reversed, and the magnetic virtue almost entirely neutralized at each operation. When the needle has been passed in this manner about twenty-five times in succession, it will be fully magnetized.

Center Pin. The center pin should occasionally be examined, and, if much dulled, should be taken out with the brass wrench or with a pair of pliers, and sharpened on a hard oilstone, the operator placing it in the end of a small stem of wood, or in a pin vise, and delicately twirling it with the fingers as he moves it back and forth at an angle of about thirty degrees with the surface of the stone.

When the point is made so fine and sharp as to be invisible to the eye, it should be smoothed by rubbing it on the surface of a soft and clean piece of leather.

TO REPLACE A LEVEL VIAL. See instructions under transits, page 66.

ATTACHMENTS FOR VERNIER COMPASS

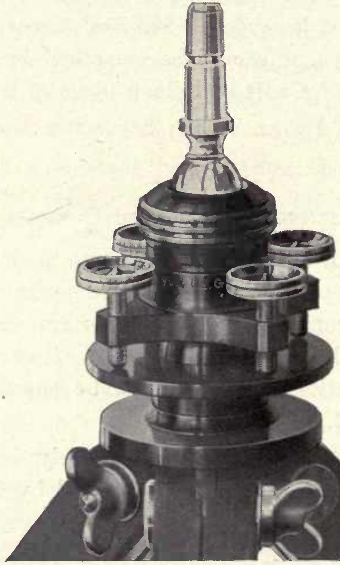
LEVELING ADOPTER. For more convenient leveling of the compass, as well as other instruments, we make a Leveling Adopter, No. 241, which is screwed to the top of the tripod like the leveling head. It can be used with a simple ball spindle and can be supplied with Compass No. 226.

The instrument is made approximately level upon the ball and finally made truly horizontal by the leveling screws.

LEVELING HEAD. We also make for use with Compass No. 226 a Leveling Head, No. 242, consisting of arms strongly ribbed with four leveling screws having dust caps, and with clamp and tangent movement.

This Leveling Head furnishes a stable support for the instrument, and affords the same conveniences for leveling and accurate adjustment in azimuth as the leveling heads on transits or levels.

TELESCOPIC SIGHT. This telescope is attached to a movable band which, as shown in the illustration, can be slipped over the sight of a compass, clamped at any point desired, and adjusted with a screw driver and a steel adjusting pin.



No. 241

FIG. 40

No. 241 LEVELING ADOPTER

To put this attachment in place, slip the band over the south sight of the compass, having the telescope at the right hand and the clamp screw on the outer surface of the sight, placing the band as low as will allow the telescope to revolve without striking the compass. This place should be marked by a line across the sight, or by a screw or pin on the inner surface of the sight, that the band may be set at the same point in subsequent use.

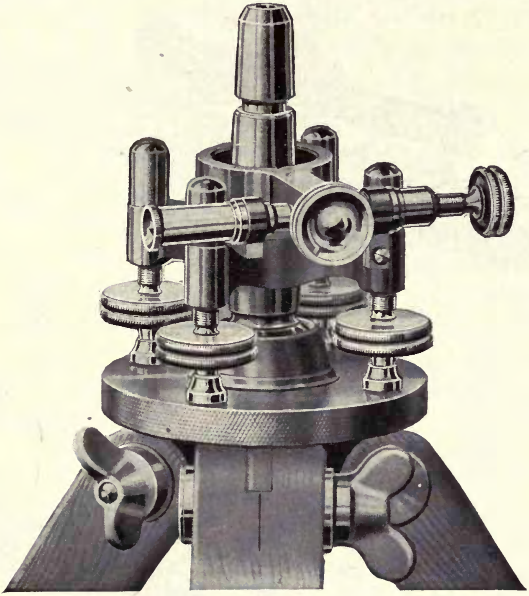


FIG. 41

No. 242 LEVELING HEAD

To fasten the band to the sight, bring up the clamp screw with a pressure just sufficient to hold the band to its place, tighten the screw on the left until the band is against the right edge of the sight, and finally tighten the clamp screw.

To focus the telescope, turn the end of the eyepiece by the spiral motion of the tube until the cross wires are brought into distinct view. The objective is then

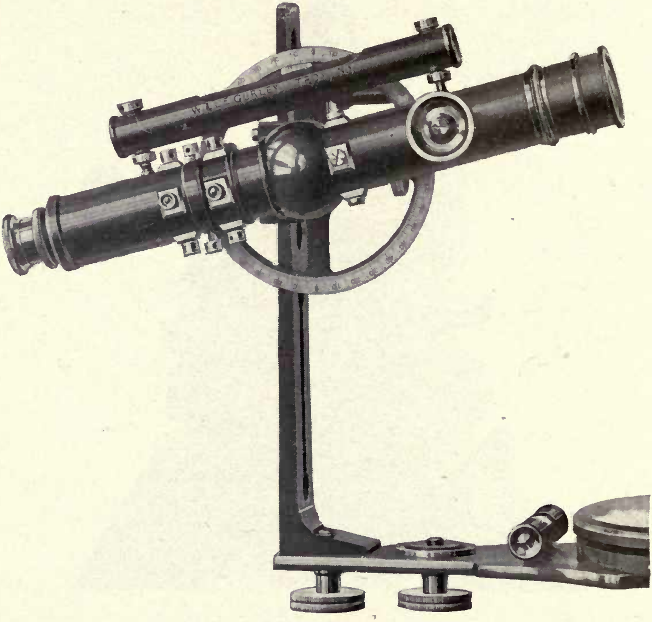


Fig. 42

NO. 262 TELESCOPIC SIGHT, WITH ATTACHED VERTICAL CIRCLE NO. 265, LEVEL ON TELESCOPE NO. 266, AND CLAMP AND TANGENT NO. 267

moved in either direction by the pinion on the side of the telescope, until the object is clearly seen.

The optical axis of the Telescopic Sight is at one side of the line of sight of the sight vanes, but parallel with it. The difference between a sight taken with the sight vanes and one taken with the telescope is so small that it may be disregarded in any survey made with the magnetic needle. If all the lines are run with the Telescopic Sight, the angles measured will be as accurate as if the optical axis of the telescope was in the line of sight of the sight vanes.

The telescope is nine inches long, has a power of about 20 diameters and is furnished with stadia wires in addition to the cross wires.

OFFSET STANDARD. When desired, the Telescopic Sight may be mounted upon an Offset Standard with Counterpoise, and so arranged that the line of sight is in line with the zeros of the compass circle. When in use, this standard with the telescope attached, is substituted for the south sight of the compass.

When furnished with a new instrument the telescope is packed in the box with the compass, but it can be safely sent by mail to any part of the country, packed in a case in which it may be kept when not in use.

In the illustration on page 160, the telescope No. 262 is shown fitted with a vertical circle, a level, and clamp and tangent. For simple sighting, the level and circle can, of course, be dispensed with, but in the use of the stadia they are very desirable.

When measurements are to be recorded in chains and links, the stadia wires should be made to cover one foot at a distance of sixty-six feet; if recorded in feet, the wires should cover one foot at a distance of one hundred feet.

The rod used with the stadia should be graduated to feet and decimals of a foot. The various styles of rods are more fully described on pages 206 to 237.

FIG. 43

COMPASS FITTED WITH NO. 262 TELESCOPIC SIGHT HAVING LEVEL, CLAMP AND TANGENT AND VERTICAL CIRCLE, MOUNTED ON NO. 268 OFFSET STANDARD WITH COUNTERPOISE

In using the stadia, the lower wire is brought by the tangent screw precisely upon an even foot graduation of the rod, the upper wire is read, the smaller reading subtracted from the larger and the distance recorded.

ADVANTAGE OF THE TELESCOPE. The advantage of the telescope over the sight vanes is readily apparent. Much longer sights can be taken, either fore or back, and lines run up and down steep hillsides with the same facility as on level ground, and with more accuracy, and with great relief to the eyes of the surveyor, often severely strained by the use of the sight vanes of the compass. Indeed, it may be said that with this simple attachment every compass can be transformed into a transit compass, and the advantages of the telescope brought within the reach of every surveyor, at small cost.

TO ADJUST THE TELESCOPIC SIGHT

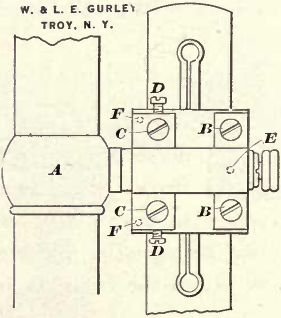
To make the adjustments, and indeed to do any correct work with a compass, the level bubbles should remain in the middle when the instrument is turned upon its spindle, and the sights should trace a vertical line when the compass is level.

The means of effecting the adjustments will be understood by referring to page 164.

TELESCOPE AXIS. To make the telescope axis horizontal, the compass being in good order, first bring the levels into the middle and place the band in position upon the sight, as before described. Focus the telescope, and set the vertical cross wire on the edge of a building, or a long plumb line, 50 to 60 feet distant. If the vertical wire is not parallel with the edge or line, loosen the capstan head screws and turn the diaphragm by the screw heads until the correction is made, then tighten the screws. Next, sight at a point on the edge or line, near the ground.

Clamp the compass to the spindle, and point the telescope to the top of the building or line. If the wire strikes to the right of the edge, it shows that the right end of the telescope axis is the lowest.

To raise it, loosen the screws, B B, C C, which hold the piece containing the axis of the telescope, and by the screws, D D, the lower of which should be unscrewed and the upper one tightened, raise the telescope until the wire will follow the vertical line.



If the cross wire strikes to the left when the telescope is raised, proceed exactly the reverse in making the correction, until the wire will follow the edge from one end to the other.

Line of Collimation. To bring the line of collimation into a position at right angles with the axis of the telescope, so that the cross wires will indicate two points in opposite directions in the same straight line, proceed as directed for transits on pages 77 to 79.

ADJUSTMENT OF TELESCOPE TO THE SIGHTS. Find an object from three hundred to four hundred feet distant, which the sight vanes will intersect. Clamp to the spindle and sight through the telescope at the object. If the vertical wire strikes to the right, loosen the screws B B, and screw up those in front, marked F F, the ends only of which are shown in the figure, until the vertical wire bisects the object, looking again through the vanes to see that the same object is seen through both telescope and sights. If the cross wire should strike to the left of the object, proceed in a manner exactly the reverse until the error is corrected.

COMPASS WITH LIMB AND TELESCOPE

1920 Model

This new model was designed to meet the needs of engineers and surveyors who do not have constant use for an expensive transit and yet desire an instrument which will enable them to do a greater variety of work than is possible with the ordinary sight compass.

It is a highly developed form of a Telescope Compass and has the added characteristics of a light Transit; thus it can be successfully used for ordinary land surveying, preliminary or reconnoissance surveys, mine surveys, etc., in fact for a variety of work in which rapidity, ease of operation and portability, rather than extreme accuracy, are the essential factors. Engineers and Surveyors, as well as Explorers, will find this instrument a desirable addition to their equipment, enabling them to reserve their valuable Transits for precise work. The needle is of unusual length for such a compact instrumnt, making it ideal for accurate compass surveys.

The weight of the compass without the tripod is seven and one quarter pounds and the tripod weighs about four and one half pounds.

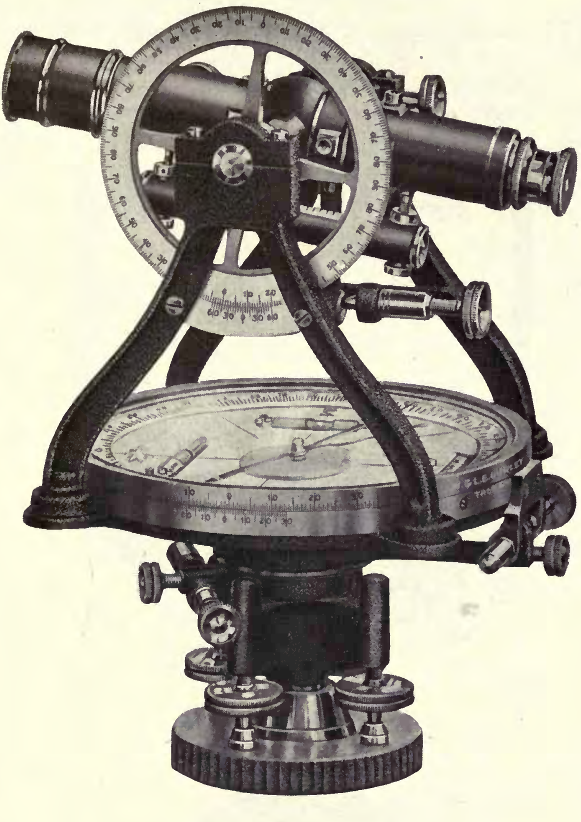


Fig. 44

No. 294 Compass with Limb and Telescope

superseding instruments previously listed as no. 293 and no. 293-A

POCKET COMPASSES

WE manufacture a variety of small instruments which are so portable and at the same time so efficient that they are often used, in preference to the larger ones, for preliminary or reconnoissance work.

FIG. 45
NO. 285 POCKET COMPASS WITH LIMB

POCKET COMPASS WITH LIMB

The limb of this compass is five inches in diameter, graduated to half degrees and figured like limb I page 36. The vernier which is placed at an angle of 30 minutes to the line of sight reads to single minutes.

The needle circle is graduated to half degrees and is figured from 0 to 90 each way. The needle is three and one half inches long and the magnetic declination can be set off to single minutes.

The sights fold down closely for convenience in packing and are made half slit and half hair so that back sights may be taken without turning the limb.

This instrument can be used for a great variety of work and with the light extension tripod is especially adapted to surveys of mines where angles must be taken independently of the needle.

GEOLOGISTS COMPASS

This compass has proven admirably adapted for topographical work, and has been adopted by the U. S. Forest Service for the use of field men in making forest surveys and maps. If properly used, accurate work can be done with this small and compact instrument.

It is made of aluminum to decrease weight and has a needle $2\frac{5}{8}$ inches long enclosed with its compass circle in a circular box set on a plate 4 inches square. With the improved needle lifter as shown, a water and dust-proof needle box is assured.

The edges of this base are beveled and graduated, two for a tangent scale and two to inch scales. One of these latter is graduated to eighths, each of which represents ten chains, and the other is decimal. The compass circle is made movable, and by a vernier attached to it on the inside the magnetic declination may be set off to 5 minutes.

On the under side of the plate is a township plat.

On the compass face is an arc of 180 degrees figured on each side of the 0 line from 0 to 90. A weighted pendulum hung from the center pin indicates, by its pointer on this arc, the angle of slope, when the compass is placed so that it rests on its west edge. On the outside of the box containing the compass circle is a movable circle, beveled and graduated on its upper edge and figured from 0 to 90, and having at each quadrant a slit for sighting.

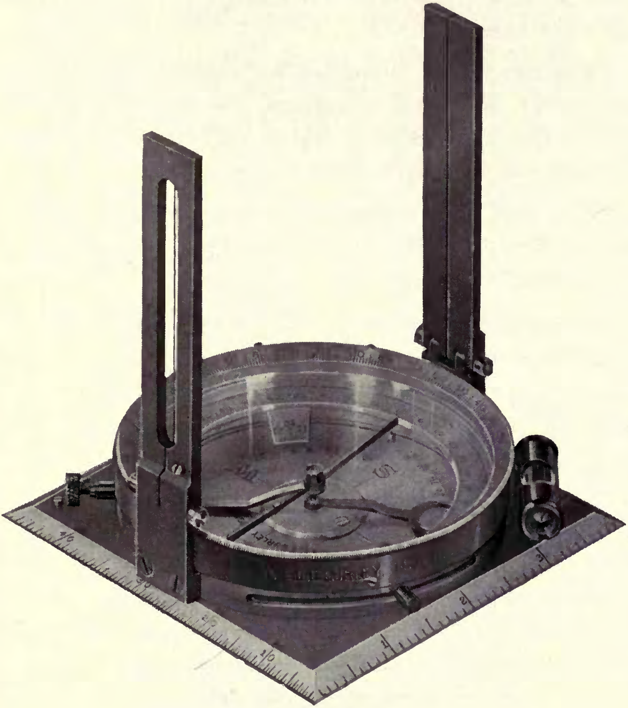


Fig. 46

No. 335 Geologists Compass

U. S. FOREST SERVICE PATTERN

Two tall folding sights are attached to the edge of the circular box, one having a slit and the other a hair. Two levels are placed at right angles with each other upon the base.

The compass is supported on a simple ball spindle and socket, with staff mountings, and is usually carried in a leather pouch with shoulder and belt straps. Such a pouch can be supplied for an extra price.

The staff cap is slotted to allow vertical angles to be read by means of the pendulum while the compass is on the staff or tripod.

Tripods Nos. 416, 421 and 426 are suitable for use with this compass.

The Dip Compass consists essentially of a magnetic needle so suspended as to move readily in a vertical direction, the angle of inclination, or "dip," being measured upon the graduated rim of the compass circle.

When in use, the ring or ball is held by the hand, and the compass box by its own weight assumes a vertical position. It must be held in the plane of the magnetic meridian. In this position the needle, when unaffected by the attraction of iron, assumes a horizontal line, as shown by the zeros of the circle. When brought over any mass of magnetic iron ore it dips, and thus detects the presence of such ore with certainty.

If the Dip Compass is held horizontal, it serves as an ordinary pocket compass, and indicates the magnetic meridian, in the plane of which it should be held when used to ascertain the dip.

Dip Compasses have a 3 inch needle, provided with a stop which is released by screwing down the clamp in the ball. The new style needle clamp enables the instrument to be held and controlled to the best advantage. The improved form of needle release is positive in action, durable in construction and not liable to injury. The Compasses have the two sides of glass and are furnished with removable brass covers.

The needle of our Dip Compasses is adjusted to read 0 at Troy, N. Y., when held in the plane of the magnetic meridian, but it may read differently in another place.

The readings of these compass needles are always relative and not absolute; therefore, if a needle is held in the plane of the meridian, in a place where it is known that there is no magnetic attraction, and the

FIG. 47
No. 341-A DIP COMPASS

reading is carefully noted; and the needle is then held in the plane of the meridian where magnetic attraction is suspected, a different reading will show the presence of some magnetic body, whether the needle is, in the first case, perfectly horizontal (reads to zero) or not.

When in use the needle should always be held so that it will swing freely in the plane of the meridian, the stops being drawn entirely out of the way.

When not in use the clamp should be unscrewed so that the needle is securely held.

There is no instrument made which will indicate the presence of gold or silver.

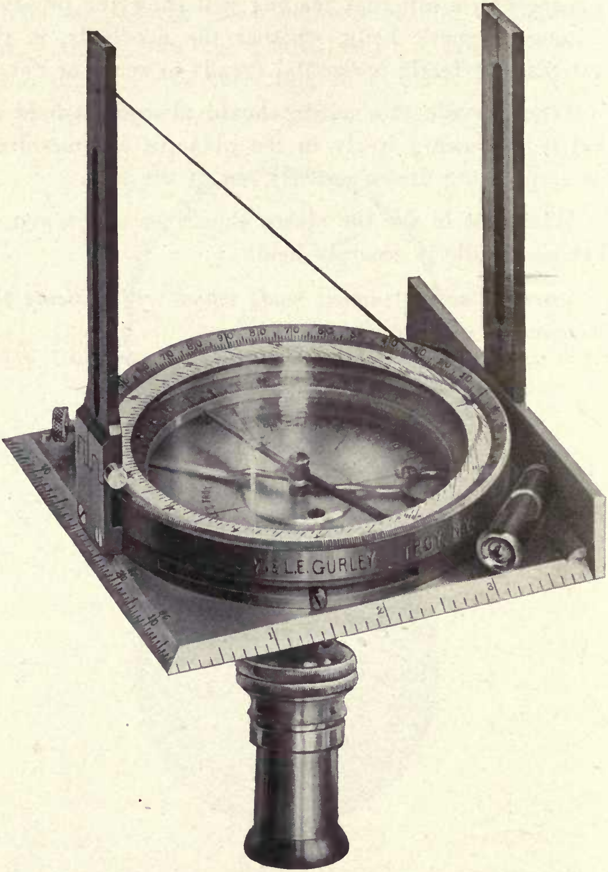


FIG. 48

No. 350 DIAL COMPASS

U. S. GEOLOGICAL SURVEY PATTERN

DIAL COMPASS

A rough method of detecting the presence of large bodies of magnetic ore is by a compass directed in the meridian by means of apparent time on a Sun dial. Allowing for the magnetic declination for that location any variation by the needle from the magnetic meridian will indicate local attraction. This instrument, made of aluminum, has a needle two and five eighths inches long, and with its compass circle is enclosed in a circular box set upon a base 4 inches square, three edges of which are chamfered and graduated, the one on the W side of the compass into inches and tenths and the two others into degrees and half degrees, and figured from a center on the southwest corner of the base.

The compass circle is movable, in order to set off the magnetic declination, and has a vernier attached to it on the inside, by which a graduated arc on the face of the compass is read to 5 minutes.

With the improved needle lifter as shown, a water and dust-proof compass box is assured. The staff cap is slotted to allow vertical angles to be read by means of the pendulum while the compass is on the staff or tripod.

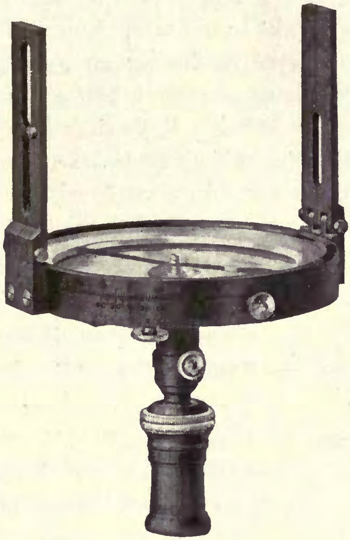
There is also on the south side of the face an arc of 180 degrees, figured from 0 to 90 on each side of the south or zero line of the face.

A pendulum with index point hung from the center pin reads this arc when the compass is set up vertical on the raised south edge, thus making it a clinometer or slope measurer.

FIG. 49

NO. 3154 WOOD BOX POCKET COMPASS

POCKET VERNIER COMPASS



NOS. 300 AND 305

The Pocket Vernier Compass is an excellent and portable instrument for preliminary work, having a fine needle and a vernier and clamping nut, by which the sights can be placed at an angle with the line of zeros, so as to set off the magnetic declination as with the Vernier Compass No. 226.

The instrument has folding sights, two levels and staff mountings, and is packed in a mahogany case.

We make two sizes of the Pocket Vernier Compass, having needles respectively three and one half and four and one half inches long. In the smaller instrument the sights have a slit in the south vane and a hair in the north vane, for readily finding an object; but in the larger size the sights are made half slit and half hair, as shown on page 180-A. Both sizes have the compass circle graduated to half degrees. In the smaller size the vernier of the variation arc reads to five minutes, and in the larger size to single minutes. The instrument may be used, if desired, upon a light tripod, No. 416, No. 421 or No. 426.

When ordered, a rack movement with pinion is added, by which the magnetic declination may be set off more readily.

The compass with three and one half inch needle weighs about one and three quarters pounds; that with four and one half inch needle about two and three quarters pounds.

LEVELING INSTRUMENTS

ENGINEERS WYE LEVEL

OF the different varieties of leveling instruments, the Wye Level is universally preferred by American engineers on account of its accuracy, durability, ease and permanence of adjustment.

We manufacture four sizes of Wye Levels, having telescopes, twenty-two, eighteen, fifteen, and twelve inches in length; the smallest size is called the Architects Level. The illustration on page 182, represents the two largest sizes.

TELESCOPE. The telescope has near its ends two rings of bell metal turned truly and of precisely the same diameter. On these rings it rotates in the wyes; or it can be clamped, when the clips of the wyes are brought down upon the rings, by pushing in the tapering pins.

The telescope of the twenty-two inch and eighteen inch levels has a pinion movement to both the objective and eyepiece slides, and an adjustment for centering the eyepiece slide, shown at AA in the sectional view, Fig. 51, page 183. The arrangement for insuring the accurate projection of the objective slide is also shown at C, in the same illustration. Both of these adjustments are protected from disturbance by thin cover bands which screw over them. The objective slides of the fifteen inch and the twelve inch levels have pinion movements but the eyepieces have spiral or screw motions.

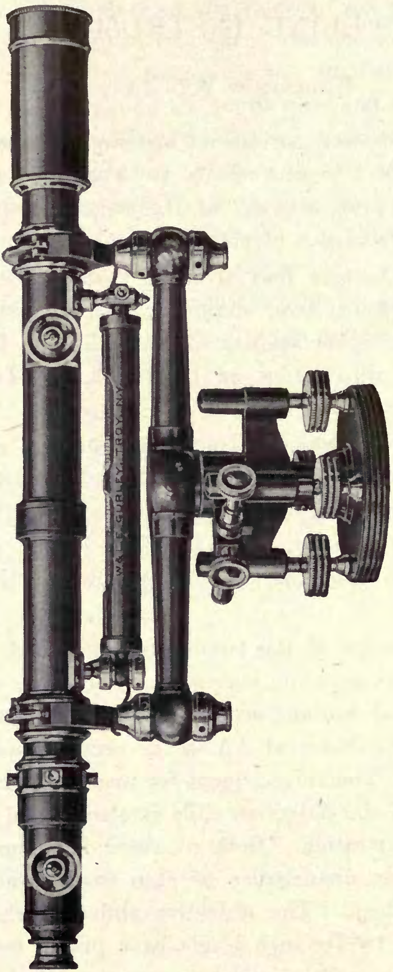


FIG. 50

No. 375 ENGINEERS WYE LEVEL, 22 IN. TELESCOPE
No. 377 ENGINEERS WYE LEVEL, 18 IN. TELESCOPE

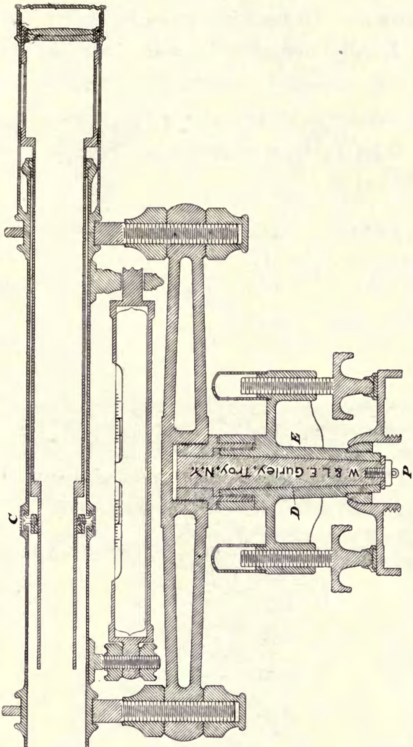


FIG. 51

SECTIONAL VIEW OF GURLEY ENGINEERS WYE LEVEL

The objective slides on the eighteen and twenty-two inch Wye Levels are fitted with our improved dust guard, Fig. 2, which is secured to the main telescope and which remains stationary while the slide is moved in or out, thus fully protecting it against injury from any outside cause.

Short Focus. The telescopes of our Wye Levels, like those of our transits, are arranged so that they may be focused upon an object much nearer the instrument than was formerly possible.

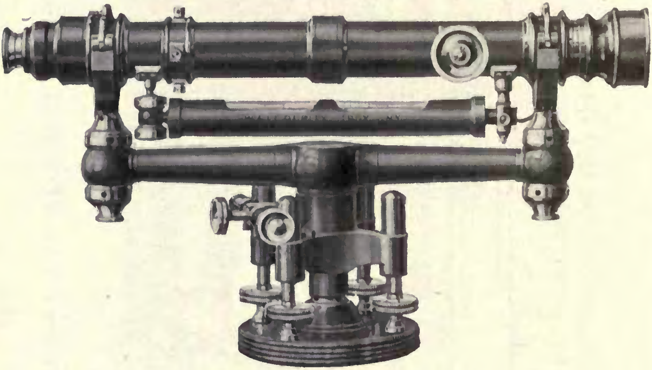


Fig. 52

No. 378 Engineers Wye Level
15 inch telescope

The improvement will often be of decided advantage to the engineer. Care, however, should be taken when using the instrument at short distances to correct the level vial if it is slightly out of center when the instrument is thrown out of balance by the projection of the slide.

Fig. 53

VIEW OF ENGINEERS WYE LEVEL EQUIPPED WITH A HORIZONTAL CIRCLE, A COMPASS, AND A LEVEL BUBBLE MIRROR.

Compass. A compass with a three inch needle for obtaining the bearings of lines is sometimes attached to the telescope in such a manner as to be readily removable when desired. Fig. 53.

Horizontal Circle. For laying off angles, a horizontal circle three and one half inches in diameter can be fitted to the leveling head of the Wye Level. The circle is graduated to degrees, and is read by vernier to five minutes. Fig. 53.

Mirror. For convenience in observing the level bubble, a mirror can be attached.

Objective Slide. The interior construction of the telescope will be understood from the sectional view, Fig. 51, page 183.

The adjustment for the objective slide, which is a distinctive feature of Gurley instruments, permits the accurate projection of the slide throughout its whole range. This adjustment makes possible the alignment of *both* cross wires with equal accuracy, which could not be accomplished without it. The slide is always adjusted in the process of manufacture and needs no attention from the engineer, unless the instrument is severely injured.

The advantages of an eyepiece pinion are that the eyepiece can be moved without danger of disturbing the telescope, and that the wires are brought more certainly into distinct view, so as to avoid any error of observation arising from instrumental parallax.

Level Vial. The level tube, with ground and graduated vial scale is attached to the under side of the telescope, and furnished at different ends with the usual movements in both horizontal and vertical directions.

The level vial F, Fig 51, is a glass tube with an even bore from end to end, and ground on its inner surface, so that the run of the air bubble may be uniform throughout its whole range. The level graduated scale is etched on the glass.

Wyes. The Wyes, Q, of our levels are large and strong, of hard bronze, and each have two adjustable capstan nuts, S. The clips are held down on the rings of the telescope tube by the Wye pins, which are tapering so as to secure the rings firmly. The clip of one of the Wyes has a pin projecting from it, which, entering a recess in the edge of the ring, insures the horizontal position of the cross wire.

LEVEL BAR. The level bar is round, of the best bell metal, and shaped for greatest strength in the parts most liable to sudden strains. Connected with the level bar is the head of the leveling socket.

SPINDLE. The instrument is supported on a tapered steel spindle which is fitted in a socket extending entirely through the leveling head.

SOCKETS. Projecting from the socket are four arms, E, heavily ribbed and tapped at the ends to receive the leveling screws. The leveling screws are so threaded that they fit the long nuts accurately, and have caps protecting the threads from dust.

BOTTOM PLATE. Attached to the end of the leveling socket by a hemispherical nut is the bottom plate of the leveling head, which is so spaced with reference to the leveling socket that it pivots easily upon it with the movement of the leveling screws.

The length of the steel spindle and the wide spacing of the leveling screws secure stability and delicacy of adjustment for the most accurate work.

LEVELING HEAD. The leveling head is similar in construction to that of the transit, (see page 42). The tangent screw has also an opposing spring, as there described.

Architects Level

The Architects Level is extensively used by architects, builders and millwrights for leveling and laying off angles of foundations for buildings, machinery, shafting, etc., as well as by engineers and surveyors for the grading of streets, sewers and drains.

The instrument has a telescope twelve inches in length, furnished with rings and wyes like that of the larger levels and is adjusted in the same manner. As now made, the telescope can be focused upon an object six and one half feet from the center of the instrument.

The leveling head has a clamp to the spindle, and a tangent movement. It has also a horizontal circle three inches in diameter, fitted to the upper end of the socket and turning readily upon it. The circle is graduated to degrees, figured from 0 to 90 each way, and is read to five minutes by a vernier which is fixed to the spindle.

The telescope is directed to any object by hand, the spindle turning readily in its socket; but it can be clamped in any position by the clamp screw and accurately pointed by means of the tangent screw.

The instrument is placed either upon a light tripod or on a small triangular plate called a "trivet," having three sharp steel points by which it is firmly set upon any surface. Both tripod and trivet are furnished with the level.

A sun shade is also supplied, to put over the objective to protect it from the glare of the sun.

ADJUSTMENTS. The adjustments of the Architects Level are made exactly as specified in the description of the larger levels. They are not liable to derangement, and will ordinarily require but little attention.

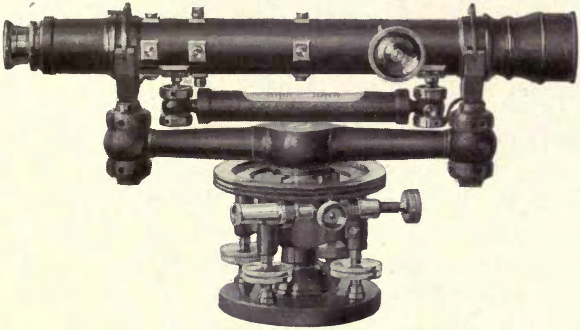


FIG. 54

NO. 381 ARCHITECTS LEVEL

ONE SIZE

TO ADJUST THE WYE LEVEL

The adjustments which are common to all Wye Levels, and with which the engineer should be familiar, are:

To adjust the line of collimation, or, in other words, to bring the intersection of the cross wires into the longitudinal axis, so that this point will remain on any given point during an entire rotation of the telescope;

To bring the level parallel with the bearings of the wye rings, or with the longitudinal axis of the telescope;

To adjust the wyes or to bring the level into a position at right angles with the vertical axis of the instrument.

Before beginning the adjustment it is well to set the cross wires approximately horizontal. This adjustment cannot be accurately made until the other adjustments are completed.

To Adjust the Line of Collimation. Set the tripod firmly, remove the wye pins from the clips so as to allow the telescope to turn freely, clamp the instrument to the leveling head, and by the leveling and tangent screws bring either of the wires upon the clearly marked edge of some object, distant from one hundred to five hundred feet. Then with the hand carefully rotate the telescope half way around, so that the position of the same wire is compared with the object selected.

Should it be found to one side of the wire, bring it half way back by the capstan head screws at right angles with it, always remembering the inverting property of the eyepiece; bring the wire again upon the object and repeat the first operation until it will reverse correctly. Proceed in the same manner with the other wire until the adjustment is complete. Should both wires be much out, it will be well to bring both nearly correct before either is finally adjusted.

When this is effected, unscrew the covering of the eyepiece centering screws, shown in the sectional view at A A, page 183, and move each pair in succession with a screw driver until the wires are brought into the center of the field of view. The inverting property of the eyepiece does not affect this operation, and the screws are moved directly.

To test the correctness of the centering, rotate the telescope and observe whether it appears to shift the position of an object. Should any movement be apparent, the centering is not perfectly effected. In all telescopes the line of collimation depends upon the relation of the cross wires and objective, and therefore the movement of the eyepiece does not affect the adjustment of the wires in any respect.

When the centering has once been effected it remains permanent, the cover being screwed on again to protect it from derangement.

TO ADJUST THE LEVEL VIAL. Clamp the instrument over either pair of leveling screws, and bring the bubble into the middle of the tube. Turn the telescope in the wyes so as to bring the level tube to one side of the middle of the bar. If the bubble runs to the end, it indicates that the vertical plane passing through the middle of the bubble is not parallel with that drawn through the axis of the telescope rings.

To correct the error, bring the bubble, by estimation, half way back by the capstan head screws on each side of the level holder, placed usually at the objective end of the tube. Again, bring the level tube over the middle of the bar and the bubble to the middle, turn the level to either side, and, if necessary, repeat the operation until the bubble will keep its position when the tube is turned half an inch or more to either side of the middle of the bar.

The necessity for this operation arises from the fact that, when the telescope is reversed end for end in the wyes in the other and principal adjustment of the bubble, we are not certain of placing the level tube in the same vertical plane, and therefore it would be almost impossible to effect the adjustment without a lateral correction.

Having now largely removed the initial difficulties, we proceed to make the level tube parallel with the bearings of the wye rings.

To do this, bring the bubble into the middle with the leveling screws, and then, without jarring the instrument, take the telescope out of the wyes and reverse it end for end. Should the bubble run to either end, lower that end, or, what is equivalent, raise the other by turning the adjusting nuts on one end of the level until, by estimation, half the correction is made. Again bring the bubble into the middle by the leveling screws, and repeat the whole operation until the reversion can be made without causing any difference in position of the bubble in the bubble.

It would be well to test the lateral adjustment from time to time during this operation and make such corrections as may be necessary in that, before the vertical adjustment is entirely completed.

TO ADJUST THE WYES. Having made the previous adjustments, it remains to bring the level into position at right angles with the vertical axis, so that the bubble will remain in the middle during an entire revolution of the instrument.

To do this, bring the level tube directly over the middle of the bar and clamp the telescope in the wyes, placing it as before, over two of the leveling screws. Unclamp the socket, center the bubble, and turn the instrument half way around, so that the level bar may occupy the reverse position in respect to the leveling screws beneath.

Should the bubble run to either end, bring it half way back by the wye nuts on either end of the bar. Place the telescope over the other pair of leveling screws, bring the bubble again into the middle, and proceed as above described, changing to each pair of screws successively until the adjustment is very nearly perfected, when it may be completed over a single pair.

When the level has been thus completely adjusted, if the instrument is properly made and the socket well fitted, the bubble will reverse over each pair of screws in any position.

This adjustment is not essential, but is convenient. If the level has been adjusted parallel to the line of collimation, the line of sight will always be a level one if the bubble so indicates. With a precise level this adjustment is not made, but the bubble is carefully viewed at the time of sighting.

Should the engineer be unable to make the instrument work correctly, the error is probably caused by some injury to the spindle or socket.

In such case the instrument should be sent directly to the maker, if possible, as the injury may require skilled attention.

The adjustments having been completed, and the instrument being precisely level, the engineer should rotate the telescope in the wyes until the pin on the clip of the wye will enter the recess in the ring to which it is fitted, and by which the horizontal position of the cross wire is insured.

When the pin is in its place, the horizontal wire may be compared with any level line, and in case it should not be parallel with it, two of the cross wire screws that are at right angles with each other may be loosened and, by the screws outside, the cross wire ring turned until the wire is horizontal. The line of collimation must then be corrected again, and the adjustments of the level will be complete.

To Adjust the Objective Slide. The adjustment of the objective slide is a distinctive feature of Gurley instruments and is always made by us so permanently as to need no attention at the hands of the engineer, unless in case of derangement by accident.

In making this adjustment, it is necessary to remove the level tube in order that the screw immediately above it may be accessible.

To adjust the objective slide, select an object as distant as may be distinctly observed, and upon it adjust the line of collimation, in the manner described on page 190, making the intersection of the wires to rotate in the wyes without passing either above or below the point or line selected. In this position the slide will be drawn in nearly as far as the telescope tube will allow.

With the pinion head then move out the slide until an object, distant about ten or fifteen feet, is brought clearly into view. Again rotating the telescope in the wyes, observe whether the wires will reverse upon this second object.

Should this be the case, it is assumed that, as the line of collimation is in adjustment for these two distances, it will be for all intermediate ones, since the bearings of the slide are true and their surfaces parallel with each other.

If, however, either or both wires fail to reverse upon the second point, by estimation, remove half the error by the screws at C (Fig. 51, page 183), at right angles with the wire to be corrected, remembering that, on account of the inverting power of the eyepiece, the slide must be moved in the direction which apparently increases the error. When both wires have been thus treated, the line of collimation is again adjusted on the near object, and the telescope again brought upon the most distant point. The tube is again rotated, the reversion of the wires upon the object once more tested, and the correction, if necessary, made in the same manner.

Explorers Level

The telescope of this level is fastened rigidly and permanently to the spindle and the level is for this reason of dumpy design.

This small, light model was designed to meet the requirements of engineers for a compact serviceable instrument for running preliminary lines in exploration work where it is not convenient to operate a large instrument. It is used by many who desire an accurate and at the same time an extremely portable level.

The Explorers Level is a companion instrument to our Explorers Transit and Explorers Alidade, and can be packed with them in an ordinary twenty-four inch suit case, including one jointed extension tripod as shown on page 59.

To Adjust the Explorers Level. By means of the leveling screws and the nuts at the ends of the level vial, adjust the level until the bubble will remain in the center when the instrument is rotated on the spindle. Then adjust the cross wires by means of the two peg method as follows. Drive two stakes, opposite sides of, and at equal distances from, the instrument, say 200 or 300 feet. Sight on a rod placed consecutively on each stake. Drive the highest one until the reading on both are alike, or make allowance for the difference in reading. The points read by the level will now be in the same horizontal line, however much the telescope may be out of adjustment. Remove the instrument to a point less than 50 feet to one side of either stake and in approximate line with both. Again level the instrument and note the heights indicated upon the rod placed on each stake. If not the same, adjust the cross wires by means of the capstan head screws over nearly the whole error on distant stake and repeat until the readings on both stakes are alike.

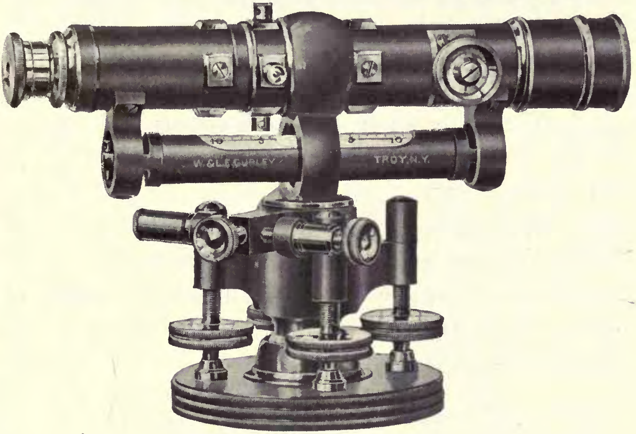


FIG. 55
No. 384 EXPLORERS LEVEL

Bring the wires into the center of the field of view, by centering the eyepiece by means of the four screws lettered A in the sectional view on page 183, which does not affect other adjustments, and the instrument is ready for use.

To Use the Level

When using a level, the legs of the tripod must be set firmly into the ground, and the bubble brought over each pair of leveling screws in turn and leveled in each position, the necessary corrections having been made in the adjustments.

Care should be taken to bring the wires precisely into focus, and the object distinctly into view, so that all errors of parallax may be avoided. In all instances, the wires and object should be brought into view so perfectly that the cross wires will appear to be fastened to the surface, and will remain in that position however the eye is moved.

In running levels it is best, wherever possible, that equal fore and back sights should be taken, to avoid any error arising from the curvature of the earth, and also to compensate for any errors of adjustment in the instrument.

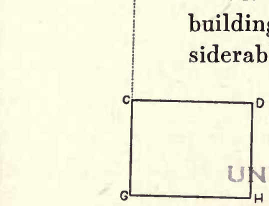
To Use the Architects Level

The instrument having been carefully leveled, focus the eyepiece and objective upon the object as before described, and the horizontal cross wire will give any number of points required, which will all be in the same level plane.

A board held erect will answer as a rod, and a pencil line drawn across it at the place cut by the horizontal wire will give the height of the starting point. Any different points on the rod, either above or below that indicated by the cross wire, will show the difference in height of the various points observed, as compared with the starting point.

Laying off Angles. In laying off angles with the Architects Level, the bubble should first be brought into the middle as before described, and the vertical cross wire made to cut the object or line from which the angle is to be taken. Then, the spindle being clamped by the milled head screw under the circle, the circle is turned around by hand until the zero lines of both circle and vernier are made to coincide. Loosen the clamp screw and turn the telescope to the point desired, and the angle between the two points will be read off on the circle.

By the use of the vernier, angles can be read on the circle to five minutes, but ordinarily only the middle line of the vernier is used, and the angle read to the nearest degree.



The point underneath the center of the instrument is indicated by the point of the plummet suspended from the leveling head.

In many cases, after the walls of a building have been carried up to a considerable height, it becomes difficult to set up the tripod, and in this case the level is screwed upon the trivet, which can be set upon the wall or a piece of board secured to the building, or indeed upon any surface nearly level and not less than six inches square.

To illustrate the value of this instrument in laying out the sites of buildings, suppose it is desired to erect a building, C D, at right angles with a building, A B, and at a given distance from its front.

First set up the level at E, and carefully center the bubble, the point of the plummet below the required distance of the side of the new building from the front, A B. Measure the same distance at the other corner of A B, and, having erected the rod, sight upon it with the telescope and clamp to the spindle.

Now carry the rod the required distance from B, and move it from side to side until it is again in line with the telescope, as at C.

Remove the instrument, and having carefully set it over the point C, by the plummet, and brought the bubble into the middle as before, sight the telescope again upon the rod placed at E or F, and clamp to the spindle. Bring the zeros of the circle and vernier to coincide, unclamp, and turn the vernier to ninety degrees; this will give a point, D, at any required distance from C, and C D will be the side of the proposed building. The side, C G, is determined by turning the telescope around until the vernier is in line with the other zero of the circle, and thus the corner, C, and the two sides, C D and C G, are at once set off, and the remaining corner, H, easily ascertained by making D H and G H equal to C G and C D, respectively.

Other uses of the level, as the setting of floor timbers, of window and door sills and the leveling of floors, will readily occur to one who has been engaged in building. To the millwright such a level is almost indispensable in the aligning and leveling of shafting, in ascertaining the fall of water obtainable, and in determining the overflow of land by a mill pond. The farmer will find it of value in locating and laying out drains, ascertaining the height of springs and similar work.

This level has become widely known, and its simplicity, excellence and moderate cost have created a great demand for it.

HAND LEVELS

FOR RAILWAY RECONNOISSANCE AND LOCATION, AND WHEREVER APPROXIMATE LEVELING IS REQUIRED

Locke Hand Level. This instrument consists of a brass tube about six inches long, having a level vial on top near the object end, as shown. There is an opening in the tube beneath, through which the bubble can be seen, as reflected by a prism immediately under

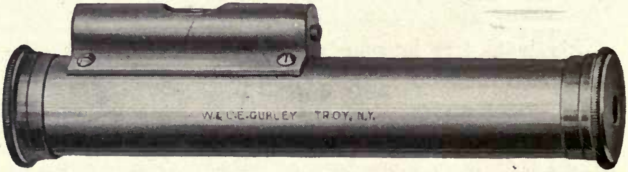


Fig. 56
No. 643 Locke Hand Level

the level vial. Both ends of the tube are closed by disks of plain glass to exclude dust, and there is at the inner end of the sliding or eye tube a semi-circular convex lens, which serves to magnify the level bubble and the cross wire beneath, while it allows the object to be clearly seen through the open half of the tube.

The cross wire is fastened to a frame moving under the level tube, and adjusted to its place by the small screw shown on the end of the level case. The level of any object in line with the eye of the observer is determined by sighting upon it through the tube, and bringing the bubble of the level into a position where it is bisected by the cross wire.

ABNEY LEVEL AND CLINOMETER. The Abney Level is a modification of the Locke Hand Level, combining with it an excellent clinometer.

The main tube being square, it can be applied to any surface, the inclination of which is ascertained by bringing the level bubble into the middle, and reading off the angle to five minutes by the arc and vernier.

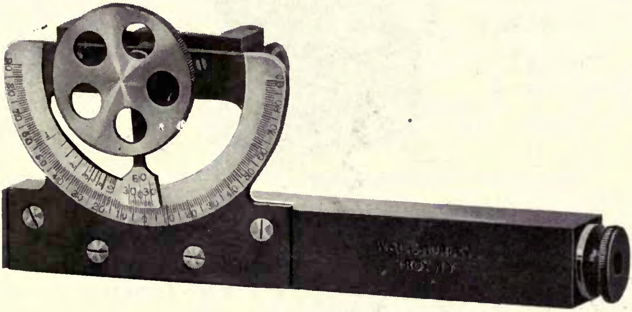


FIG. 57

No. 646 ABNEY LEVEL

When sighted at an object and the bubble brought into the middle, the vertical angle from the height of the eye is indicated. When at zero it indicates a level line.

The inner and shorter arc indicates the lines of different slopes, the left edge of the vernier plate being applied to the lines, and the bubble brought into the middle as usual. Graduations can also be furnished to indicate per cent of grade. A small compass, with needle about one and one half inches long, is sometimes attached to the upper surface of the Abney Level, with a plain staff socket below.

Fig. 58

No. 640 Monocular Hand Level

The Monocular Hand Level, shown in No. 640, consists of a tube to which are fitted the lenses of a single opera glass, and which also contains a reflecting prism, a cross wire, and a level vial, the latter being seen in the open part of the tube.

The eye lens, as indicated in the illustration, is composed of two separate pieces, the larger one being the usual concave eye lens of the opera glass, and the smaller a segment of a plano-convex lens having its focus on a cross wire under the level vial and above the reflecting prism.

The observer holds the tube horizontal with the level opening uppermost, and observes the object to which the instrument is directed, and the position of the level bubble with reference to the cross wire on the under side of the level vial.

When the hand level is held truly horizontal the cross wire will bisect the bubble, and will determine the level of any object seen through the telescope, thus securing to the observer a clear view of the object, magnified by the telescope.

LEVELING RODS

A GOOD Leveling Rod is as important a part of the essential equipment of every engineer or surveyor as a good Transit or Level. It should, therefore, be selected with equal care, always bearing in mind that a permanently accurate and durable rod cannot be obtained at a low price.

Gurley rods have steadily grown in favor with discriminating users, whose experience has convinced them that the greatest satisfaction under varying service conditions can be obtained with these rods. With the intention of having Gurley rods absolutely the best that can be made, constant study and experiments are carried on and no expense is spared.

A good rod has accurate graduations, retains its straightness, never binds, stands the hard knocks of field use, is easy to read and stays that way for years. As official evidence of the accuracy of Gurley rods, we are prepared to submit copies of reports made from tests by the United States Bureau of Standards. The rods tested were furnished from our regular stock to the people who secured the certificates; they were not selected for the purpose.

Gurley rods are used extensively by many departments of the U. S. Government and the most critical work, necessitating the utmost precision, has been performed with rods of our manufacture.

Special Rods. Many engineers need rods of special pattern, graduation or shape adapted to the particular requirements of their practice. We make to order rods of any design and will submit estimates of cost to those who desire them and who furnish us with data showing the details required.

CONSTRUCTION

THE first essential in the manufacture of rods is the material, and experience has shown that certain localities produce wood better suited for this purpose than others. Our expert personally examines a large quantity of the lumber and selects only that which straightness of grain and freedom from flaws make fit for our use. The peculiarities of grain and texture that develop in the different woods due to the varying climatic conditions under which they have grown must be kept in mind when making this selection.

The blanks, after having been cut to the desired sizes, are stored and carefully air dried until they are thoroughly seasoned. Any blank that warps in drying is immediately rejected.

The blanks are especially treated to enable the rods to withstand the varying climatic conditions to which they will be subjected. This method of careful preparation and inspection is expensive, but is justified by the excellence of the finished product.

GRADUATING. The engine which graduates the rods was invented and built in the Gurley factory, and is the result of years of experience in this special line of work. It is adapted to receive and graduate all kinds of rods accurately in the decimal, fractional or metric system, and in any other system which may be desired for special use.

On Gurley rods the graduations are not merely printed on the surface, but are impressed into the rod, thus increasing their durability.

Every detail is carefully observed in the graduation of the rod; the engine and the room in which it is used are so arranged that they are kept at a uniform temperature, both winter and summer. The bases from which the graduations are made are linear standards, every division of which has been verified and certified by the highest authority in the world on all matters pertaining to Weights and Measures, the International Bureau of Weights and Measures, Sevres, France.

FINISHING. An unusual amount of attention is paid to the finishing of the rods, and materials are used which are made especially for us. A number of coats of preservative varnish are applied and rubbed down thoroughly. Besides being noted for their beautiful finish, Gurley rods possess unequaled wearing qualities.

Wherever possible, the exterior corners are rounded, making the handling or carrying of the rod more agreeable. With the improved form of clamp, the slide is effectually clamped with but a slight pressure of the screw.

The Targets are stamped from one piece of metal and have a raised perimeter, or rounded rim, which increases the strength and protects the face. The targets are so reinforced that the screws are not liable to bend, and wherever possible the use of nipples is avoided, as they often work loose.

Carrying Cases. To prevent the defacing of the graduations in transportation, a canvas case to hold the rod can be supplied. This case is substantially made of heavy material and is recommended for all rods used in precise leveling.

Repairs and Regraduating. Owing to their durable construction, Gurley rods can be restored at moderate cost to first class condition for further service, after they have become worn or damaged by excessive use or accident. As this cannot be done with a rod cheaply made, this advantage of a Gurley rod should be considered when purchasing.

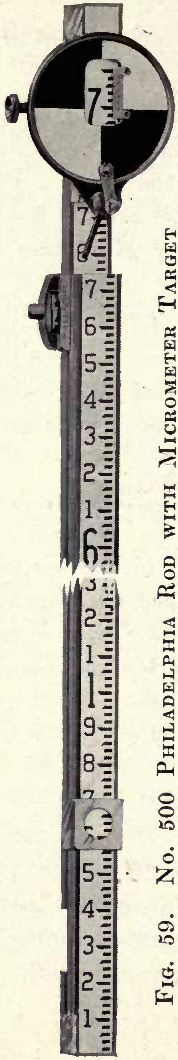


Fig. 59. No. 500 Philadelphia Rod with Micrometer Target

Philadelphia Rod No. 500

This Rod is made in two parts, each about $\frac{3}{4}$ inch thick by $1\frac{1}{2}$ inch wide and $7\frac{3}{10}$ feet long. The parts are connected by two metal sleeves, the upper one of which has a clamp screw for fastening the two parts together when the rod is extended for a higher reading than 7 feet. This clamp can be so adjusted as to regulate the friction on the rod.

Both faces of the back strip and one face of the front are recessed $\frac{1}{16}$ inch below the edges. These surfaces are painted white, graduated into feet, tenths and hundredths of a foot, and the feet and tenths figured. The graduations and figures are slightly impressed on the recessed surfaces, thus increasing their durability.

The front piece reads from the bottom upward to 7 feet, the foot figures being red and the tenths figures black. When the rod is extended to full length the front surface of the rear half reads from 7 to 13 feet, and the whole front of the rod is figured continuously and

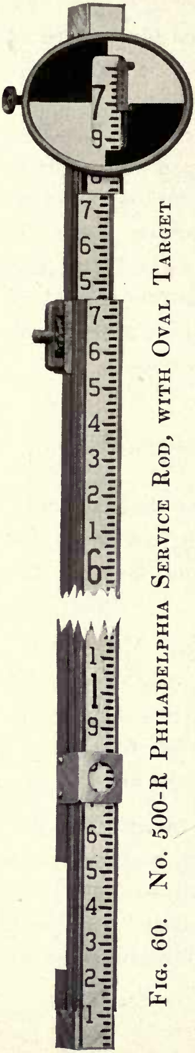


FIG. 60. No. 500-R PHILADELPHIA SERVICE ROD, WITH OVAL TARGET

becomes a self-reading rod, 13 feet long, reading to hundredths of a foot.

The back surface of the rear half is figured from 7 to 13 feet, reading from the top down. It has a vernier scale by which the rod is read to thousandths of a foot as it is extended. The target has a raised perimeter and is painted in white and red quadrants. It has also a vernier scale on its chamfered edge, reading to thousandths of a foot. The target has a micrometer attachment which permits rapid and accurate setting.

When a level of less than 7 feet is desired, the target is moved up or down the front surface, the rod being closed and clamped; but when a greater height is required the target is fixed at 7 feet and the rear half extended, the vernier scale on the back giving the readings like those of the target to thousandths of a foot.

SERVICE ROD, WITH OVAL TARGET, No. 500-R

The new Service rod is of the standard Philadelphia type and similar to our No. 500 Rod, but with the following modifications: It is equipped with a target, oval in form; the clamp and fixtures are of bronze, the screw being rein-

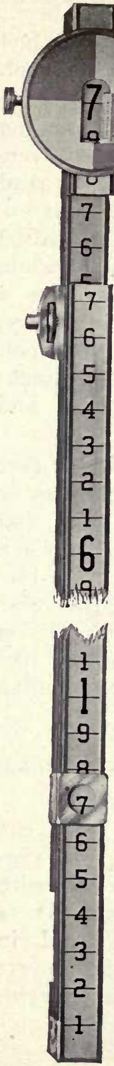


Fig. 61. No. 500-B Philadelphia Rod

forced and protected by a guard and designed for easy clamping, especially when wearing gloves or mittens in cold weather; the finish is not quite so refined as that of our No. 500 Rod, but this new rod will give the same service which has made all Gurley rods so popular. In general, the No. 500-R Rod will answer every requirement in point of accuracy and service.

500-B Philadelphia Rod

Many engineers desire a Philadelphia Rod which can be directly read at a maximum distance from the instrument.

Philadelphia Rod No. 500-B is graduated in feet, tenths, and half tenths with the tenth figures 0.06 feet high. In Fig. 61, the half tenth graduations are not shown.

A scale on the target and on the back of the lower section enables the rod to be read to 1/100 of a foot. This rod is found very useful in highway and railroad cross section work.

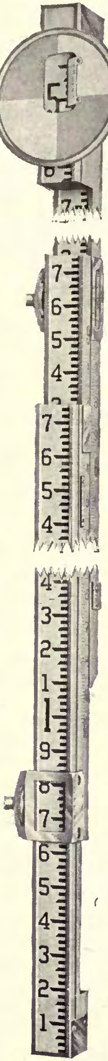


FIG. 62. NO. 501 PHILADELPHIA ROD, THREE PLY

NO. 501 PHILADELPHIA ROD

IN THREE PARTS

To provide a rod of the same general design and use as the Philadelphia rod, but capable of being closed to shorter lengths, we supply the Philadelphia rod in three parts. This rod is five and three tenths feet long when closed, and when extended reads to thirteen feet.

In reading above five feet, first the rear part is extended to its full length and next the middle piece, the readings being made on the graduated edges of the rod by vernier to thousandths of a foot.

When fully extended the front surface becomes a self-reading rod to thirteen feet, the graduations being to hundredths of a foot.

On account of ease in transportation, as well as the general character and excellence of this rod, we believe it will be approved by those who use it.

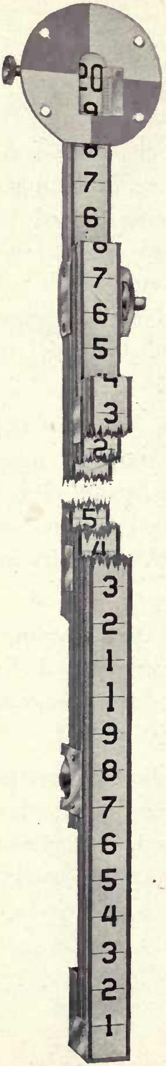


Fig. 63. No. 501-B Self-Reading Rod, Three Ply

No. 501-B Self Reading Rod

A rod which is very popular as a long self reading three ply Philadelphia Rod is our No. 501-B.

This rod is seven and six-tenths feet high when closed and extends to twenty feet. It is graduated on four faces to feet and tenths and on the back of the front section to feet, tenths and hundredths. It reads by two scales to half hundredths.

The target is of aluminum and the rod is regularly supplied with a canvas carrying case.

Mining Rods

For underground operations we are prepared to furnish two ply standard Philadelphia Rods like No. 500 or Service Rods like No. 500-R in the following special lengths:

3.3 feet closed, sliding to 5 feet
4.3 feet closed, sliding to 7 feet
5.3 feet closed, sliding to 9 feet

FIG. 64. No. 505 NEW YORK ROD

No. 505 New York Rod

This rod is made in two parts, the pieces sliding one on the other, the same end being always held on the ground and the graduations starting from that point.

The graduations are made to tenths and hundredths of a foot, the tenth figures being black, and the feet marked with a large red figure.

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

The target is made with a raised rim to strengthen it and to protect it from defacement. It is arranged with an improved clamp, which can be so adjusted as to regulate the friction on the rod, allowing the target to be easily moved up and down or to be clamped by a slight turn of the binding screw.

Fig. 65. Nos. 510 and 511 Architects Rods

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

The opening in the face of the target is nearly two-tenths of a foot long, so that in any position a figure denoting a tenth of a foot can be seen on the surface of the rod.

The vernier on the right hand edge of the opening is graduated into ten equal spaces corresponding to nine hundredths on the rod, and reads to thousandths of a foot. The graduations start from the horizontal line which separates the colors of the face.

The rod is fitted with an improved clamp similar to that on the target.

Architects Rods Nos. 510 and 511

Architects Rod No. 510 is a very light and simple sliding rod made in two equal parts, each 7/8 inch square, and when closed the rod is about 5 feet 6 inches long.

As shown, the face of the front part and the side of the rear part are graduated to feet, inches and sixteenths,

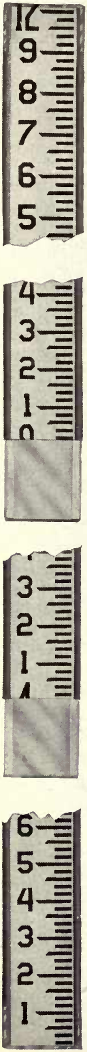


Fig. 66. No. 517 Slip-Jointed Rod

and read by an index on the target and on the side of the rod.

The target is similar to those of the rods already described, and moves on the closed rod when levels of less than 5 feet 5 inches are to be taken.

When a greater height is needed, the target is fixed at the highest graduation, the rear part carried above the front part and clamped by the clamp screw at any point desired, and the height up to 10 feet read off by the index on the side of the lower part.

Architects Rod No. 511 is similar to No. 510 except that the face of the front part and the side of the rear part are graduated to feet, tenths, and hundredths, and read by verniers on the target and side to thousandths of a foot.

No. 517 Slip-Jointed Leveling Rod 1920 Model

This rod was designed for engineers desiring an extremely portable leveling or

Fig. 67. Front and Rear Views of No. 517 Slip-Jointed Rod Showing Joints

Fig. 68. No. 514-B and 514-C Stadia Rod

stadia rod. It is twelve feet long and is graduated on a surface two inches wide to feet, tenths and hundredths. The two joints are secured and released by spring catches. The rod being in three sections is carried in a canvas case about three and three tenths feet long.

Telemeter or Stadia Rods Nos. 514-B to 514-E

No. 514-B Stadia Rod is made in one piece, without target, ten feet long, four inches wide, with brass ends and is graduated on recessed face of three and one-half inches width to feet, tenths and hundredths.

No. 514-C Stadia Rod is similar to No. 514-B, but twelve feet long.

The graduations of Nos. 514-B and 514-C begin at the base and end at the

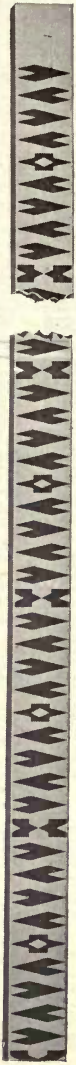


Fig. 69. No. 514-D and 514-E Stadia Rod

Fig. 70. View of Hinges, Ribbed Brace and Clamp of Telemeter or Stadia Rod

top of the rods. The illustration does not show completed graduations.

No. 514-D Stadia Rod is made in one piece, without target, ten feet long, three and one-eighth inches wide, with brass ends and is graduated on flat face to feet, tenths and two-one hundredths.

No. 514-E Stadia Rod is similar to No. 514-D, but twelve feet long.

Stadia Rods Nos. 514-B, 514-C, 514-D, or 514-E can be made with a hinge joint to permit folding, at an additional cost.

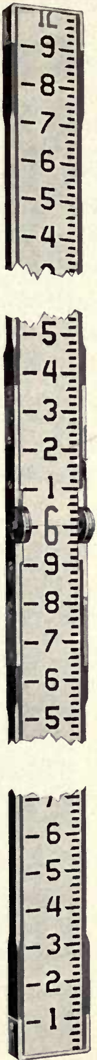


Fig. 71. No. 513 Telemeter or Stadia Rod

Telemeter or Stadia Rod

No. 513

This Rod is formed of two pieces of pine, each two and one-half inches in width and 6 feet long. The inner surfaces of the rod are recessed and painted white, with graduations in black to feet, tenths and hundredths, the feet figured in red and the tenths in black. The two pieces are connected by strong brass hinges and are folded in transportation. When in use they are opened and are held firmly in line by a strong metal brace and clamp on the back of the rod.

The rod tapers toward the top, from a thickness of $1\frac{1}{8}$ inches at the bottom.

This is a self-reading rod, and is often used in connection with the stadia to ascertain distances by simple observation, in the same manner as the Philadelphia Rod.

Fig. 72. No. 516 Cross Section Rod

Cross Section Rod, No. 516

This Rod is made of well seasoned pine, and is ten feet long, with ends one and three-eighths inches thick and two inches wide. It is about four inches thick at the middle, where there is an opening for the hand, as shown. Both sides are graduated on a recessed white surface, the graduations being painted black like those of a leveling rod, and figured from the end of the rod. There is also an adjustable spirit level at each end, as shown in the illustration.

Plain Leveling Rods
Nos. 518-A to 521-B

These self-reading Rods are made of seasoned white pine, recessed and graduated on one face like the Philadelphia Rod. A rib at the back, extending through the length of the rod, gives great rigidity, while it does not materially increase its weight.

They are furnished in lengths varying from ten to sixteen feet and the ten foot, twelve foot and fourteen foot rods are made either in one piece or with a hinged joint. The sixteen foot rod is made only with a hinged joint.

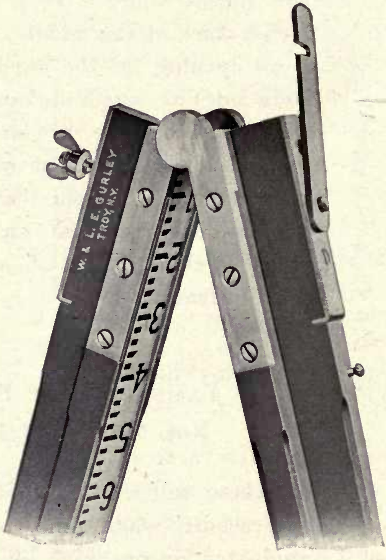


FIG. 73

VIEW OF HINGED JOINT

Note the sturdy construction of the hinges and the manner in which the strong metal brace is anchored into the wooden rib; also the wing nut clamp screw.

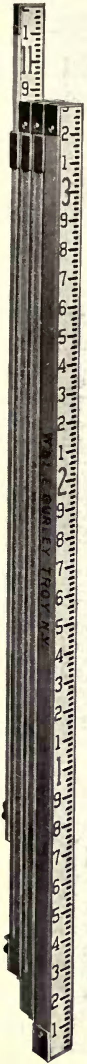


FIG. 74. No. 524-A PLAIN LEVELING ROD WITHOUT TARGET

PLAIN LEVELING ROD
IN FOUR PARTS
No. 524-A

This is a simple form of self-reading rod in four parts, very light and compact, capable of extension to eleven and two-tenths feet, and reading to hundredths of a foot. This same form of rod is also made in two parts, extending to ten, twelve, or fourteen feet. See Nos. 522-A, B and C.

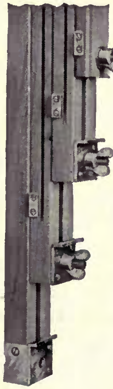


FIG. 76. REAR VIEW OF LOWER PORTION OF FOUR PLY ROD No. 524-A

FIG. 75. VIEW OF CLAMP OF PLAIN TWO PLY LEVELING RODS

FIG. 77. No. 522-A PLAIN TWO PLY LEVELING ROD

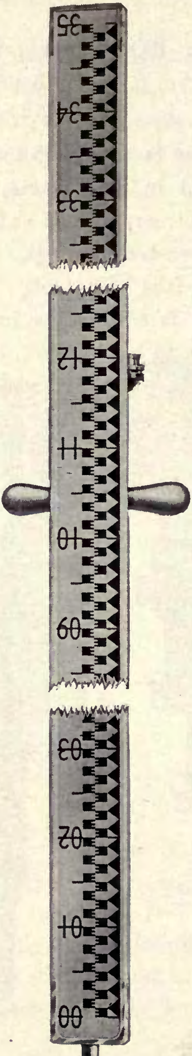


FIG. 78. No. 551-R MOLITOR PRECISE ROD, FRONT VIEW

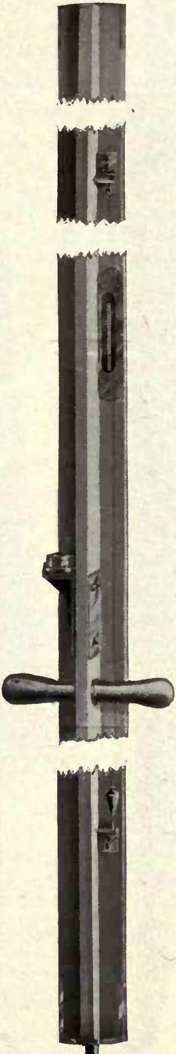


FIG. 79. No. 551-R MOLITOR PRECISE ROD, REAR VIEW

FIG. 80. No. 552-R SELF-READING TAPE LEVELING ROD, FRONT VIEW

GURLEY PRECISE ROD, MOLITOR PATTERN

The Precise Leveling Rod, Molitor Pattern, as shown on page 224, is of T-shaped section, 12 ft. long, and is graduated to feet, tenths and hundredths. It can be graduated to millimeters, if desired. It is equipped with a circular level, two wooden handles, a plumbing attachment and plummet, an enclosed thermometer, a canvas case and a turning point. It is packed in a special pine box with hinged cover, handles and lock.

GURLEY SELF-READING TAPE LEVELING ROD

The Tape Rod is a self-reading rod of decidedly different design from the Philadelphia Rod. It is a wooden rod, made in one piece with a metal roller set in it near each end. Passing over these rollers is a continuous steel band twenty feet long and one-tenth foot wide, on the outside of which, for its entire length,

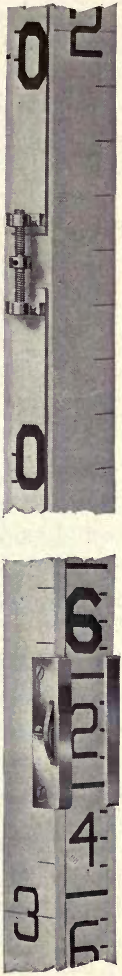


FIG. 81. No. 552-R SELF-READING TAPE LEVELING ROD, SIDE VIEW

is painted a scale graduated to feet, tenths and half-tenths, with the details of the numbers so designed that readings to the nearest one-hundredth of a foot can readily be read.

It is provided with a clamp so that the metal band, or tape, can be set at any desired reading and held firmly in that position.

Where there are a large number of elevations to be calculated, it will save much time to use a tape rod which is so arranged that no elaborate figuring is required. In this rod, the numbers increase from the top toward the bottom, the opposite way from ordinary rods. The level is set up at a convenient point and the rod held on a bench mark. The tape, or band, on the rod is then moved up or down as directed by the levelman until he reads the feet, tenths and hundredths which are the same as those of the elevation of the benchmark, e. g., if the elevation of the B. M. is 195.62, the tape will be moved until it reads 5.62. If the rod is then held on a point 1.61 feet lower than the bench, the rod-reading will be 4.01, since with this rod the readings decrease as the rod is lowered. The elevation of the point is then 194.01 feet, or sufficiently precise for topographic work, 194.0 feet. In this way the elevations are read directly on the rod to feet and decimals of feet, the tenths and hundredths of feet being supplied mentally. Obviously the only notes kept are the columns of stations and elevations.

The rod is 10 ft. 8½ inches long and graduated on one edge to feet and tenths. A canvas case can be supplied for the above rod.

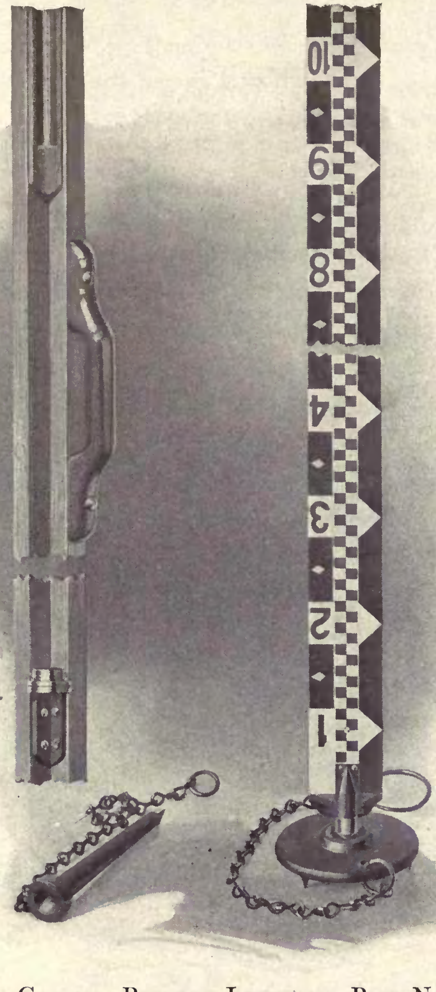


FIG. 82. GURLEY PRECISE LEVELING ROD NO. 550-R

Gurley Precise Rod

WITH TURNING POINT AND PLATE

The Precise Leveling Rod, as shown on page 227, is made in the cross-shaped section and is graduated on three faces to yards, tenths and hundredths. It reads to 3½ yards, and has silver-faced plugs at each half yard enabling it to be checked to a steel tape of standard length. It is fitted with wooden handle, thermometer, and fixed circular rod level. In addition there is a canvas case and a turning point and plate, all neatly packed in a special pine box with hinged cover, handles and lock.

FLEXIBLE OR POCKET LEVELING RODS

The flexible self-reading rod is a convenient form where extreme accuracy is not essential and where ease in carrying is desirable. It is made of specially prepared canvas, so treated as to insure permanence in length within reasonable limits, and is graduated on its painted surface to feet, tenths, and hundredths, or to special design. In use it is fastened to a board with thumb tacks, and can be rolled up easily and carried in the pocket in tin case with which it is provided.

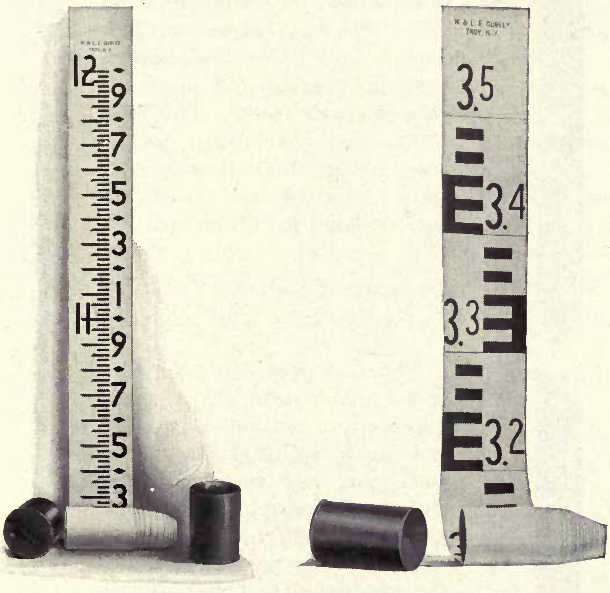


FIG. 83

NOS. 525-B TO 528

FLEXIBLE OR POCKET LEVELING RODS

FIG. 84. NO. 530, 531 COMBINED LEVELING POLE AND FLAGSTAFF

METRIC RODS

Besides the usual graduation of leveling rods into feet and parts of a foot, we graduate them, when desired, into meters, decimeters and centimeters, without extra charge.

The scales on the targets and sides of the rods read the centimeters to millimeters on all except the Telemeter, Telescopic and Plain Rods, which have no targets and are read only to centimeters. The New York, and Architects metric rods are graduated, when desired, to read by vernier to one-tenth of a millimeter.

COMBINED LEVELING POLE AND FLAGSTAFF NOS. 530 AND 531

The Leveling Pole, No. 530, is a combination of a plain self-reading rod and a flagstaff. It is made with flat face, front and rear, and rounded sides. One face is graduated to feet and hundredths of a foot, while the other face and sides are graduated to feet only and are painted red and white alternately.

FIG. 85. NO. 534 TO 536 WOODEN FLAGSTAFF

The pole is made 7 and 9 feet long, the graduated faces reading to 6 and 8 feet, respectively, and when used as a rod is read as shown in the illustration.

WOODEN FLAGSTAFFS NOS. 534 TO 538-B

Wooden Flagstaffs, or Ranging Poles, Nos. 534 to 536 are made in three sizes and are octagonal in form, tapering from the bottom to the top, and have metal shoes. They are graduated to feet, and painted alternately red and white. When desired they are graduated metrically, five spaces to each meter.

Jointed Wooden Flagstaffs Nos. 537-A to 538-B are especially designed for convenience in use and for ease in carrying when traveling. They are about 1 inch in diameter, and are made in equal length sections, which are firmly joined together by protected metal screw joints. If desired, a heavy canvas case is furnished to contain the several parts, and to protect them from injury in transportation. See illustration on page 232.

IRON AND STEEL RANGING POLES NOS. 540-A TO 544

Ranging Poles Nos. 540-A to 540-B are made in two lengths, of a solid hexagonal steel rod, $\frac{1}{2}$ in. in diameter, are graduated to feet and are painted alternately red and white.

Ranging Poles Nos. 541 to 544 are made of an iron tube, $\frac{13}{16}$ inch in diameter, in three lengths, are graduated to feet and are painted alternately red and white.

Any of the above staffs and poles can be furnished with metric graduations (5 to a meter).

FIG. 86. NOS. 540-A TO 544 IRON AND STEEL RANGING POLES

SCREW-JOINTED WOODEN FLAGSTAFFS

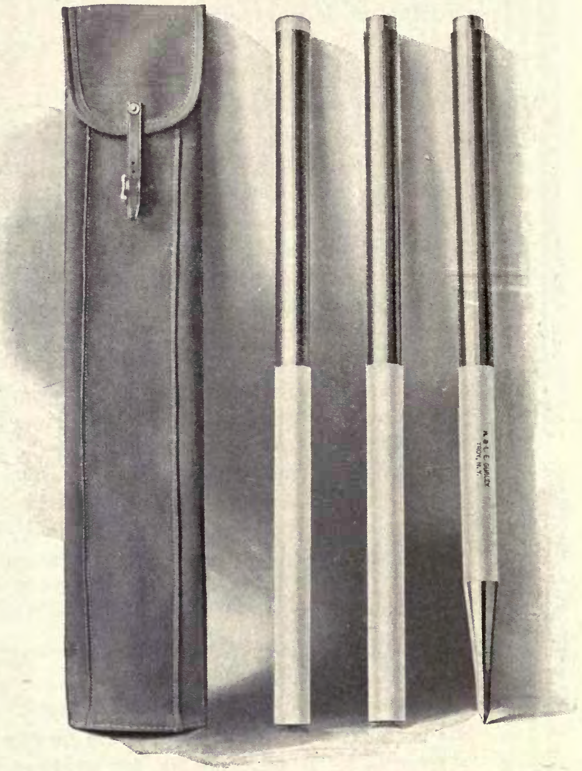


FIG. 87. NOS. 537-A TO 538-B FLAGSTAFFS

The above illustration shows Flagstaff No. 537-D, 6 feet in length, in 3 sections of 2 feet each, having protected metal screw joints. The heavy canvas case, for protecting the rod from injury in transportation, also is shown.

GURLEY ROD LEVELS

We make four patterns of Rod Levels for the accurate plumbing of leveling rods and ranging poles.

No. 545 is adaptable to any rod. It is held in place by the hand or it may be secured by a string or rubber band snapped over hooks attached to each plate of the level.

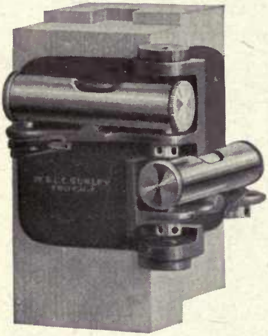


FIG. 88. NO. 545 ROD LEVEL AS APPLIED TO A ROD

No. 546 has a circular level vial, which folds against the rod when not in use. This level is attached permanently to the rod and cannot be used where there is a target or clamp band to slide past it. It is intended for rods made of one piece, and also for those which fold.

FIG. 89. No. 546 ROD LEVEL

GURLEY ROD LEVELS

For use with Precise Rods where greater accuracy and ease of observation are required, we recommend Rod Level No. 547.

The case, with vial 30 millimeters in diameter, is supported on a bracket which may be securely attached to the rod. Three screws fasten the case to the bracket and provide means of ready adjustment.

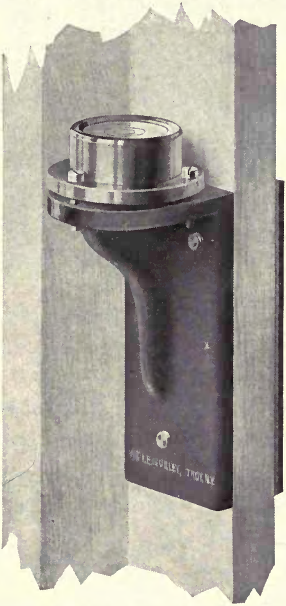


FIG. 90. NO. 547 ROD LEVEL

No. 548 has an aluminum frame and is so made that it can be used on sliding rods such as Nos. 500 to 505.

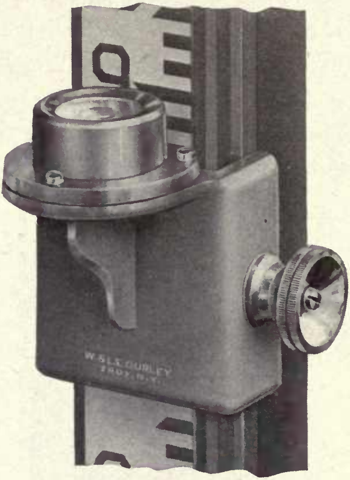


Fig. 91. No. 548 Rod Level

Note—All circular Rod Levels have one-piece hermetically sealed vials which, unless broken, will not leak. This feature overcomes a serious defect in circular levels made of two pieces of glass and which cannot be guaranteed against leakage or evaporation.

ANGLE TARGETS

Angle targets, extending over the graduated face and one side of the rod, can be supplied with Rods Nos. 500-R, 500-B, 501, 502-A and 505, instead of the regular target, at an extra cost.

MICROMETER TARGETS

Micrometer Targets, similar to the target shown with Philadelphia Rod No. 500 on page 210, can be supplied with Rods Nos. 500-R, 500-B, 501, 502-A and 505, instead of the regular target, at an extra cost.

ANGLE MICROMETER TARGETS

Angle Micrometer Targets can be supplied with Rods Nos. 500-R, 500-B, 501, 502-A and 505, instead of the regular target, at an extra cost.

REPAIRING AND REGRADUATING RODS

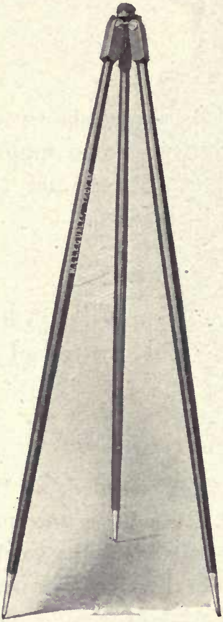
Old and worn rods need not be discarded, as they can be repaired and regraduated. We have unequaled facilities and our method is such that when the work is done, the rods are as good for service as they were when new.

The average cost of repainting and regraduating two-ply rods, such as No. 500 and No. 505, varies from $4.50 to $7.00. These prices include new parts such as clamp screws, etc., which are frequently required.

Estimates for repairing other patterns will be submitted upon request.

Gurley Tripods

The legs of all Gurley Tripods are made of straight grained hardwood, and are about 4 feet 8 inches long from head to point. The upper part of the leg is



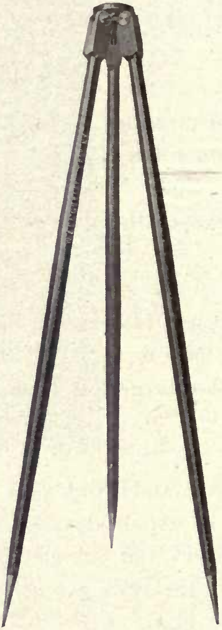


Fig. 92

Nos. 415 and 416
Solid Round Leg Tripods
For Compasses

Nos. 400 and 430
Solid Round Leg Tripods
For Transits and Levels

flattened and slotted to fit closely on each side of a tenon projecting from the under side of the tripod head, to which it is firmly held by a brass bolt, with large head and thumb nut on opposite sides of the leg. The tripod head is of the best bronze metal, the tenons and upper

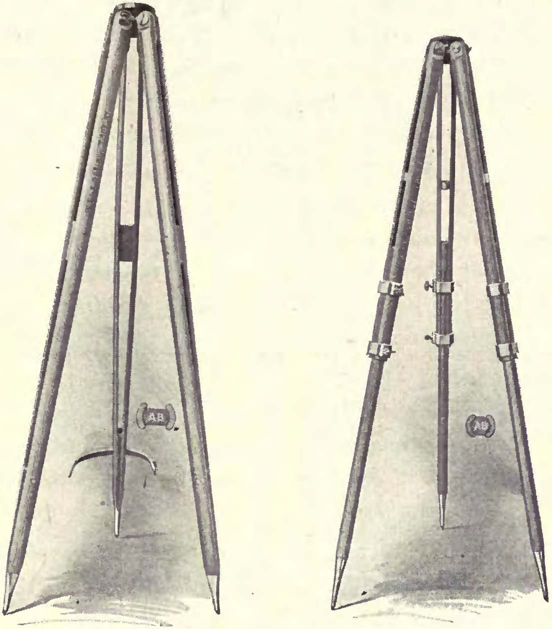


Fig. 93

Nos. 405 and 435
Split Leg Tripods
For Transits and Levels

Nos. 410 and 440
Extension Leg Tripods
For Transits and Levels

part being cast in one piece. The point or shoe is a tapering ferrule, having an iron end. It is cemented and firmly riveted to the wood.

Solid Round Leg Tripods. These are made in three sizes, as follows: Tripod No. 400, the heavy size, has a metal head $4\frac{1}{4}$ inches in diameter, with legs $1\frac{3}{8}$ inches in diameter at the top, $1\frac{3}{4}$ inches at the swell and $1\frac{1}{8}$ inches near the point. This pattern is suitable for use with the Precise Transits Nos. 6-A to 10-A and No. 18-A, and with the Engineers Wye Levels, but, unless otherwise ordered, we regularly supply Split Leg Tripods Nos. 405 and 435 with these instruments.

Tripod No. 415, the medium size, has a head about 3 inches in diameter, and legs which are about 1 inch in diameter at the top, $1\frac{3}{8}$ inches at the swell and $\frac{7}{8}$ inch near the point. This tripod is designed for use with Vernier Compass No. 226.

Tripod No. 416, the small size, is for use with Pocket Compasses. It is of the same pattern as No. 415, but has a smaller head and legs. The legs are nearly $\frac{3}{4}$ inch in diameter at the top and bottom, and $1\frac{1}{8}$ inches at the swell.

Split Leg Tripods. The form of the improved Split Leg Tripods, Nos. 405 and 435, is shown in section at A-B in the illustration.

The legs are of straight grained hardwood, combining stiffness and strength with reduced weight, and allowing greater ease in carrying. Several sizes of this tripod are made for use with transits, levels and compasses.

Extension Leg Tripods, Nos. 410 and 440, shown in section at A-B, are very popular, as they combine strength and rigidity with light weight and are especially easy and convenient to carry. The shape of the side pieces allows the middle piece to be clamped firmly with the bands and screws, while slight changes in length can be made by twisting the middle piece up or down. In carrying, the points are usually reversed in position, and the total length is reduced to thirty-eight inches.

FIG. 94

NOS. 412 AND 443 JOINTED EXTENSION LEG TRIPODS FOR EXPLORERS TRANSITS AND LEVELS

These tripods are made in several sizes. The large size is used with the large transits and levels, and the medium size with the Light Mountain Transits. A smaller size is used with the smaller transits, Architects Level and large compasses. The smallest size is used with the Pocket Compasses.

For use in mines, which have shallow veins or seams, we are prepared to furnish special extension tripods which have a minimum height of about twenty-two inches and a maximum height of about thirty-six inches. The price is the same as for tripods of full size.

Jointed Extension Leg Tripods. For use with Explorers Transits Nos. 20-A to 24-A and Explorers Level No. 384 we furnish a special light weight tripod, each leg of which has a protected metal screw joint in addition to the extension feature. The minimum length when assembled for carrying is only twenty-four inches, so that it can be packed in an ordinary size suitcase. A leather-trimmed canvas carrying case, with handle, is furnished.

Carrying Cases for Tripods

To protect the tripod in transportation, a carrying case can be furnished. One style of case is substantially made of heavy canvas, with leather trimmings. Another form is made of sole leather, with cap and carrying handle.

THE PLANE TABLE OUTFIT

THE PLANE TABLE OUTFIT consists of a drawing board to hold the paper, supported on a tripod so that it may be leveled, a level vial, compass, and alidade or combined sight and ruler.

THE DRAWING BOARD is built up to prevent warping. For use in some localities, as the Philippine Islands, cleats are screwed to the underside. The screws pass through the cleats in oblong slots with metal bushings which fit closely under the heads but allow the screws to move freely when drawn by the contraction or expansion of the board, caused by climatic conditions. The paper is held firmly by brass screws passing through the edges of the paper into brass sockets let into and slightly below the surface of the board. This method offers no obstruction to the movement of the alidade about the surface of the board.

COMPASS. A square brass plate with a magnetic compass and levels is used for leveling and orienting the board and if placed against the edge of the alidade gives the magnetic bearing. Another form is a trough compass either inserted in the edge of the board, or mounted on the alidade blade, with a circular level on the blade of the alidade.

THE PLUMBING ARM, shown in the illustration on page 244, is equipped with an index that may be brought to a given place on the paper, the plummet hanging to it indicates the corresponding point on the ground.

The Johnson Movement

Plane Tables are generally mounted on the Johnson Plane Table Movement, which has been adopted as standard equipment by the U. S. Geological Survey and by many State Geological Departments. The construction of the Johnson Movement is shown in the cut on page 245. It consists of a ball and socket head with an inner spindle. Loosening the upper nut A allows the board to be leveled in any direction, to orient the board loosen the lower nut B.

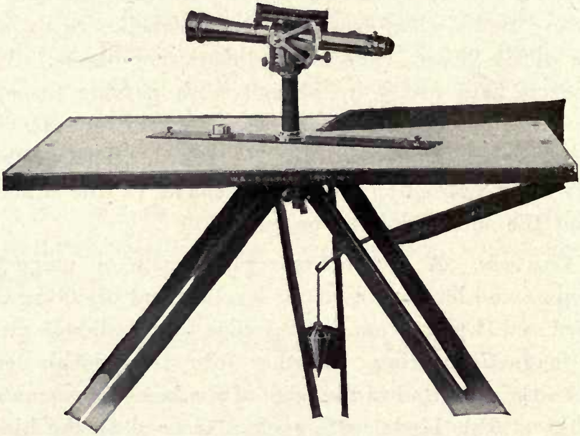


Fig. 95

No. 576-C Plane Table Outfit, with Johnson Movement No. 570, Standard Telescopic Alidade No. 584-C, and 24″ x 31″ Drawing Board No. 573.

PLANE TABLE

The Plane Table method of map making and surveying is rapidly increasing in popularity as its principles and advantages are becoming better understood. On account of their combined efficiency and portability, the several Gurley Instruments designed especially for this class of work have become standard equipment with the principal users of Plane Table Outfits. This method consists of locating graphically on a map, at the time of the survey, the points desired,

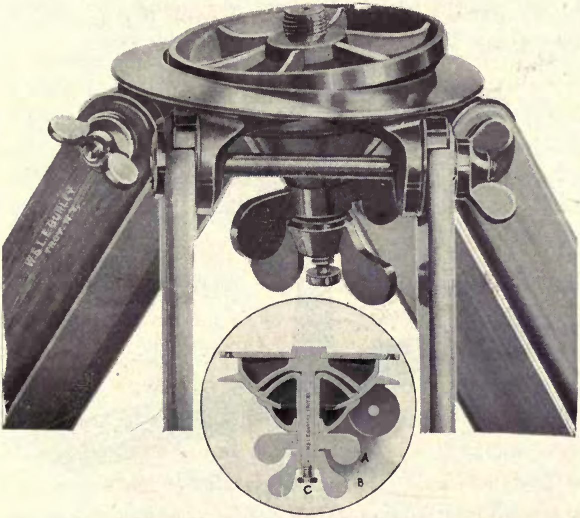


FIG. 96

No. 570 JOHNSON PLANE TABLE MOVEMENT, WITH SPLIT LEG TRIPOD no other notes or figuring being required. Points are located either by intersecting lines sighted from different stations, by tape measurement, or by stadia.

Since the map is made in the field where everything can be viewed, the likelihood of omitting necessary details is reduced, most of them can be put in with but little work. This method avoids the necessity of taking notes, of reading horizontal angles and the calculation of the same. It is very easy to detect errors, since checking is accomplished by simply sighting on a given point from various stations. It is more rapid than ordinary methods of transit surveying, particularly where much topographical detail is desired.

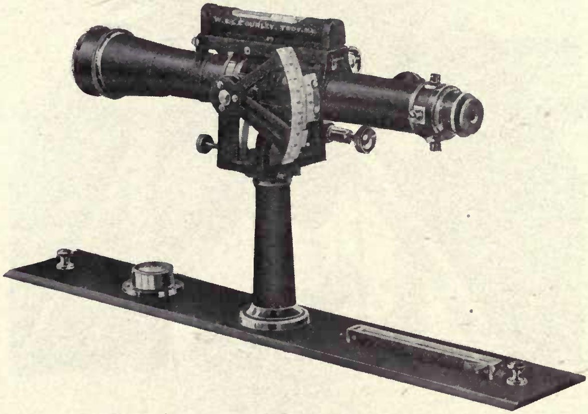


FIG. 97

NO. 584-C TELESCOPIC ALIDADE, WITH DETACHABLE STRIDING LEVEL, EDGE GRADUATED VERTICAL ARC COMBINED WITH BEAMAN STADIA ARC, CIRCULAR LEVEL, AND TROUGH COMPASS.

Two sizes of the Johnson Movement are made. No. 570 is the regular size, used with the larger boards, and No. 571, a special light weight model generally used with the smaller boards and the Explorers Alidade No. 592-C. Any of the alidades, however, can be used with the Johnson Plane Table.

TELESCOPIC ALIDADES

ALIDADE No. 584-C has a brass ruler eighteen inches long and three inches wide, with the edge beveled. On this blade is mounted a circular spirit level, the glass body of which is hermetically sealed, and which is sensitive enough to permit the plane table to be leveled with sufficient accuracy. Attached also to the ruler is a trough compass having a four inch needle, and whose meridian line is parallel to the fiducial edge. If desired, the trough compass can be omitted from the blade and be furnished separately for insertion along one edge of the drawing board.

The telescope, which is mounted on a column attached to the ruler, is eleven inches long, and is equipped with an enlarged objective, platinum cross wires and stadia wires, and a detachable striding level with revolving shield. The telescope is regularly furnished with an inverting eyepiece, and is fitted with a diagonal prism. (If an erecting eyepiece is desired, it can be had with Alidade No. 584-B, which is otherwise similar to Alidade No. 584-C, except that the telescope does not have an enlarged objective.) For easy adjustment of the line of collimation, the telescope can be revolved on its longitudinal axis through 180 degrees. The telescope axis is equipped with clamp and tangent movement.

The vertical arc is graduated on sterling silver and reads by vernier to one minute. For convenience in reading the point of zero deflection is marked 30° The reading of vertical angles is made easier by the arc and vernier being graduated on their edges.

The Beaman Stadia Arc is combined with the edge graduated vertical arc and vernier, thus greatly increasing the usefulness and efficiency of the instrument. This patented attachment, as described on pages 90 to 96, mechanically reduces stadia readings and eliminates the necessity of using stadia tables, slide rules or diagrams. The value of the Beaman Stadia Arc is evidenced by the fact that this attachment is regular equipment on all Alidades used by the U. S. Geological Survey, whose engineers are the largest users of topographic instruments in this country. Many hundreds of these attachments are in use on transits and telescopic alidades and are giving universal satisfaction.

Alidade No. 584-C is standard with the U. S. Geological Survey, which is using large numbers of Gurley Instruments of this pattern. Johnson Plane Table Outfit No. 576-C, as illustrated and described on page 244, is part of its regular equipment and has been developed and improved by co-operation with its engineers.

GURLEY EXPLORERS ALIDADE

No. 592-C EXPLORERS ALIDADE is of special interest to topographers, geographers, geologists and landscape engineers needing a serviceable, dependable, light weight alidade.

The Explorers Alidade is a modification of the well known No. 584-C Gurley Alidade, U. S. Geological Survey standard. It is smaller and lighter, yet built with precisely the same care and accuracy.

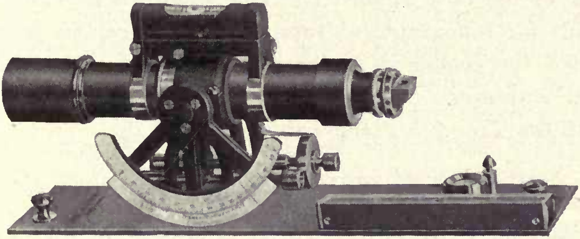


FIG. 98

No. 592-C EXPLORERS ALIDADE, WITH GRADIENTER AND BEAMAN STADIA ARC

The majority of these alidades are ordered with the Beaman Stadia Arc, a patented device controlled by us which gives accuracy and speed to stadia surveying that can be obtained by no other method. See pages 90 to 96.

The Gradienter attachment will prove useful in the measurement of distances and the establishment of grades. The Gradienter head and index are graduated on sterling silver, thus the graduations are clear, distinct and permanent. The entire attachment is of such construction and workmanship that it can be depended upon for accurate work. See pages 97 to 100.

The Explorers Alidade constitutes an appropriate companion to our well known Explorers Transit and Explorers Level, and the three instruments can be packed conveniently in a 24 inch dress suit case.

In connection with our special light weight Johnson Plane Table Movement No. 571, and either the 15 x 15 inch or the 18 x 24 inch Drawing Board, it provides an outfit for topographical surveying which cannot be excelled for combined accuracy and extreme portability. The Explorers Alidade can also be used successfully with the Traverse Plane Table.

To Use the Plane Table

To obtain the best results with the plane table a certain number of control stations should first be located by means of more accurate instruments, such as a transit and spirit level. The extent of this control will depend on the requirements of the survey and the scale of the map. The plane table may be oriented by sighting the previously located control stations, whose positions have been carefully plotted on the drawing paper. With reasonable care any direction may be represented in true azimuth, with no error that can be measured on the map and with far greater accuracy than that obtained by plotting angles with a protractor. The plane table may be used in traverse work with orientation obtained by compass needle or solar chart. Or a direction may be assumed and a traverse executed by the "fore and backsight" method — that is, by drawing a long line for the fore-sight and using the same line at the forward station for the backsight. In other words, the plane table, though it can not be used for determining angular values in degrees, minutes, and seconds, is capable of measuring all horizontal directions that can be measured by a transit and of performing these functions with errors less than those that can be measured on the map. The accuracy of measurements of distances by tape depends, of course, on the tape and not on the plane table. The avoidance of errors in plotting distances by the plane table, as in plotting distances from transit notes, depends on the care and skill of the surveyor. Under average conditions the errors by one method will be no greater than by the other.

In making an accurate map of a large area by the plane table, two or more control points, the distances between which are known, must be given, and the elevation of at least one of these points must also be given. These points should be plotted on the plane-table paper in their proper relative positions. If the scale of the map is too small to justify the location of the principal points by stadia, they may be accurately located by intersecting lines drawn from two or more stations. Elevations are computed from vertical angles, the distances being scaled from the plane-table sheet. After a sufficient number of points have been located the contours and the other topographic features may be sketched on the sheet. The number of stations that should be occupied and the number of points that should be located to produce an accurate map must be determined by the character of the country and the requirements of the scale of the map.

After the topographic details that are visible from the first station are drawn on the plane-table paper other stations are occupied, where the same operations are performed until the entire area is covered. This completes the field work, and the only additional work that may be required is that of inking the pencil lines if the map is to be reproduced by photography. The inked map is used by the Geological Survey as the final copy for the engraver.

If a plane-table station must be established at a point not previously located, its exact relative position on the paper can be found in a few minutes by the well-known "three-point method" provided three or more previously located points are visible.

The plane-table method may be recommended for nearly all topographical mapping. In high latitudes, however, where outdoor work is limited to two or three months in the year and much time is lost by storms, even in midsummer, every minute spent in station work is of great value.

Although the plane table is generally regarded as the instrument best fitted for topographic mapping; it is also useful for making reconnaissance or preliminary surveys for railways and highways, for locating canals and ditches, for mapping civic improvements such as parks and subdivisions of lots, and for any other field surveys in which it is not necessary to determine and record angles in figures.

Before beginning such a survey with the plane table the accuracy of the setting of the stadia wires in the telescope of the alidade should be tested by measuring off a horizontal distance of about 1,000 feet, comparing the distance as measured by tape and stadia for each 100 feet, and making a correction table for the stadia measurements if it is necessary.

The following procedure may be adopted in making a reconnaissance survey with the plane table:

Set up the plane table and level it by means of the circular level on the alidade. The board need not be exactly level, though it is more convenient to have its surface very nearly so. Test the adjustments of the alidade and correct if necessary. Turn the board till one edge is parallel with a north and south line as indicated by the compass attached to the alidade. This line should then be plainly marked on the paper for use at subsequent stations. The survey is then carried forward according to the general method employed when a transit is used. The topographer places stakes at intervals of 100 feet along the proposed route and plots them at once in their proper positions on the map instead of recording bearings and distances in a notebook as he does when he uses a transit. The alidade is pointed toward each feature that is to be located, and its distance as found by stadia is laid off in the direction thus indicated. The elevation is found from vertical angles or by direct leveling. From each plane-table station the topographer locates accurately upon the sheet the land corners, road intersections, and other conspicuous features and, with the area in plain view, draws the contours. He then carries the plane table forward 500 or 1,000 feet to another station and repeats the process. In thick timber or brush, or in places where hills intervene between stations, it may be necessary to set up the plane table at stations off the line in order to cover a wider area with the sketching than that which is visible from the main stations. As many elevations as are desired may be determined and recorded on the map in figures.

Cross sections on the line can be computed by the usual methods, but careful contouring will usually give results that are equally valuable for computing cuts and fills. For preliminary surveys tape measurements can be dispensed with and stadia distances depended on entirely. The methods just described have been used for railway surveys. Those who are familiar with the plane table are fully convinced that a map made by its use for a railway or for a similar work differs in no essential feature from a map made by a transit survey, and the plane table has the advantage of affording greater speed and of obtaining satisfactory results at less cost.

The objection has been made that the scale of a plane-table sheet is impaired by exposure to the weather.

No textbook fails to call attention to the danger of such exposure, so that many have been led to believe that the scale of the map may be affected in this way, but under ordinary circumstances no serious change of scale occurs even in a plane-table sheet that has been exposed to the elements for a long time. One of the United States Geological Survey's maps that was recently brought in from the field was carefully measured with the same standard scale by which it was originally constructed and the change in its dimensions was found to be of no consequence. The measurements showed no change in its width at top or bottom and a change of only one one-hundredth of an inch throughout its length of 22.8 inches — a change so trifling as to be negligible. Other similar tests have given like results.

ADJUSTMENTS OF TELESCOPIC ALIDADES

There are three field adjustments to be checked when using the instruments.

The adjustment of the striding level,
The adjustment of the line of collimation,
The adjustment of the vernier setting.

The last adjustment will probably not be necessary for the No. 584-C Alidades.

THE STRIDING LEVEL is adjusted as follows: level up the telescope, reverse the striding level end for end and correct half of the apparent error by means of the adjusting screw at one end of the vial, repeating the operation until the bubble remains in the center of the vial for both positions of the striding level.

LINE OF COLLIMATION. Loosen the knurled collar in front of the longitudinal telescope bearing. Focusing the telescope on a distant point, revolve the telescope 180° in its collar and if the intersection of the cross hairs remains on the distant point the line of collimation is in the optical center of the telescope. If this condition does not obtain correct one half of the apparent error by means of the capstan head nuts on the exterior of the telescope and repeat the adjustment operation.

To make the vertical wire truly vertical, level the table by means of the sensitive striding level and make the vertical wire traverse a distant point when the telescope is moved on its horizontal axis. Correct the total apparent error.

TO ADJUST THE VERNIER. Make sure that the striding level and the line of collimation are in perfect adjustment, clamp the telescope and with the tangent screw bring the level bubble to the center.

When the bubble is in the center of the level the vernier should read exactly 30°. On the No. 592-C Alidades the vernier can be brought into the proper position by means of the tangent screw. On the large No. 584-B and C Alidades it would be necessary to move the vernier. This can be accomplished by loosening the two screws which hold the vernier in place and moving it slightly to get the proper setting.

GURLEY TRAVERSE PLANE TABLE

The illustration No. 586 represents a simple form of plane table and alidade first made by us for the U. S. Geological Survey, and in its present improved form is used extensively for traverse work. While not capable of as accurate work as the larger plane tables, it constitutes a light and portable instrument for topography.

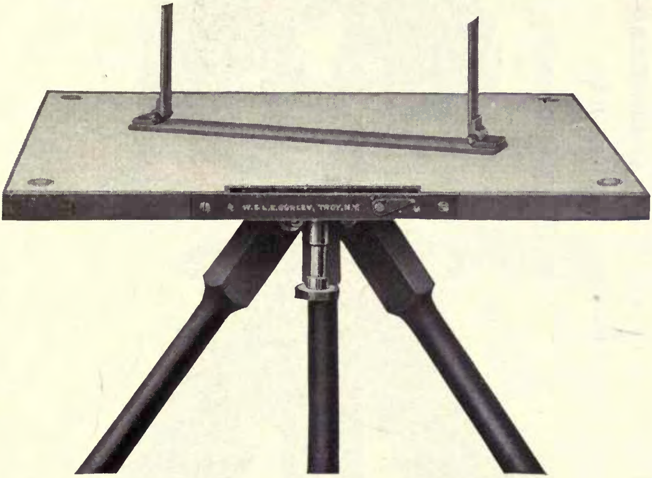


FIG. 99
No. 586 TRAVERSE PLANE TABLE OUTFIT

The board can be equipped with the extension leg tripod or with the jointed extension leg tripod.

The board is 15 inches square, and has on its under side a strong brass flange with spring, in which the plunger clamp of the tripod head engages, allowing the board to be clamped or oriented as desired. Small clamp screws with sockets for holding the paper are placed at the corners of the board. Inserted in one edge of the board is a small box compass with needle, 4 inches long.

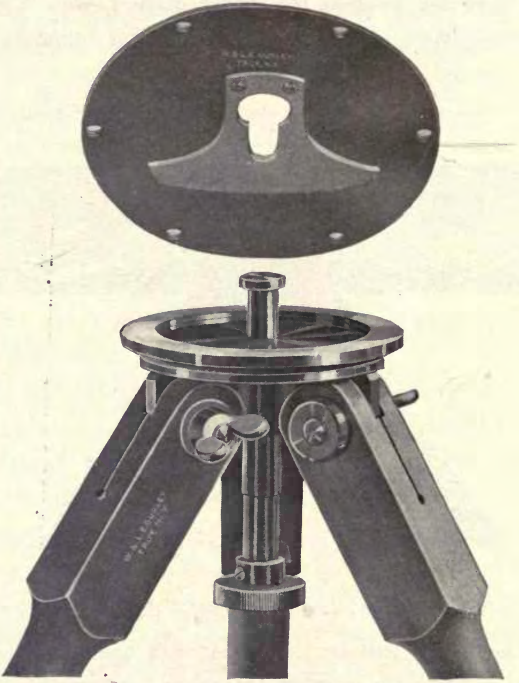


FIG. 100

TRAVERSE PLANE TABLE MOVEMENT, SHOWING THE TRIPOD HEAD AND LEGS, THE PLUNGER CLAMP SCREW, AND THE IMPROVED SPRING BOARD PLATE

The alidade consists of a brass ruler 10 inches long, graduated on the beveled edge to a scale of 40 parts to the inch, and having at each end hinged sights which fold close to the surface of the ruler. One sight has a slit and the other a hair. The alidade is furnished with a leather pouch.

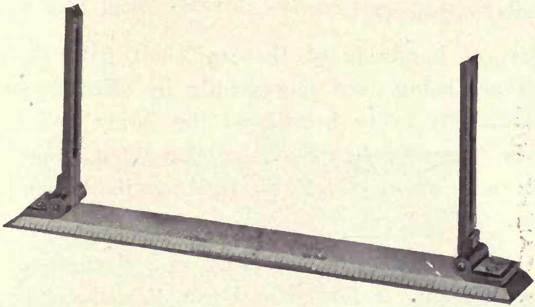


FIG. 101

NO. 590-A POCKET SIGHT ALIDADE, WITH FOLDING SIGHTS

POCKET SIGHT ALIDADE NO. 590-A is 6″ long and has hinged sights which fold down flat on the ruler.

The beveled edge is graduated the entire length to read 1/10 and 1/20 of a mile for ratios of 1/90,000 and 1/45,000 respectively. The middle part of the edge is further divided to read 1/50 and 1/100 of a mile respectively for the same two ratios.

This alidade is furnished with leather case having pencil pockets.

ARMY SKETCHING CASE

THIS instrument for topographic map making was originally designed especially for the use of U. S. Army Engineers, but since its introduction has been found unusually serviceable for a similar class of work by foresters, geologists, road engineers, timber cruisers and civil engineers.

Several hundreds of these efficient field sketching outfits are being used successfully by officers and men in practically every branch of the Army and by the various Army Service Schools; also by military academies, militia organizations, civil engineers and surveyors.

In addition to the simplicity and strength of construction fitting it for general use, this sketching case possesses a unique feature in that the board does not require to be oriented in taking observations. So far as we know, this is the only practical sketching case on the market having this valuable feature, which makes its operation very simple and rapid. The use of a tripod is unnecessary and there is no complicated protractor to operate. In fact, anyone can readily learn to use this instrument after studying the directions carefully.

Construction

The Army Sketching Case consists of a plane table board, six inches by twelve inches, made of seasoned pine with mahogany end pieces. This construction insures a strong, durable board which will not warp nor pull apart under hard service. To the lower right hand side is attached a compass box with floating dial, three inches in diameter, beveled on the edge and graduated into 360 degrees.

A protected opening in the compass box permits the graduated dial to be read either from above or when the board is held level with the eye of the observer.

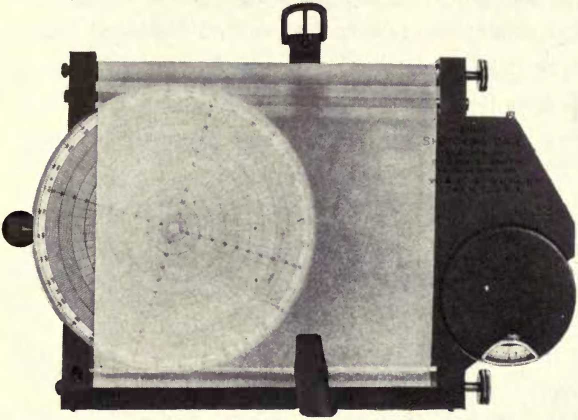


FIG. 102

NO. 594 ARMY SKETCHING CASE
PATENTED SEPT. 1, 1908

Designed by Lt. Col. Glenn S. Smith of the U. S. Geological Survey

Rifle sights which are placed in line with the center of the compass and parallel with the edge of the board, are used as an alidade in taking bearings.

On the upper side of the board is mounted a circular plate, six inches in diameter, and pivoted at the center. This plate is attached to an L-shaped base at the upper end of which is a cylinder through which passes a rod parallel with and secured to the top of the board.

A metal strip let into a slot in the middle of the board guides the lower edge of the L-shaped base.

Upon the guides as described, the base carrying the circular plate can be moved from side to side over the upper surface of the board and clamped at will by a set screw in the cylinder at the top.

A clamp with index line is so attached to the base that the circular plate mounted upon it may be set at any desired position.

A card of aluminum is attached to the circular plate and upon this card a combined protractor and scale are printed.

The protractor is graduated into 360 degrees and the scale consists of a series of equally spaced concentric circles.

Different protractor cards are furnished for the various scales used in map making.

Rollers with friction brakes, attached to two edges of the board, receive the paper and hold it snugly against the surface of the protractor which travels underneath it. An aluminum shield protects the paper and prevents soiling.

To the under side of the board a swiveling strap, with buckle, is attached, by means of which the case can be firmly secured to the observers arm. There is also a socket by which a tripod or staff may be attached. A simple clinometer attachment for taking slopes is also provided.

As far as possible the metal parts are made of aluminum, so that the case weighs only about two pounds, and they are of dark finish to avoid reflection of sunlight.

Care in the selection of a proper material for use on the case in recording observations is essential to successful operation, and tracing cloth should be avoided as too smooth for the use of a pencil. Vellum tracing paper has a slightly roughened surface, little affected by moisture and on which the pencil works well, is recommended.

On completion of the survey, the sketch may be taken from the instrument and blue prints made directly from the original.

Detailed directions for using the Army Sketching Case are furnished with each instrument. A descriptive circular containing these instructions will be sent free to any address on request.

FIALA SCOUT SKETCHING CASE

The interest in map sketching as practiced by army engineers is increasing, and the necessity for a more general knowledge along these lines is evidenced by the taking up of such work by various organizations of the National Guard.

FIG. 103

SHOWING METHOD OF USING FIALA SCOUT SKETCHING CASE

For convenience in making maps in the field various forms of sketching cases are used, consisting of a small drawing board provided with a magnetic compass, alidade (or scale) with sights, and rollers for carrying a supply of paper. Sketches are made with colored pencils.

With such equipment, topographical maps can be accurately and rapidly made to show the character of the land, whether level or mountainous, fertile or barren; the location of railroads, highways, water courses, and bridges or structures of any kind.

Map making is a very necessary part of a Boy Scout's course in surveying. By means of a sketching case he can make a record of the country traversed on his "hikes," and thus develop his sense of proportion, direction and distance in an instructive and interesting manner. Canoeists and campers also can use a device of this kind to advantage.

The Fiala Scout Sketching Case is a practical instrument in every particular. It was designed and made from suggestions by Mr. Anthony Fiala, the explorer, whose experience in the Arctic regions and with Colonel Roosevelt in South America places him in a position to fully understand the needs of those engaged in outdoor pursuits.

Designed along the same general lines as the Army professional model, No. 594, which we have made for a number of years for military topographers and others, the Fiala case is much less elaborate and expensive but is efficient and convenient as well as of value for educational purposes.

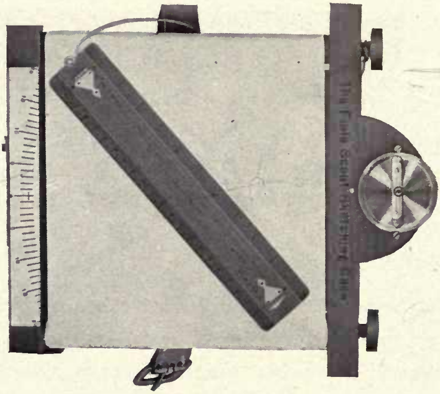


FIG. 104
No. 596 FIALA SCOUT SKETCHING CASE

The Fiala Scout Sketching Case consists of a thoroughly seasoned white pine drawing board, 6 inches wide x 5 inches long, having $5/8$ inch diameter rollers at each end which carry a strip of white, strong, smooth-faced architects paper, $5\frac{3}{4}$ x 36 inches. An adjustable device on the rollers holds the paper flat against the board and prevents it from uncoiling. Fitted into the right hand end of the board is a brass compass having a $1\frac{1}{2}$ inch needle with needle stop and slotted revolving cover. Holes bored into the left hand end of the board contain three sketching pencils, black, red and blue. These are held securely by means of a brass spring clip.

A boxwood ruler, 6 inches long, with small brass folding sights at each end, enables the user to establish the bearings of lines. The ruler has scale of 6 inches to 1 mile on one edge, and 3 inches to 1 mile on the other. Two rubber bands are used to aid in holding the ruler on the paper. The ruler is fastened to one of the roller knobs by a cord and when not in use is securely held against the back of the board by a brass spring clip.

There is a simple form of clinometer for determining angles of slope. The ruler alidade is arranged to swing across the surface of the paper and the angles of slope are read on a scale attached to the left hand edge of the case.

In use, the sketching case is fastened to the forearm of the sketcher by a leather strap on the back of the board. It weighs about 30 ounces and measures 9 x $7\frac{3}{4}$ x 1 inch. Packed for parcel post shipment, it weighs 3 pounds. Architects Drawing Paper, in rolls $5\frac{3}{4}$ x 36 inches, per roll, is furnished for use with this case.

CHAINS AND TAPES

The Surveyors and Engineers Chains are the measuring instruments by which our oldest surveys were made and many farm surveys are made.

We furnish tapes of all standard units and lengths in Nos. 8 and 10 refined iron wire and in Nos. 8, 10 and 12 best steel wire. Steel chains are preferred on account of their greater strength, although they are more expensive than those of iron.

BRAZED STEEL CHAINS. A very light and strong chain is made of No. 12 steel, securely brazed. The wire is of a low spring temper, and the chain, though light, is almost incapable of being broken or stretched in careful use.

METER AND VARA CHAINS. The meter is used as a standard measure of length in many countries, and chains of ten and twenty meters are often ordered. The chains are of Nos. 10 and 12 iron or steel wire, each meter being divided into five links. The old surveys of Texas were made with the vara as the unit of measure and we supply Vara Chains of Nos. 8, 10 and 12 iron or steel wire.

CHAIN TAPES

Chain tapes are generally used on bridge, road and street work, and as standards for comparison of other chains and tapes. They are made of a thin ribbon of steel about one quarter of an inch wide, and of straight spring temper, and in lengths of from sixty-six to five hundred feet.

STEEL RIBBON CHAIN TAPES

One-quarter inch wide, heavy steel ribbon, deeply etched graduations, large detachable handles and a wooden reel with nickel trimmings.

The sixty-six and one hundred thirty-two feet lengths are usually graduated at each Gunter's link for use in land surveying, and the one hundred to five hundred feet lengths are graduated at each foot, with the first and last foot marked in tenths, for city work.

METALLIC TAPES

These are of linen, about five eighths of an inch wide, and have fine brass wires interwoven through their whole length. They are thus measurably correct, even when wet.

They are graduated in feet and tenths or in feet and inches, on one side, as ordered, and are marked in links on the reverse side. They are wound in a leather case having a folding handle.

STEEL TAPES

The best tapes are made of a thin ribbon of steel in one piece, of straight spring temper, and either one quarter, three eighths or one half inch wide.

They are made in all lengths from twenty-five to two hundred feet, graduated to feet, inches, and eighths of an inch, or more usually feet, tenths and hundredths of a foot.

They are also graduated at each Gunter's link, on the reverse side if desired. The figures and graduations are etched on the surface of the steel.

The Engineers Pattern steel tapes are made of thin steel ribbon, about one quarter of an inch wide and of straight spring temper. They can be detached from the case when desired, and used with a pair of handles for chain measurements. They can also be used with handles having a compensation scale for variations of temperature.

These tapes are U. S. standard measure at 62° Fahrenheit, with about twelve pounds strain. A hundred foot tape expands .0756 inch for each 10° rise in temperature.

The tapes arc wound in a leather or metal case with folding handle.

Our steel tapes Nos. 850 to 854-B are very popular for underground work. They are one half inch wide, and are mounted on an open brass frame, nickel plated, and with double folding flush handle. They are easily wound and unwound, and the open frame allows the evaporation of moisture. This feature is also characteristic of the reels supplied on our Wolverine Tapes Nos. 814 to 817.

METRIC AND VARA TAPES

We can furnish any of our metallic tapes, and steel tapes, with metric or vara measure on the reverse side instead of links. Tapes of metric or vara measure only can also be supplied.

Our extra heavy metric chain tapes, Nos. M20 to M100, are graduated with metric measure only, and are marked in decimeters, with the first meter in centimeters and the first decimeter in millimeters. If graduated with vara measure only, they are marked in tenths of a vara.

MARKING PINS

In chaining, eleven marking pins are needed, made either of iron, steel or brass wire, as preferred. They are about fourteen inches long, pointed at one end to enter the ground, and formed into a ring at the other end for convenience in handling.

Marking pins are sometimes loaded with a little mass of lead around the lower end, to serve as a plumb when the pin is dropped to the ground from the suspended end of the chain.

PLUMMETS

We manufacture plain brass plummets like that illustrated in Fig. 105 in the following sizes: 6 oz., 10 oz., 16 oz., 24 oz., and 32 oz.

If the work at hand requires a long plummet of small diameter No. 460 twelve ounce plummet is supplied.

FIG. 105
NOS. 450 TO 458 PLAIN PLUMMETS

ADJUSTABLE BRASS PLUMMET No. 465 has a concealed reel R, Fig. 106, around which the string is wound by turning the milled head on top. The friction upon the reel will hold the plummet at any desired point of the line.

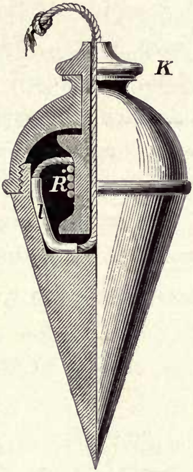


FIG. 106

No. 465 ADJUSTABLE PLUMMET

SHOWING DETAILS OF CONCEALED REEL

HYDRAULIC ENGINEERING INSTRUMENTS

THE importance of an exact knowledge concerning the surface water supply of the country has been recognized for many years. The immediate necessity of stream flow data, to be used by those interested in or engaged upon problems of hydraulic engineering, including water power, domestic water supply, inland navigation, irrigation, swamp and overflow land drainage and flood prevention, has created a constantly increasing demand for a means of obtaining such data accurately.

The data required is the area of cross-section, the velocity of flow and the elevation of the water, with which the quantity or volume of flow can be readily computed.

The area of cross-section is obtained by the usual methods of surveying.

Velocity is measured by Current Meter Measurements.

The varying height of the water level is automatically recorded by Water Stage Register.

CURRENT METERS

FOR more than thirty years W. & L. E. Gurley have made Current Meters under the patents of W. G. Price, the Assistant Engineer of the Corps of Engineers, United States Army, who in 1885 devised the initial pattern. The general features are retained in the latest models, although somewhat modified as the result of suggestions from many hydraulic engineers who have had large experience in current meter observation under all conditions of service.

The many hundreds of Gurley Current Meters in use in all parts of the world, their constantly increasing sale and their accuracy and reliability under all conditions, show that they are the standard instruments for the accurate measurement of the velocity of water in streams and open conduits.

A current meter for measuring the velocity of flowing water comprises two essential parts: (a) a wheel arranged so that when suspended in flowing water the pressure of the water against it causes it to revolve; (b) a device for recording or indicating the number of revolutions of this wheel. The relation between the velocity of the moving water and the revolutions of the wheel is determined by rating each meter.

The distinguishing characteristics of a good current meter are (a) simplicity in construction, with no delicate parts which easily get out of order; (b) a small area of resistance to the velocity of the water; (c) a simple and effective device for indicating the number of revolutions of the wheel; and (d) easy adaptability to use under all conditions.

SELECTING THE PROPER TYPE OF CURRENT METER

The experience of many years has shown that but two patterns of the Gurley meter are needed to adequately meet the requirements of practically all engineers engaged in measuring the flow of water. Accordingly, we have discontinued making the large pattern formerly listed as Meter No. 600, and also two of the smaller patterns, previously listed in different combinations as Meters Nos. 617, 618, 621 and 624.

We will continue to make only the two standard models, namely Accoustic Meter No. 616, and Electric Meter No. 623. The latter may be supplied with such a variety of equipment that it will be the equivalent of, and can be used for the same work as, the discontinued Meters Nos. 617, 618, 621 and 624.

The selection of a meter should be made after consideration has been given to the following factors:

(1) The purpose for which the instrument is to be used.
(2) The manner in which it is supported.
(3) The amount of weight to be used.
(4) The frequency of the revolutions to be indicated.

Current Meter No. 616. When it is possible for the observer to approach the stream closely, and to hold the meter in position by means of its suspension rod,

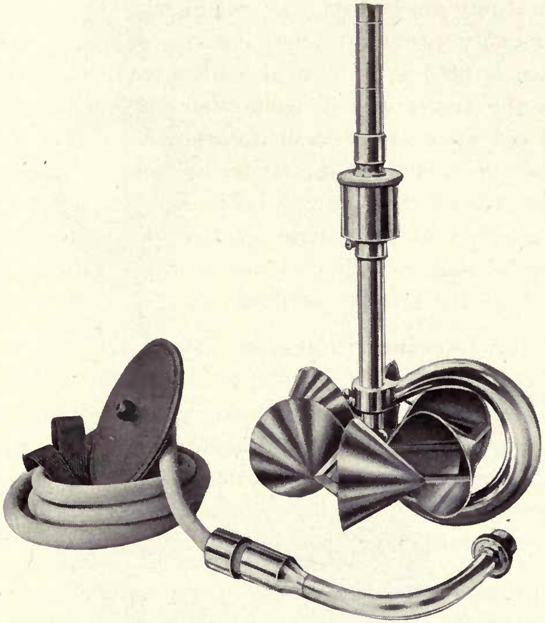


Fig. 107

No. 616 Acoustic Current Meter Outfit

with jointed wading rods, rubber tube, ear piece and connection, indicating each tenth revolution

especially in channels of small depth, the Acoustic Current Meter, No. 616, is very useful.

This meter indicates every tenth revolution of the bucket wheel by the sound of a hammer striking against a diaphragm, one blow for every 10 revolutions. The indicating mechanism is completely enclosed and thoroughly protected from injury. When in use the meter is held by a jointed wading rod, which screws into the frame and in connection with a rubber tube and ear piece attached to it, forms a passage through which the sound of the hammer stroke is transmitted to the ear of the observer. This enables him to count the number of revolutions of the wheel in any given space of time, and they by means of the rating table to ascertain the velocity of flow.

THE ELECTRIC INDICATOR. Many observers prefer an electric type of revolution indicator. This indicating device is protected from injury by enclosure in the contact chambers, or commutation boxes, and the revolutions of the bucket wheel are indicated by a telephone ear piece, which is generally fastened in a convenient position on the observer's coat.

CURRENT METER NO. 623 combines all of the advantages of all other meters previously listed. It can be suspended by cable or by jointed wading rod, and is equipped with two interchangeable commutator boxes for indicating each revolution, or each fifth revolution, of the bucket wheel.

The combination of these features provides an outfit which has been adopted as standard by the most efficient hydraulic engineers. This meter is used extensively by the Water Resources Branch of the United States Geological Survey, the leading organization devoted to the precise measurement of water.

Two contact chambers, one to indicate each revolution, the other each fifth revolution of the bucket wheel,

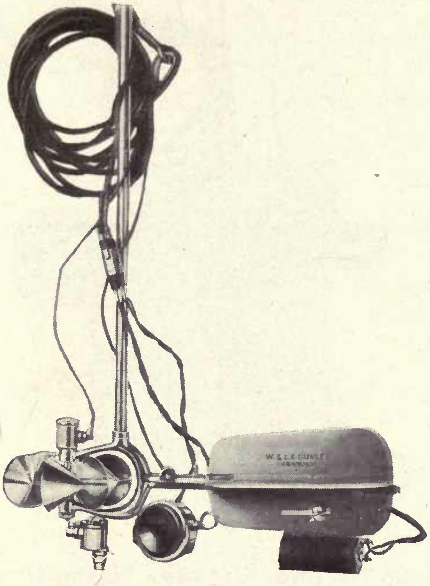


Fig. 108

No. 623 Electric Current Meter Outfit
with meter suspended by jointed wading rods

are provided. These contact chambers may be readily interchanged, the only change being in the shaft and consisting of the insertion of a cam on the end of the bucket shaft when a single revolution is to be indicated, or the insertion of a worm when it is desired to indicate every fifth revolution.

A more complete description of current meters and their parts, as well as water stage registers, is given in

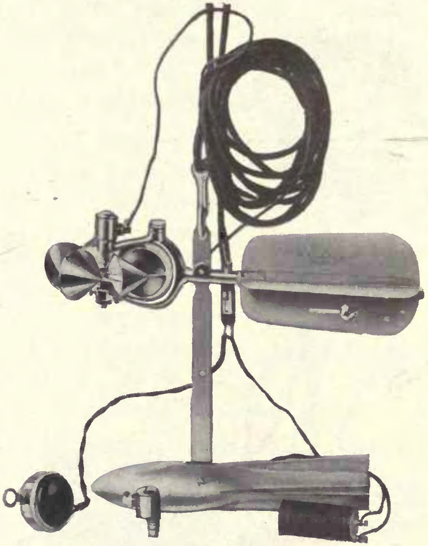


Fig. 109
No. 623 Electric Current Meter Outfit
WITH METER SUSPENDED BY CABLE

"A Manual of Gurley Hydraulic Engineering Instruments", which will be sent upon request. The Manual, besides describing the meters, gives the calibration charts for the various types and full instructions regarding the use of hydraulic instruments in general.

ELECTRIC REGISTER

WHENEVER it is desirable to record the revolutions of the bucket wheel of Meters Nos. 617, 621 and 623, an Electric Register may be substituted for the telephone ear piece ordinarily used.

Electric Register No. 609 has been developed recently by us and is a great improvement over the former pattern. It is suitable for use with current meters or any

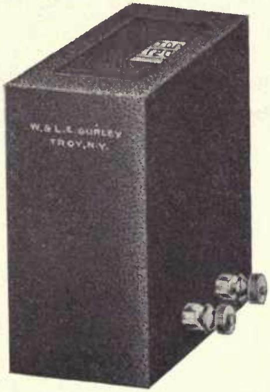


FIG. 110
No. 609 ELECTRIC REGISTER

other intermittent contact device of which a record is desired.

This device consists of a three figure "Veeder" counter operated by an electro-magnet and springs, and is so arranged that the same force acts on the counter regardless of how much current is used. This results in a uniform action and guarantees against any skipping or missing, under widely varying conditions.

This instrument will operate under favorable conditions with one good dry cell, but should have two, as a protection against deterioration of the battery. It requires but 0.31 ampere with two cells, which is a much smaller current than was necessary with the old style register, and which will not burn the current meter contacts.

There are no dials to read, the total result being shown directly by the figures, so that there is small chance of an error in reading.

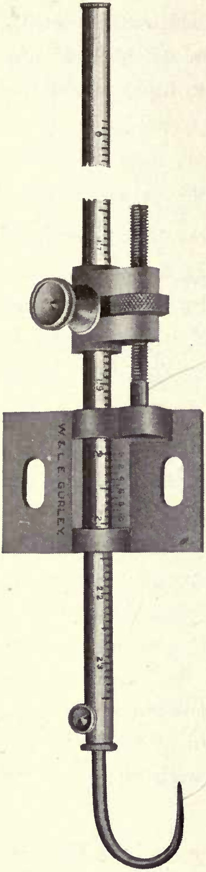


Fig. 111
No. 628
Hook Gage

HOOK GAGE

THIS new type of Hook Gage was designed in accordance with suggestions made by Messrs. Metcalf and Eddy, Consulting Hydraulic Engineers, of Boston, Mass., and is a great improvement over other patterns. Its entire arrangement is such that the readings can be taken by the observer with the greatest possible convenience and at some distance from the surface of the stream or ditch being measured. This is often a decided advantage, especially so in the East, where many of the streams are contaminated by dye stuffs and other undesirable material, rendering it unpleasant for the observer to get too close to the water.

The Hook Gage is nickel-plated throughout. The tube is regularly made to read to 2.2 feet but may be made longer if desired. It is graduated to feet, tenths and hundredths, and is read to thousandths by a vernier which is capable of fine adjustment by means of a slow motion screw. Elongated holes in the base furnish means for bolting the gage to the side of the flume. The hook is adjustable within the tube and allows for a movement of 12 inches independent of the gage, thus permitting it to be set accurately to the exact surface of the water.

Use of the Hook Gage

The hook gage is used in a box attached to a flume at any convenient point near the weir, the water from the flume being conveyed to the box by rubber or lead pipes, thus indicating the precise level of the water in the flume, the surface of the water in the box being at rest.

When the depth of the water passing over a weir is required, the exact level of the crest of the weir should be taken by a leveling instrument and rod, and marked by a line drawn in the still water box at the surface of the water. The scale of the gage being previously set at zero with the vernier, the base is fastened to the box above the water in a vertical position and at such a height that the point of the hook is at the same level as the crest of the weir, the precise point being secured by moving the hook in the tube. The point of the hook will of course be under water and level with the crest of the weir.

The depth of water flowing over the weir is the distance between the point of the hook in the position named and the exact surface of the water. To ascertain this, the hook is raised by turning the milled head nut until the point of the hook, appearing a little above the surface, causes a distortion in the reflection of the light from the surface of the water. A slight movement of the hook in the opposite direction will cause the distortion to disappear, and will indicate the surface with precision. The reading of the scale will then give the depth of water passing over the weir, in thousandths of a foot.

It will be understood from the illustration that the longer movements of the scale are made by loosening the large clamp screw and sliding the graduated tube through the frame, the finer adjustments being made by the milled nut.

WATER STAGE REGISTERS

THE growing importance of water power development, the great possibilities for its use in irrigation and the many other ways in which this great gift of nature may be employed in the service of man, have made more essential, as in recent years its value has been better appreciated, the accurate determination of the volume of water in streams available for such use.

The energy of some of the foremost engineers in the world has been enlisted in the work, and both methods and appliances have been perfected as the result of experience.

For many years Gurley Current Meters have been in use in all parts of the world and are considered standard in determining the velocity of the flow of water in streams.

The discharge of a stream is usually ascertained by a comparison of gage heights with a rating table of the discharge of the stream at varying heights, compiled from a series of current meter observations.

The greatest error in these estimates is due to inaccurate determination of the gage heights, ordinarily secured from a few observations taken during the day, or even more infrequently.

It has been found that on many streams there is a considerable daily fluctuation due to natural or artificial control, making it impossible to obtain accurate gage heights without the use of an automatic register which will record the height of water at regular intervals during the entire twenty-four hours, or over a longer period of time.

In the endeavor to produce instruments satisfactory for such purposes, we have for several years been engaged in designing Water Stage Registers by which the varying height of water in streams may be gaged and a dependable continuous record be obtained.

As a result of our efforts, coupled with the suggestions made by eminent engineers, familiar with the problems involved, we have produced several patterns of Water Stage Registers which are satisfactorily meeting the demands of the service for reliable instruments giving accurate and uniform records.

Automatic Water Stage Registers are divided into two classes — those making a printed record, and those making a graphic record. In the first type a printed record of the height and time is made, while in the second type the record is traced by a pen or pencil on the surface of a paper sheet, moving in harmony with the time and height.

The first type of register is designed to give printed records of the rise and fall of water continuously for a long period of time, and is especially adapted for places where it is impractical or impossible, by reason of inaccessibility, for the observer to visit the station for long intervals of time and where the record, to be of service, should be continuous.

No. 630 Printing Water Stage Register

Patented January 10, 1911

The difficulty of scaling with precision the records made by a graphic register, the tendency of the paper to be affected by moisture or other causes, and the limited time for which the record can be taken, have led to our introducing a register which prints on a continuous paper strip, at intervals of 15 minutes, the height of the water in feet and hundredths of a foot for a period of time dependent on the range of fall allowed the driving weights, which move at the rate of one and one half inches during a period of 24 hours.

This register is the result of years of study and experiment, and is made in the best manner and of the best material. It has had the original inspection and approval of some of the most eminent hydraulic engineers, and has been tested under severe conditions of actual service with most satisfactory results. We, therefore, have no hesitation in recommending its use to all who require accuracy and efficiency in water measurements.

Construction. By reference to the illustrations, a clear idea can be gained of the mechanical construction of the register.

An iron base about fourteen inches square, at either corner of which is an iron rod approximately twenty-one inches long supporting an iron top, forms a frame for the register. On the base are also erected the standards which support the recording mechanism, the spools for holding the paper and carbon ribbon and the driving mechanism.

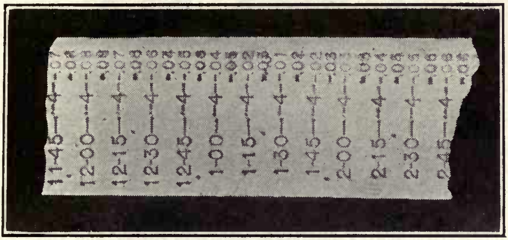


Fig. 112

SECTION OF PAPER TAPE, SHOWING PRINTED RECORD MADE ON A NO. 630 PRINTING REGISTER

The recording mechanism consists of three parallel type wheels, on the faces of which are raised figures and divisions indicating respectively the period of time from one to twelve hours at intervals of 15 minutes, as desired, the number of feet from zero to thirty-six, and the hundredths of a foot.

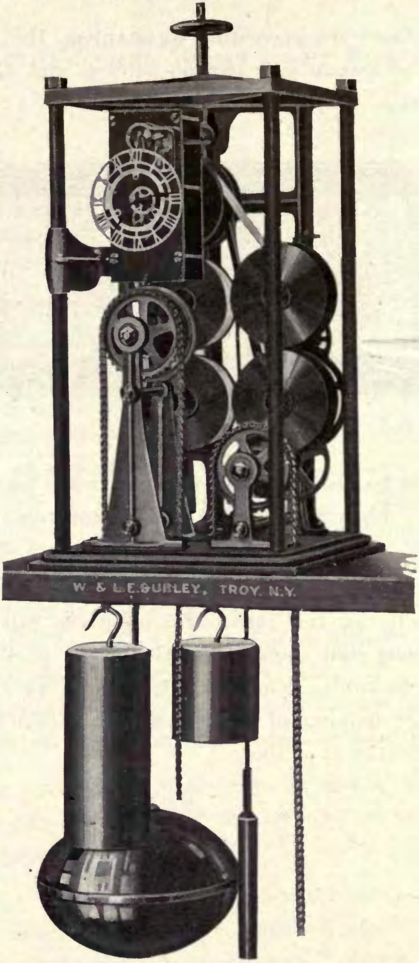


FIG. 113

NO. 630 PRINTING WATER STAGE REGISTER

FRONT VIEW, SHOWING CLOCK, FLOAT AND WEIGHTS

The type wheel indicating time is controlled by a weight driven clock of finest construction, with full jeweled escapement and compensated to endure variations of climate without variation in its regular operation.

The two type wheels indicating heights of water are moved by a sprocket wheel connected to the float and counterweight by a perforated metal band, so that any change in the height of water is immediately indicated by a corresponding movement of the type wheels.

Four reels mounted on the main standard of the instrument carry and receive the paper strip with its carbon backing on which the record is made, and which passes over the type wheels, and is held taut by the tension of a weight on the receiving reel.

Three weighted hammers, pivoted on a shaft and with cushioned faces opposite the center of the type wheels, are controlled in their action by a saw-toothed cam, moved by the clock in such a manner that at intervals of 15, 30 or 60 minutes the hammers are released and strike a blow on the type wheels, thus making on the tape covering them an imprint of the indicated time, and height of water.

The large diameter of the copper float, 10 inches, enables it to respond immediately to any variations in the height of the water, the slightest change being recorded. Its size and shape render it extremely sensitive, and the top is rounded so that foreign matter cannot lodge on it and change the degree of immersion.

The frame and mechanism as above described are covered by a metal hood, fitting tightly at the bottom in a rubber gasket and having at the top a clamp nut which may be secured by a lock, preventing the removal of the case by unauthorized persons. A glass-covered opening allows an easy reading of the clock, which may be wound from the outside at such intervals as required without the removal of the case or disturbance of the instrument.

For the convenience of our customers we publish the "Manual of Gurley Hydraulic Engineering Instruments." This book describes in detail the construction and best methods of installing Gurley Hydraulic Registers.

GRAPHIC WATER STAGE REGISTERS

An improved Graphic Register is shown in Fig. 114 having several unique and valuable features. It is of simple construction, with few parts; is designed for easy operation, and adapted for a wide range of conditions. Its construction is such that no lost motion will develop from continuous service and it can be operated with minimum care and expense.

Vertical scales ranging from zero to twenty feet are supplied and time scales of 1 day, 4 days, or 7 days can be furnished. As the record of stage is made around the cylinder, there is no limit to the number of revolutions possible, and hence to the range of stage. Therefore, it is advisable to use as low a range as possi-

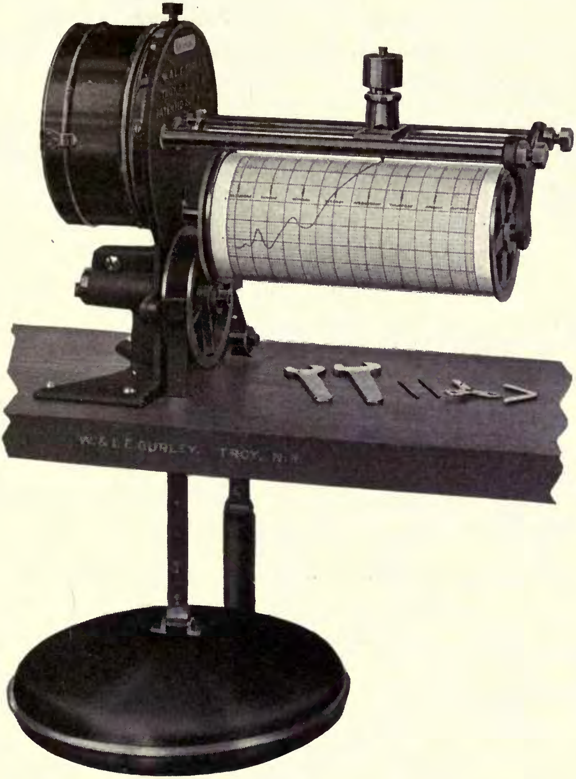


Fig. 114

No. 633 Graphic Water Stage Register

spring-driven clock

ble and obtain a more accurate reading of the water stage. If occasionally the water stage is above the range of the register, no trouble will be experienced in reading the water level.

Complete descriptions and illustrations of our hydraulic equipment is furnished in "A Manual of Gurley Hydraulic Engineering Instruments," which will be sent upon request.

CONSTRUCTION

The Graphic Water Stage Register combines admirably scientific design and rugged construction.

An extra heavy, spring or weight driven clock is geared to two time screws which are supported at each end. Mounted on the screws is a carriage holding a weighted pencil, this carriage and pencil move forward without lost motion in accord with the turning of the clock shaft.

A counterweighted float ten inches in diameter and three and one half inches thick operates the record cylinder either directly or by means of gears according to the vertical range desired.

The whole instrument is enclosed in a sheet metal cover which makes it waterproof and dust proof.

Gurley Long Distance Graphic Water Stage Register and Indicator

AS the result of several years experimenting in co-operation with a number of leading hydraulic engineers, W. & L. E. Gurley have developed a Long Distance Water Stage Register which is the most accurate, efficient and reliable instrument of its type on the market.

The value to engineers of segregating distant gage readings at one point is apparent. In power plant operation, particularly, the use of this instrument proves invaluable, as it provides means of determining instantly the varying water levels at distant points, and thus permits of a more efficient use and control of the water available.

The outfit consists of a float-operated Sender which is installed at the gaging station and by which the varying water levels are transmitted by means of an electric circuit to the Receiver, which is generally located in the power house or in the office of the engineer responsible for the efficient operation of the plant.

The Receiver may consist of an indicating device only, or it may include a Register making a graphic record, or the apparatus may comprise a combination of both, as desired. Furthermore, it is possible, with one Sender, to operate several Receivers, of the indicating or recording type, at different locations.

The Sender and the Receiver are of simple construction and high grade workmanship and are very positive and uniform in their operation.

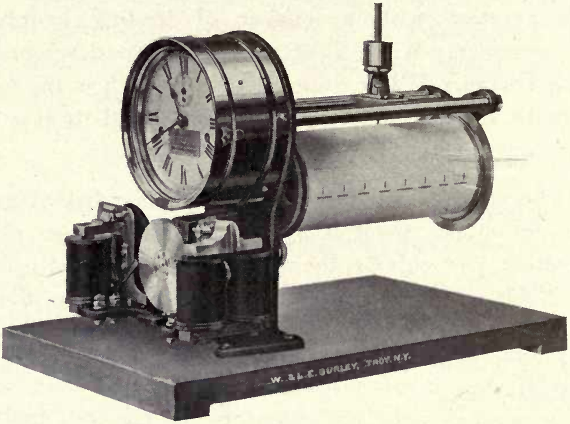


FIG. 115

NO. 637 LONG DISTANCE
GRAPHIC WATER STAGE REGISTER

In modern hydraulic practice it is often desirable to record or indicate in the office or power house, the water stage at some distant point.

Gurley Long Distance Registers and Indicators are electrically operated and will record or indicate accurately the fluctuations of any liquid level at any distance.

THE SENDER, located at the point where the water stage is to be measured, is operated by a float and counterweight similar to those used on our other registers. It is equipped with two electrical contacts, one of which closes for a fraction of a second every time the float rises, the other when the float falls 1/20 of a foot. These contacts, which were developed in the Gurley factory, have been subjected to tens of thousands of tests with heavy load at 120 volts, without any failure or even a sign of deterioration.

THE RECEIVER consists of one of our No. 633 Graphic Registers, but modified so that the record cylinder is operated by magnets instead of directly by the float. The drum is turned by means of gears and a ratchet wheel which is operated by two pairs of powerful magnets, one for rising, the other for falling water. The operating arms which are attached to the magnet armatures turn the ratchet wheel one notch each time either magnet is energized. These arms also carry interlocking stops which positively prevent the wheel from turning more than one notch, until the magnet is released and ready for the next step. The rear end of the drum carries a dial and pointer, so that the water stage may be read directly without looking at the chart.

The circuits necessary to connect the Sender and Receiver may consist either of 3 wires or 2 wires and a "ground" return. A satisfactory circuit may be obtained by leasing a private telephone line of 2 wires. The current required to operate the receiver is 0.1 ampere and this flows through the line for only a fraction of a second when the contact is made. At all other times the circuits are open. The resistance of the coils is 40 ohms. The power may be supplied by dry cells or storage batteries. For long distances it is better to take it from a 110 volt D. C. power or storage battery line, if continuously available throughout the 24 hours of the day. A lamp placed in the circuit will cut down the current to the proper amount, that is, 0.1 ampere. The power may be connected into the circuit at any point in the line.

Any number of Receivers or Indicators may be used on the circuit for one Sender.

Blue prints showing the necessary wiring connections will be furnished upon request.

THE LONG DISTANCE WATER STAGE INDICATOR answers the purpose where a record of the water level is not desired but only an indication of the level at some distant point. This operates with the same Sender and circuits described above for the Long Distance Graphic Water Stage Register. Instead of the No. 633 Register, a large dial 12 inches in diameter, with a moving pointer, is operated by electro-magnets and a ratchet wheel, in the same manner as the Long Distance Register. This dial shows the height of the water at the distant gage house, at any instant. A larger dial can be furnished if desired. Prices, which depend upon the size, will be quoted upon application.

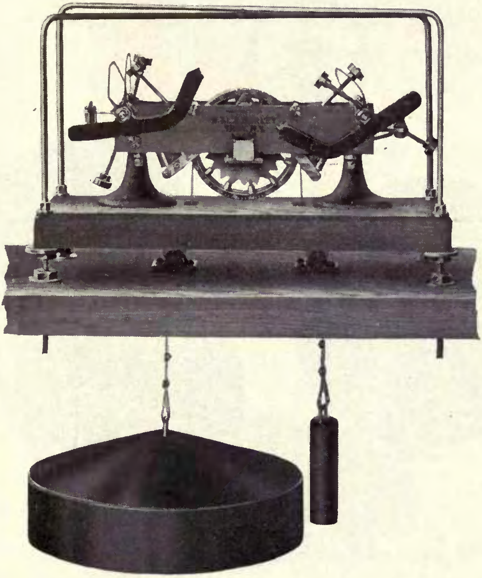


Fig. 116

No. 638 Float Operated Sender, for Long Distance Graphic Register

This Indicator may also be put on the same circuit with a Register. In many cases it will be desirable to have an Indicator in the power plant for the information of the operator, while the Register may be placed in the office of the chief engineer, where the records will be kept and studied.

Detailed information concerning the solution ot special gaging problems of hydraulic engineers will be furnished upon request.

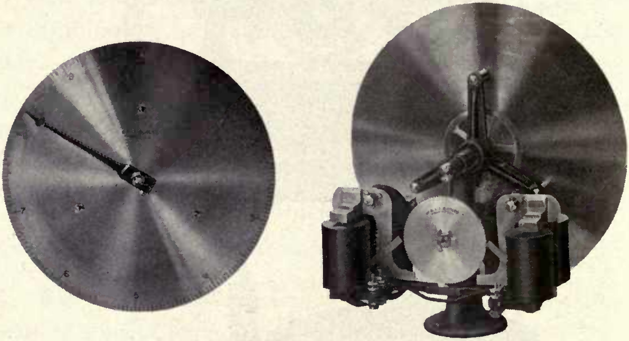


Fig. 117

No. 639 Long Distance Indicator with 12″ Dial

Indicating Gage No. 639-A will be found a great help in the checking of gage heights in stilling wells in which automatic recording gages are installed. It can be used also wherever water levels are to be observed.

This instrument is designed to replace the ordinary hook, chain and staff gages where very accurate readings are required. The sprocket wheel is one foot in circumference and is divided into 100 parts, and the feet may be read on the counter up to 100. This gage will be furnished with or without the float.

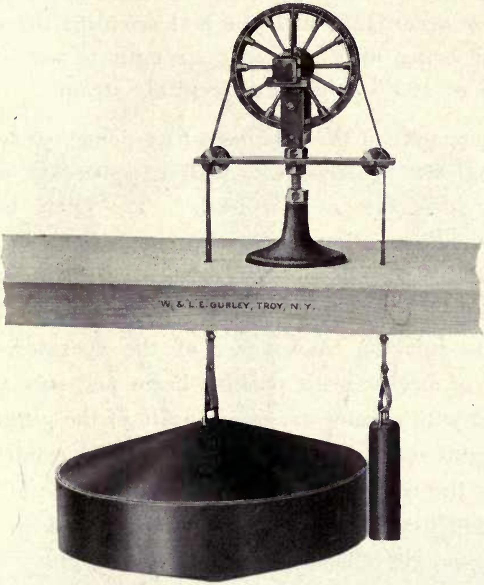


Fig. 118

No. 639-A Indicating Gage

PRECISION BALANCE

THE GURLEY PRECISION BALANCE is the highest development of a weighing instrument and is constructed strictly in accordance with the best scientific principles, all parts being of a sufficient strength to support an overload of 100% without perceptible strain.

The capacity of the balance is fifty pounds or twenty-five kilograms in each pan, with a sensibility of one grain or .06 gram at full load. The beam is of a special aluminum alloy which will remain constant under all conditions, and is equipped with a vertically adjustable weight by which the sensibility reciprocal can be altered to suit the convenience of the operator. The pillar is of bronze with positive beam and pan arrestment and with pointer swinging inside of the pillar over a horizontal scale, back of which is placed a mirror to facilitate the readings. All bearings are made of agate and the knife edges are of the best hardened steel. The pan hangers are of bronze and aluminum, and the pans are of nickel plated brass. The base is of highly polished oak or mahogany, with attached spirit level and four leveling screws.

The base is about 40 inches long and 15 inches wide. The overall height of the Balance is about 40 inches.

In addition to the balance illustrated above, we also manufacture Precision Weights and Measures used as official standards. These are of the highest degree of accuracy, and are guaranteed to conform to the specifications of the National Bureau of Standards. A certificate of test from this bureau will be furnished when desired.

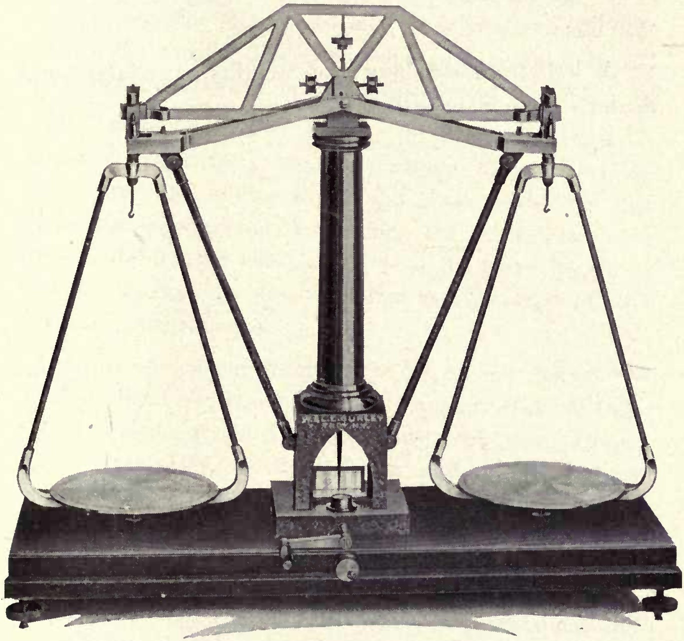


FIG. 119

No. 9570 PRECISION BALANCE

We have made official weights and measures for the Bureau of Standards and for practically all of the Departments of Weights and Measures in this country; also for China, the Philippine Islands, Porto Rico and Haiti. We are prepared to furnish weights and measures to conform to the standards of any foreign country.

A bulletin describing the weights, measures, and Sealer's equipment will be sent upon request.

GENERAL INFORMATION

Extent of Our Business

FOR many years our facilities for the manufacture of Engineering and Surveying Instruments have been far superior to those of any other similar establishment in the world. They are being constantly increased by the introduction of new machinery and tools.

We make in our own factory the lenses for the telescopes of our instruments, the platinum filament for the cross wires and stadia wires, the glass vials for the levels, the wooden boxes in which the instruments are carried, the leather cases and straps for these boxes, as well as the castings and all other metal parts of the instruments themselves.

Thousands of our instruments have been distributed to all parts of the United States, Canada, Mexico, Central America, West Indies, South America, China, Japan, Australia, Africa, India and other foreign countries.

Our Guarantee

All instruments of our own make are examined and tested before being shipped, and are sent to the purchaser adjusted, ready for immediate use. They are warranted correct in all their parts — we agreeing in the event of any original defect appearing after reasonable use, to repair or replace with new and perfect instruments, promptly at our own cost, express charges included; or we will refund the money and the express charges paid by the purchaser.

It sometimes happens in a business as large and widely extended as ours that instruments reach our customers in bad condition, owing to careless transportation, or to defects escaping the closest scrutiny of our inspectors. We consider the retention of such instruments by the purchaser an injury very much greater to us than to himself. We also consider that a sale is not completed until the purchaser is satisfied in every detail.

TRIAL OF INSTRUMENTS

If requested to do so, we will ship to the express station nearest the person giving the order and will instruct the express agent to collect the amount of our bill and hold the money three days. This will give the purchaser an opportunity to test the instrument in the field and if it is not found as represented, he may return it to the express agent who will refund the full amount paid, including transportation charges.

This privilege of trial applies only to our large instruments such as Transits, Levels, Compasses, etc., is not given unless requested, and is allowed only in the United States. Privilege of trial is not allowed by the Great Northern or Southern Express Companies. All express companies, however, will allow examination of instruments at their offices, if the shipper requests it for the purchaser.

ORDERING

In ordering always give the Catalogue Numbers of the instruments and accessories selected.

If full particulars concerning each item accompany the order, delay will often be avoided, as it will probably be unnecessary for us to write you.

If no shipping directions are given, we will always ship by the quickest and safest method.

When any articles can be sent safely by mail, we have printed the approximate cost of postage so that, by remitting with the order the cost of the article and the postage, the goods can be sent at small expense. Should the amount sent exceed the actual postage, the balance will be returned.

All articles can be insured at an extra cost which varies according to the value of the package. For details see Parcel Post Regulations.

PACKING AND DELIVERY

Each of our Transits, Levels and Surveyors Compasses is packed in a well finished mahogany case, furnished with lock and key, and leather strap for convenience in carrying.

When sent to the purchaser the mahogany cases are carefully enclosed in outside packing boxes of pine, made a little larger on all sides to receive elastic packing material.

We make no charge for packing boxes or packing, and our instruments are delivered F. O. B. Troy, N. Y., to the express company or freight house.

Charges for transportation are in all cases to be paid by the purchaser, we guaranteeing the safe arrival of our goods at the destination indicated at the time of shipment.

Terms of Payment

Terms of payment are *uniformly cash,* and we have but one price, whether ordered in person or by mail. Our prices are as low as instruments of first quality can be made.

Remittances may be made by a cashier's bank draft, payable to our order, or by Express Company or Post Office money order payable at Troy, N. Y. These may be sent by mail with the order for the instrument, and if lost or stolen on the route can be replaced by a duplicate, and without additional cost.

The customer may also send the money in advance by registered mail, or by the express agent, or instruct us to forward the shipment C. O. D. Goods ordered for shipment to foreign countries must be paid for in advance of shipment.

Customers ordering instruments and desiring *changes in construction* from our regular patterns, must make a payment in advance *when ordering* of fifty per cent. of the price.

Instruments for Foreign Countries

Fig. 120

Instruments packed for foreign shipment which are to have ocean passage are wrapped in waterproof material and enclosed in strong packing boxes which are strengthened and protected by special band wire.

The cash for all orders for foreign shipments by steamship must, in every case, accompany the order; and if it is desired that we attend to the shipment of the instruments, the remittance must be made ten per cent. more than the catalogue price of the instruments if the order amounts to $250 or less; or eight per cent. more than catalogue price if the order amounts to from $300 to $500; or six per cent. more than catalogue price if the order amounts to from $600 to $1,000.

This extra remittance is to cover cost of shipping charges, freight and insurance, which must always be paid in advance on all shipments except those consigned to Canada and some parts of Mexico.

If the amount remitted is more than enough to cover these expenses, the balance will be returned to the purchaser with the receipted bill and bill of lading, unless we are directed to hold it to his credit.

Remittances must be made by bank draft on New York City or London, England, and such drafts can be purchased in any of the large cities of the different countries.

Our registered cable address is "GURLEY, TROY." Use Bentley's, Western Union, A. B. C. Fifth Edition, or Lieber's Codes. *See Private Cable Code on pages 315 to 323.*

Repair of Instruments

Each year we receive hundreds of instruments of our own and other makes sent to us for refitting and repairs.

We advise our customers who have instruments in need of repairs to send them directly to us, as our facilities enable us to do the work economically and promptly.

They should always be placed in their own boxes, and then enclosed in an outside packing case, at least an inch larger in all its dimensions, and the space between the two filled with paper wadding, hay or shavings.

The owner's name and address should always appear on the package and a note specifying the repairs needed should accompany the instrument. A letter should also be sent by mail to us, giving not only directions as to the repairs, but also stating when the return of the instrument is required, and the precise location to which it should be forwarded.

It should also be remembered that *each instrument is made to fit its own spindle,* and no other; and therefore the leveling head complete (centers and spindle) should always be sent with it.

The tripod legs and brass head in which they are inserted need not be sent unless in need of repairs.

When requested to do so, we will furnish an estimate of the cost of the repairs on any instrument sent us, before beginning the work.

SELECTION OF INSTRUMENTS

For ordinary land surveying, the Vernier Compass is required where the variation of the needle is to be allowed, as in retracing the lines of an old survey, etc.

When, in addition to the variation of the needle, local attraction must be taken into account and angles taken independently of the needle, an instrument with a graduated limb must be used, and for this purpose a Compass with horizontal limb is required. See No. 294.

For municipal engineering, railroad and highway construction, bridge building, drainage and irrigation work, selection should be made from our Precise Transits Nos. 6-A to 10-A, 26-A to 29-A, Light Mountain Transits Nos. 26 to 29; and Engineers Wye Levels Nos. 375 to 378.

The Light Mountain Transits (regular and Precise types) are also ideal instruments for surveys of mining claims, especially in high elevations, and for surveys of mines in general.

For United States Public Land Surveys an instrument with the Solar Attachment is required and the Solar Transit is used; see Nos. 30-A, 32-A and 23-A.

No. 18-A "Hell Gate Model" Precise Transit is capable of executing triangulation surveys demanding the highest degree of accuracy and refinement.

The various Plane Table Outfits have a recognized utility for topographical surveys and map drawing.

The Current Meters are almost indispensable in measuring the velocity of the flow of water in harbors, rivers, small streams and irrigation ditches.

The Automatic Water Stage Registers are used for determining the variations in the height or stage of the water in connection with water power development, irrigation investigations and sewage discharge.

The Hook Gage is utilized for ascertaining the depth of water flowing over weirs, etc.

The Architects Level is employed in laying out buildings, determining the level of their floors, sills and windows, and in the general work of the builder and contractor.

The Explorers Transit, the Reconnoissance Transit, the Explorers Level and the various forms of Pocket Compasses are designed for preliminary surveys where extreme lightness and portability are required.

When iron ores are to be traced, the Dip Compass and the Dial Compass are used.

We do not make any instrument by which veins of gold and silver can be traced, or the presence of these metals detected.

Exchanging Old Instruments

Correspondence is solicited relating to exchanging old instruments of our make for those of the latest patterns.

We are constantly making such exchanges to the entire satisfaction of our customers and if the old instruments are salable as second-hand, after being rebuilt and refinished, a liberal allowance is made.

Invitation to Visit Our Factory

A cordial invitation is extended to our customers to visit our Factory in Troy, N. Y. Opportunities are thus had for examining the various instruments we make and for observing the processes of manufacture. Visitors who call on us are greatly impressed with the size of our establishment and also with the elaborate equipment which is required to produce high grade instruments.

LITERATURE

We publish a variety of attractive bulletins containing special information relative to our products. They will be supplied to our correspondents who express an interest in or a desire for some particular instrument.

GURLEY SOLAR EPHEMERIS

The Solar Ephemeris is published annually. It is an abridgment of the Nautical Almanac, issued by the United States Government, and contains a Table of Mean Refractions in Declination and Tables of Times of Elongation, Culmination and Azimuths of Polaris. It can be conveniently carried in the vest pocket. A copy will be sent postpaid to any engineer or surveyor, on request.

PRIVATE CABLE CODE

CABLE CODE: "GURLEY"

Use Bentley's, Western Union, Lieber's; or A. B. C. 5th Edition, Codes

Cat. No.	Description	Code Word
6-A	Precise Transit, Engineers size	Abaab
7-A	Precise Transit, Engineers size	Ababa
8-A	Precise Transit, Engineers size	Ababs
9-A	Precise Transit, Engineers size	Abaca
10-A	Precise Transit, Engineers size	Abacy
10-A-3	Precise Transit, with Three-Screw Leveling Head	Abagn
18-A	Precise Transit, Hell Gate Model	Abago
25-A	Precise Transit, Mountain size	Abaha
26-A	Precise Transit, Mountain size	Abahi
27-A	Precise Transit, Mountain size	Abahl
28-A	Precise Transit, Mountain size	Abahs
29-A	Precise Transit, Mountain size	Abaib
30-A	Precise Transit, Mountain size	Abaig
32-A	Precise Transit, with Telescopic Solar	Abail
20-A	Explorers Precise Transit	Abaek
21-A	Explorers Precise Transit	Abaen
22-A	Explorers Precise Transit	Abaer
23-A	Explorers Precise Transit	Abaet
24-A	Explorers Precise Transit	Abagu
25	Light Mountain or Mine Transit	Atimy
26	Light Mountain or Mine Transit	Atjip
27	Light Mountain or Mine Transit	Atkir
28	Light Mountain or Mine Transit	Atler
29	Light Mountain or Mine Transit	Atmar
30	Light Mountain or Mine Transit	Atnas
102	Reconnoissance Transit	Avseb
103	Reconnoissance Transit	Abaim
	Limb I	Abaip
	Limb IV	Abaiy
131	Variation Arc	Arbuc
135-B	Vertical Circle	Arfen
136	Vertical Circle	Arfid
137	Vertical Circle	Argog
138	Vertical Circle	Arins

Cat. No.	Description	Code Word
139	Vertical Circle	Abajo
139-A	Vertical Arc	Arkal
139-B	Vertical Arc	Arkon
140	Vertical Arc	Arlik
141	Aluminum Guard	Armil
145	Level on Telescope	Arnon
146	Reversion Telescope Level	Arobs
148	Clamp and Tangent	Aroms
149	Beaman Stadia Arc	Arpal
149-A	Beaman Stadia Arc	Abake
149-B	Beaman Stadia Arc	Abaks
149-C	Beaman Stadia Arc	Abaku
150	Gradienter	Arram
151	Stadia Wires, Adjustable	Abald
152	Stadia Wires, Fixed	Abalk
154	Dust Guard	Abalo
155	Pinion Movement	Abalt
157	Sights on Telescope	Arren
158	Sights on Standards	Arrot
160	Detachable Side Telescope and Counterpoise	Arsan
161	Detachable Riding Telescope	Artap
165	Reflector for Transit Cross Wires	Artot
166	Reflector for Level Cross Wires	Arvit
167	Elbow Eyepiece	Abaly
168	Diagonal Prism	Arwet
169	Eyepiece Cap	Abalu
170	Plummet Lamp	Arzub
180	Attached Magnifier	Asbid
181	Attached Microscopes	Abamo
182	Attached Microscopes	Abams
185	Limb Graduation	Ascog
186	Limb Graduation	Asdig
187	Vertical Circle Graduation	Asels
188	Vertical Circle Graduation	Asgle
189	Vertical Circle Graduation	Abamu
190	Burt Solar Attachment	Ashik
192	Solar Screen	Abana
193	Patent Latitude Level	Asilt
196	Striding Level	Askon
197	Adjusting Bar	Abang
226	Vernier Compass	Agwen
241	Leveling Adopter	Afbir
242	Leveling Head	Afcot

Cat. No.	Description	Code Word
262	Telescopic Sight	Apbat
265	Vertical Circle for No. 262 Telescopic Sight	Apfob
266	Level on Telescope for No. 262 Telescopic Sight	Aphic
267	Clamp and Tangent for No. 262 Telescopic Sight	Aplad
268	Offset Standard and Counterpoise for No. 262 Telescopic Sight	Apost
285	Pocket Compass with Limb	Addip
294	Compass with Limb and Telescope	Abans
300	Pocket Vernier Compass	Afrad
305	Pocket Vernier Compass	Afseg
325	Clamp and Tangent	Agbet
326	Rack and Pinion Movement	Agcat
327	Leveling Adopter	Agdix
328	Leveling Head	Agern
335	Geologists Compass	Afnid
341	Dip Compass	Afkob
341-A	Dip Compass	Aflam
350	Dial Compass	Afirl
375	Engineers Wye Level	Akary
377	Engineers Wye Level	Akdul
378	Engineers Wye Level	Akgun
381	Architects Level	Ajrot
384	Explorers Level	Abaoh
400	Transit Tripod	Axnig
401	Transit Tripod	Axots
405	Transit Tripod	Axrul
406	Transit Tripod	Axtil
410	Transit Tripod	Axvim
411	Transit Tripod	Axyan
412	Transit Tripod	Abaok
415	Compass Tripod	Awact
416	Compass Tripod	Awder
420	Compass Tripod	Awfit
421	Compass Tripod	Awify
425	Compass Tripod	Aworl
426	Compass Tripod	Awrif
430	Level Tripod	Axbar
431	Level Tripod	Axcet
435	Level Tripod	Axdox
436	Level Tripod	Axfoy
440	Level Tripod	Axgub
441	Level Tripod	Axhob
443	Level Tripod	Abapa

Cat. No.	Description	Code Word
450	Plain Plummet	Abaph
452	Plain Plummet	Abapt
454	Plain Plummet	Abapy
456	Plain Plummet	Abarb
458	Plain Plummet	Abarc
460	Plain Plummet	Abarf
465	Adjustable Plummet	Abari
471	Iron Spads	Abarm
472	Stake Tacks	Abarp
473	Stake Tacks	Abars
474	Plummet Cord	Abaso
475	Leather Case	Abasp
476	Leather Case	Abast
478	Leather Case	Abasy
479	Leather Case	Abata
480	Leather Case	Abath
485	Leather Case	Abaty
486	Leather Case	Abaud
487	Leather Case	Abaur
490	Leather Pouch	Abaux
491	Leather Pouch	Abauz
492	Leather Pouch	Abauj
494	Tripod Case	Abava
496	Tripod Case	Abavi
497	Tripod Case	Abavy
498	Leather Field Bag	Abawi

If metric graduations are wanted, specify "METRIC" after the code word for the Rod.

Cat. No.	Description	Code Word
500	Philadelphia Rod	Albol
500-A	Philadelphia Rod	Abaxo
500-B	Philadelphia Rod	Alcun
500-R	Service Rod	Abayu
501	Philadelphia Rod	Aldon
501-B	Special Self-Reading Rod	Alfop
502-A	Philadelphia Mining Rod	Algor
504	Troy Rod	Alimb
505	New York Rod	Aljer
510	Architects Rod	Alnew
511	Architects Rod	Alond
513	Telemeter Rod	Alrob
514	Telemeter Rod	Alsay
514-B	Stadia Rod	Abaye
514-C	Stadia Rod	Abayr
514-D	Stadia Rod	Abayt

Cat. No.	Description	Code Word
514-E	Stadia Rod	Abaza
515	Telescopic Rod	Altic
516	Cross Section Rod	Alubs
517	Slip-Jointed Rod	Abbej
518-A	Plain Rod	Alvof
518-B	Plain Rod	Alwed
519-A	Plain Rod	Amand
519-B	Plain Rod	Ambin
520-A	Plain Rod	Amcus
520-B	Plain Rod	Amdut
521-B	Plain Rod	Amfis
522-A	Plain Rod	Amgit
522-B	Plain Rod	Amhow
522-C	Plain Rod	Amild
524-A	Plain Rod, 4 ply	Amkoy
525-B	Flexible or Pocket Leveling Rod	Ampod
526-A	Flexible or Pocket Leveling Rod	Amrid
526-B	Flexible or Pocket Leveling Rod	Amsed
527	Flexible or Pocket Leveling Rod	Amtad
528	Flexible or Pocket Leveling Rod	Amudy
530	Combined Leveling Pole and Flagstaff	Akhon
531	Combined Leveling Pole and Flagstaff	Akkip
534	Wood Flagstaff	Abazi
535	Wood Flagstaff	Abazy
536	Wood Flagstaff	Abbac
537-A	Screw-Jointed Wood Flagstaff	Abbaf
537-B	Screw-Jointed Wood Flagstaff	Abbal
537-C	Screw-Jointed Wood Flagstaff	Abbam
537-D	Screw-Jointed Wood Flagstaff	Abbap
538-A	Screw-Jointed Wood Flagstaff	Abbas
538-B	Screw-Jointed Wood Flagstaff	Abbaw
540-A	Steel Ranging Pole	Abbed
540-B	Steel Ranging Pole	Abbeh
541	Iron Tubular Ranging Pole	Abbek
543	Iron Tubular Ranging Pole	Abben
544	Iron Tubular Ranging Pole	Abbet
550-R	Gurley Precise Rod	Abbig
551-R	Molitor Precise Rod	Abbif
552-R	Tape Leveling Rod	Abbic
545	Rod Level	Amnez
546	Rod Level	Amnit
547	Rod Level	Amnor
548	Rod Level	Abbev
570	Johnson Plane Table Movement	Abbil
570-A	Johnson Plane Table Movement	Abbim

Cat. No.	Description	Code Word
571	Johnson Plane Table Movement	Abbip
573	Drawing Board	Abbis
573-A	Drawing Board	Abbiy
573-B	Drawing Board	Abboh
573-T	Drawing Board	Abbot
573-X	Drawing Board	Abbok
574	Plumbing Arm and Plummet	Abbon
575	Combined Compass and Levels	Abbor
576-B	Plane Table Outfit	Abboz
576-C	Plane Table Outfit	Abbud
584-B	Telescopic Alidade	Abnot
584-C	Telescopic Alidade	Abbuk
585	Box Compass	Abome
586	Traverse Plane Table Outfit	Ankud
587	Traverse Plane Table Movement and Drawing Board	Anlic
588	Box Compass	Anmid
589	Ruler Sight Alidade	Anoby
590-A	Pocket Sight Alidade	Anpad
590-B	Pocket Sight Alidade	Anruk
592-C	Explorers Alidade	Abcag
592-D	Explorers Plane Table Outfit	Abcal
592-F	Explorers Plane Table Outfit	Abcam
592-H	Explorers Plane Table Outfit	Abcap
594	Army Sketching Case	Abcas
596	Fiala Scout Sketching Case	Abced
609	Electric Register for Current Meters	Acrub
616	Current Meter	Acvod
617	Current Meter	Acwid
619	Time Recorder or Stop Watch	Adaft
621	Current Meter	Adbel
623	Current Meter	Adbot
628	Hook Gage	Abcek
630	Printing Water Stage Register	Anvel
632	Tape Reel	Anwat
633	Graphic Water Stage Register	Abcet
634	Graphic Water Stage Register	Abcev
634-A	Graphic Water Stage Register	Abcic
636	Graphic Water Stage Register	Abcif
637	Long Distance Register	Abcik
638	Long Distance Sender	Abcil
639	Long Distance Indicator	Abcin
639-A	Indicating Gage	Abcir
640	Monocular Hand Level	Aklut
643	Locke Hand Level	Akpow
646	Abney Hand Level	Aksoy

Cat. No.	Description	Code Word
646-A	Abney Hand Level	Abcil
647	Abney Hand Level	Abcim
647-A	Abney Hand Level	Abcip
648	Abney Hand Level	Abcuv
649	Stadia Hand Level	Aktye
650	Iron Chain	Abcis
651	Iron Chain	Abciy
652	Iron Chain	Abcod
653	Iron Chain	Abcoh
656	Steel Chain	Abcok
658	Steel Chain	Abcon
662	Steel Chain	Abcox
670	Brazed Steel Chain	Abpit
671	Brazed Steel Chain	Abret
672	Brazed Steel Chain	Absat
673	Brazed Steel Chain	Abtoy
690	Vara Chain	Abcur
691	Vara Chain	Abcut
694	Vara Chain	Abcux
695	Vara Chain	Abcyb
700	Vara Chain	Abcyc
704	Vara Chain	Abcyf
708	Vara Chain	Abcyg
710	Vara Chain	Abcyl
715	Meter Chain	Acbul
719	Meter Chain	Acfon
723	Meter Chain	Acily
730	Meter Chain	Acker
732	Meter Chain	Aclar
740	Marking Pins	Abcym
742	Marking Pins	Abcys
743	Marking Pins	Abdah
744	Marking Pins	Abdan
748	Marking Pins	Abdat
749	Marking Pin Carrying Ring	Abdav
750	Timber Scribe	Abdax
774	Steel Ribbon Chain Tape	Abdaz
775	Steel Ribbon Chain Tape	Abdeb
776	Steel Ribbon Chain Tape	Abdec
777	Steel Ribbon Chain Tape	Abdef
778	Steel Ribbon Chain Tape	Abdeg
779	Steel Ribbon Chain Tape	Abdep
M-20	Metric Steel Ribbon Chain Tape	Abdes
M-25	Metric Steel Ribbon Chain Tape	Anper
M-30	Metric Steel Ribbon Chain Tape	Anrot

Cat. No.	Description	Code Word
M-50	Metric Steel Ribbon Chain Tape	Ansub
M-100	Metric Steel Ribbon Chain Tape	Antic
V-20	Vara Steel Ribbon Chain Tape	Abdew
V-30	Vara Steel Ribbon Chain Tape	Abdid
V-50	Vara Steel Ribbon Chain Tape	Abdik
V-100	Vara Steel Ribbon Chain Tape	Abdin
780	Metallic Tape	Abdir
782	Metallic Tape	Abdit
783	Metallic Tape	Abdix
786	Metallic Tape	Abdob
790	Metallic Tape without Case	Abdoc
791	Metallic Tape without Case	Abdof
792	Metallic Tape without Case	Abdog
794	Metallic Tape without Case	Abdol
795	Reliable Steel Tape	Abdom
796	Reliable Steel Tape	Abdop
797	Reliable Steel Tape	Abdos
798	Reliable Steel Tape	Abduc
799	Reliable Steel Tape	Abduf
800	Reliable Junior Steel Tape	Abdug
801	Reliable Junior Steel Tape	Abdul
808	Rival Steel Tape	Abdum
809	Rival Steel Tape	Abdup
810	Rival Steel Tape	Abdus
811	Rival Steel Tape	Abduv
812	Rival Steel Tape	Abdye
813	Rival Steel Tape	Abdyk
814	Wolverine Steel Tape	Abdyr
815	Wolverine Steel Tape	Abdyt
816	Wolverine Steel Tape	Abdyu
817	Wolverine Steel Tape	Abead
820	Engineers Steel Tape	Abeah
821	Engineers Steel Tape	Abeaj
822	Engineers Steel Tape	Abeak
823	Engineers Steel Tape	Abean
824	Engineers Steel Tape	Abear
831	Engineers Steel Tape	Abeat
832	Engineers Steel Tape	Abeax
833	Engineers Steel Tape	Abebe
834	Engineers Steel Tape	Abebo
835	Engineers Steel Tape	Abebu
841	Steel Tape Handles	Abech
842	Steel Tape Handles	Abeco
844	Spring Balance for Tapes	Abect
846	Steel Tape Clamp Handles	Abeda

Cat. No.	Description	Code Word
849	String Level	Abeds
850	Extra Wide Steel Tape	Abedy
851	Extra Wide Steel Tape	Abeeb
852	Extra Wide Steel Tape	Abeec
853	Extra Wide Steel Tape	Abdiz
854-A	Extra Wide Steel Tape	Abeef
854-B	Extra Wide Steel Tape	Abeeg
860	Pocket Steel Tape	Abeel
863	Pocket Steel Tape	Abeem
866	Pocket Steel Tape	Abeep
870	Pocket Steel Tape	Abees
873	Pocket Steel Tape	Abefa
875	Pocket Steel Tape	Abefi
877	Pocket Steel Tape	Abefs
879	Pocket Steel Tape	Abefy
885	Punch and Riveter	Abega
886	Extra Eyelets	Abegi
887	Eureka Tape Outfit	Abegs
3153	Wood Box Pocket Compass	Abegy
3154	Wood Box Pocket Compass	Abehe
3155	Wood Box Pocket Compass	Abeho
3215	Brunton Pocket Transit	Abeht

RENSSELAER POLYTECHNIC INSTITUTE

TROY, NEW YORK

A School of Engineering and Science

RECORD. Founded in 1824, the Institute is the oldest school of Science and Engineering, having a continuous existence, to be established in any English speaking country. Students have come to it from all the States and Territories of the Union and from more than thirty foreign countries. Its graduates have become distinguished in the practice of their profession all over the civilized world.

UNDERGRADUATE COURSES—Courses in Civil, Mechanical, Electrical and Chemical Engineering and in General Science, each four years in duration, leading to the degrees Civil Engineer (C. E.), Mechanical Engineer (M. E.), Electrical Engineer (E. E.), Chemical Engineer (Ch. E.), and Bachelor of Science (B. S.) are now given, as well as special courses in Chemistry, Water Analysis, Drawing, Surveying Theory and Practice, Railroad Engineering Theory and Practice, Joinery and Pattern Making, Machine Shop Practice, and in various branches of Theoretical and Applied Engineering, including work in the Chemical, Physical, Mechanical, Electrical and Materials Testing Laboratories.

GRADUATE COURSES—Graduate courses leading to Masters' degrees in the five subdivisions given as undergraduate courses are also provided. These are each one year in duration and lead to the degrees M. C. E., M. M. E., M. E. E., M. Ch. E., and M. S. Graduate courses in various branches of science and engineering, each three years in duration, leading to the degrees Doctor of Philosophy, Ph. D., Doctor of Science, Sc. D., and Doctor of Engineering, D. Eng., are also given.

BUILDINGS—Most of the buildings of the Institute are situated on a plot of ground, containing about twenty-three and one-half acres, extending from Eighth Street eighteen hundred feet easterly to Fifteenth Street. The Carnegie Building, Proudfit Laboratory, Walker Laboratory, Russell Sage Laboratory, Pittsburgh Administration Building and Library, '87 Gymnasium, White Dormitory, Hunt Dormitory, Campus Dormitory, Russell Sage Dining Hall, Central Heating and Power Plant, and Rensselaer Union Club House are situated upon it. The Machine Shop and old Gymnasium are situated upon adjacent plots. The Athletic Field is beside the Club House on the main plot.

APPARATUS—The chemical, physical, electrical, mechanical and testing laboratories are completely equipped with the most modern machines and apparatus. These include many forms of steam engines and turbines, gas and oil engines, pumps, water wheels and turbines, electrical generators and motors, powerful machines for testing the strength of metals, wood, stone, brick, etc., as well as full collections of apparatus for work in all the laboratories and a complete assortment of surveying instruments for field work.

INSTRUCTION—Instruction is given in the design and construction of roads, railroads, bridges, arches, roofs, water works, sewers, canals, river improvements, tunnels, foundations, boilers, steam engines, steam turbines, gas engines, ships, pumps, water wheels, heating and refrigerating apparatus, electric machinery, dynamos and telephone and electric lighting systems. Instruction is also given in chemical analysis, electro-chemistry, assaying, metallurgy, mineralogy and geology.

PHYSICAL CULTURE—Lectures on hygiene are given and a large modern gymnasium and an athletic field, with a competent corps of instructors, provide opportunity for athletic exercise necessary for the health of the students.

OTHER STUDENT ACTIVITIES—Quarters for the Band, Glee Club, and other Musical Clubs, publications and other student activities are provided in the Club House, controlled by a Student Committee.

EXPENSES—The tuition for undergraduate courses is either $250 or $260 a year, depending upon the course taken, and that for graduate courses is $150 a year. Board and furnished lodgings, either in the Institute Dining Hall and Dormitories or in private houses, may be obtained at a cost, for both, of from about $7 to $10 a week.

OTHER INFORMATION—For Catalogues and other pamphlets giving full information apply to the Director of Rensselaer Polytechnic Institute, Troy, N. Y.

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Price List
GURLEY MANUAL
Forty-Eighth Edition
TROY, N. Y., U. S. A.
APRIL, 1921

All prices in this list are in U. S. Currency. State which Edition of Manual when ordering, and give Catalogue number. This Price List supersedes all previous Editions.

TRANSITS

		Price
	Precise Transits, Engineers Size, with one Piece Truss Standard, 6.25 in. limb, 3½ in. needle, 11 in. telescope, mahogany box and split leg tripod.	
No. 6-A	with clamp and tangent to telescope axis	$299.00
No. 7-A	with level on telescope and clamp and tangent to telescope axis	318.00
No. 8-A	with 5 in. vertical circle, level on telescope and clamp and tangent to telescope axis	346.00
No. 9-A	with vertical arc 3 in. radius, level on telescope and clamp and tangent to telescope axis	346.00
No. 10-A	with vertical arc 3 in. radius, level on telescope and Gradienter combined with clamp and tangent to telescope axis (see page 47)	364.00
No. 10-A-3	like No. 10-A, but with three-screw leveling head (see page 53)	392.00
No. 18-A	Precise Transit, Hell Gate Model, 6.7 in. limb, 3½ in. needle, 11 in. telescope, level on telescope, clamp and tangent to telescope axis, two vernier vertical circle 5 in. diameter and level on guard; mahogany box and split leg tripod (see page 49)	575.00
	Precise Transits, Explorers Size, with One Piece Truss Standard, 4 in. limb, 2.13 in. needle, 6.5 in. telescope, leather covered mahogany box and jointed extension leg tripod.	
No. 20-A	with 4 in. vertical circle, level on telescope and clamp and tangent to telescope axis (see page 57)	315.00
No. 21-A	with vertical arc 2 in. radius, level on telescope and clamp and tangent to telescope axis	315.00
No. 22-A	with vertical arc 2 in. radius, level on telescope and Gradienter combined with clamp and tangent to telescope axis	333.00
No. 23-A	like No. 21-A, but with Burt Solar Attachment	411.00
No. 24-A	like No. 20-A, but with a two vernier vertical circle having a level attached to the guard	363.00

Price

Precise Transits, Light Mountain Size, with One Piece Truss Standard, 5.65 in. limb, 3 in. needle, 8 in. telescope, mahogany box and extension leg tripod.

No. 25-A	with clamp and tangent to telescope axis........	$293.00
No. 26-A	with level on telescope and clamp and tangent to telescope axis..............................	312.00
No. 27-A	with 4½ in. vertical circle, level on telescope, clamp and tangent to telescope axis (see page 44)	340.00
No. 28-A	with vertical arc 2.5 in. radius, level on telescope and clamp and tangent to telescope axis......	340.00
No. 29-A	with vertical arc 2.5 in. radius, level on telescope and Gradienter combined with clamp and tangent to telescope axis........................	358.00
No. 30-A	like No. 28-A, but with Burt Solar Attachment (see page 119)..................................	436.00
No. 32-A	like No. 27-A, but with Telescopic Solar Attachment (see page 138)..........................	515.00

The horizontal limbs of Transits Nos. 6-A to 18-A and Nos. 25-A to 32-A are figured in two rows 0 to 360 each way, reading in opposite directions and known as Limb 4, (see page 37).

Light Mountain Transits, 5.65 in. limb, 4 in. needle, 8 in. telescope, mahogany box and extension leg tripod.

No. 25	with clamp and tangent to telescope axis........	268.00
No. 26	with level on telescope and clamp and tangent to telescope axis..............................	287.00
No. 27	with 4½ in. vertical circle, level on telescope and clamp and tangent to telescope axis......	315.00
No. 28	with vertical arc 2.5 in. radius, level on telescope and clamp and tangent to telescope axis.......	315.00
No. 29	with vertical arc 2.5 in. radius, level on telescope and Gradienter combined with clamp and tangent to telescope axis.....................	333.00
No. 30	like No. 28, but with Burt Solar Attachment....	411.00

Reconnoissance Transits, 5 in. limb, 3½ in. needle, 9 in. telescope, mahogany box and extension leg tripod.

No. 102	with 4½ in. vertical circle, level on telescope and clamp and tangent to telescope axis (see page 61)	235.00
No. 103	with vertical arc 2.5 in. radius, level on telescope clamp and tangent to telescope axis...........	244.00

The horizontal limbs of Transits Nos. 20-A to 24-A, Nos. 25 to 30, and Nos. 102 and 103, are figured 0 to 90 each way, inner row, and 0 to 360, outer row, known as Limb 1, (see page 36).

ATTACHMENTS AND EXTRAS FOR GURLEY TRANSITS

The following prices are for attachments only when furnished with a new instrument.

When fitted to a completed instrument, the cost of alterations must be added to the price of the new parts.

		Price
No. 131	Variation Arc added to Transits when sent for repairs	$25.00
No. 135-B	Vertical Circle, 4 in. diameter, with vernier reading to 1 minute	18.00
No. 136	Vertical Circle, 4.5 in. diameter, with vernier reading to 1 minute (see page 85)	18.00
No. 137	Vertical Circle, 5 in. diameter, with vernier reading to 1 minute	22.00
No. 138	Vertical Circle, 5 in. diameter, with two opposite double verniers, reading to 1 minute, and with guard (see page 86)	50.00
No. 139	Vertical Circle, 4.5 in. diameter, with graduations on edge or rim, protected by a metal guard. Circle graduated to 30 minutes, with vernier reading to 1 minute (see page 87)	45.00
No. 139-A	Vertical Arc, 2 in. radius, with vernier reading to 1 minute, movable by tangent screw	28.00
No. 139-B	Vertical Arc, 2.5 in. radius, with vernier reading to 1 minute, movable by tangent screw	28.00
No. 140	Vertical Arc, 3 in. radius, with vernier reading to 1 minute, movable by tangent screw (see page 88)	28.00
No. 141	Detachable Aluminum Guard for Vertical Circle (see page 88)	9.00
No. 145	Level on Telescope, with ground and graduated vial (see page 89)	19.00
No. 146	Level on Telescope, with Reversion Vial (see page 89)	27.00
No. 148	Clamp and Tangent to Telescope Axis (see page 89)	9.00
No. 149	Beaman Stadia Arc, for Transit having a one-vernier vertical circle or vertical arc (see page 40)	22.00
No. 149-A	Beaman Stadia Arc, for Transit having a two-vernier vertical circle No. 138	50.00
No. 149-B	Beaman Stadia Arc, for Telescopic Alidades Nos. 592 and 592-A	20.00
No. 149-C	Beaman Stadia Arc with edge graduations, for Telescopic Alidade No. 584-B	45.00
No. 150	Gradienter, combined with Clamp and Tangent (see page 96)	27.00
No. 151	Platinum Stadia Wires, adjustable, and diaphragm	8.00
No. 152	Platinum Stadia Wires, fixed, and diaphragm	10.00
No. 154	Dust Guard to objective slide (see page 26)	7.00
No. 155	Pinion movement to eyepiece slide	8.00
No. 157	Sights on Telescope, with folding joints	12.00
No. 158	Sights on Standards, at right angles with telescope	12.00
No. 160	Detachable Side Telescope and Counterpoise, for vertical sighting (see page 101)	40.00
No. 161	Detachable Riding Telescope, for vertical sighting (see page 101)	40.00

		Price
No. 165	Reflector for illuminating cross wires (see page 103)	$12.00
No. 166	Reflector for illuminating cross wires of large Wye Level (see page 103)	15.00
	The elliptical reflecting pieces on Reflectors Nos. 165 and 166 are of sterling silver.	
No. 167	Elbow Eyepiece, in addition to regular eyepiece, and interchangeable	50.00
No. 168	Diagonal Prism for eyepiece of telescope (see page 103)	12.00
No. 169	Eyepiece Cap with darkener glass in shutter, for direct solar observations	3.00
No. 170	Plummet Lamp for mine surveying (see page 104)	15.00
No. 180	Attached Magnifier, with three universal joints, to read verniers (see page 106) each	8.00
No. 181	Attached Microscopes to read verniers of horizontal limb, as shown with No. 18-A Transit (see page 106) per pair	30.00
No. 182	Attached Microscopes to read verniers of No. 138 vertical limb, as shown with No. 18-A Transit (see page 106) per pair	30.00
No. 185	Graduation of horizontal limb to read to 20 or 30 seconds, extra	15.00
No. 186	Graduation of horizontal limb to read to 10 seconds, extra	35.00
No. 187	Graduation of 4.5 or 5 in. Vertical Circle to read to 20 or 30 seconds, extra	10.00
No. 188	Graduation of No. 138 Vertical Circle to read to 20 or 30 seconds, extra	15.00
No. 189	Graduation of No. 138 Vertical Circle to read to 10 seconds	35.00
No. 190	Burt Solar Attachment, with declination arc, hour circle, polar axis, patent latitude level, adjusting level and adjusting bar (see page 115)	96.00
No. 192	Solar Screen, to fit eyepiece of telescope (see page 106)	12.00
No. 193	Patent Latitude Level, for use with Burt Solar Transit	9.00
No. 196	Striding or Adjusting Level	8.00
No. 197	Adjusting Bar for Solar Attachment of Transit	2.25

For prices of Parts of Instruments Liable to Loss or Injury, see pages 21 to 25.

SURVEYORS COMPASSES

Vernier Compass

		Price	Postage
No. 226	5 in. needle, brass cover, outkeeper, mahogany box and jacob staff mountings (see page 150)	$65.00	

Attachments and Extras for No. 226 Compass

No. 241	Leveling Adopter (see page 158)	10.00	.40
No. 242	Leveling Head, with four leveling screws and clamp and tangent fitted to use with Tripods Nos. 415, 420 and 425 (for Tripods see page 238).	25.00	

		Price	Postage
No. 262	Achromatic Telescope, 9 in., aperture of objective 0.69 in., power about 20 diam., with platinum cross wires and stadia wires, level, clamp and tangent and 3 in. vertical circle, reading by vernier to 5 min., (see page 160)...................	$53.00	.50
No. 268	Offset Standard with counterpoise, to bring the telescope over the line of zeros (see page 162)............................	10.00	

Pocket Compass with Limb

No. 285	5 in. limb, with one vernier reading to one minute, $3\frac{1}{2}$ in. needle, folding sights, two levels, mahogany box, jacob staff mountings and tripod (see page 168)..........	75.00	
	Or with Extension leg tripod..........	80.00	

Compass with Limb and Telescope

No. 294	4 in. limb, with one vernier reading to one minute, $4\frac{1}{2}$ in. needle, 6.5 in. telescope, level on telescope, clamp and tangent to telescope axis, 4 in. vertical circle with vernier to one minute, leveling head, mahogany box and solid round leg tripod (see page 167).........................	150.00	
	Or with Extension leg tripod...........	155.00	

Pocket Vernier Compass

No. 300	$3\frac{1}{2}$ in. needle, folding sights, two levels, mahogany box and jacob staff mountings (see page 180-A)......................	28.00	.70
No. 305	$4\frac{1}{2}$ in. needle, folding sights, two levels, mahogany box and jacob staff mountings (see page 180-A)......................	33.00	1.00
No. 491	Leather Pouch for No. 300..............	5.75	.20
No. 492	Leather Pouch for No. 305..............	7.00	.25

ATTACHMENTS AND EXTRAS FOR POCKET COMPASSES

No. 325	Clamp and Tangent to ball spindle of Compasses Nos. 285, 300 and 305...........	6.00	
No. 326	Rack and Pinion to variation arc of Compasses Nos. 300 and 305................	6.00	
No. 327	Leveling Adopter for Compasses Nos. 285, 300 and 305.......................	7.50	.25

Geologists Compass (Aluminum)

No. 335	United States Forest Service pattern, $2\frac{5}{8}$ in. needle, graduated movable sighting circle, graduated base, variation arc, folding sights, two levels, clinometer, mahogany box and jacob staff mountings (see page 171).............................	35.00	.35
No. 490	Leather Pouch for No. 335..............	5.00	.20

		Price
No. 500-R	Service Rod, self-reading, 2 ply, 7-3/10 ft. closed, sliding to 13 ft., graduated to feet, 10th and 100ths, with verniers reading to 1000ths and with oval target (see page 211)	$15.00
No. 500-B	Philadelphia Rod, 2 ply, 7-3/10 ft. closed, sliding to 13 ft., graduated to feet, 10ths and half 10ths, with both target and rod reading to natural scales to 100ths; the 10ths figures are 0.06 ft. high (see page 212)	20.00
No. 501	Philadelphia Rod, 3 ply, 5-3/10 ft., closed, sliding to 13 ft., graduated to feet, 10ths and 100ths, with verniers reading to 1000ths (see page 213)	27.50
	Nos. 500-B and 501 have plain targets. If with Micrometer target, add	2.50
	If with Angle target, add	2.50
	If with Micrometer Angle target, add	3.50
No. 501-B	Special Self-reading Rod, 3 ply, 7-6/10 ft. closed, sliding to 20 ft., graduated on four faces to feet and 10ths, and on back of the front section to feet, 10ths and 100ths; also reading by two scales to half-hundredths. With aluminum target and canvas case (see page 214)	31.25
No. 502-A	Philadelphia Mining Rod, 2 ply, 3-3/10 ft. closed, sliding to 5 ft., graduated to feet, 10ths and 100ths, with vernier reading to 1000ths	18.00
	Canvas Cases for Rods Nos. 500, 500-A, 500-R, 500-B and 501	4.50
No. 505	New York Rod, 2 ply, 6-8/10 ft. closed, sliding to 12 ft., graduated to feet, 10ths and 100ths, with vernier reading to 1000ths (see page 215)	20.00
No. 510	Architects Rod, 2 ply, 5½ ft. closed, sliding to 10 ft., graduated to feet, inches and 16ths (see page 216)	10.00
No. 511	Architects Rod, 2 ply, 5½ ft. closed, sliding to 10 ft., graduated to feet, 10ths and 100ths, with verniers reading to 1000ths	10.00
No. 513	Telemeter or Stadia Rod, without target, hinge joint, 6 ft. folded, unfolding to 12 ft., graduated to feet, 10ths and 100ths (see page 220)	15.00
No. 514	Telemeter or Stadia Rod, without target, hinge joint, 7 ft. folded, unfolding to 14 ft., graduated to feet, 10ths and 100ths..	16.00
No. 514-B	Stadia Rod, one piece, without target, 10 ft. long, 4 in. wide, with brass ends, graduated on recessed face of 3½ in. width to feet, 10ths and 2/100ths (see page 218)	12.50
No. 514-C	Stadia Rod, similar to No. 514-B, but 12 ft. long	15.00

		Price
	The graduations of Nos. 514-B and 514-C begin at the base and end at the top of the rods. The illustration on page 218 does not show completed graduations.	
No. 514-D	Stadia Rod, one piece, without target, 10 ft. long, 3⅛ in. wide, with brass ends, graduated on flat face to feet, 10ths and 2/100ths (see page 218)...........	$9.50
No. 514-E	Stadia Rod, similar to No. 514-D, but 12 feet long	10.50
	Hinge Joint for Stadia Rods Nos. 514-B, 514-C, 514-D or 514-E, to permit folding, extra	5.00
	Rods Nos. 513 to 514-E can be furnished in any length up to 16 ft. Prices on application.	
No. 515	Telescopic Rod, 3 ply, without target, 5 ft. closed, sliding to 14 ft., graduated to feet, 10ths and 100ths.................	25.00
No. 516	Cross Section Rod, one piece, without target, 10 ft. long, with level at each end, graduated to feet, 10ths and 100ths (see page 221)	17.50
No. 517	Slip-Jointed Leveling or Stadia Rod, 12 ft. long, two inch graduated, recessed face, three sections (two slip joints), graduated in feet, 10ths and 100ths. The joints are secured and released by spring catches. (See page 217). With canvas carrying case	17.00
No. 518-A	Plain Rod, one piece, without target, 10 ft. long, graduated to feet, 10ths and 100ths (see page 221)..........................	7.50
No. 518-B	Plain Rod, without target, hinge joint, 5 ft. folded, unfolding to 10 ft., graduated to feet, 10ths and 100ths..............	11.25
No. 519-A	Plain Rod, one piece, without target, 12 ft. long, graduated to feet, 10ths and 100ths	8.75
No. 519-B	Plain Rod, without target, with hinge joint, 6 ft. folded, unfolding to 12 ft., graduated to feet, 10ths and 100ths.........	13.75
No. 520-A	Plain Rod, one piece, without target, 14 ft. long, graduated to feet, 10ths and 100ths	10.00
No. 520-B	Plain Rod, without target, with hinge joint, 7 ft. folded, unfolding to 14 ft., graduated to feet, 10ths and 100ths..........	15.00
No. 521-B	Plain Rod, without target, with hinge joint, 8 ft. folded, unfolding to 16 ft., graduated to feet, 10ths and 100ths.........	16.25
No. 522-A	Plain Rod, 2 ply, without target, 5-3/10 ft. long, sliding to 10 ft., graduated to feet, 10ths and 100ths.......................	11.25
No. 522-B	Plain Rod, 2 ply, without target, 6-3/10 ft. long, sliding to 12 ft., graduated to feet, 10ths and 100ths.......................	12.50
No. 522-C	Plain Rod, 2 ply, without target, 7-3/10 ft. long, sliding to 14 ft., graduated to feet, 10ths and 100ths.......................	13.75

		Price	Postage
No. 524-A	Plain Rod, 4 ply, without target, 3-3/10 ft. long, sliding to 11-2/10 ft., graduated to feet, 10ths and 100ths (see page 223)...	$17.50	
	Canvas Case for No. 524-A...............	3.00	
No. 525-B	Pocket Rod, 10 ft. long, graduated to feet, 10ths and 100ths (see page 229)........	4.50	.25
No. 526-A	Pocket Rod, 12 ft. long, graduated to feet, 10ths and 100ths......................	5.50	.28
No. 526-B	Pocket Rod, 12 ft. long, graduated to feet, inches and 8th........................	5.50	.28
No. 527	Pocket Rod, 14 ft. long, graduated to feet, 10ths and 100ths........................	7.00	.30
No. 528	Pocket Rod, 3½ meters long, graduated to centimeters	5.50	.30
No. 530	Wooden Leveling Pole and Flagstaff, 7 ft. long	6.25	
No. 531	Wooden Leveling Pole and Flagstaff, 9 ft. long	7.50	
No. 534	Wooden Flagstaff, octagonal, 6 ft. long...	3.50	
No. 535	Wooden Flagstaff, octagonal, 8 ft. long...	4.25	
No. 536	Wooden Flagstaff, octagonal, 10 ft. long... (see page 230).	5.25	
No. 537-A	Jointed Wooden Flagstaff, round, 6 ft. long, in 2 sections..........................	5.50	
No. 537-B	Jointed Wooden Flagstaff, round, 6 ft. long, in 2 sections and with canvas case......	8.75	
No. 537-C	Jointed Wooden Flagstaff, round, 6 ft. long, in 3 sections..........................	8.75	
No. 537-D	Jointed Wooden Flagstaff, round, 6 ft. long, in 3 sections and with canvas case......	12.00	
No. 538-A	Jointed Wooden Flagstaff, round, 9 ft. long, in 3 sections..........................	9.50	
No. 538-B	Jointed Wooden Flagstaff, round, 9 ft. long, in 3 sections and with canvas case...... (see page 232).	13.00	
No. 540-A	Steel Ranging Pole, solid, hexagonal, 6 ft. long, ½ in. diameter....................	4.00	
No. 540-B	Steel Ranging Pole, solid, hexagonal, 8 ft. long, ½ in. diameter....................	4.75	
No. 541	Iron Tubular Ranging Pole, 6 ft. long, 13/16 in. diameter.....................	3.75	
No. 543	Iron Tubular Ranging Pole, 8 ft. long, 13/16 in. diameter.....................	4.50	
No. 544	Iron Tubular Ranging Pole, 10 ft. long, 13/16 in. diameter..................... (see page 231).	5.00	
No. 550-R	Gurley Precise Leveling Rod, cross-shape section, graduated on three faces to yards, 10ths and 100ths, reading to 3½ yards, with silver-faced plugs at each half yard. Fitted with wooden handle, thermometer, fixed circular rod level, canvas case, turning point and plate. Packed in a special pine box with hinged cover, handles and lock (see page 227)............	110.00	

		Price
No. 551-R	Molitor Precise Leveling Rod, T-shape section, 12 ft. long, graduated to feet, 10ths and 100ths, or to millimeters if preferred, and with circular level, two wooden handles, plumbing attachment and plummet, enclosed thermometer, canvas case, and turning point. Packed in special pine box with hinged cover, handles and lock (see page 224)	$85.00
No. 552-R	Self-Reading Tape Leveling Rod; rod made of pine, 10 ft. 8½ in. long, and graduated on one edge to feet and 10ths. The steel ribbon graduated to feet, 10ths and half-10ths; all graduations on rod and tape are painted (see page 225)	47.50
	Canvas Case for above rod	5.00

ROD LEVELS

No. 545	(See page 233)	5.00
No. 546	(See page 234)	6.00
No. 547	(See page 235)	10.00
No. 548	(See page 236)	13.00

PLANE TABLES

Plane Tables, Equipment and Parts

(See pages 243 to 259)

No. 570	Johnson Plane Table Movement and split leg tripod	45.00
No. 570-A	Johnson Plane Table Movement and extension leg tripod	57.00
No. 571	Johnson Plane Table Movement, special light weight model, with special light weight extension leg tripod	50.00
	Canvas Case, leather trimmed, for No. 571	9.00
No. 573	Drawing Board, 31 x 24 in., with brass screw plate fitted, and with eight clamp screws and sockets for paper	9.00
	Canvas-covered Wooden Case for No. 573	8.00
	Flexible Canvas Case with shoulder strap, for No. 573	4.75
	Eggshell Drawing paper, single mounted, 31 x 24 in., per sheet	1.25
	Eggshell Drawing Paper, double mounted (muslin between), so that drawings can be made on both sides, 31 x 24 in., per sheet	2.50
No. 573-A	Drawing Board, 18 x 24 in., with brass screw plate fitted, and eight clamp screws and sockets for paper	8.00
	Canvas-covered Wooden Case for No. 573-A	6.25
	Flexible Canvas Case with shoulder strap, for No. 573-A	3.00
	Eggshell Drawing paper, single mounted, 18 x 24 in., per sheet	.85

		Price
	Eggshell Drawing Paper, double mounted (muslin between), so that drawings can be made on both sides, 18 x 24 in., per sheet	$1.50
	Note: If desired, we can supply a Drawing Board, 20 x 20 in., together with Cases and Paper, for the same prices as listed under No. 573-A.	
No. 573-B	Drawing Board, 15 x 15 in., with brass screw plate fitted and four clamp screws and sockets for paper..................	6.00
	Flexible Canvas Case with shoulder strap, for No. 573-B..........................	2.50
	Eggshell Drawing paper, single mounted, 15 x 15 in., per sheet.................	.50
	Eggshell Drawing Paper, double mounted (muslin between), so that drawings can be made on both sides, 15 x 15 in., per sheet	1.10
No. 573-X	Drawing Board, 31 x 24 in., with brass screw plate fitted, and with eight clamp screws and sockets for paper. Especially constructed for use in tropical climates, of heavy stock and with expansion cleats	11.00
	Flexible Canvas Case with shoulder strap, for No. 573-X.........................	8.25
No. 574	Plumbing Arm and 10 oz. plummet.......	6.25
No. 575	Combined Compass with levels and square base	25.00

For Nos. 570, 570-A or 571

Leather Hood to protect Johnson Tripod Head........	3.00
Upper or Lower Wing Nut Clamp Screw, A or B, each	1.60
Keeper Screw, C, each............................	.20
Bolt with Wing Nut and Washer, for tripod head, each	1.10
Wing Nut for tripod bolt, each....................	.45
Extra Board Plate, each...........................	3.30
Clamp Screw and Socket for paper, complete, each...	.40
Clamp Screw only, each...........................	.20
Socket only, each................................	.20
Cap for Johnson Tripods Nos. 570, 570-A or 571.......	1.25
Split Tripod Legs for No. 570, each..................	3.30
Extension Tripod Legs for No. 570, each.............	7.50
Extension Tripod Legs, special light weight model, for No. 571, each..................................	5.25

Plane Table Outfits

U. S. Geological Survey Standard

		Price
No. 576-C	Plane Table Outfit, consisting of Johnson Movement No. 570, with split leg tripod; Drawing Board No. 573, 31 x 24 in., with brass screw plate fitted, and with eight clamp screws and sockets for paper.....	$54.00
	Flexible Canvas Case with shoulder strap, for No. 573 Drawing Board.............	4.75
	Plumbing Arm and Plummet, No. 574......	6.25
	Alidade No. 584-C, with 11 in. telescope, inverting eyepiece with diagonal prism, power about 22 diameters, enlarged objective, 1.38 in. aperture, platinum cross wires and stadia wires; detachable striding level with revolving shield; edge graduated vertical arc reading to 1 min., combined with Beaman Stadia Arc; clamp and tangent to telescope axis; blade 18 x 3 in., with left hand edge beveled; circular level, and box compass with 4 in. needle, mounted on blade. In mahogany carrying case. See illustration on page 246......	200.00
	Complete, as shown on page 244.........	265.00
No. 576-B	Plane Table Outfit, like Outfit No. 576-C, but with Alidade No. 584-B substituted for Alidade No. 584-C..................	265.00

ALIDADES, Telescopic

No. 584-C	Telescopic Alidade, as described above, in Outfit No. 576-C, and as shown on page 246	200.00
No. 584-B	Telescopic Alidade, similar to Alidade No. 584-C, but equipped with an erecting eyepiece, power about 26 diameters, objective 1.19 inches aperture....................	200.00

A Gradienter can be combined with the clamp and tangent movement on Alidades Nos. 584-C or 584-B, at an extra cost of $18.00.

If Alidade No. 584-C or No. 584-B is desired without the Beaman Stadia Arc attachment, deduct $45.00.

Parts for Alidades Nos. 584-C and 584-B

No. 585	Box Compass, rectangular metal case, 4 in. needle, for Alidades Nos. 584-B or 584-C	12.50
	Striding Level, complete.................	20.00
	Extra Glass Vial only, for Striding Level...	2.25
	Circular Level, complete.................	6.50
	Extra Glass Vial only, for Circular Level..	4.50
	Quarter interval wire, midway between upper stadia wire and horizontal cross wire...	2.75

Explorers Alidade, Telescopic

		Price
No. 592-C	11 in. blade, one edge beveled and graduated to 1/50 in., box compass with 4 in. needle, circular level, 8 in. telescope, aperture 1 in., power about 13 diameters, platinum cross wires and stadia wires, spiral movement to eyepiece, pinion movement to objective slide, Gradienter, combined with clamp and tangent to telescope axis, detachable striding level, sensitiveness about 90 seconds, vertical arc reading by vernier to one minute, vernier movable by tangent screw, Beaman Stadia Arc, combined with the vertical arc, mahogany carrying case. Weight 3.25 lbs., with case 5 lbs. (see page 249)	$154.00

Extras for No. 592-C Alidade

Striding Level Vial, sensitiveness 60″ or 40″	No extra charge
If the Beaman Stadia Arc is omitted, deduct	22.00
If the Gradienter is omitted, deduct	9.00
Special Graduations on Blade, extra	6.50
Striding Level, complete	16.50
Extra Glass Vial only, for Striding Level	1.65
Circular Level, complete	5.50
Extra Glass Vial only, for Circular Level	3.85
Quarter interval wire, midway between the upper stadia wire and horizontal cross wire	2.75
Leather covered mahogany box instead of plain box	10.00

Explorers Plane Table Outfits

No. 592-D Explorers Plane Table Outfit, consisting of Johnson Movement No. 570, with split leg tripod; Drawing Board No. 573-A, 18 x 24 in., with brass screw plate fitted, and eight clamp screws and sockets for paper.

Flexible Canvas Case with shoulder strap, for No. 573-A Drawing Board.

Explorers Alidade No. 592-C, with Gradienter and Beaman Stadia Arc.

Complete 210.00

No. 592-F Explorers Plane Table Outfit, consisting of Johnson Movement No. 571, special light weight model, with special light weight extension leg tripod; Drawing Board No. 573-A, 18 x 24 in., with brass screw plate fitted, and eight clamp screws and sockets for paper.

Flexible Canvas Case with shoulder strap, for No. 573-A Drawing Board.

Explorers Alidade No. 592-C, with Gradienter and Beaman Stadia Arc.

Complete, as shown on page 249.......... 215.00

		Price
No. 592-H	Explorers Plane Table Outfit, consisting of Johnson Movement No. 571, special light weight model, with special light weight extension leg tripod; Drawing Board No. 573-B, 15 x 15 in., with brass screw plate fitted, and four clamp screws and sockets for paper.	
	Flexible Canvas Case with shoulder strap, for No. 573-B Drawing Board.	
	Explorers Alidade No. 592-C, with Gradienter and Beaman Stadia Arc, complete as specified on page 249....................	$212.50

Paper for Drawing Boards Nos. 573-A and 573-B

	For No. 573-A 18 x 24 in.	For No. 573-B 15 x 15 in.
Eggshell Drawing Paper, single mounted, per sheet..........	$0.85	$0.50
Eggshell Drawing Paper, double mounted (muslin between), so that drawings can be made on both sides, per sheet.........	1.50	1.10

Traverse Plane Table Outfit

No. 586	Consisting of Traverse Movement No. 587, with solid round tripod legs; No. 573-T Drawing Board, 15 x 15 in., with spring board plate, Box Compass No. 588 inserted in one edge, and four clamp screws and sockets for paper; Ruler Sight Alidade No. 589, with graduated edge, folding sights and leather pouch; complete as shown on page 257............	38.50

Extras for Traverse Plane Table

Extension Leg Tripod, instead of Solid Round Leg Tripod, extra	6.50
Jointed Extension Leg Tripod, closing to 23 in., with canvas case, instead of Solid Round Leg Tripod, extra	16.00
Flexible Canvas Case with shoulder strap, for Drawing Board No. 573-T, extra.........................	2.50
Eggshell Drawing Paper, single mounted, 15 x 15 in., per sheet	.50
Eggshell Drawing Paper, double mounted (muslin between), so that drawings can be made on both sides, 15 x 15 in., per sheet.....................	1.10

No. 587	Traverse Plane Table Movement, with solid round leg tripod; Drawing Board, 15 x 15 inches, with spring board plate, and four clamp screws and sockets for paper....	16.50
No. 573-T	Drawing Board, 15 x 15 in., with spring plate fitted, and with four clamp screws and sockets for paper..................	6.00

		Price
No. 588	Box Compass, rectangular metal case, 4 in. needle	$10.00
No. 589	Ruler Sight Alidade, 10 in. long, with graduated edge, folding sights and leather pouch	15.00
Spring Plate for Drawing Board, each		2.50
Center Plunger Clamp Screw, complete, each		3.00
Clamp Screw and Socket for paper, complete, each		.40
Solid Round Tripod Legs, each		1.75
Extension Tripod Legs, each		4.00
Bolt, with wing nut and washer, for tripod head, each		1.00
Wing Nut for tripod bolt, each		.45

Pocket Sight Alidade

No. 590-A	Pocket Alidade, 6 in. long, with graduated edge and folding sights, and with leather case having pencil pockets (see page 259)	9.50
No. 590-B	Extra Folding Sights, for Alidade No. 590-A, per pair	4.00

SKETCHING CASES

No. 594	Army Sketching Case, Glenn S. Smith Model, with one Protractor card, as selected (see page 261)	25.00

Extras for the Above

Extra Protractor Cards, each............. 1.00

	Distance between each circle
Scale A, 1 inch to 1 mile	132 ft., or 1/40 mile
*Scale B, 2 inches to 1 mile	66 ft., or 1/80 mile
Scale C, 3 inches to 1 mile	52.8 ft., or 1/100 mile
Scale D, 1 to 24,000 and 1 to 48,000	1/100 mile and 1/50 mile
Scale F, 1 to 100,000 Metric	100 meters (10 to 1 kilo)

*Scale B is also suitable for a map scale, 1 inch to 400 feet, each circle representing 10 feet distance.

Flexible Canvas Pouch, with leather shoulder strap		2.25
Sole Leather Pouch, with shoulder strap		7.50
Tripod, with solid round legs		4.50
Staff, 2 ft. long, with metal shoe		1.25
Vellum Tracing Paper, in rolls, 8 x 36 in., per roll		.10
Translucent Celluloid, in rolls, 8½ x 50 in., per roll		.75

Celluloid is more durable than paper and not affected by moisture.

No. 596	Fiala Scout Sketching Case	7.50
	Architects Drawing Paper, in rolls 5¾ x 36 in., per roll, postpaid	.05

CURRENT METERS

Acoustic Current Meter

		Price
No. 616	Acoustic Current Meter, indicating each 10th revolution, equipped with rubber tube, ear piece and connection; also two lengths of sleeve jointed wading rod, graduated to measure 4 ft. from plane of bucket wheel. Wooden case with lock and strap and including accessories of oil can, wrench, screw driver and pivot bearing (see page 277)	$66.00

Accessories for No. 616

Wading Rod, sleeve-jointed and graduated, per 2 ft. length	3.50
Canvas Case for two, three or four lengths of Rod	4.50
Time Recorder, or Stop Watch, No. 619, open face, nickel case, stem winder, with fly-back attachment for starting and stopping. Registering minutes, seconds and fifths of seconds	10.00

Electric Current Meters

No. 623	Electric Current Meter with two interchangeable commutator boxes, one indicating each revolution and the other indicating each fifth revolution of the bucket wheel, Covert Yoke, telephone sounder, dry battery, 20 ft. of cable, 10 lb. lead weight and weight hanger. All packed in wooden box with lock, hooks and strap and including accessories of oil can, wrench, screw driver, extra pivot bearing, binding screws and nipple (see page 280)	110.00
No. 617	Electric Current Meter. This is like No. 623, except that it has only one commutator box indicating each revolution of the bucket wheel	93.50
No. 621	Electric Current Meter. This is like No. 623, except that it has only one commutator box indicating each fifth revolution of the bucket wheel	93.50

Accessories for Current Meters Nos. 617, 621 and 623

Extra Cable, per foot	.15
Extra Dry Cell Battery	.35
Extra Lead Weight, 10 lbs	5.00
Extra Lead Weight, 15 lbs	6.25
Time Recorder, or Stop Watch, No. 619, as described above under Meter No. 616	10.00

	Price	Postage
Wading Rods, sleeve-jointed and graduated, per 2 ft. length	$3.50	
Wading Rods, flush-jointed and graduated, for use with double-end Hanger, per 2 ft. length	3.50	
Wading Rods, flush-jointed, 4 sections, graduated to measure 8 feet from plane of bucket wheel, at $3.25 per section	14.00	
Double-end Hanger, for use with flush-jointed Rods	4.00	
Base, for use with Rod	2.75	
Leather Case for rods, base and hanger	13.00	
Canvas Case for rods, base and hanger	4.50	
Electric Register, No. 609, as described on page 281	30.00	

ELECTRIC REGISTER

No. 609	(See page 281)	30.00

HOOK GAGE

No. 628	(See page 283)	25.00

WATER STAGE REGISTERS

No. 630	Printing Register (see page 290)	385.00
No. 632	Tape Reel for use with No. 630 Register	27.50
No. 633	Graphic Register with spring driven clock (see page 293)	145.00
No. 636	Graphic Register, with weight driven clock	145.00
No. 634	Graphic Register, with spring driven clock, range 0 to 1 ft., time scale 7 days	95.00
No. 634-A	Graphic Register, range 0 to 2 ft., time scale 7 days	110.00

LONG DISTANCE WATER STAGE REGISTER

No. 637	Long Distance Register (see page 296)	275.00
No. 638	Long Distance Sender (see page 299)	110.00
No. 639	Long Distance Indicator (see page 300)	155.00
No. 639-A	Indicating Gage (see page 301)	55.00

PRECISION BALANCE

No. 9570	(See page 303)	450.00

Miscellaneous Instrument Parts and Supplies

Prices of Parts for Gurley Instruments,
Liable to Loss or Injury

	Price	Postage
Solid Round Tripod Legs only, for Engineers Transit or Level, per set	7.50	
Split Tripod Legs only, for Engineers Transit or Level, per set	12.50	
Extension Tripod Legs only, for Engineers Transit or Level, per set	16.00	
Clamp Screw and Band for extension tripod leg, each	1.25	.05
Tripod Head only, with bolts and nuts, for Engineers Transit or Level	7.50	.50
Cap for tripod head, each	1.25	.12

	Price	Postage
Brass Bolt and Nut to fit tripod head, each	$1.00	.05
Metal Point or Shoe for tripod leg, each	.65	.05
Shawl Strap (superior), for extension tripod	1.25	.10
Steel Screw Driver with wooden handle, each	.35	.05
Steel Adjusting Pins, each	.08	.01
Steel Adjusting Pins, with eye, for attaching to key ring, each	.20	.02
Rubber Tips, for bottom of instrument box, per set	.80	.08
Leather Strap and Buckle for transit box	1.00	.10
Leather Strap and Buckle for level box	1.25	.10
Lock and Key for instrument box	1.00	.03
Reading Glass for transit, each	1.25	.02
Brass Plummet with screw cap, for transit or level, each	2.00	.20
Waterproof Hood, for transit or level, each	1.25	.06
Clamp with Clamp Screw, for New York Rod	3.25	.15
Clamp with Scale and Clamp Screw, for Philadelphia Rod	4.00	.15
Target with Clamp Screw and Spring, for New York or Philadelphia Rod	4.00 to 8.50	.35
Chain Handle, with staple and nuts, each	1.00	.08
Chain Tallies, per set of 9	.65	.06
Instrument Oil, finest grade, small bottle	.45	.05
Camel Hair Brush	1.25	.02

Parts for Gurley Transits

	Price	Postage
Needle with jeweled center and center pin	5.00	.12
Center Pin only	.75	.01
Ground Glass Level Vials, for plate, each	1.25	.02
Ground Glass Level Vials, brass mounted complete, for plate, each	3.00	.14
Ground Glass Level Vial, for telescope, unmounted,	2.75 to 3.50	.14
Cap for eyepiece or object glass, each	1.00	.03
Shade for object glass	1.00	.03
Clamp Screws for horizontal limb, each	1.00	.02
Tangent Screw for leveling head	1.00 to 2.00	.13
Clamp Screw for leveling head	1.00	.03
Leveling Screw for leveling head, each	1.25 to 2.00	.14
Eyepiece complete, including lenses and settings, and omitting cap	8.00	.14
Object Glass complete	8.00	.14
Platinum Cross Wires and Diaphragm	4.50	.15
Platinum Stadia Wires, adjustable, and diaphragm	8.00	.15
Platinum Stadia Wires, fixed, and diaphragm	10.00	.15
Platinum Cross Wires only fitted to old diaphragm	3.50	
Platinnm Cross Wires and adjustable Stadia Wires fitted to old diaphragm	6.00	
Platinum Cross Wires and fixed Stadia Wires fitted to old diaphragm	8.00	
Brass packing box for mailing any of the above diaphragms	.50	
*Mahogany Box with lock and strap, and fitted inside, according to size	$12.00 to 15.00	

*When ordering, specify length of telescope, length of compass needle, height of the instrument from bottom plate of the leveling head to the tops of the standards, and also state whether

	Price	Postage
it has a vertical arc or a full vertical circle. Unless the Transit is sent to us, the new box will be furnished with the packing pieces or blocks not fitted in position.		
Plummet Screw and Chain for bottom of leveling head.	$0.45	.04
Adjusting Pins, each	.08	.01
Adjusting Pins, with eye for attaching to key ring, each	.20	.02
Screw driver, small size	.35	.04
Screw driver, large size	.65	.06
Waterproof Hood	1.25	.10
Instrument Oil, finest grade, small bottle	.45	.05

Parts for Gurley Wye Levels

Ground Glass Level Vial, unmounted, graduated and figured, for 22-inch Wye Level	5.00	.25
Ground Glass Level Vial, unmounted, not graduated or figured, for 22-inch Wye Level	4.50	.25
Ground Glass Level Vial, unmounted, graduated and figured, for 15-inch, 18-inch or 20-inch Wye Level	4.50	.20
Ground Glass Level Vial, unmounted, not graduated or figured, for 15-inch, 18-inch or 20-inch Wye Level	4.00	.20
Ground Glass Level Vial, unmounted, extra sensitive (value of each graduation 10 seconds), graduated and figured, for 18-inch, 20-inch or 22-inch Wye Level	10.00	.25
Ground Glass Level Vial, unmounted, extra sensitive (value of each graduation 10 seconds), not graduated or figured, for 18-inch, 20-inch or 22-inch Wye Level	9.50	.25
Ground Glass Level Vial, unmounted, for Architects Level	2.25	.05

Note: Whenever possible the metal case or tube should be sent us so that the vial can be properly set. The extra cost is 75 cents.

Cap for eyepiece or object glass, each	1.00	.03
Clamp Screw for leveling head	1.00	.03
Tangent Screw for leveling head	1.50 to 2.00	.13
Leveling Screw for leveling head, each	1.50 to 2.75	.14
Eyepiece complete, including lenses and settings, and omitting cap	8.00	.14
Object Glass, complete	10.00	.14
Platinum Cross Wires and Diaphragm	4.50	.15
Platinum Adjustable Stadia Wires, Cross Wires, and Diaphragm	8.00	.15
Platinum Fixed Stadia Wires, Cross Wires, and Diaphragm	10.00	.15

*Mahogany Box with lock and strap, and fitted inside, according to size..........................$7.50 to 15.00

*Note: When ordering, specify the exact length of the telescope when both the eyepiece and the objective slides are not extended; also state the height of the instrument from the bottom plate of the leveling head to the top of the wyes and mention the diameter of the bottom plate of the leveling head. Unless the Level is sent

	Price	Postage
to us, the new box will be furnished with the packing pieces or blocks not fitted in position.		
Adjusting Pins, each	$0.08	.01
Adjusting Pins, with eye for attaching to key ring, each	.20	.02

Parts for Surveyors Compasses with 4 in., 5 in. or 6 in. needle, like model No. 226

Needle with jeweled center and center pin	5.00	.12
Center pin only	.75	.01
Ground glass level vials, each	.60	.02
Ground glass level vials, brass, mounted, complete, each	2.50	.14
Brass cover for compass of our make	1.25	.25
Outkeeper	1.25	.13
Glass circle, unmounted, old style flat glass, for compass face	.35	.15
Glass circle, unmounted, new style, beveled edge plate glass, for compass face	2.00	.15
Wrench for center pin	.15	.01
Staff mountings, brass head and clamp, without spindle	2.50	.25
Staff mountings, steel point	.65	.18
Cap only for staff socket or tripod head	1.00	.12
Ball spindle fitted to new or old socket	4.00	.30
Sight vanes only, each	3.00	.20
Clamp screw for spindle or sight vane	.65	.03
Socket complete, including clamp screw, spring catch, needle lifting screw and lifter	10.00	.50
Needle lifter	.50	.05
Needle lifting screw	.65	.05
Spring catch	.65	.05
Bolt with nut and washer for tripod head	.85	.05
Nut and washer for tripod bolt	.40	.04
Mahogany box with lock and strap	7.50	

Parts for Compasses Nos. 285 and 294

Needle with jeweled center and center pin	5.00	.12
Center pin only	.75	.02
Glass Circle, unmounted, beveled edge plate glass for No. 285	2.00	.15
Glass circle, unmounted, for No. 294	,35	.15
Plate level vials only for No. 285, each	1.25	.05
Plate level vials with case and adjusting screws for No. 285, each	3.00	.14
Plate level vials only for No. 294, each	.50	.04
Plate level vials with case and adjusting screws for No. 294, each	1.50	.10
Telescope level vial only for No. 294	3.00	.14
Telescope level complete for No. 294	7.50	.25
Folding sights for No. 285, each	6.00	.15
Tangent screw and nut for any movement	1.50	.12
Opposing spring plunger and case for tangent screw	1.25	.05
Clamp screw for telescope axis	.65	.05
Clamp screw for limb or leveling head	1.00	.05
Leveling screw for No. 294	1.25	.05
Dust cap for leveling screw	.50	.03

	Price	Postage
Dust cap or sunshade for objective, each............	$1.00	.05
Eyepiece cap	1.00	.05
Spindle and socket, clamp screw and cap for jacob staff socket or tripod for No. 285................	4.00	.20
Spindle and socket and clamp screw, without cap for No. 285	3.25	.17
Jacob staff socket and cap for No. 285...............	1.50	.15
Cap only for jacob staff socket or tripod for No. 285	.75	.08
Shoe for jacob staff or tripod leg....................	.65	.05
Bolt with nut and washer for tripod head..........	.85	.05
Nut and washer for tripod bolt.......................	.40	.04
Mahogany box for No. 285...........................	5.00	.30
Mahogany box for No. 294...........................	12.00	.60

Parts for Pocket Compasses
Nos. 300, 305, 335 and 350

Needle with jeweled center and center pin..........	5.00	.12
Center pin only..	.75	.02
Level vials only, each................................	.50	.04
Level vials with case and adjusting screws, each......	1.50	.10
Glass circle	.35	.15
Folding sights for No. 305, each.....................	4.00	.17
Folding sights for Nos. 300, 335, and 350, each......	3.50	.17
Removable sight for No. 350.........................	2.00	.12
Needle lifting screw..................................	.35	.02
Clamp nut for variation arc..........................	.25	.02
Clamp nut for spindle.................................	.35	.02
Spindle and socket, clamp screw and jacob staff socket with cap, for Nos. 300, 335 and 350.............	3.00	.15
Spindle and socket, clamp screw and jacob staff socket with cap for No. 305...........................	4.50	.20
Jacob staff socket and cap for Nos. 300, 335 and 350..	1.00	.15
Jacob staff socket and cap for No. 305...............	1.50	.15
Cap only for staff socket or tripod for Nos. 300, 335 and 350	.50	.06
Cap only for staff socket or tripod for No. 305......	.75	.08
Shoe for jacob staff or tripod leg....................	.65	.05
Bolt with nut and washer for tripod head..........	.85	.05
Nut and washer for tripod bolt.......................	.40	.04
Mahogany box for No. 300, 335 and 350.............	3.00	.20
Mahogany box for No. 305...........................	3.50	.25

CHAINS

Made by W. & L. E. Gurley

Brazed Steel Chains

No. 670	33 ft., 50 links, No. 12 tempered steel wire, brazed links and rings.................	5.75	.45
No. 671	50 ft., 50 links, No. 12 tempered steel wire, brazed links and rings.................	7.00	.55
No. 672	66 ft., 100 links, No. 12 tempered steel wire, brazed links and rings.............	10.50	.70
No. 673	100 ft., 100 links, No. 12 tempered steel wire, brazed links and rings............	11.50	1.00

Steel Snaps to make full chains into half chains, without extra charge, if ordered with the chain.

Vara Chains (1 vara=33.333 inches)

		Price	Postage
No. 708	10 varas, 50 links, oval rings, No. 12 tempered steel wire, brazed links and rings	$5.75	.35
No. 710	20 varas, 100 links, oval rings, No. 12 tempered steel wire, brazed links and rings	10.50	.65

Meter Chains (1 meter=39.371 inches)

No. 730	10 meters, 50 links, oval rings, No. 12 tempered steel wire, brazed links and rings	5.75	.45
No. 732	20 meters, 100 links, oval rings, No. 12 tempered steel wire, brazed links and rings	10.50	.70

Marking Pins

No. 740	Set of 11 Pins, No. 4 iron wire, nickel-plated, 14 in. long....................	1.45	.50
No. 743	Set of 11 Pins, 3/16 steel wire, 14 in. long, japanned red and white, alternating each inch. Quickly located in brush or grass	2.00	.40
No. 749	Spring Steel Carrying Ring for marking pins	.30	

TAPES

Steel Ribbon Chain Tapes

One-quarter inch wide, heavy steel ribbon, deeply etched graduations, large detachable handles and wooden reel with nickeled trimmings.

No. 774	Steel Ribbon, 66 ft., graduated to 100 links	7.00	.40
No. 776	Steel Ribbon, 100 ft., graduated each foot	8.50	.50

The 66 foot tape has the first and last links in 10ths.

The 100 foot tape has the first and last feet in 10ths.

Metric Measure Only

M - 20	Steel Ribbon, 20 meters, graduated to decimeters	6.00	.40
M - 30	Steel Ribbon, 30 meters, graduated to decimeters	9.25	.50

These tapes have the first meter in centimeters with the first decimeter in millimeters.

Vara Measure Only

V - 20	Steel Ribbon, 20 varas, graduated to tenths of a vara............................	8.50	.40
V - 30	Steel Ribbon, 30 varas, graduated to tenths of a vara............................	10.50	.45

Metallic Tapes

No. 782	Metallic Tape, 50 ft., in 10ths or 12ths, and links	4.25	.20
No. 786	Metallic Tape, 100 ft., in 10ths or 12ths, and links	7.00	.30

Metallic Tapes without Cases

		Price	Postage
	These tapes can be put into the leather cases when the original tape line is worn out.		
No. 791	Metallic Tape, 50 ft., in 10ths or 12ths, and links	$2.50	.16
No. 794	Metallic Tape, 100 ft., in 10ths or 12ths, and links	5.00	.20
	We can furnish Metallic Tapes Nos. 791 and 794, with metric or vara measure on reverse side, instead of links at an extra cost of two cents per foot.		

Reliable Steel Tapes (Best Quality)
Instantaneous Readings

		Price	Postage
	Three-eighths inch wide, in leather case with nickeled trimmings and double folding flush handle opened by pressing on opposite side.		
No. 798	Steel Tape, 100 ft., in 10ths or 12ths, and links	14.75	.30
	Tape No. 798 can be furnished with metric or vara measure on reverse side, instead of links, at an extra cost of two cents per foot.		

Reliable Junior Steel Tapes,
Instantaneous Readings

		Price	Postage
	One-quarter inch wide, in leather case with nickeled trimmings and double folding flush handle opened by pressing on opposite side.		
	A convenient vest pocket tape, being an exact counterpart of the "Reliable," and not much over one-half its size and weight.		
No. 800	Steel Tape, 25 ft., in 10ths or 12ths.....	4.75	.15
No. 801	Steel Tape, 50 ft., in 10ths or 12ths.....	7.25	.20
	Tapes Nos. 800 and 801 supplied with vara, metric measure, or links on reverse side, at an extra cost of two cents per foot.		

Wolverine Steel Tapes,
Instantaneous Readings

		Price	Postage
	One-quarter inch wide, with open metal reel having folding handle and leather strap on reverse side, by which the tape can be firmly held when winding.		
No. 817	Steel Tape, 100 ft., in 10ths or 12ths, and links	18.00	.35
	Tape No. 817 supplied with vara or metric measure on reverse side, instead of links, without extra charge.		

Engineers Pattern Steel Tapes (Best Quality)
Instantaneous Readings

		Price	Postage
	One-quarter inch wide, in cases with folding flush handles, opened by pressing pin on opposite side. Nickel-plated trimmings.		
No. 824	Steel Tape, 100 ft., in 10ths or 12ths, and links	$14.50	.35
	In metal lined hard leather case.		
No. 835	Steel Tape, 100 ft., in 10ths or 12ths, and links	13.50	.35
	In black enameled steel case.		

Tapes Nos. 824 and 835 are detachable from their cases and are furnished with an extra handle, No. 841, and can be used as a chain tape.

They are graduated to feet, tenths and hundredths of feet, or to feet, inches and eighths of inches, as desired, on one side, and to links and poles, vara or metric, as desired, on the reverse side.

Tape Repair Outfits

		Price	Postage
No. 885	Punch and Riveter, with two packages of eyelets	4.50	.30

This Punch cuts a clean hole in steel tapes of the usual thickness, and the eyelet is then inserted and quickly and neatly riveted. The punch is 7¾ inches long. For the repair of all tapes except heavy ribbon chain tapes.

		Price	Postage
No. 887	Eureka Tape Repair Sleeves. One dozen sleeves	.60	.05
	Half-Dozen sleeves........................	.40	.05

These sleeves of thin sheet metal are coated with a combination of solder and flux so sensitive that they make a perfect adhesion with the tape by the heat of a lighted match. The repair can be made in the field in one minute. Complete directions accompany each set.

When ordering, be sure to specify width of tape and if heavy or light ribbon.