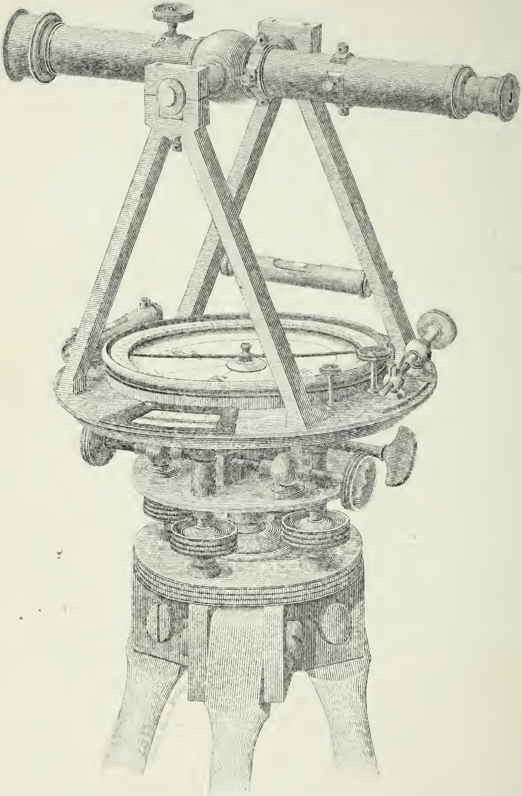
AMERICAN
ENGINEERS AND SURVEYORS
INSTRUMENTS.

ENGINEER'S TRANSIT.



Made by

W. & L. E. GURLEY.

TROY, N.Y.

A

MANUAL

OF THE PRINCIPAL

INSTRUMENTS

USED IN

American Engineering and Surveying,

MANUFACTURED BY

W. & L. E. GURLEY.

THIRD EDITION.

TROY, N. Y.:
PUBLISHED BY W. & L. E. GURLEY.
1857.

D. H. Jones & Co., Printers,
Troy, N. Y.

PRICE LIST.

COMPASSES.

Plain, with Jacob Staff mountings, 4 inch needle,..............	$20,00
" " " " " 5 " "	25,00
" " " " " 6 " "	28,00
Vernier, " " " 6 " "	35,00
Rail Road, " " " $5\frac{1}{2}$ " "	55,00

EXTRAS.

Compass Tripod, with Cherry legs,..........................	5,00
" " " lev'g screws and Clamp and Tang't movem't,	12,00
" " " " " without " " " "	10,00
Compound Tangent Ball,......................................	4,00
Brass Cover for compass glass,..............................	1,00

TRANSITS.

Vernier, plain telescope * 6 inch needle, with compass tripod,...	60,00
Surveyors' " " 4 " " " adjusting " ...	100,00
" " " 5 " " " " " ...	100,00
" " " $5\frac{1}{2}$ " " " " " ...	100,00
Engineers' " " 4 " " " " " ...	120,00
" " " 5 " " " " " ...	125,00
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" " theodolite axis,...........	150,00
" " two telescopes, ...	190,00

EXTRAS.

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" " $4\frac{1}{2}$ " " " " " single "	10,00
Clamp and Tangent movement to axis of telescope,..............	5,00
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Rack and pinion movement to eye glass,..........................	5,00
Sights on telescope with folding joints,........................	5,00
" " Standards at right angles to telescope,.................	5,00

LEVELING RODS.

Yankee, or Boston,..	12,00
New York, with improved mountings,..........................	12,00

* A "plain" telescope is one without any of the attachments, as the clamp and tangent, vertical circle and level.

LEVELING INSTRUMENTS.

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Eighteen " " " " "	90,00
Twenty " " " " "	90,00
Twenty-two " " " "	90,00
Farm level, " " " "	45,00
Builders' level, " " " "	50,00

CHAINS.

100 feet, with oval rings, No. 5 wire, iron,....	7,50
" " " " " " 6 " "	6,00
50 " " " " " 5 " "	4,00
" " " " " " 6 " "	3,50
66 " " round " " 8 " "	3,00
33 " " " " " 8 " "	1,75
66 " " " " " 10 " "	2,50
33 " " " " " 10 " "	1,50
66 " " " " " 10 " steel,......	5,00
33 " " " " " 10 " "	2,75
Set 11 marking Pins,......................................	,75

MEASURING TAPES.

Chesterman's steel, 33 feet,..............................	7,50
" " 50 "	11,50
" " 66 "	14,50
" " 100 "	20,00
" metallic 33 "	2,50
" " 50 "	3,00
" " 60 "	3,25
" " 66 "	3,50
" " 70 "	3,75
" " 80 "	4,00
" " 100 "	5,00

POCKET COMPASSES.

With folding sights, 2½ inch needle, very serviceable for retracing lines once surveyed,........	6,00
" " " " " " with jacob staff mountings,..	7,50
" " " 3½ " " " " " "	9,00
" " " " " " without " "	8,00
Without sights, 1 to 2 " " ....from 25 cts. to	2,50
Miners' Compasses, for tracing iron ore,.........................	6,00

For prices of Drawing Instruments, Drawing, Profile and Cross-Section Paper; Colors, Pencils, and a list of Standard Works on Surveying and Civil Engineering, we refer to the Supplement.

Information to Purchasers.

Instruments Wanted.—In regard to the best kind of instruments for particular purposes, we would here say, that where only common surveying, or the bearing of lines in the surveys for county maps is required, a Plain Compass is all that is necessary. In cases where the variation of the needle is to be allowed, as in running over the lines of an old farm, or the surveys of Government lands, the Vernier Compass, or the Vernier Transit, is required.

Where, in addition to the variation of the needle, horizontal angles are to be taken, in cases of local attraction, the Rail Road Compass is preferable; and for a mixed practice of surveying and engineering, we consider the Surveyors' Transit superior to any other instrument made by us or any other manufacturers.

Where Engineering is the exclusive design, the Engineers' Transit and the Leveling Instruments are of course indispensable.

The Farm and Builders' Levels, are intended for laying out mill seats and determining the levels of buildings in course of erection.

Warranty —All our instruments are examined and tested by us in person, and are sent to the purchaser adjusted and ready for immediate use.

They are warranted correct in all their parts—we agreeing in the event of any defect appearing after reasonable use, to repair or replace with a new and perfect instrument, promptly and at our own cost, express charges included, or we will refund the money and the express charges paid by him.

Instances may sometimes occur in a business as large and as widely extended as ours, where owing to careless transportation or to defects escaping the closest scrutiny of the maker, instruments may reach our customers in bad condition. We consider the retention of such instruments in all cases an injury very much greater to us than to the purchaser himself.

Packing, &c.—Each instrument is packed in a well finished mahogany case, furnished with lock and key and brass hooks, the larger ones having beside these a leather strap for convenience in carrying. Each case is provided with screw-drivers, adjusting pin, and wrench for centre pin, and if accompanied with a tripod, with a brass plumb-bob; with all instruments for taking angles, without the needle, a reading microscope is also furnished.

Unless the purchaser is already supplied, each instrument is accompanied with our "Manual," giving full instructions for such adjustments and repairs as are possible, to one not provided with the facilities of an instrument maker.

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 allow the introduction of elastic material, and so effectually are our instruments protected by these precautions, that of several thousand sent out by us during the last thirteen years, in all seasons, by every mode of transportation, and to all parts of the Union, and the Canadas, not more than three or four have sustained serious injury.

Means of Transportation.—Instruments can be sent by Express to almost every town in the United States and Canadas, regular agents being located at all the more important points, by whom they are forwarded to smaller places by stage. The charges of transportation from Troy to the purchaser are in all cases to be borne by him, we guaranteeing the safe arrival of our instruments to the extent of express transportation, and holding the Express Companies responsible to us for all losses or damages on the way.

Terms of Payment are uniformly cash, and we have but one price. Our prices for instruments are nearly one-third less than those of other makers of established reputation. They are as low as we think instruments of equal quality can be made, and will not be varied from the list given on the previous pages.

Remittances may be made by a draft, payable to our order at Troy, Albany, New York, Boston, or Philadelphia, which can be procured from Banks or Bankers in almost all of the larger villages.

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 draft, obtained as before, and without additional cost.

Or the customer may pay the bill on receipt of the instrument to the express agent, taking care to send funds bankable in New York or Boston.

All persons ordering instruments by mail, or by proxy, may rely on receiving as perfect and cheaply as if ordered in person.

W. & L. E. GURLEY,

Mathematical Instrument Makers,

Fulton St., opposite Union R. R. Depot, Troy, N. Y.

PREFACE.

In offering this little work to the public, the publishers have designed to supply a want which an experience of many years in the manufacture of Instruments, as well as practice in the field, has taught them, is very generally felt by American Surveyors and Engineers.

The various Instruments employed in English and European practice are so different from those preferred by the great majority of American Engineers, that no description of the former, however excellent, is applicable to such as are manufactured and used in our own country.

The entire absence of any treatise upon American Instruments, as well as the numerous enquiries which are made by our business correspondents, has led us to believe that a Manual, furnishing a full description of the peculiarities and adjustments of those manufactured at our establishment, would be acceptable, not only to our own customers, but to the profession generally.

With the hope, therefore, that our little book may enable the Engineer and Surveyor to understand their instruments, and discover and rectify any derangement in their adjustments, or injury from ordinary accidents, we now commit it to the indulgence of those for whom it has been designed.

W. & L. E. GURLEY.

Troy, May 1, 1857.

SURVEYING INSTRUMENTS.

The various instruments used in Surveying may be conveniently arranged, into two general divisions.

(1.) Needle instruments,—or such as owe their accuracy and value to the magnetic needle only, embracing the Plain and Vernier Compasses, and the Vernier Transit.

(2.) Angular instruments, including those in which the horizontal angles, are measured by a divided circle and verniers, as well as by the needle also ; as the Rail Road Compass, the Surveyors' and Engineers' Transits, &c.

In the present work we shall consider first, those instruments comprised in the first division, and, as in these the accuracy of the horizontal angles indicated, depends upon the delicacy of the needle, and the constancy with which it assumes a certain direction, termed the "magnetic meridian," we shall here remark briefly upon, the *form*, the *length* and the *movement* of

The Magnetic Needle.—The *forms* of the needle are almost infinitely varied, according to the taste or fancy of the maker or surveyor, but may be resolved into two general classes, one having the greatest breadth in a horizontal, the other in a vertical direction.

We have usually made our needles about one twentieth of an inch broad and one third as thick, parallel from end to end, the north and south poles being distinguished from each other, by a small scollop on the north end.

The *length* of the needle varies in different instruments, from four to six or even seven inches, those of five and a half, or six inches long, being generally preferred by surveyors.

The *movement* of the needle, with the least possible friction, is secured by suspending it, by a jeweled centre upon a hardened steel pivot, the point of which is made perfectly sharp and smooth.

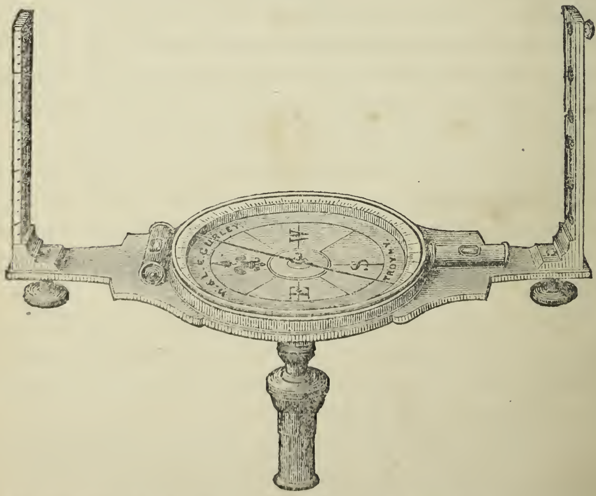
The test of the delicacy of a magnetic needle is the number of horizontal vibrations, which it will make in a certain arc, before coming to rest—besides this, most surveyors prefer also to see a sort of quivering motion in a vertical direction.

This quality which is manifested more in a horizontal, than in a vertical needle and depends upon the near coincidence of the point of suspension, with the centre of gravity of the needle, serves to show merely, that the cap below is unobstructed.

Having now considered the different qualities of a good needle, we shall proceed to speak of those instruments of which it makes so important a part; of these the most simple is that termed the

PLAIN COMPASS.

Fig. 1.



As represented above, the Plain Compass, has, a needle six inches long, a graduated circle, main plate, levels, and sights, and is placed upon the brass head of the "Jacob staff."

THE COMPASS CIRCLE, in this, as in all our instruments, is divided to half degrees on its upper surface, the whole degree marks being also cut down on the inside circumference, and is figured from 0 to 90, on each side of the centre or "line of zeros."

The circle and face of the compass are silvered.

THE SPIRIT LEVELS are placed at right angles to each other so as to level the plate in all directions, and are balanced, upon a pivot underneath the middle of the tube, so as to be adjustable by a common screw-driver.

THE SIGHTS, or standards, have fine slits cut through nearly their whole length, terminated at intervals by large circular apertures, through which the object sighted upon is more readily found. Sometimes a fine horse-hair or wire is substituted for one half the slote, and placed alternately with it on opposite sights.

TANGENT SCALE.—The right and left hand edges of the sights of our compasses, have respectively an eye-piece, and a series of divisions, by which angles of elevation and depression, for a range of about twenty degrees each way, can be taken with considerable accuracy.

Such an arrangement is very properly termed a "tangent scale," the divided edges of the north sight, being tangents to segments of circles having their centres at the eye-pieces, and their points of contact with the tangent lines at the zero divisions of the scale.

The cut shows the eye-piece and divisions for angles of depression; those for angles of elevation, concealed in this cut, are seen in that of the Railroad Compass.

THE JACOB STAFF mountings which are furnished with all our compasses, and packed in the same case, consist of the brass head already mentioned, and an iron ferule or shoe pointed with steel so as to be set firmly in the ground.

The staff to which the mountings should be well fitted and driven on, is procured from any wheelright, or selected by the surveyor himself, from a sapling of the forest.

To adjust the Compass.

THE LEVELS.—First bring the bubbles into the centre, by the pressure of the hand on different parts of the plate, and then turn the compass half way around ; should the bubbles run to the end of the tubes, it would indicate that those ends were the highest ; lower them by tightening the screws immediately under, and loosening those under the lowest 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 centre, during an entire revolution of the compass.

THE SIGHTS may next be tested by observing, through the slits, a fine hair or thread made exactly vertical by a plumb. Should the hair appear on one side of the slit the sight must be adjusted by filing off its under surface on that side which seems the highest.

THE NEEDLE is adjusted in the following manner :—Having the eye nearly in the same plane with the graduated rim of the compass circle, with a small splinter of wood, or a slender iron wire, bring one end of the needle in line with any prominent division of the circle, as the zero, or ninety degree mark, and notice if the other end corresponds with the degree on the opposite side ; if it does, the needle is said to "cut" opposite degrees ; if not, bend the centre-pin by applying a small brass wrench, furnished with our compasses, about one-eighth of an inch below the point of the pin, 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 centre-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 centre pin only, the needle being 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 divided surface.

To use the Compass.

In using the Compass the Surveyor should keep the south end towards his person, and read the bearings from the north end of the needle. He will observe that the E and W letters on the face of the compass are reversed from their natural position, in order that the direction of the line of sight may be correctly read.

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

Sometimes, however, a small vernier is placed upon the south end of the needle, and reads the circle to five minutes of a degree—the circle being in that case graduated to whole degrees.

This contrivance, however, is quite objectionable on account of the additional weight imposed on the centre-pin, and the difficulty of reading a vernier which is in constant vibration, and is therefore but little used.

To Take Angles of Elevation.—Having first leveled the compass, bring the south end towards you, and place the eye at the little button, or eye piece, on the right side of the south sight, and with the hand fix a card on the front surface of the north sight, so that its top edge will be at right angles to the divided edge, and coincide with the zero mark; then sighting over the top of the card, note upon a flag-staff the height cut by the line of sight; then 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 we shall have the angle required.

For Angles of Depression.—Proceed in the same manner, using the eye-piece and divisions on the opposite sides of the sights, and reading from the top of the standards.

Jacob Staff Socket.—The compass is furnished with a ball spindle, or socket, upon which it turns, and by which it is leveled. The ball may be placed in a single or "jacob staff" socket, as represented in the figure, or in a compass tripod, such as is shown in the cut of the Vernier Transit beyond.

Clamp Screw.—In the side of the hollow cylinder, or socket, of the compass which fits to the ball spindle, is a screw by which the instrument may be clamped to the spindle in any position.

Spring Catch.—Besides the clamp screw, we have recently fitted to the sockets of our compasses a little spring catch, which, as soon as the instrument is set upon the spindle, slips into a groove and thus removes all danger of falling when the instrument is carried.

Needle Lifter.—There is also, underneath the main plate, a needle lifting screw which, by moving a concealed spring, raises the needle from the pivot, and thus prevents the blunting of the point in transportation.

When the compass is not in use it is the practice of many surveyors to let down the needle upon the point of the centre-pin, and let it assume its position in the magnetic meridian so as to retain or even increase its polarity.

We would advise in addition, that after the needle has settled it should be raised against the glass, in order not to dull the point of suspension.

ELECTRICITY.—A little caution is necessary in handling the compass, that the glass covering be not excited by the friction of cloth, silk, or the hand, so as to attract the needle to its under surface.

A brass cover is sometimes fitted over the glass as a precaution against disturbances of this kind.

When, however, the glass becomes electric, the fluid may be removed by breathing upon it, or touching different points of its surface with the moistened finger.

An ignorance of this apparently trifling matter has caused many errors and perplexities in the practice of the inexperienced surveyor.

Repairs of the Compass.

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

1. THE NEEDLE.—It may sometimes happen that the needle has lost its polarity, and needs to be re-magnetized; this is effected in the following manner:

The operator being provided with an ordinary permanent magnet,* and holding it before him, should pass with a gentle pressure each end of the needle from centre to extremity over the magnetic pole, describing before each pass a circle of about six inches radius, to which the surface of the pole is tangent, drawing the needle towards him, and taking care that the north and south ends are applied to the *opposite* poles of the magnet.

Should the needle be returned in a path near the magnetic pole, the current induced by the contact of the needle and magnet in the pass above described, would be reversed, and thus the magnetic virtue almost entirely neutralized at each operation.

When the needle has been passed about twenty-five times in

* A magnet suitable for this purpose costs from 12 to 25 cents.

succession, in the manner just described, it may be considered as fully charged.

A fine brass wire is wound in two or three coils on the south end of the needle, and may be moved back or forth, in order to counterpoise the varying weight of the north end.

2. The Centre-Pin.—This should occasionally be examined, and if much dulled, taken out with the brass wrench, already spoken of, or with a pair of plyers, and sharpened on a hard oil stone—the operator placing it in the end of a small stem of wood, or a pin vice, and delicately twirling it with the fingers as he moves it back and forth at an angle of about 45° to the surface of the stone.

When the point is thus 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.

3. To put in a New Glass.—Unscrew the "bezzel ring" which holds it, take out the little brass ring and the old glass, and scrape out the putty; then if the new glass does not fit, smooth off its edges by holding it obliquely on the surface of a grind-stone until it will enter the ring easily; then put in new putty, spring in the brass ring, and the operation will be completed.

4. To replace a Spirit Level.—Take out the screws which hold it on the plate, pull off the brass ends of the tube, and with a knife-blade scrape out the plaster from the tube; then with a stick, made a little smaller than the diameter of the tube, and with its end hollowed out, so that it will bear only on the broad surface of the level vial, push out the old vial, and replace it with a new one, taking care that the crowning side, which is usually marked with a file on the end of the vial, is placed on the upper side.

When the vial does not fit the tube it must be wedged up by putting under little slips of paper until it moves in snugly.

After the vial is in its place, put around its end a little boiled plaster, mixed with water to the consistency of putty, taking care not to allow any to cover the little tip of the glass, then slip in the brass ends, and the operation will be completed.

A little beeswax, melted and dropped upon the ends of the vial is equally as good as the boiled plaster, and often more easily obtained.

We would here remark that an extra glass and level vials are always furnished, free of charge, with our instruments, whenever desired by the purchaser.

Sizes of the Plain Compass.

Three different sizes of this instrument are in common use—having respectively four, five, and six inch needles, and differing also in the length of the main plate, which in the four inch Compass is twelve and a half inches long, and in the larger sizes fifteen and a half inches.

The six inch needle compass is generally preferred.

Weight of the Plain Compasses.

The average weights of the different sizes, with the brass mountings of the Jacob Staff, are,

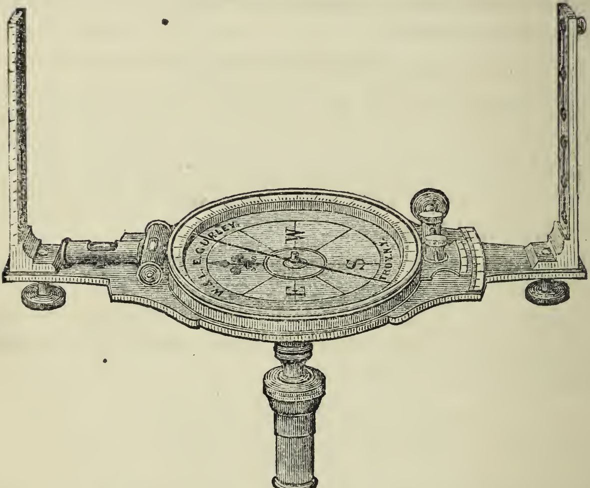
For the 4 inch needle, 6 lbs.
For the 5 inch needle, 7½ lbs.
For the 6 inch needle, 8½ lbs.

The Plain Compass, which was the only one in use in this country previous to the time of David Rittenhouse, has gradually given way to the superior advantages of the Vernier or Rittenhouse Compass, which we shall now proceed to describe.

SURVEYING INSTRUMENTS.

THE VERNIER COMPASS.

Fig. 2



The Vernier Compass, represented in fig. 2 differs from the instrument just described, in having its compass circle with a vernier attached, movable about a common centre, by turning the "tangent screw," seen at the south end of the plate.

The superiority of the Vernier over the Plain Compass consists in its adaptation to the retracing the lines of an old survey, and in the surveys of the U. S. public lands, where the lines are based on a true meridian.

Variation of the Needle.

It is well known that the magnetic needle, in almost all parts of the United States, points more or less to the east or west of a true meridian, or north and south line.

This deviation, which is called the Variation of Declination of the needle, is not constant, but increases or decreases to a very sensible amount in a series of years.

Thus at Troy, N. Y., a line bearing in 1830, N. 31° E. would now, 1857, with the same needle, have a bearing of about N. 32° E., the needle having thus in that interval, travelled a full degree to the west.

For this reason, therefore, in running over the lines of a farm from field notes of some years standing, the Surveyor would be obliged to make an allowance, both perplexing and uncertain, in the bearing of every line.

To avoid this difficulty the *vernier* was devised, the arrangement of which we shall now describe.

The Vernier is divided on its edge to thirty equal parts, and figured in two series on each side of the centre.

In the same plane with the vernier is an arc or limb, fixed to the main plate of the compass, and graduated to half degrees.

The surfaces of both vernier and limb are silvered.

On the vernier are thirty equal divisions, which exactly correspond in length with thirty-one of the half degrees of the limb.

Each division of the vernier, is therefore, one-thirtieth, or, in other words, one minute longer than a single division of the limb.

To Read the Vernier.—In "reading" the vernier, if it is moved to the right, count the minutes from its zero point to the left, and vice versa. Proceed thus until a division on the vernier is found exactly in line with another on the limb, and the lower row of figures on the vernier will give the number of minutes passed over. When the vernier is moved more than fifteen minutes to either side, the number of the additional minutes up to thirty or one-half degree of the limb is given by the upper row of figures on the opposite side of the vernier.

To read beyond thirty, add the minutes given by the vernier to that number, and the sum will be the correct reading.

In all cases when the zero point of the vernier passes a whole degree of the limb, this must be added to the minutes, in order to define the distance over which the vernier has been moved.

To Turn off the Variation.—It will now 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 variation.

He therefore places his instrument on some well defined line of the old survey, and turns the tangent screw until the needle of his compass indicates the same bearing as that given in the old field notes of the original survey.

Then screwing up the clamp screw underneath the vernier, he can run all the other lines from the old field notes without further alteration.

The reading of the vernier on the limb in such a case, would give the change of variation at the two different periods.

The variation of the needle 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 variation is east or west, until the arc passed over on the limb is equal to the angle of variation; and then turning the compass until the needle is made to cut the zeros on the divided circle, when the line of the sights would give the direction of the true meridian of the place.

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

"The line of no variation," as it is called, or that 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 Erie to cape Hatteras, on the coast of North Carolina.

A Compass needle, therefore, placed east of this line, would have a variation to the west, and when placed west of the line, the variation would be to the east, and in both cases the variation would increase as the needle was carried farther from the line of no variation.

Thus in Minnesota the variation is from 15° to 16° to the east, while in Maine it is from 17° to 18° to the west.

At Troy, in the present year, 1857, the variation is about 7° 47′ to the west, and is increasing in the same direction from two to three minutes annually.

To Read to Minutes.—A less important use of the vernier is to give a reading of the needle to single minutes, which is obtained as follows:

First be sure, as in all observations, that the zero of the vernier exactly corresponds with that of the limb; then noting the number of whole degrees given by the needle, move back the compass circle with the tangent screw until the nearest whole degree mark is made to coincide with the point of the needle, read the vernier as before described, and this reading, added to the whole degrees, will give the bearing to minutes.

To Use the Vernier Compass.

Proceed in the same manner as directed in regard to the Plain Compass, when making new surveys, always taking care that the vernier is set at zero and securely clamped by screwing up the nut beneath the plate.

In surveying old farms, allowance and correction must be made for the variation, as just described.

Sizes of the Vernier Compass.

We make but one size of this instrument, having a six inch needle and a main plate fifteen and a half inches long.

Weight of the Vernier Compass.

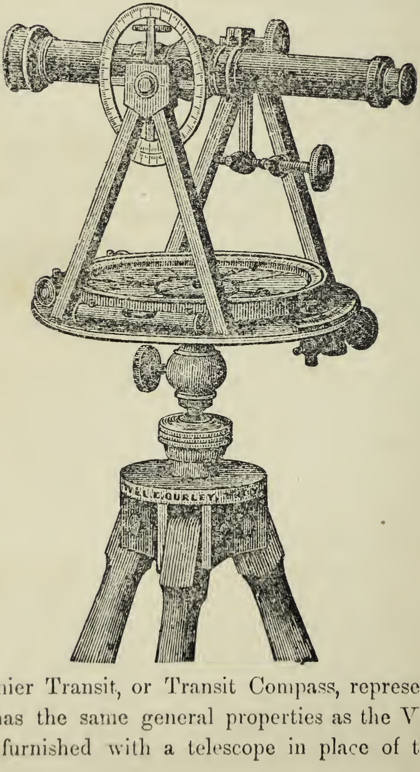
The average weight of this instrument, with the jacob staff mountings, is about 9½ pounds.

The adjustments of the Vernier Compass are mainly those of the instrument first described, and need not here be repeated.

SURVEYING INSTRUMENTS.

THE VERNIER TRANSIT.

Fig. 3.



The Vernier Transit, or Transit Compass, represented in the cut above, has the same general properties as the Vernier Compass, but is furnished with a telescope in place of the ordinary sights.

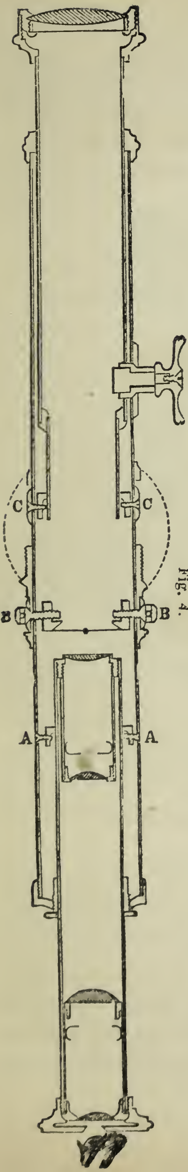


Fig. 4.

The telescope is from ten to twelve inches long, and sufficiently powerful to see and set a flag at a distance of two miles, in a clear day.

The cross-bar in which it is fixed, turns readily in the standards, so that the telescope can be turned in either direction, and back and fore sights be taken without removing the instrument.

Like all telescopes used by us in our instruments, it shows objects in an erect position.

THE TELESCOPE.—The interior construction of the telescope of the Vernier Transit which is very similar to those of the other instruments we shall describe, is well shown in the longitudinal section represented in fig. 4.

As here seen, the telescope consists essentially of an object-glass, an eye-piece tube, and a cross-wire ring, or diaphragm.

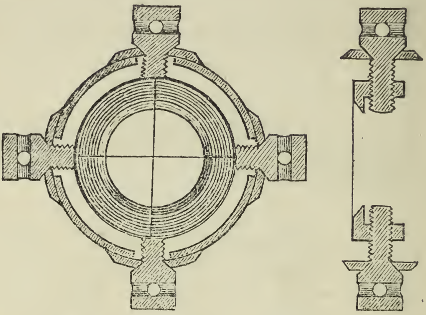
The object-glass is composed of two lenses, one of flint, the other of crown glass, which are so made and disposed, as to show the object seen through it without color or distortion.

The object-glass, and the whole telescope is therefore said to be "achromatic."

The eye-piece is made up of four plano-convex lenses, which, beginning at the eye end, and proceeding on, are called respectively, the eye, the field, the amplifying, and the object lenses.

Together, they form a compound microscope, magnifying the minute image of any object formed at the cross-wires by the interposition of the object-glass.

Fig. 5.



The Cross-Wires.—The cross-wire diaphragm, two views of which are here exhibited, is a small ring of brass, suspended in the tube of the telescope by four capstan head screws, which press upon the washers shown on the outside of the tube.

The ring can thus be moved in either direction, by working the screws with an ordinary adjusting pin.

Across the flat surface of the ring two fine fibres of spider's web are extended at right angles to each other, their ends being cemented with beeswax, or varnish, into fine lines cut in the metal of the ring.

The intersection of the wires forms a very minute point, which, when they are adjusted, determines the optical axis of the telescope, and enables the Surveyor to fix it upon an object with the greatest precision.

The imaginary line passing through the optical axis of the telescope, is termed the "line of collimation," and the operation of bringing the intersection of the wires into the optical axis, is called the "adjustment of the line of collimation." This will be hereafter described.

The openings in the telescope tube are made considerably larger than the screws, so that when these are loosened, the whole ring can be turned around for a short distance in either direction.

The object of this will be seen more plainly, when we describe the means by which the wire is made truly vertical.

The sectional view of the telescope (fig 4,) also shows two moveable rings, one placed at A Á, the other at C C, which are respectively used, to effect the centering of the eye-piece, and the adjustment of the object-glass slide.

The centering of the eye-tube is performed after the wires have been adjusted, and is effected by moving the ring, by means of the screws, shown on the outside of the tube, until the intersection of the wires is brought into the centre of the field of view.

The adjustment of the object slide, which will be fully described in our account of the Leveling Instrument, secures the movement of the object-glass in a straight line, and thus keeps the line of collimation in adjustment through the whole range of the slide, preventing at the same time what is termed the "travelling" of the wires.

This adjustment which is peculiar to our telescopes, is always made in the process of construction, and needing no further attention at the hands of the Engineer, is concealed within the hollow ball of the telescope axis.

Optical Principles of the Telescope.

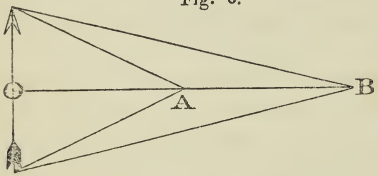
In order that the advantages gained by the use of the telescope may be more fully understood, we shall here venture briefly to consider the optical principles involved in its construction.

We are said to "see" objects because the rays of light which proceed from all their parts, after passing through the pupil of the eye, are by the crystalline lens and vitreous humor, converged to a focus on the retina, where they form a very minute inverted image; an impression of which is conveyed to the brain by the optic nerve.

The rays proceeding from the extremities of an object, and crossing at the optic centre of the eye, form the "visual angle," or that under which the object is seen.

The apparent magnitude of objects depends on the size of the visual angle which they subtend, and this being great or small, as the object is near or distant—the objects will appear large or small, in an inverse proportion to the distances which separate them from the observer.

Fig. 6.



Thus, (in fig. 6,) if the distance O A is one-half of O B, the visual angle, subtended by the object at the point A, and therefore the apparent magnitude of the object will be twice that observed at B. If, therefore, the visual angle subtended by any object, can be made by any means twice as large, the same effect will be produced as if the observer were moved up over one-half the intervening distance.

Now this is the principal advantage gained in the use of a telescope.

The object-glass receiving the rays of light which proceed from all the points of a visible object, converges them to a focus at the cross-wires, and there forms a minute, inverted, and very bright image, which may be seen by placing a piece of ground glass to receive it at that point.

The eye-piece acting as a compound microscope, magnifies this image, restores it to its natural position, and conveys it to the eye.

The visual angle which the image there subtends, is as many times greater than that which would be formed without the use of the telescope, as the number which expresses its magnifying power.

Fig. 7.

Thus, a telescope which magnifies twenty times, increases the visual angle just as much, and therefore diminishes the apparent distance of the object twenty times—or in other words, it will show an object two hundred feet distant, with the same distinctness, as if it was distant only ten feet from the naked eye.

The accompanying cut, (fig. 7,) which we are kindly permitted to copy from an excellent treatise on surveying, by Prof. Gillespie of Union College, will give a correct idea of the manner in which the rays of light coming from an object are affected, by passing through the several glasses of a telescope.

We shall only consider the rays which proceed from the extremities; these, after passing through the object-glass, here shown as a single lens, are conveyed to the point B, the centre of the cross-wires and the common focus of the object and eye glasses. At this place the rays cross each other and the image is inverted.

The rays next come to the object lens C, and passing through it are refracted so as again to cross each other, and come thus to the amplifying lens D. By this they are again refracted, made more nearly parallel and thus reach the large field lens E. After passing through this, they form a magnified and erect image in the focus of the eye lens G. By the eye lens the image is still further magnified, and at last enters the eye of the observer, subtending an angle as much greater than that at the point O, as is the magnifying power of the telescope.

In place of the eye-piece of four lenses, which we have just been considering, and which is exclusively used in all American instruments made at the present day; another, which has but three lenses, is often seen in the telescopes of imported instruments.

This latter, which inverts the object, though saving a little more light than the former, is exceedingly troublesome to the inexperienced observer, and has never been popular in American Engineering.

To ascertain the Magnifying Power of a Telescope.

Set up the instrument about twenty or thirty feet from the side of a white wooden house, and observe through the telescope the space covered by one of the boards in the field of the glass; then, still keeping that eye on the telescope, hold open the other with the finger, if necessary, and look with it at the same object. By steady and careful observation there will appear on the surface of the magnified board, a number of smaller ones seen by the naked eye, count these, and we shall obtain the magnifying power.

If the limits of the magnified board, as seen through the telescope, can be noted so as to be remembered after the eye is removed, the number of boards contained in this space may then be easily counted.

The side of an unpainted brick wall, or any other surface, containing a number of small, well marked and equal objects, may be observed, in place of the surface we have described.

The operation described requires great care and close observation, but may be performed with facility after a little practice.

We have spoken of the effect of the telescope in magnifying objects, but have not mentioned what is termed its "illuminating power."

This arises from the great diameter, or aperture of the object-glass, compared with that of the pupil of the eye, which enables the observer to intercept many more rays of light, and bring the object to the eye highly illuminated.

The advantage gained in this increase of light depends, as is evident, on the size of the object glass, and the perfection with which the lenses transmit the light without absorbing or reflecting it.

The superficial magnifying power of a telescope, is found by squaring the number which expresses its linear magnifying power; thus a telescope which magnifies twenty times, increases the surface of an object four hundred times.

Before an observation is made with the telescope, the eye-piece should be moved in or out, until the wires appear distinct to the eye of the operator; the object glass is then adjusted by turning the pinion head until the object is seen clear and well defined, and the wires appear as if fastened to its surface.

The intersection of the wires, being the means by which the optical axis of the telescope is defined should be brought precisely upon the centre of the object to which the instrument is directed.

Having thus briefly considered the principles, we shall now proceed to describe the

Attachments of the Telescope.

A telescope is said to be "plain" when it is without any appendages to its tube or axis, as the Engineers' Transit shown on the frontispiece, and most instruments are made in that manner.

Many surveyors, however, prefer to add these conveniences, and we shall now consider them in detail.

Clamp and Tangent.—This consists essentially of a ring, encircling the axis of the telescope, and having two projecting arms, the one above being slit through the middle and holding the clamp screw, the other much longer and below, is connected with the tangent screw.

As soon as the clamp screw is tightened, the ring is brought firmly around the axis, and the telescope can then be moved up or down by turning the tangent screw.

The clamp and tangent ought always to accompany the vertical circle and the level on the telescope.

Vertical Circle.—A divided circle as seen in the cut of the Vernier Transit, is often attached to the axis of the telescope, giving, with a vernier, the means of measuring vertical angles with great facility.

We make two sizes of these circles, one of about $3\frac{1}{2}$ inches diameter, seen with this instrument, the other an inch larger, and shown in the cut of the Engineer's Transit, Fig. 12. The former is graduated to single degrees, and reads, by the vernier, to five minutes of a degree. The latter, divided to half degrees, gives a reading, with the vernier, to single minutes.

The vertical circle is fitted firmly to the telescope axis, and fastened with a screw, so that it remains permanent.

The vernier however, may be shifted in either direction, by loosening the screws which confine it to the standards.

The vernier of the small circle is divided into twelve equal parts, which correspond with thirteen degrees on the circle.

Each division of the vernier is, therefore, one-twelfth of one degree, or five minutes longer than a single divison of the circle, so that the angles are read to five minutes of a degree.

The vernier is double, having its zero point in the middle, and the reading up to thirty minutes, is said to be direct; that is, if the circle is moved to the right, the minutes are read off on the right side of the vernier, and vice versa.

The minutes beyond thirty are obtained on the opposite side, and in the lower row of figures.

By following these directions, and noticing the first divisions on the circle and vernier, which exactly correspond, the surveyor can obtain a reading to five minutes, with great facility.

Level on Telescope.—Besides the vertical circle, there is sometimes a small level attached to the telescope of this, and other instruments, which we shall hereafter describe.

Such an attachment is shown in the cut of the Surveyor's Transit, and its adjustment and advantages will be explained in our account of that instrument.

Sights on Telescope.—We are sometimes desired by surveyors, to place a pair of short sights on the upper side of the telescope tube.

They are best made to fold close to the tube, when not in use, like those of the pocket compass, described hereafter.

These sights are thought to be useful in taking back sights without turning the telescope, and in sighting through bushes or in the forest.

We believe, however, that a telescope is incomparably better, in every situation, and would never advise their construction or use.

Sights for Right Angles.—Besides the sights just mentioned, we have often attached others to the plate of the instrument, on either side of the compass circle, or on the standards.

These being adjusted to the telescope, give a very ready means of laying off right angles, or running out offsets, without changing the position of the instrument.

To Adjust the Vernier Transit.

The Levels of this instrument have a capstan head screw at each end, and are adjusted with a steel pin in the same manner as those of the Plain Compass.

The Needle is adjusted as described in our account of the Plain Compass.

Line of Collimation.—To make this adjustment, which is, in other words, to bring the intersection of the wires into the optical axis of the telescope, so that the instrument, when placed in the middle of a straight line will, by the revolution of the telescope, cut its extremities—proceed as follows:

Set the instrument firmly on the ground and level it carefully; and then having brought the wires into the focus of the eye-piece, adjust the object-glass on some well defined point, as the edge of a chimney, or other object, at a distance of from two to five hundred feet; determine if the vertical wire is plumb, by clamping the instrument firmly to the spindle and applying the wire to the vertical edge of a building, or observing if it will move parallel to a point taken a little to one side; should any deviation be manifested, loosen the cross-wire screws, and by the pressure of the hand on the heads outside the tube, move the ring around until the error is corrected.

The wires being thus made respectively horizontal and vertical, fix their point of intersection on the object selected; clamp the instrument to the spindle, and having revolved the telescope, find or place some good object in the opposite direction, and at about the same distance from the instrument as the first object assumed.

Great care should always be taken in turning the telescope, that the position of the instrument upon the spindle is not in the slightest degree disturbed.

Now, having found or placed an object which the vertical wire bisects, unclamp the instrument, turn it half way around, and direct the telescope to the first object selected; having bisected this with the wires, again clamp the instrument, revolve the telescope, and note if the vertical wire bisects the second object observed.

Should this happen, it will indicate that the wires are in adjustment, and the points bisected are with the centre of the instrument, in the same straight line.

If not, however, the space which separates the wires from the second point observed, will be double the deviation of that point from a true straight line, which may be conceived as drawn through the first point and the center of the instrument, since the error is the result of two observations, made with the wires when they are out of the optical axis of the telescope.

Fig. 8.

For as in the diagram, let A represent the centre 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 made to revolve.

When the instrument is turned half around, and the telescope again directed to B, and once more revolved, 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 very apparent.

In order to correct it, use the two capstan head screws on the sides of the telescope, these being the ones which affect the position of the vertical wire.

Remember that the eye-piece inverts the position of the wires, and therefore, that 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. Having in this manner moved back the vertical wire until, by estimation, one-quarter of the space, D E, has been passed over, return the instrument to the point, B, revolve the telescope, and if the correction has been carefully made, the wires will now bisect a point, C, situated midway between D and E, and in the prolongation of the imaginary line, passing through the point B and the centre of the instrument.

To ascertain if such is the case, turn the instrument half around, fix the telescope upon B, clamp to the spindle, and again revolve the telescope towards C. If the wires again bisect it, it will prove that they are in adjustment, and that the points B, A, C, all lay in the same straight line.

Should the vertical wire strike to one side of C, the error must be corrected precisely as above described, until it is entirely removed.

Another method of adjusting the line of collimation, often employed in situations where no good points in opposite directions can be selected upon which to reverse the wires, may here be described.

The operator sets up the instrument in some position which commands a long sight in the same direction, and having leveled his instrument, clamps to the spindle, and with the telescope locates three points which we will term A, B, and C, which are distant from the instrument about one, two, and three hundred feet, respectively.

These points, which are usually determined by driving a nail into a wooden stake set firmly into the ground, will all lie in the same straight line, however much the wires are out of adjustment, since the position of the instrument remains unchanged during the whole operation.

Having fixed these points, he now moves the instrument to B, and sets its centre directly over the nail head, by letting down upon it the point of a plumb-bob suspended from the tripod.

Then having leveled the instrument, he directs the wires to A, clamps to the spindle, and revolves the telescope towards C. Should the wires strike the nail at that point, it would show that they were in adjustment.

Should any deviation be observed, the operator must correct it by moving the wire with the screws until, by estimation, half the error is removed.

Then bringing the telescope again upon either A or C, and revolving it, he will find that the wires will strike the point in the opposite direction, if the proper correction has been applied.

If not, repeat the operation until the telescope will exactly cut the two opposite points, when the intersection of the wires will be in the optical axis, and the line of collimation in adjustment.

In our description of the previous operation, we have spoken more particularly of the vertical wire, because in a revolving telescope this occupies the most important place, the horizontal one being employed mainly to define the centre of the vertical wire, so that it may be moved either up or down without materially disturbing the line of collimation.

The wires being adjusted, their intersection may now be brought into the centre of the field of view.

THE EYE-PIECE, is centred by moving the screws A A, shown in the sectional view of the telescope, Fig. 4, which are slackened and tightened in pairs, the movement being now direct, until the wires are seen in their proper position.

It is here proper to observe that the position of the line of collimation depends upon that of the object-glass, solely, so that the eye-piece may, as in the case just described, be moved in any direction, or even entirely removed and a new one substituted, without at all deranging the adjustment of the wires.

THE STANDARDS.—In order that the wires may trace a vertical line as the telescope is moved up or down, it is necessary that both the standards of the telescope should be of precisely the same height.

To ascertain this and make the correction if needed, proceed as follows:

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

Level the instrument, fix the wires on the top of the object, and clamp to the spindle; then bring the telescope down, until the wires bisect some good point, either found or marked at the base; turn the instrument half around, fix the wires on the lower point, clamp to the spindle, and raise the telescope to the highest object.

If the wires bisect it, the vertical adjustment is effected; if they are thrown to either side, this would prove that the standard opposite that side, was the highest, the apparent error being double that actually due to this cause.

To correct it, we now 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 hold on the cap of the standard, the adjustment is made with the utmost precision.

This arrangement which is common to all our telescope instruments is very substantial and easily managed.

The Vertical Circle.—When this attachment requires adjustment, proceed by leveling the instrument carefully, and having brought into line the zeros of the wheel and vernier, find, or place some well defined point, or line, which is cut by the horizontal wire.

Turn the instrument half around, revolve the telescope, and fixing the wire upon the same point as before, note if the zeros are again in line.

If not, loosen the screws, and move the zero of the vernier over half the error; bring the zeros again into coincidence, and proceed precisely as at first described, until the error is entirely corrected, when the adjustment will be completed.

Should it be desired, at any time, the circle can be removed by the surveyor, and replaced at pleasure.

The Level on Telescope.—The adjustment of this will be best considered when we come to speak of the Surveyors Transit.

Adjustments in General.—We ought here to say, that the above adjustments, as well as all the others which we have previously explained or may hereafter describe, are always made by us in person, but are given in this work in order that the Surveyor and Engineer may fully understand their instruments, and be enabled to detect and remedy errors and accidents which in practice will often occur.

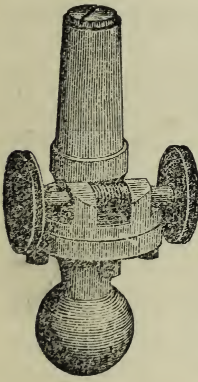
To Use the Vernier Transit.

This instrument is used on the ordinary ball and spindle placed most commonly in the compass tripod as shown in Fig. 3.

TRIPOD HEAD.—Sometimes leveling screws with the parallel plates, and which together we shall designate the "tripod head" with a clamp and tangent movement, are used with this instrument as well as with the Surveyors Transit.

This tripod head can be unscrewed from the legs, and is packed in the instrument box ; it is of very moderate cost, and in almost every situation is infinitely superior to a ball and socket support.

BALL AND SOCKET.—This we also make in all cases where the tripod head is furnished, by cutting a screw upon the lower end of the jacob staff, a ball and spindle being also supplied so that the Surveyor can use the same instrument either upon a jacob staff, a compass tripod, or a leveling tripod.



[Fig. 9.]

COMPOUND BALL.—We also manufacture what may be termed a "compound ball spindle," which has a tangent movement, and gives all the perfection of more costly arrangments, with a very moderate expense.

As represented in the cut, it has an interior spindle, around which an outside hollow cylinder is moved, by turning the double-headed tangent screw, which has in the middle, an endless screw, working into teeth, cut spirally around in a groove of the cylinder. The compass, or other instrument, revolves on the outside socket, precisely as if placed on a common ball spindle; but when a slower movement is required, can be made fast by the clamp screw, and then turned gradually around the interior spindle, by the tangent screw, until the slote of the sight, or the intersection of the wires, is made to bisect the object with the utmost certainty.

The compound ball may be placed either in a jacob-staff socket, or compass tripod.

THE SPRING CATCH, described in our account of the Plain Compass, is always attached to the socket of this instrument,

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whether placed upon a ball or tripod, so that it cannot slip off from the spindle in carrying.

The Clamp Screw, in the side of the socket of this instrument, is shown in Fig. 3, and by pressing a brass spring in the interior against the spindle, serves to fix the instrument in any position.

The Vernier is moved by the tangent screw, now always, placed above the plate, precisely as described in our account of the Vernier Compass, and is read to minutes in the same manner.

There is also a clamp nut underneath the vernier, by which it is securely fixed in any position, which must be loosened whenever the vernier is moved by the tangent screw.

The Needle Lifting Screw is the same as those of the compasses previously described.

In Surveying with this instrument, the operator proceeds precisely as with the Vernier Compass, keeping the south end towards his person, reading the bearings of lines from the north end of the needle, and using the telescope in place of sights, revolving it as objects are selected in opposite directions.

Parallax.—Before an observation is made with the telescope, the eye-piece should be moved in or out until the wires appear distinct to the eye of the operator; the object-glass may then be placed in position, by turning the pinion head on the top of the telescope until the object is seen clear and well defined, and the wires appear as if fastened to its surface.

When on the contrary, the wires are not perfectly distinct, the observer by moving his eye to either side of the small aperature of the eye-piece will cause the wires to "travel" on the object, and thus occasion what is termed the "error of parallax."

The intersection of the wires being the means by which the optical axis of the telescope is defined, should be brought precisely uopn the centre of the object to which the instrument is directed.

TO TAKE ANGLES OF ELEVATION.—Level the instrument carefully, fix the zeros of the circle and vernier in line, and note the height cut upon the staff or other object by the horizontal wire; then carry the staff up the elevation, fix the wire again upon the same point, and the angle of elevation will be read off by the vernier.

By careful usage, the adjustments of the vernier transit will remain as permanent as those of the ordinary compass, the only one liable to derangement, being that of the line of collimation. This should be examined occasionally, and corrected in the manner previously described.

Repairs of the Vernier Transit.

These being in great part already spoken of, it will be necessary to consider only such as belong to the telescope.

TO REPLACE THE CROSS-WIRES.—Take out the eye-piece tube, together with the little ring by which it is centred, and having removed two opposite cross-wire screws, with the others turn the ring until from the open end of the telescope tube, one of the screw holes is brought into view; in this thrust a stout splinter of wood or a small wire, so as to hold the ring while the other screws are withdrawn; the ring is then taken out and is ready for the wires.

For these the web of the spider is to be preferred above any thing else, but when this is not obtainable, a fine silk fibre may be substituted.

We usually procure our webs from the living manufacturer directly, selecting those of a yellowish-brown color as furnishing the most perfect product.

The spider being held between the thumb and finger of an assistant, in such position as to suffer no serious injury, and at the same time be unable to make any effectual resistance with his extremities, the little fibre may be drawn out at pleasure, and being placed in the fine lines cut on the surface of the diaphragm, is then firmly cemented to its place by applying softened beeswax with the point of a knife blade.

In case the spider is not procurable, a fine strand of a web which is free from dust, and long enough to serve for both wires, may be selected.

In such times as the spiders remain in their winter quarters, we have been able to procure very good fibres from a box in which a number had been confined.

When the wires are cemented, the ring is returned to its position in the tube, and either pair of screws being inserted, the splinter or wire is removed and the ring turned until the other screws can be replaced.

Care must also be taken that the same side of the ring is turned to the eye-piece as before it was removed.

When this has been done, the eye-tube is inserted and its centering ring brought into such a position that the screws in it can be replaced, and then by screwing on the end of the telescope, the little cover into which the eye tube is screwed, the operation will be completed.

To Clean the Telescope.—The only glasses that will ordinarily require cleaning are the object-glass on its outside surface, and the little eye lens, which is exposed when the cap of the eye tube is removed.

To remove the dust from these use a very soft and clean silk or cotton cloth, and be careful not to rub the same part of the cloth a second time on the surface of the glass.

No one should ever be allowed to touch the glasses with the fingers or with a dusty cloth.

Excellencies of the Vernier Transit.

These are due chiefly to the telescope and its attachments, and from what has been already said, it will appear are such as to render this instrument greatly superior to one provided with the ordinary sights.

1. The magnifying power of the telescope enables the surveyor to take accurate observations at distances entirely beyond the reach of the naked eye.

2. The fine intersection of the cross-wires can be set precisely upon the centre of the object.

3. The revolving property of the telescope gives the means of running long lines up or down steep ascents or descents with perfect ease, where, with the short sights of the ordinary compass, two or three observations would have to be taken.

4. The use of a telescope entirely avoids the incessant trying of the eyes, experienced in surveys with the ordinary sights.

5. With the telescope, lines can be run through the forest or brushwood, and the flagstaff distinguished with much greater certainty than through the sights of a compass.

This statement may appear very unreasonable to those not familiar with the instrument, and these in fact, raise the greatest objection to a telescope, from its supposed unfitness for surveys in such locations.

They have only to use it a few times in this kind of work, in connection with a flagstaff painted white or covered with paper, to distinguish it from the surrounding objects, to be convinced of its great superiority.

In the Vernier Transit, as furnished by us, is supplied, as we believe to the surveyor, the most perfect of all needle instruments, and this at a cost but little above that charged by other makers for a sight compass.

The advantages of the telescope and its attachments are so great, that a surveyor, accustomed to them, would find it difficult to content himself with the ordinary compass, and such in fact is the universal testimony of those familiar with the Vernier Transit.

Weight of the Vernier Transit.

The weight of this instrument, exclusive of the tripod legs, and plain telescope, is about 10 lbs.

NEEDLE INSTRUMENTS.

We have now described the instruments included under the division termed Needle Instruments, in the beginning of this work.

As there stated, the Plain and Vernier Compasses and the Vernier Transit depend for their accuracy and value, mainly upon the perfection of movement of the magnetic needle.

With such instruments, the greater part of the surveying in our country has been, and will for a long time in the future, continue to be done.

And though with the improvements made in these instruments, a good surveyor may, with great care and skill, do work with a surprising degree of accuracy and perfection, yet all needles are liable to many irregularities.

Imperfections of the Needle.

These may arise either from the loss of magnetic virtue in the poles, the blunting of the centre-pin, or the attraction exerted upon it by bodies of iron whose presence may be entirely unsuspected.

The two first of these errors may be easily remedied in the manner we have described.

Local Attraction.—The third and most frequent source of inaccuracy, may be detected by taking back sights as well as fore sights upon every line run with the needle, and by the agreement of the bearings the true direction of the line will be determined.

Sometimes a compass may have little particles of iron concealed within the surface of the metal circle or plates.

It is the business of the maker to examine every instrument, in search of this defect, by trying the reversion of the needle upon all points of the divided circle.

If the needle should fail to reverse when the compass is turned half around and the sights directed a second time upon any object, the instrument should be thrown aside and never sold.

Besides the difficulties caused by the above imperfections, the variation of the needle is a frequent source of annoyance.

What is termed the secular variation, we have already mentioned in our account of the Vernier Compass, we will now speak of the

Diurnal Variation.—This is owing to the influence of the sun, which in summer will cause the needle to vary from ten to fifteen minutes in a few hours, when exposed to its fullest influence.

To guard against these causes of inaccuracy in the use of needle instruments, the surveyor will need the greatest care and attention; and yet, with all the precautions that can be suggested, the difficulty of measuring horizontal angles with certainty, and to a sufficient degree of minuteness by the needle alone, has caused a demand to be felt more and more sensibly in all parts of the country for instruments, in the use of which, the surveyor may proceed with assured accuracy and precision.

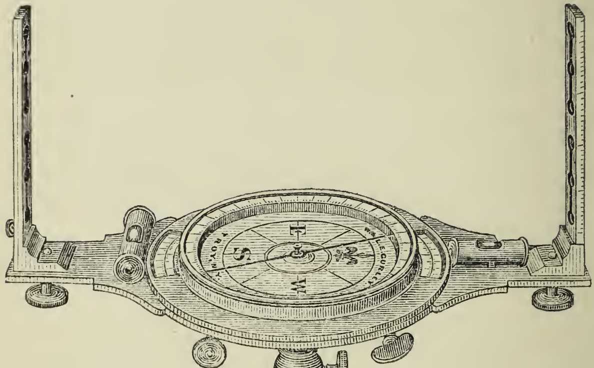
Indeed, in Canada, so great is the distrust of needle instruments, that the Provincial Land Surveyors are forbidden to use an instrument in their land surveys, unless it is capable of taking angles independently of the needle.

To supply the demand thus created for increased perfection in the implements of the surveyor, we manufacture a variety of instruments: two of which we shall now describe, under the names of *The Railroad Compass*, and *The Surveyors' Transit.*

SURVEYING INSTRUMENTS.

THE RAIL ROAD COMPASS.

Fig. 10.



As shown in Fig. 10, this instrument has the main plate, levels, sights, and needle of the ordinary instrument, but is also provided with a circle on the outside of the compass box, divided all around and reading by two opposite verniers to single minutes of a degree.

The openings through which the divided circle and verniers are seen, are closed by plates of glass, so as to effectually exclude the dust and moisture; the openings are now made on the sides, at right angles to the position they occupy in the cut, in order to read the divisions with greater convenience.

The verniers are fixed to the main plate, and this, by a contrivance of our own invention, has long sockets which give it great stability, and a motion around the circle almost perfectly free from friction.

In this arrangement, the compass circle is very firmly attached to the socket, of which the lower part only is seen in the cut.

The vernier or main plate moves around the divided circle or limb, the divisions on both vernier and limb being horizontal and in the same plane.

There is also, beneath the main plate, a clamp and tangent movement, by which, after the main plate has been moved nearly in position by the hand, it can be clamped to the socket, then with the tangent screw, the verniers are moved slowly around the limb, and the sights fixed upon the desired object with the greatest precision.

The graduated circle or limb is divided to half degrees, and figured in two rows, viz: from 0° to 90°, and from 0° to 360°; sometimes but a single series is used, and then the figures run from 0° to 360°, or from 0° to 180° on each side.

The figuring, which is the same upon this as in the other angular instruments we shall hereafter describe, is varied according to the taste of the engineer, the first method is our usual practice.

The Verniers are double, having on each side of the zero mark thirty equal divisions, corresponding precisely with twenty-nine half degrees on the limb.

They thus read to single minutes, and the number passed over is counted from the zero mark in the same direction in which the vernier is moved.

The use of two opposite verniers in this and other instruments gives the means of "cross questioning" the graduations, the perfection with which they are centred, and the dependence which can be placed on the accuracy of the angles indicated.

The movement of the vernier plate with the sights attached around the compass circle, gives the surveyor the power of laying off the variation of the needle, while the graduated circle enables him to take horizontal angles with great accuracy and minuteness, entirely independent of the needle.

The Needle of this instrument is about five and a half inches long, and made precisely like those previously described.

The Adjustments of this instrument, with which the surveyor will have to do, have been already described.

To Use the Rail Road Compass.

It can be set upon the common compass ball, or still better, the tangent ball already described, placed either in a jacob-staff socket, or, as most surveyors prefer, in a compass tripod.

We have also adapted to many of these instruments, the leveling tripod head, with clamp and tangent movement described on page 50, and this is preferable to any other support.

To Take Horizontal Angles.—First level the plate and set the limb at zero, fix the sights upon one of the objects selected, and clamping the whole instrument firmly to the spindle, unclamp the vernier plate and turn it with the hand, until the sights are brought nearly upon the second object; then clamp to the limb, and with the tangent screw fix them precisely upon it.

The number of degrees and minutes read off by the vernier, will give the angle between the two objects taken from the centre of the instrument.

It will be understood that the horizontal angles can be taken in any position of the verniers, with reference to the zero point of the limb; we have given that above as being the usual method and liable to the fewest errors.

It is advisable where great accuracy is required, in this and other instruments furnished with two verniers, to obtain the readings of the limb from both, add the two together and halve their sum; the result will be the mean of the two readings, and the true angle between the points observed.

Such a course is especially necessary when the readings of the verniers essentially disagree, as may sometimes happen when the instrument has been injured by an accident.

To Turn off the Variation of the Needle.—Having leveled the instrument, set the limb at zero, and place the sights upon the old line, note the reading of the needle, and make it agree with that given in the field notes of the former survey, by turning the whole instrument upon its spindle.

Now clamp to the spindle, unclamp the vernier plate and again fix the sights upon the old line; the number of degrees or minutes passed over by the vernier, will be the change of variation in the interval between the two surveys.

To Survey with this instrument, the operator should fix the south side of the compass face towards that end of the main plate which has the spirit level placed cross wise, and having brought the zeros of the limb and vernier plate, in contact, clamp them, and proceed as directed in our account of the Plain Compass.

Of course, it will be understood that lines can be run and angles measured, by the divided limb and verniers, entirely independent of the needle, which, in localities where local attraction is manifested, is very serviceable.

The accuracy and minuteness of the horizontal angles, indicated by this instrument, together with its perfect adaption to all the purposes to which the Vernier Compass can be applied, have brought it into use in many localities, where the land is so valuable as to require more careful surveys than are practicable with a needle instrument.

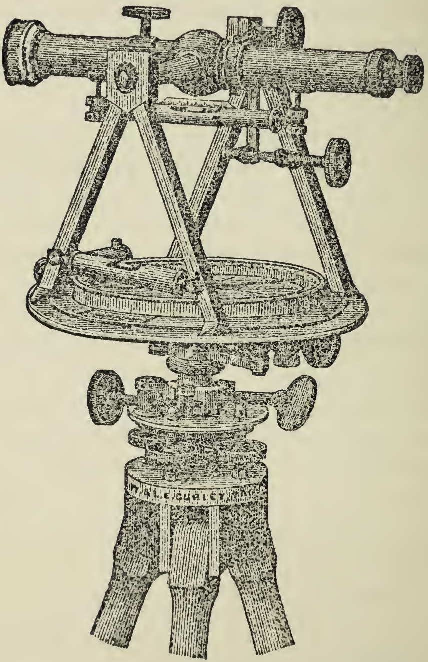
Weight of the Rail Road Compass.

The average weight of this instrument, including the brass head of the Jacob staff, is about 11½ lbs.

SURVEYING INSTRUMENTS.

THE SURVEYORS' TRANSIT.

Fig. 11.



The Surveyors' Transit, of which the above cut is a representation, is in principle, very similar to the instrument just described, differing from it mainly in the substitution of the telescope with its appendages, for the ordinary compass sights.

The Telescope is of somewhat finer quality than that used with the Vernier Transit; as here shown, it is furnished with a small level, having a ground bubble tube and a scale; sometimes also a vertical circle is connected with its axis.

The Standards are made precisely like those of the Vernier Transit, the bearings of the axis of the telescope being conical, and fitted with the utmost nicety; there is also in one of them the moveable piece for the adjustment of the wires to the tracing of a vertical line.

The Spirit Levels are placed above the upper surface of the vernier plate, one being fixed on the standard so as not to obstruct the light which falls on the vernier opening beneath.

Both levels are adjustable with the ordinary steel pin.

The Needle, like that of the previous instrument, is five and a half inches long.

The Vernier Plate, which carries the verniers and telescope, is made to move with perfect ease and stability around the graduated circle or limb, attached to the compass box, thus allowing the telescope and verniers to be set to any variation of the needle, and turn off horizontal angles in any direction.

The Verniers, as in all our angular instruments, are double, reading either way from the centre mark, and to single minutes of a degree.

There are two verniers placed on opposite sides of the instrument at right angles to the telescope; only one of these is shown in the cut.

The Divided Circle, or limb, is graduated to half degrees, reads to minutes by the verniers, and is figured as described in our account of the previous instrument.

The Clamp and Tangent movement of the vernier plate is the same as that of the Rail Road Compass; it is partly shown in the figure.

The Tripod Head.—This instrument should always be used on a leveling tripod.

The one shown in the cut, and which is termed the *Light Leveling Tripod*, has the upper parallel plate thickened on its under side, so as to give a long bearing for the four leveling screws.

The under plate supports the feet of the screws, and has beneath a cavity or bowl, in which moves a hemispherical nut screwed to the spindle of the tripod.

This nut serves both to connect the plates together, and as a support on which the upper plate is moved by the leveling screws.

The under parallel plate has also a screw on the under side, by which the tripod head may be disconnected from the legs, and packed in a box with the instrument.

The leveling screws are made of bell metal, have a large double milled head and a deep screw of about forty threads to the inch; their ends set into little brass cups, so that the screws are worked without indenting the under plate. Sometimes a piece of leather is put in place of the cups.

When the screws are loosened, the upper plate can be shifted around, so as to bring the leveling screws in any position with reference to the plates and telescope of the instrument.

The clamp and tangent screws are seen on the upper plate of the tripod. In place of the single tangent screw, we have, in all our later instruments, substituted the double tangent movement, shown in the engraving of the Engineers' Transit on the frontispiece.

The spindle of this tripod head rises above the upper plate, and the instrument can be removed from it by pulling out a little pin made to spring into a groove, and thus keep the instrument from falling when the tripod is carried upon the shoulder.

In the lower end of the spindle, and underneath the plates, is screwed the loop for attaching the string of the plumb-bob.

In the operation of leveling the tripod, the engineer takes hold of the opposite screw heads with the thumb and fore finger of each hand, and turning both thumbs in or out, as may be necessary, raises one side of the upper parallel plate and depresses the other until the desired correction is made.

To Adjust the Surveyors' Transit.

The Levels are adjusted with a steel pin as those of the Vernier Transit, and it need only be added here, that in this as well as other instruments having two plates moving upon sockets independent of each other, the levels, when adjusted on one plate, should still keep their position when both are clamped together and turned upon a common socket.

Otherwise, however accurately the telescope might trace a vertical line, when revolved upon the socket of one plate, it would give a very different result as soon as the position of the other plate was changed.

The Needle and telescope with its other attachments being adjusted, as described in our account of the Vernier Transit, we shall here consider only that of the

Level on Telescope.—For the adjustment of this attachment we shall give two methods, the first being that usually practiced by us:

1. First level the instrument carefully, and with the clamp and tangent movement to the axis, make the telescope horizontal as near as may be with the eye, then having the line of collimation previously adjusted, find or place some good object at a convenient distance, say from one to three hundred feet, which the horizontal wire will bisect; then, without moving the telescope, turn the instrument upon the spindle, and with the same wire find or place another object in the opposite direction, and at the same distance from the instrument as the first point selected.

These two points will be in the same horizontal line, however much the telescope may be out of level.

Having determined these, and still retaining them, remove the instrument one or two hundred feet to one side of either of these points, and in line with them, level it again and bring the wires upon the nearest object. Then turn the instrument in the direction of the other, and note the position of the horizontal wire.

If it does not bisect the point, the telescope is not horizontal, and the wire must be carried back over half the error, by moving the telescope with the tangent screw. When this has been done, the engineer needs only to alter the position of the level, by the little nuts at the ends, until the bubble is brought into the centre of the tube, when, if the telescope has not been moved from the point where it was fixed, the adjustment will be completed.

2. Choose a piece of ground nearly level, and having set the instrument firmly, level the plates carefully, and bring the bubble of the telescope into the centre with the tangent screw. Measure in any direction from the instrument, from one to three hundred feet, and drive a stake, and on the stake set a staff and note the height cut by the horizontal wire, then take the same distance from the instrument in an opposite direction, and drive another stake.

On that stake set the staff and note the height cut by the wire when the telescope is turned in that direction.

The difference of the two observations is evidently the difference of level of the two stakes.

Set the instrument over the lowest stake, or that upon which the greatest height was indicated, and bring the levels on the plates and telescope into adjustment as at first.

Then, with the staff measure the perpendicular distance from the top of the stake to the centre of the eye-piece; from that distance subtract the difference of level between the two stakes, and mark the point on the staff thus found; place the staff on the other stake, and with the tangent screw bring the horizontal wire to the mark just found, and the line will be level.

The telescope now being level, bring the bubble of the level into the centre, by turning the little nuts at the ends of the tube, and noting again if the wires cut the point on the staff; screw up the nuts firmly and the adjustment will be completed.

With such a level carefully adjusted, the engineer by taking equal fore and back sights, can run horizontal lines with great rapidity, and a good degree of accuracy.

To Use the Surveyors' Transit.

In surveying with this instrument, the plates must be set so that the zeros of the circle and the verniers correspond, and firmly clamped together, the south end of the compass face being turned towards the eye end of the telescope when it is in the position shown in Fig. 11.

The surveyor may then proceed precisely as with the plain compass.

To Turn off Angles.—When angles are to be measured independently of the needle, proceed precisely as directed in the description of the Rail Road Compass.

The Variation of the Needle is also set off as mentioned in our account of that instrument.

Sizes of the Surveyors' Transit.

We make three sizes of the Surveyors' Transit, viz:

The 4 inch needle, with divided horizontal limb of 6 inches,

The 5 inch needle, with limb of 6½ inches, and

The 5½ inch needle, with limb of 7 inches diameter.

They are all used with the light adjusting tripod head already mentioned.

The average weights of the three sizes, exclusive of the tripod legs, and with plain telescopes, are respectively as follows:

4 inch Needle,	12 lbs.
5 inch Needle,	13 lbs.
5½ inch Needle,	14 lbs.

Merits of the Surveyors' Transit.

In this instrument, as just described, the surveyor will recognize advantages not possessed by any other instrument with which we are acquainted.

Combining the capabilities of a needle instrument, with a fine telescope, and the accuracy of a divided limb and verniers, and having also the means for turning off the variation of the needle, it is for a mixed practice of accurate surveying and engineering, such indeed as is required of most city engineers, the best instrument ever constructed.

The arrangement of the sockets which we have alluded to in our account of the Rail Road Compass, is very perfect and stable, and the movement of the plates almost entirely free from friction.

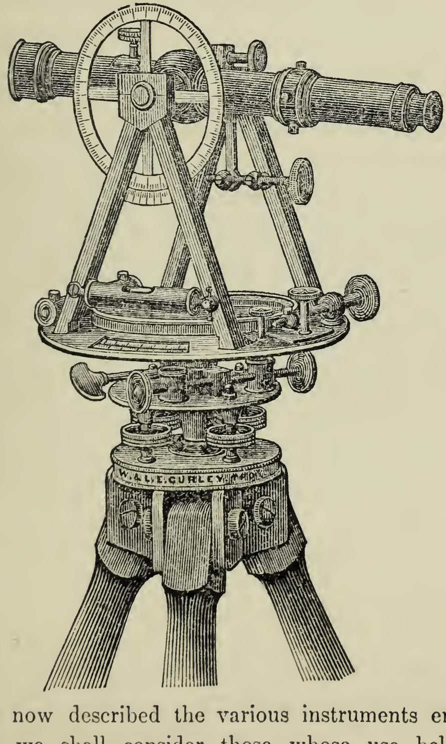
We made the first of our Surveyors' Transits about three years ago, and, from that time to this, have found their sale continually increasing, and those that have been in use satisfying invariably the best expectations of the purchaser.

The peculiar construction of the sockets and plates of this instrument are entirely our own invention, and we feel the utmost confidence in recommending it to all whose practice is such as to require the use of the needle combined with that of the divided circle and verniers.

ENGINEERS' INSTRUMENTS.

THE ENGINEERS' TRANSIT.

Fig. 12.



Having now described the various instruments employed in surveying, we shall consider those whose use belongs more especially to the practice of the civil engineer, and of these the first in importance is that termed the Engineers' Transit.

It differs from the instrument just described in having the compass circle, verniers and standards, attached to the same plate, and moving together above the divided circle or limb.

The engraving on the frontispiece will convey a good idea of our latest improved Engineers' Transit, and to this the reader will please refer in the following detailed description of its different parts.

The Telescope is from twelve to thirteen inches long, and is of the finest quality.

Like all those of our own instruments, it is capable of reversion only at the object end, though we have often, when desired, made the other or even both ends to reverse.

The rack and pinion movement of the object-glass is usually placed, as shown, on the top of the telescope tube, though sometimes on the side, as the engineer may prefer.

Pinion to Eye-Glass.—We have often adapted to the eye-piece of this and our other Transits, a rack and pinion movement which is placed on the side of the tube, and is very excellent in bringing the cross-wires precisely into focus.

The Shade.—A short piece of thin tube called a shade, is always made to accompany this and the previous instrument, and is used to protect the object-glass from the glare of the sun, or from moisture; it must be removed whenever the telescope is reversed, unless the telescope is made to reverse at the eye-end, as is sometimes desired.

The interior construction of the telescope is similar to those already described.

The Standards are made of well hammered brass, firm and strong.

On one of them will be seen the little moveable box with the capstan head screw underneath, by which the cross-wires are adjusted to trace a vertical line, as described on pages 35 and 36, in our account of the Vernier Transit.

The Limb or divided circle is seven inches in diameter, is graduated to half degrees, and read by two opposite verniers to single minutes.

THE VERNIERS are double, reading both ways from the centre, and are placed on the sides of the plate at right angles to the telescope.

THE NEEDLE is five inches long, and is raised by a milled screw head shown in the cut, placed above the plate.

THE CLAMP AND TANGENT SCREWS are also above, so as to be very accessible, and out of the reach of ordinary accidents. The clamping of the limb is effected in the interior, the aperture being covered with a washer to exclude the dust and moisture.

THE LEVELS, as shown in the cut, are above; they are both adjustable with the ordinary steel pin.

The glass vials used in the levels of this and the Surveyors' Transit, are ground on their upper interior surface, so that the bubble moves very evenly and with great sensitiveness.

THE TRIPOD HEAD of this instrument is made considerably heavier than that of the Surveyors' Transit.

The upper plate is about five inches diameter, made thick and of well hammered brass; into this are screwed the long nuts or sockets for the leveling screws, and on the upper surface is seen the clamp, with the two butting tangent screws.

With these, the movement is made very slowly, and much more firmly than is possible with a single tangent screw.

The leveling screws are of bell metal, and have a broad three milled head; they rest on the lower plate, in the little cups spoken of in our account of the previous instrument.

In the engraving on the frontispiece it will be seen that the screws are entirely covered above the plate, by little brass covers which protect the threads from dust and corrosion.

The lower plate is a little smaller than the upper, milled on the edge, and made to connect by a screw, with the tripod legs.

This tripod head is attached to the sockets of the limb and vernier plate, and is removed with them, when the instrument is packed in the box for transportation.

The loop for the plumb-bob is connected by a screw to the spindle of the vernier plate, so that it is always suspended from the exact centre of the instrument.

The Attachments of the Transit.

The wood cut, fig. 12, shows the vertical circle of four and a half inches diameter, which is read by a double vernier to minutes, and also the clamp and tangent movement to the axis of the telescope.

These, with the addition of a level on the telescope, are often used with this instrument, though the majority of engineers prefer an instrument with "plain telescope," like that shown on frontispiece.

Micrometer.

It is sometimes very convenient in the use of both the Transit and Leveling Instrument, to employ some simple method of ascertaining the distances of objects without resorting to actual measurements.

This is well effected by what is termed "Micrometer," by the French called "Stadia," placed in the plane of the cross-wires in the interior of the telescope.

In those we have sometimes made, two horizontal wires are fastened to the diaphragm, at such a distance apart that they will just include a tenth of a foot on a rod placed one hundred feet distant.

When nicely adjusted to this interval they will cover two-tenths at two hundred feet; three, at three hundred, and in the same proportion for any intermediate or greater distance.

In this manner the engineer can estimate the distances of his assistants with surprising accuracy, and by a simple observation.

To adjust the Transit.

The adjustment of this instrument and its attachments have been described in our account of those previously considered.

To use the Engineers' Transit.

But little need be added to what has been already given in the previous pages.

THE NEEDLE is of service principally as a rough check upon the readings of the verniers in the measurment of horizontal angles, any glaring mistake being detected, by noticing the angles indicated by both, in the different positions of the telescope.

It may also be used as in the compass, to give the direction in which the lines are run, but its employment is only subsidiary to the general purposes of the Transit.

Sizes of the Transit.

We make two different sizes of this instrument, viz:

THE FIVE INCH TRANSIT just described, which, exclusive of the tripod legs, weighs about 13½ lbs., and the

FOUR INCH TRANSIT, precisely similar in style, but about one-fourth smaller and lighter in all its parts.

It has a telescope of about ten inches long, a four inch needle, and a divided limb of six inches diameter.

Weight of the Attachments.

As it may sometimes be desirable to know the weights of the different extras or attachments, often used in this and the other Transits previously described, we here add them in detail.

Ground level tube, with vial complete,....	7½ oz.
Vertical circle, with vernier,............	6 oz.
Clamp and Tangent to axis,.............	4 oz.

Besides the simple form of the Engineers' Transit, we also make important modifications, which may be desired by the engineer; a few of these we shall now enumerate.

The Watch Telescope.

A telescope is sometimes attached to a socket, moving in a hollow cylinder which surrounds the lengthened socket of the limb, and is thus capable of moving around under the plates, and of a short vertical motion.

The cylinder which supports it, may be clamped firmly to the limb, and the wires of the telescope thus fixed upon any object, by the tangent movement of the tripod head.

The object of the watch telescope, is to guard against, and detect any inaccuracy arising from the disturbance of the limb, during the progress of an observation, or the measurement of angles.

Thus, if the wires of both telescopes are fixed upon the same object, and the watch telescope kept still upon it, while the vernier plate is unclamped, and the upper telescope shifted to the second point, a reference to the watch telescope will immediately betray any disturbance in the position of the limb.

But, in spite of its excellencies in cases where great nicety is required, the additional weight and complication of the watch telescope, have caused it to be regarded by most American engineers as an encumbrance, rather than an advantage to the Transit.

The Theodolite Axis.

In place of the ordinary axis of the telescope represented in our engraving, we sometimes make one resembling the Y axis of the English Theodolite.

This modification is desirable, in cases where this instrument is intended to subserve the purposes of both level and transit.

In such an arrangement, the telescope is confined in the axis with clips, by loosening which, it may be revolved in the wyes, or taken out and reversed end for end, precisely like that of the leveling instrument.

The standards also allow its transit, or complete revolution in a vertical direction.

In such an instrument, the adjustment of the wires, and level of the telescope, is effected in the same manner as those of the leveling instrument, the tangent movement of the axis serving, instead of the leveling screws, to bring the bubble and wires into position.

With this modification of the transit, we have also frequently added, that of a small level bar, wyes, &c., into which the telescope may be transferred, making thus a miniature leveling instrument.

This may be placed upon the socket and tripod head of the transit, and made capable of taking levels with a good degree of accuracy.

When desirable, a vertical wheel may be placed on the axis of the telescope of this instrument, and thus all the properties of the English Theodolite, united with those of the American Transit.

Two Telescope Instruments.

We have occasionally manufactured instruments provided with two telescopes, having their centres in the same vertical line, and one above the other.

The upper telescope has a range of about 35° each way, in a vertical direction, and like that of the Engineers' Transit, is carried on a vernier plate, furnished with levels, needle and tangent movement, and reading to minutes on the horizontal limb; the lower one is placed in the centre of the expanded vertical axis of the limb, by which it is moved horizontally; and it has also a range of about 20° each way in a vertical direction.

When the line of collimation of both telescopes is fixed upon the same object, the zeros of the vernier and limb are in coincidence, and when the vernier plate is turned 180 degrees the wires of the telescopes will cut the extremities of a straight line, in one point of which, the centre of the instrument is placed.

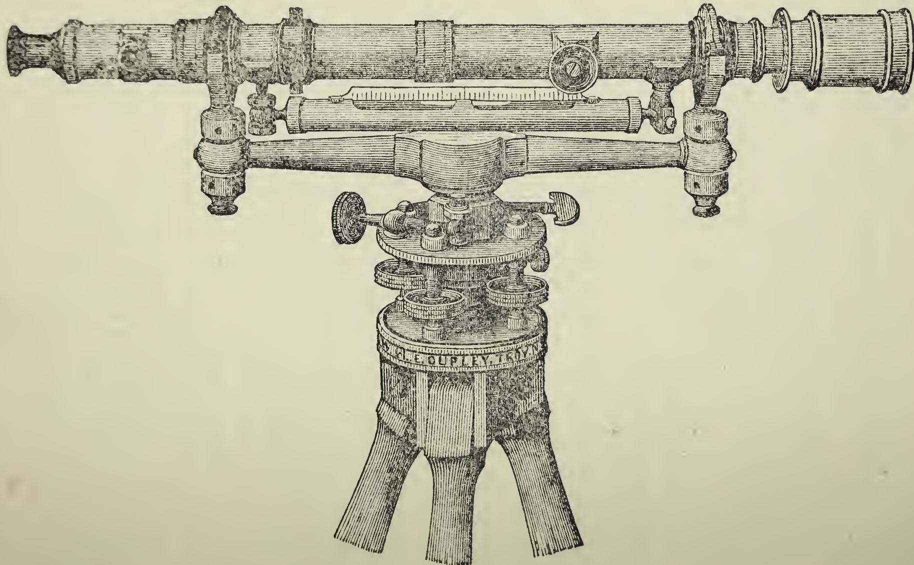
In the same manner, it is manifest that any angle may be laid off on the limb, and the points be indicated by the wires of both telescopes, without changing the position of the limb.

The lower telescope may also be used as a guard or watch, to detect any disturbance in the instrument during the time of an observation.

THE Y LEVEL.

TWENTY INCH TELESCOPE.

Fig. 13.



THE LEVELING INSTRUMENT.

Of the different varieties of the Leveling Instrument, that termed the Y Level, has been almost universally preferred by American engineers, on account of the facility of its adjustment, and superior accuracy.

Of these Levels we manufacture four different sizes, having telescopes of sixteen, eighteen, twenty, and twenty-two inches long, respectively.

The cut on the opposite page represents our twenty inch Level; that of the sixteen inch telescope will be shown beyond.

We shall consider the several parts of the instrument in detail:

The Telescope has at each end a ring of bell-metal, turned very truly and both of exactly the same diameter; by these it revolves in the wyes, or can be at pleasure clamped in any position when the clips of the wyes are brought down upon the rings, by pushing in the tapering pins.

The telescope has a rack and pinion movement to both object and eye-glasses, an adjustment for centering the eye-piece, shown at A A, in the longitudinal section of the telescope, (page 64,) and another seen at C C, for ensuring the accurate projection of the object-glass, in a straight line.

Both of these are completely concealed from observation and disturbance, by a thin ring which slides over them.

The telescope has also a shade over the object-glass, so made, that whilst it may be readily moved on its slide over the glass, it cannot be dropped off and lost.

The shade of our sixteen inch level, is made to take off, like that of the Engineers' Transit.

The interior construction of the telescope will be readily understood from fig. 14, which represents a longitudinal section, and exhibits the adjustment which ensures the accurate projection of the object-glass slide.

As this is peculiar to our instruments, and is always made by the maker so permanently as to need no further attention at the hands of the engineer, we shall here describe the means by which it is effected, somewhat in detail.

The necessity for such an adjustment will appear, when we state, that it is almost impossible to make a telescope tube so that it shall be perfectly straight on its interior surface.

Such being the case, it is evident that the object-glass slide which is fitted to this surface, and moves in it, must partake of its irregularity, so that the glass and the line of collimation depending upon it, though adjusted in one position of the slide, will be thrown out when the slide is moved to a different point.

To prove this, let any level be selected which is constructed in the usual manner, and the line of collimation adjusted upon an object taken as near as the range of the slide will allow; then let another be selected, as distant as may be clearly seen; upon this revolve the wires, and they will almost invariably be found out of adjustment, sometimes to an amount fatal to any confidence in the accuracy of the instrument. The arrangement adopted by us to correct this imperfection, and which so perfectly accomplishes its purposes, is shown in the adjoining cut, fig. 14.

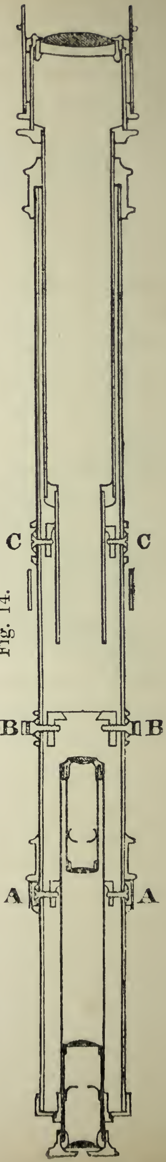


Fig. 14.

Here are seen the two bearings of the object-glass slide, one being in the narrow bell metal ring which slightly contracts the diameter of the main tube, the other in the small adjustable ring, also of bell metal, shown at C C, and suspended by four screws in the middle of the telescope.

Advantage is here taken of the fact, that the rays of light are converged by the object-glass, so that none are obstructed by the contraction of the slide, except those which diverge, and which ought always to be intercepted, and absorbed in the blackened surface of the interior of the slide.

Now, in such a telescope, the perfection of movement of the slide, depends entirely upon its exterior surface, at the points of the two bearings.

These surfaces are easily and accurately turned concentric, and parallel with each other and being fitted to the rings, it only remains necessary to adjust the position of the smaller ring, so that its centre will coincide with that of the optical axis of the object glass.

When this has been once well done, no further correction will be necessary, unless the telescope should be seriously injured.

The manner in which the adjustment of the object-glass slide is effected will be considered when we come to speak of the other adjustments.

Rack and Pinion.—As seen in fig. 13, our Level telescopes are usually furnished with the ordinary rack and pinion movement to both object and eye tubes.

The advantages of an eye-piece pinion, are, that the eye-piece can be shifted without danger of disturbing the telescope, and that the wires are more certainly brought into distinct view, so as to avoid effectually any error of observation, arising from what is termed the instrumental parallax.

The position of the pinion on the tube is varied in different instruments according to the choice of the engineer.

We usually place our object slide pinion on the top of Transit telescopes, and on the side of those of the Level. The pinion of the eye tube, is always placed on the side of the telescope.

The Level or ground bubble tube is attached to the under side of the telescope, and furnished at the different ends with the usual movements, in both horizontal and vertical directions.

The aperture of the tube, through which the glass vial appears, is about five and one-fourth inches long, being crossed at the centre by a small rib or bridge, which greatly strengthens the tube.

The level scale which extends over the whole length, is graduated into spaces a little coarser than tenths of an inch, and figured at every fifth division, counting from zero at the centre of the bridge; the scale is set close to the glass.

The bubble vial is made of thick glass tube, selected so as to have an even bore from end to end, and finely ground on its upper interior surface, that the run of the air bubble may be uniform throughout its whole range.

The sensitiveness of a ground level, is determined best by an instrument called a level tester, having at one end two Y's to hold the tube, and at the other a micrometer wheel divided into hundredths, and attached to the top of a fine threaded screw which raises the end of the tester very gradually.

The number of divisions passed over on the perimeter of the wheel, in carrying the bubble over a tenth of the scale, is the index of the delicacy of the level. In the tester which we use, a movement of the wheel ten divisions, to one of the scale, indicates the degree of delicacy generally preferred for rail road engineering.

For canal work practice, a more sensitive bubble is often desired, as for instance, one of seven or eight divisions of the wheel, to one of the scale.

The Wyes of our levels are made large and strong, of the best bell metal, and each have two nuts, both being adjustable with the ordinary steel pin.

The clips are brought down on the rings of the telescope tube by the Y pins, which are made tapering, so as to clamp the rings very firmly.

The Level Bar is made round, of well hammered brass, and shaped, so as to possess the greatest strength in the parts most subject to sudden strains.

Connected with the level bar is the head of the tripod socket.

The Tripod Socket is compound ; the interior spindle, upon which the whole instrument is supported, is made of steel, and nicely ground, so as to turn evenly and firmly, in a hollow cylinder of bell metal ; this again, has its exterior surface, fitted and ground to the main socket of the tripod head.

The bronze cylinder is held upon the spindle by a washer and screw, the head of this having a hole in its centre, through which the string of the plumb bob is passed.

The upper part of the instrument, with the socket, may thus be detached from the tripod head ; and this, also, as in the case of all our instruments, can be unscrewed from the legs, so that both may be conveniently packed in the box.

A little under the upper parallel plate of the tripod head, and in the main socket, is a screw which can be moved into a corresponding crease, turned on the outside of the hollow cylinder, and thus made to hold the instrument in the tripod, when it is carried upon the shoulders.

It will be seen from the cut, that the arrangement just described allows long sockets, and yet brings the whole instrument down as closely as possible to the tripod head, both objects of great importance in the construction of any instrument.

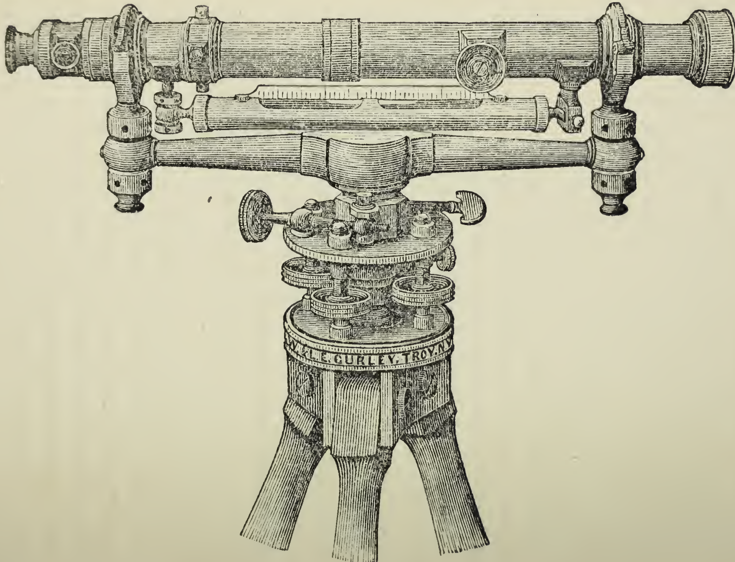
The Tripod Head has the same plates and leveling screws, as that described in the account of the Engineers' Transit ; the tangent screw, however, is commonly single.

For our sixteen inch level we make a smaller tripod head, resembling that used with the lighter engineer's transit.

THE Y LEVEL.

SIXTEEN INCH TELESCOPE.

Fig. 15



The Adjustments.

Having now completed the description of the different parts of the Leveling Instrument, we are ready to proceed with their adjustment, and shall begin with that of the object-slide, which, although always made by the maker, so permanently as to need no further attention at the hands of the engineer, unless in cases of derangement by accident, is yet peculiar to our instruments and therefore not familiar to many engineers.

To Adjust the Object Slide.—The maker selects an object as distant as may be distinctly observed, and upon it adjusts the line of collimation, in the manner hereafter described, making the centre of the wires to revolve without passing either above or below the point or line assumed.

In this position, the slide will be drawn in nearly as far as the telescope tube will allow.

He then, with the pinion head, moves out the slide until an object, distant about ten or fifteen feet, is brought clearly in view; again revolving the telescope in the Ys, he observes whether the wires will reverse upon this second object.

Should this happen to be the case, he will assume, that as the line of collimation is in adjustment for these two distances, it will be so for all intermediate ones, since the bearings of the slide are supposed to be true, and their planes parallel with each other.

If, however, as is most probable, either or both wires fail to reverse upon the second point, he must then, by estimation, remove half the error by the screws C C, (fig. 14,) at right angles to the hair sought to be corrected, remembering at the same time, that on account of the inversion of the eye-piece, he must move the slide in the direction which apparently increases the error. When both wires have thus been treated in succession, the line of collimation is adjusted on the near object, and the telescope again brought upon the most distant point; here the tube is again revolved, the reversion of the wires upon the object once more tested, and the correction, if necessary, made in precisely the same manner.

He proceeds thus, until the wires will reverse upon both objects in succession; the line of collimation will then be in adjustment at these, and all intermediate points, and by bringing the screw heads, in the course of the operation, to a firm bearing upon the washers beneath them, the adjustable ring will be fastened so as for many years to need no further adjustment.

When this has been completed, the thin brass ferule is slipped over the outside ring, concealing the screw heads, and avoiding the danger of their disturbance by an inexperienced operator.

In effecting this adjustment it is always best to bring the wires into the centre of the field of view, by moving the little screws A A, (fig. 14,) working in the ring which embraces the eye-piece tube.

Should the engineer desire to make this adjustment, it will be necessary to remove the bubble tube, in order that the small screw immediately above its scale may be operated upon with the screw driver.

The adjustment we have now given is preparatory to those which follow, and are common to all leveling instruments of recent construction, and are all that the engineer will have to do with in using our own instruments. What is still necessary then is—

1. *To adjust the line of collimation*, or in other words, to bring both wires into the optical axis, so that their point of intersection will remain on any given point, during an entire revolution of the telescope.

2. *To bring the level bubble parallel* with the bearings of the Y rings, and with the longitudinal axis of the telescope.

3. *To adjust the wyes*, or to bring the bubble into a position at right angles to the vertical axis of the instrument.

To Adjust the Line of Collimation, set the tripod firmly, remove the Y pins from the clips, so as to allow the telescope to turn freely, clamp the instrument to the tripod head, and by the leveling and tangent screws, bring either of the wires upon a clearly marked edge of some object, distant from one to five hundred feet.

Then with the hand carefully turn the telescope half way around, so that the same wire is compared with the object assumed.

Should it be found above or below, bring it half way back by moving the capstan head screws at right angles to it, remembering always the inverting property of the eye-piece; now 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 completed.

Should both wires be much out it will be well to bring them nearly correct before either is entirely adjusted.

When this is effected, slip off the covering of the eye-piece centering screws, shown in the sectional view (fig. 14) at A A, and move each pair in succession with a small screw driver, until the wires are brought into the centre of the field of view.

The inversion of the eye-piece does not effect this operation, and the screws are moved direct.

To test the correctness of the centering, revolve the telescope, and observe whether it appears to shift the position of an object.

Should any movement be perceived, the centering is not perfectly effected.

It may here be repeated, that in all telescopes the position and adjustment of the line of collimation depends upon that of the object-glass; and therefore, that the movement of the eye-piece does not affect the adjustment of the wires in any respect.

When the centering has been once effected it remains permanent, the cover being slipped over to conceal and protect it from derangement at the hands of the curious, or inexperienced operator.

To Adjust the Level Bubble.—Clamp the instrument over either pair of leveling screws, and bring the bubble into the centre of the tube.

Now turn the telescope in the wyes, so as to bring the level tube on either side of the centre of the bar. Should the bubble run to the end it would show that the vertical plane, passing through the centre of the bubble, was not parallel to that drawn through the axis of the telescope rings.

To rectify the error, bring it by estimation half way back, with the capstan head screws, which are set in either side of the level holder, placed usually at the object end of the tube.

Again, bring the level tube over the centre of the bar, and adjust the bubble in the centre, turn the level to either side, and, if necessary, repeat the correction until the bubble will keep its position, when the tube is turned half an inch or more, to either side of the centre 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, in great measure, removed the preparatory difficulties, we proceed to make the level tube parallel with the bearings of the Y rings.

To do this, bring the bubble into the centre 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 small adjusting nuts, on one end of the level, until by estimation half the correction is made; again bring the bubble into the centre and repeat the whole operation, until the reversion can be made without causing any change in the bubble.

It would be well to test the lateral adjustment, and make such correction as may be necessary in that, before the horizontal adjustment is entirely completed.

To Adjust the Wyes.—Having effected the previous adjustments, it remains now to describe that of the wyes, or, more precisely, that which brings the level into a position at right angles, to the vertical axis, so that the bubble will remain in the centre during an entire revolution of the instrument.

To do this, bring the level tube directly over the centre of the bar, and clamp the telescope firmly in the wyes, placing it as before, over two of the leveling screws, unclamp the socket, level the bubble, and turn the instrument half way round, so that the level bar may occupy the same position with respect to the leveling screws beneath.

Should the bubble run to either end, bring it half way back by the Y nuts on either end of the bar; now move the telescope over the other set of leveling screws, bring the bubble again into the centre and proceed precisely 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.

The object of this approximate adjustment, is to bring the upper parallel plate of the tripod head into a position as nearly horizontal as possible, in order that no essential error may arise, in case the level, when reversed, is not brought precisely to its former situation. When the level has been thus completely adjusted, if the instrument is properly made, and the sockets well fitted to each other, and the tripod head, the bubble will reverse over each pair of screws and in any position.

Should the engineer be unable to make it perform correctly, he should examine the outside socket carefully to see that it sets securely in the main socket, and also notice that the clamp does not bear upon the ring which it encircles.

When these are correct, and the error still is manifested, it will, probably, be in the imperfection of the interior spindle.

After the adjustments of the level have been effected, and the bubble remains in the centre, in any position of the socket, the engineer should carefully turn the telescope in the wyes, and sighting upon the end of the level, which has the horizontal adjustment along each side of the wye, make the tube as nearly vertical as possible.

When this has been secured, he may observe, through the telescope, the vertical edge of a building, noticing if the vertical hair is parallel to it; if not, he should loosen two of the cross-wire screws at right angles to each other, and with the hand on these, turn the ring inside, until the hair is made vertical; the line of collimation must then be corrected again, and the adjustments of the level will be complete.

To use the Level.

When using the instrument the legs must be set firmly into the ground, and neither the hands nor person of the operator be allowed to touch them, the bubble should then be brought over each pair of leveling screws successively, and leveled in each position, any corrections being made in the adjustments that may appear necessary.

Care should be taken to bring the wires precisely in focus, and the object distinctly in view, so that all errors of parallax may be avoided.

This error is seen when the eye of an observer is moved to either side of the centre of the eye-piece of a telescope, in which the foci of the object and eye-glasses, are not brought precisely upon the cross-wires and object; in such a case, the wires will appear to move over the surface, and the observation will be liable to inaccuracy.

In all instances the wires and object, should be brought into view so perfectly, that the spider lines will appear to be fastened to the surface, and will remain in that position however the eye is moved.

If the socket of the instrument becomes so firmly set in the tripod head as to be difficult of removal in the ordinary way, the engineer should place the palm of his hands under the wye nuts at each end of the bar and give a sudden upward shock to the bar, taking care also to hold his hands so as to grasp it the moment it is free.

Weight of Leveling Instrument.

The average weight of the different sizes of Levels, exclusive of the tripod legs, are as follows:

16 inch	Telescope,	$11\frac{1}{2}$	lbs.
18 "	"	12	"
20 "	"	$12\frac{1}{2}$	"
22 "	"	13	"

The Farm Level.

Besides the various engineers levels, we make a smaller and cheaper instrument, styled the Farm Level, for laying out mill seats, draining lands, and such other purposes as will readily occur to the intelligent agriculturist.

This instrument has a telescope of from fourteen to sixteen inches long, with Y and bubble adjustments and leveling tripod, like one of the larger instruments.

The tripod head is made like that figured in the cut of the Surveyors' Transit, but is usually without the clamp and tangent movement.

There is, however, a clamp screw on the side of the socket by which it may be held on the spindle, while the adjustments are being perfected.

Builders' Level.

We have also made several small levels for Masons use, similar to that just described, but generally more perfect and expensive.

These instruments have been found extremely serviceable in the construction of extensive buildings, on account of the facility with which level points may be determined on every side, by the simple revolution of the telescope.

LEVELING RODS.

The two kinds most generally used by American engineers, are both sliding rods, divided into hundredths of a foot and reading by verniers to thousandths.

Boston Rod.

That known as the Boston or Yankee Rod, is formed of two pieces of light baywood or mahogany, each about six and a half feet long, connected together by a tongue, and sliding easily by each other, in both directions.

One side is furnished with a clamp screw and vernier at each end, the other carries the divisions, marked on strips of satin wood, inlaid on either side,

The target is a rectangle of wood, fastened near one end of the divided side, and having its horizontal line just three-tenths from the extremity.

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

This kind of rod is very convenient from its great lightness, but the parts are made too frail to endure the rough usage of this country, and, therefore, American engineers have generally given the preference to another, made heavier and more substantial.

The New York Rod.

This rod, which is shown in the engraving, as cut in two, so that the ends may be exhibited, is made of satin wood, in two pieces like the former, but sliding one from the other, the same end being always held on the ground, and the graduations starting from that point.

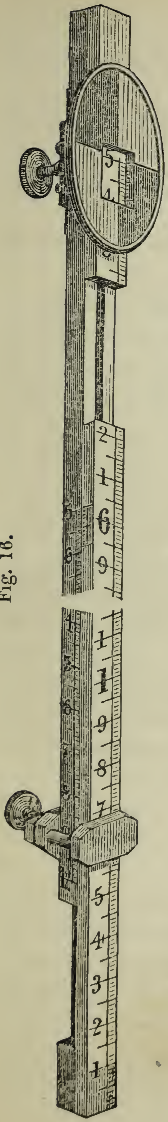


Fig. 16.

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 six and a half feet; when a greater height is required, the horizontal line of the target is fixed at that point, 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 twelve feet.

The mountings of this rod are differently made by different manufacturers. We shall give those which we have adopted.

The target is round, made of thick brass, having, to strengthen it still more, a rib raised on the edge, which also protects the paint from being defaced.

The target moves easily on the rod, being kept in any position by the friction of the two flat plates of brass which are pressed against two alternate sides, by small spiral springs, working in little thimbles attached to the band which surrounds the rod.

There is also a clamp screw on the back, by which it may be securely fastened to any part of the rod.

The face of the target is divided into quadrants, by horizontal and vertical diameters, which are also the boundaries of the alternate colors with which it is painted.

The colors usually preferred are white and red: sometimes white and black.

The opening in the face of the target is a little more than a tenth of a foot long, so that in any position a tenth, or a foot figure, can be seen on the surface of the rod.

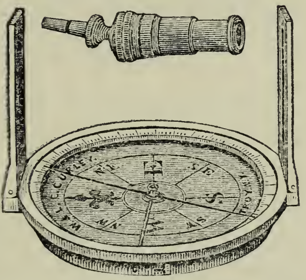
The right edge of the opening is chamfered, and divided into ten equal spaces, corresponding with nine hundredths on the rod; the divisions start from the horizontal line which separates the colors of the face.

The vernier, like that on the other side of the rod, reads to thousandths of a foot.

The clamp, which is screwed fast to the lower end of the upper sliding piece, has a movable part which can be brought by the clamp screw firmly against the front surface of the lower half of the rod, and thus the two parts immovably fastened to each other, without marring the divided face of the rod.

THE POCKET COMPASS.

Fig. 17.



This little instrument, shown with jacob staff socket in fig. 17, though not used in extensive surveys like the larger compasses we have described, is found very convenient in making explorations, or in retracing the lines of government surveys, as in locating land warrants, &c.

The sights are made with a slote and a hair, on opposite sides; they also have joints near the base, so as to fold over each other above the glass, when the compass is packed in its case.

The circle is graduated to degrees, and figured from 0 to 90 each way, as in the larger instruments.

The needle is suspended upon a jeweled centre, and is raised by the lifter shown in the cut.

The jacob staff socket is often used with the compass, being screwed to the under side, and detached at pleasure.

The mountings are all that are furnished, the staff itself being easily made out of a common walking stick.

We make two sizes of the pocket compass, differing mainly in the needle, which in one is two and a half, in the other three and a half inches long.

GENERAL MATTERS.

TRIPODS.

In the tripods of all our instruments, the upper part of the leg is flattened, and fitted closely in the surfaces of the brass cheek pieces.

The cheeks are made very broad, and give a firm hold upon the leg, which may be tightened at any time by screwing up the bolts which pass through the top of the legs; this is especially necessary after the surface of the wood has been much worn.

The legs are round, and taper in each direction from a swell, turned about one-third the way down, from the head to the point.

The point, or shoe, is a tapering brass ferule, having an iron end; it is cemented, and riveted firmly to the wood.

The legs of all our tripods are about four feet eight inches long, from head to point. We make three sizes of tripods, which we will now separately describe.

1. The Compass Tripod, seen in part in the cut of the vernier transit, and having the brass plate to which the cheeks are attached, three and three-fourth inches in diameter, and legs which are about one inch at the top, one and three-eighths at the swell, and seven-eighths at the bottom.

The legs are usually made of cherry, sometimes of mahogany, and the tripod is used with the various kinds of compasses, and with the vernier transit.

2. The Medium Sized Tripod, shown with the surveyors' transit, and having a plate of same diameter as above, but with the cheeks made considerably broader, by curving at each end; the legs being also about an eighth of an inch larger throughout.

This tripod has mahogany legs, and is used with the surveyors' transit, the light engineers' transit, and the sixteen inch level.

3. The Heavy Tripod, shown with the engineers' transit, having a brass plate of four and one-fourth inches diameter, with extended cheek pieces, and with legs one and three-eighths of an inch at the top, one and three-fourths at the swell, and one and an eighth at the point.

The heavy size has also mahogany legs, and is used with the engineers' transit, and larger leveling instruments.

Lacquering.

All instruments are covered with a thin varnish, made by dissolving gum shellac in alcohol, and applied when the work is heated.

As long as this varnish remains, the brass surface will be kept from tarnishing, and the engineer, by taking care not to rub his instrument with any dusty cloth, or to expose it to the friction of his clothes, can preserve its original freshness for a long time.

Bronze Finish.

Instead of the ordinary brass finish, some engineers prefer instruments blackened or bronzed. This is done with an acid preparation, after the work has been polished, and gives the instrument a very showy appearance, besides being thought advantageous on account of not reflecting the rays of the sun as much as the ordinary finish.

When well lacquered, the bronzing will last a considerable time, but as soon as it becomes a little worn the appearance of the instrument is much worse than one finished in the usual style.

CHAINS.

Four Pole Chains.

The ordinary surveyor's chain is sixty-six feet, or four poles long, composed of one hundred links, each connected to the other by two rings, and furnished with tally marks at the end of every ten links.

We make our chains of the best No. 8 iron wire, the rings being sawed and the ends of the link filed and bent close, so as to avoid kinking.

A link in measurement includes a ring at each end.

The handles are of brass, each forming part of the end link, and connected to it by a nut, by moving which the length of the chain is adjusted.

The tallies are also of brass, and have one, two, three, or four notches, as they are ten, twenty, thirty or forty links from either end; the fiftieth link is rounded, so as to distinguish it from the others.

Two Pole Chains.

A chain of two rods, or thirty-three feet long, is often used by surveyors, and we have occasionally made our four pole chains so that by detaching a steel snap in the middle, the parts could be separated, and the handle being transferred to the forty-ninth link in the same manner, a two pole chain is readily obtained.

Engineers' Chains

Differ from the common or Gunter's chain in that the links are each one foot long; the wire is also much stronger. They are fifty or one hundred feet long, furnished with handles and tallies, and usually with a swivel in the middle, so as to avoid twisting.

The wire of our Engineers' chain is of size No. 5 or 6, and the whole is made in the most substantial manner.

In the place of the round rings ordinarily used, we have lately substituted in these chains other rings of an oval form, and find them about one-third stronger, when made of the same kind of wire.

Steel Chains.

These are often preferred, on account of their greater lightness, and are made of any desired length; their cost is about double that of iron chains.

The wire used in our steel chains is of size No. 10, and is very stiff and strong.

Marking Pins.

With the chain there are also needed ten marking pins or chain stakes, made of stout iron wire, about twelve inches long, pointed at one end to enter the ground, and formed into a ring at the other, for convenience in handling.

The length of a chain should always be taken from its extreme ends, so that the pins are set on the outside of the handles.

It is best that the surveyor carefully lay down on the surface of the ground the length of his chain while it is yet new, and mark the points by monuments, the position of which will not be disturbed by the frost or accident.

He will thus have a standard measure, to which his chain may be adjusted in case of alterations to which all are liable.

In using the chain it should be drawn straight, and examined at intervals so as to detect and remove any kinks or other cause of inaccuracy.

TAPE MEASURES.

The best are Chesterman's steel tapes, made of a thin ribbon of steel, which is jointed at intervals, and wound up in a leathern case, having a folding handle.

These tapes are of all lengths, from thirty-three to one hundred feet, divided into inches and links, or more usually, tenths of a foot, and links, the figures and graduations being raised on the surface of the steel.

The great cost of the steel tape has always prevented its general use, and the metallic tape of the same manufacturer is the only one commonly employed in American Engineering.

These are of linen, and have also fine brass wires interwoven through their whole length.

They are thus measurably correct, even when wet.

They are mounted like the steel tapes, of like lengths, and similarly graduated.

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TABLE OF CONTENTS.

SUPPLEMENT TO MANUAL.

DRAWING INSTRUMENTS.

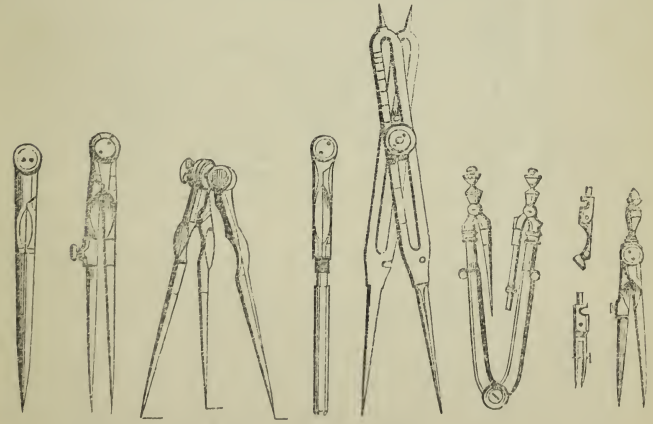
To guide the surveyor and engineer in the selection of Drawing Instruments, we here add a detailed description, with illustrations and prices of the separate pieces, and cases of the different kinds in general use.

Those we shall first mention are of German and French manufacture, are of good quality and finish, and such as the great majority of purchasers select and use.

The Swiss instruments are of better quality and finish, and are held at much higher rates.

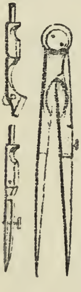
The prices given with all the instruments described are the same as those of other importers.

FRENCH AND GERMAN INSTRUMENTS.



1 2 3 4 5 6 7

FIGURE.		PRICE.
1.	Brass Dividers, brass joints, rivet-heads, 5 inch 12 cts , 6 inch	$0,18
1.	“ “ steel joints, screw-heads, 5 inch 25 cts., 6 inch	,37
1.	Fine Dividers, steel joints, turned cheeks, 4 inch 50 cts., 5 inch 62 cts., 6 inch, - - - - - - - -	,75
2.	Fine Dividers, steel joints, hair spring, 5 inch $1,00, 6 inch -	1,37
2.	“ “ “ “ superior, 5 inch $1,37, 6 inch	1,75
1.	German Silver, steel joints, turned cheeks, superior, 5 inch, -	,75
1.	“ “ “ “ “ 6 inch, -	,87
2.	“ “ “ hair spring, fine, 5 inch $1,50, 6 inch	1,75
2.	“ “ “ “ superior, 5 inch $1,75, 6 inch	2,00
3.	Three legged Dividers, brass, $2,62, Ger. Silver, $2,75 to -	3,50
	Bisecting, German Silver, $1,00 to - - - - -	2,50
4.	Pocket Dividers, German Silver, - - . - - -	2,00
5.	Proportional Compasses, brass, $1,50 to $3 ; full divided $7 to	8,50
5.	“ “ German Silver, $7.25 to - -	9,00
6.	Pillar Compasses, brass, $5,50 and $5,75, Ger. Silver, $6,75 and	8,00
7.	Dividers, brass, 3 inch, with pen and pencil point, med. quality,	1,25
7.	“ Ger. Silver, “ “ “ fine “	2,50



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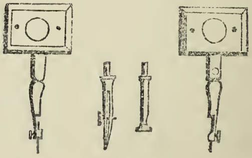

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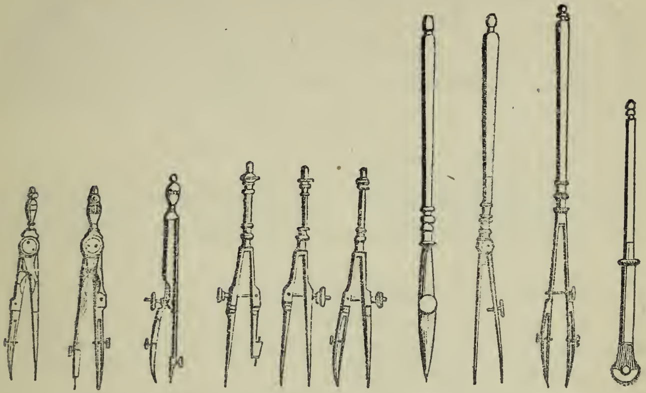
8.	Dividers, brass, 5 inch, med. quality, with pen and pencil point,	,75
	6 inch, - - - - - - - -	,87
8.	“ “ 5 inch, med. quality, with addition of lengthening bar, - - - - - - - - - -	,87
8.	Dividers, German Silver, 6 inch, fine quality, pen, pencil, bar and needle point, - - - - - - - -	3,25
9.	Furniture for Beam Compasses, brass, $3 ; with adjusting screw,	3,75
9.	“ “ “ “ German Silver, $4,25 to -	5,00

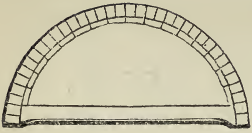
BOW PENS AND PENCILS, SPACING DIVIDERS AND DRAWING PENS.



10 11 12 13 14 15 16 17 18 19

FIGURE.		PRICE.
10.	Bow Pens, brass, 50 cts. to - - - - - - - -	$1,25
11.	" " with joint in each leg, German Silver, - -	2,25
	Bow Pencils. " " " " " - -	2,25
12.	Bow Pens, with adjusting screw, brass, $1,25 ; German Silver,	1,50
12.	" " " " " and hinges to pen, brass, -	1,50
	German Silver, - - - - - - - -	2,00
12.	Bow Pens and adj screw and pencil point, German Silver, -	2,25
12.	Bow Pens with adjusting screw, German Silver, with pencil and needle point and extra pen point, - - - -	3,50
13.	Bow Pencils, solid steel, German Silver or Ivory handles, -	1,75
14.	Spacing dividers, " " " " -	1,50
15.	Bow Pens, " " " " -	1,75
16.	Drawing Pens, 25, 37 and - - - - - - -	,50
17.	" " with hinge, - - - - - -	,50
17.	" " " " and protracting pin, 62 and -	,75
17.	" " " " extra fine, - - - - -	1,25
17.	" " all German Silver for red ink, - - -	,75
18.	" " double or Railroad Pens, $1,75 and - -	2,50
19.	Roulettes, for dotting lines, 50, 62 and - - - -	,75

SQUARES, PROTRACTORS, &C.



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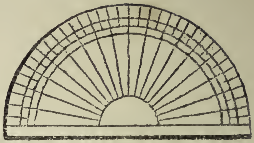

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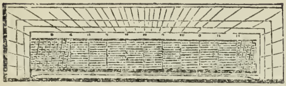


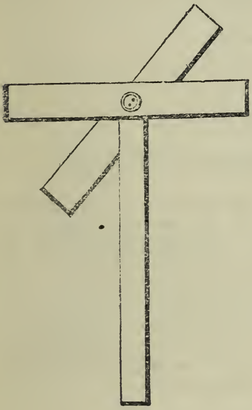
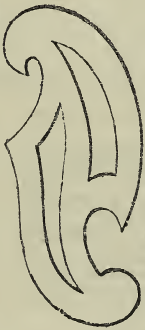
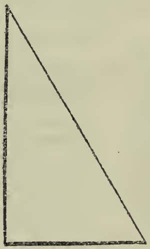
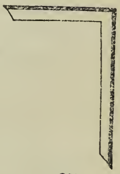
22

23

FIGURE.		PRICE.
20.	Brass Protractors, assorted sizes, 12½ cts. to - -	$1,50
20.	" " with steel blade, 2 to 3 feet long, -	7,50
20.	German Silver Protractors, with horn centre and movable arm, divided to ½ degrees, $4, to - - - - - - -	6,50
20.	German Silver Protractors, whole circle, horn centre, and movable arm, divided to ½ degrees, $4,75 to - - -	8,75
21.	Horn Protractors, 4 inch 12½ cts., 5 inch 25 cts., 6 inch -	,37
22.	Ivory Protractors for Engineers, 6 inch, $1,50, 2,00 2,50, and	3,00
22.	" " " " 2¼ inch wide, very superior, 6 inches long, $3,50 and - - - - -	5,00
22.	Ivory Protractors for Engineers, 12 inch, extra wide and full,	8,00
	Ivory Scales, 6 inch, usual quality, - - - -	,62
23.	Ivory Scales, 12 inch, chain on edge only, 20x40, 30x50, 40x60, $2,25 to - - - - - - - -	3,00
23.	Ivory Scales, 12 inch, chain on edge only, 50x100, -	3,75
	" " 12 inch, for Architects, 2,25, 2,50, 3,00 and -	3,25
	" " 12 inch, 16 scales off edge, in tenths, or twelfths, $3,50 and - - - - - -	4,00
23.	Boxwood Scales, 6 inch, usual quality, . - -	,25
22.	" Protracting Scales, 6 inch, - - -	,62
23.	" Scales, 12 inch chain, 10 to 60 on edge, -	1,00
	" " 12 inch, 16 scales off edge, in tenths and twelfths,	1,50
	" " 12 inch Architects, graduated from ⅛ to 3 inches,	1,50
	" " 3 sided chain, giving 6 scales all on edge, $.150,	3,00
	Boxwood Scales, 3 sided, Architects, giving 12 scales all on edge, $1,50 to - - - - - -	3,00

FIGURE, PRICE.

23. Boxwood Gunter Scales, 1 foot, 37 and 75 cts, two feet, - $0,75
" Pocket Rules, 1 foot, 4 fold, 25 to 75 cts. Ivory do, 62 cts. to - - - - - - - 2,00
Paper Scales, 18 inches long, in sets of six, graduated from $\frac{1}{8}$ to three inches, per set, - - - - - 1,25

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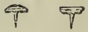
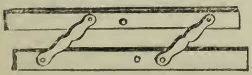


28

24 25 26 29

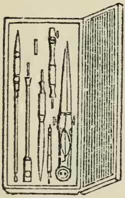
24. T Squares, wood, with arm, 18 to 30 inches long, - $0,75
24. " " " " and swivel head, - - 1,25
24. " " " " " " " and brass edges to arm, $1,75 to - - - - - 2,75
25. Irregular Curves, various sizes, 25 to 37 and - - ,50
26. Ebony Triangles, 37 cts. Pear wood do. - - ,25
27. German Silver Squares and Triangles, 50 cts. to - - 2,50
28. Pins to fasten paper to the drawing board, brass, 25, 37 and 50 cts. German Silver, per dozen, - - - - ,60
29. Horn Centres, to prevent the dividers from marking the paper, ,18




30 31

FIGURE.		PRICE.
30.	Parallel Rules, Ebony, 6 inch 37 cts, 9 in. 62, 12 in. 75, 15 in.	$1,00
30.	" " Ivory, 6 inch, - - - -	1,00
30.	" " Brass, fine, 9 in $1,75, 12 in. $2,50, 16 in -	3,12
	" " " on rollers, 6 inch $4,25, 12 inch, -	5,75
	" " Ebony, " 12 in $2,62, 15 in. $3,37, 18 in	4,00
	" " Ivory, " graduated edges, 12 in. -	4,25
	18 inch, - - - - - -	6,00
31.	Pentagraphs of Ebony, very accurately made, - -	14,00
32.	" of Brass, " " " - -	22,00

CASES OF MATHEMATICAL DRAWING INSTRUMENTS.



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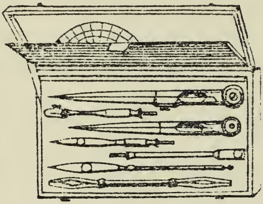

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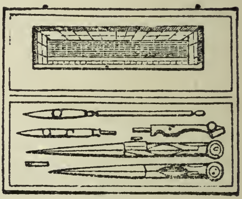


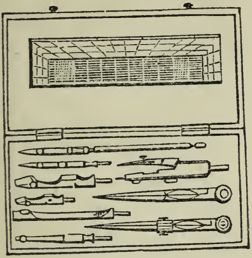
35

33.	No. 636, Morocco case—small German Silver Instruments—Needle point, 4 inch dividers, fine quality, -	3,50
33.	No. 25, wood box, brass instruments, without needle points, medium quality, - - - - -	1,25
34.	No. 32, wood box, brass instruments, 5 inch dividers, medium quality, box scale, - - - - -	1,75
34.	No. 33, wood box, brass instruments, 6 inch dividers, medium quality, Ivory scale, - - - -	2,25
34.	No. 600, Morocco, brass instruments, common quality, box protractor, (fig. 22), - - - - -	3,50
35.	No. 154, Morocco, German Silver instruments, fine quality, Ivory protractor, (22), - - - - -	3,50
35.	No. 054, Morocco, German Silver instruments, with addition of lengthening bar, - - - - -	4,25
35.	No 645, Morocco, German Silver instruments, without plain dividers, - - - - - -	3,00

FIGURE. PRICE.

35. No. 023, Morocco box, brass instruments, good quality, - $2,50

35. No. 599, " " " " common quality, box protractor, - - - - - - 1,25



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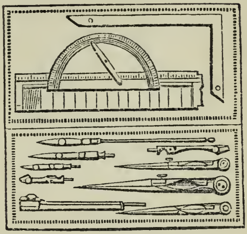

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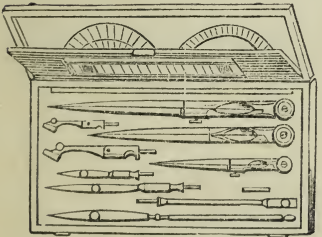
36. No. 736, Morocco box, German Silver instruments, fine quality Ivory protractor, - - - - - 6,50

37. No. 745, Morocco box, German Silver instruments, fine quality, 6,50



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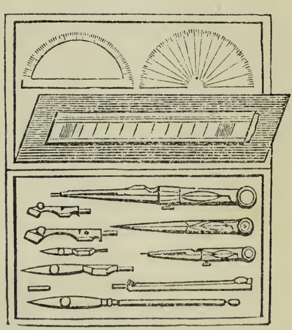

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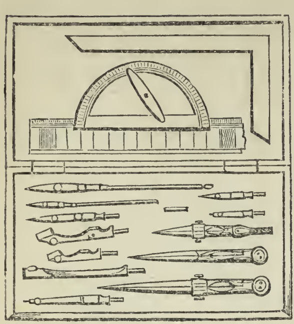
38. No. 15, wood box, brass instruments, medium quality, - 3,50

39. " 29, " " " needle points, med. qual. 3,75

39, " 39, " " " " with bow pen, 4,25

39. " 40, wood box, brass instruments, needle points, with bow pen and proportional compasses, - - - 6,00

39. No. 585, Morocco case, brass instruments, fine quality, - 5,50



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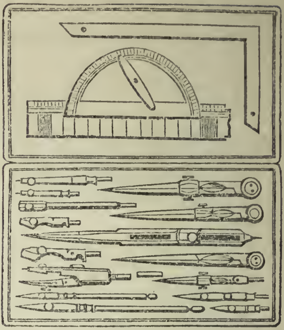

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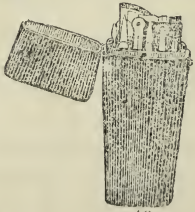
FIGURE,		PRICE.
40.	No. 305, wood box, German Silver instruments, fine quality,	$10,00
40.	" 535, " " " with bow pen,	13,00
40.	" 036, " " " " " and hair dividers, - - - - - -	14,00
41.	" 845, wood box, German Silver instruments, fine quality,	25,00
41.	" 655, " " " with addition, of Railroad Pen, (fig. 18) - - - -	27,00
41.	" 455. wood box, lock and key, superior quality, without the proportional compasses, but with double drawing pen, (fig, 18) and additional pen, (fig. 17) - -	30,00
41.	" 126, wood box, lock and key, German Silver instruments, superior quality, with addition of Railroad Pen, (fig. 18) and one Pen, (fig. 17) - - - -	40,00
41.	" 326, same as No. 126, but with addition of furniture for Beam Compasses, (fig. 9) - - - -	48,00



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42.	No. 5, Fish skin cases, brass instruments, box scale, -	2,50
	" 55, " " " " Ivory scale, -	2,75
	" 57, " " " " Ivory scale, steel joints,	3,50

German Silver Swiss Drawing Instruments.

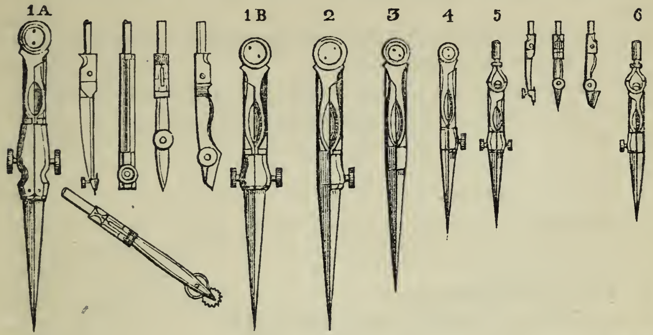


FIGURE.	PRICE.
No. 1 A, Drawing Compass, joints in legs, 6½ to 7 inches long, with pen, pencil-holder, needle pt., lengthening bar and dot. pen,	$6,50
No. 1 B, Drawing Compass, 6 inches long, with pen, pencil-holder, lengthening bar and needle point, - - -	5,00
2. Hair Spring Divider, 5–6 inch, - - -	2,00
3. Plain Divider, 4½ inch, - - - - -	1,37½
3. " " 5–6 " - - - -	1,50
4. Hair " 4½ " - - - - -	1,75
5. Drawing Compass, 4 in., with pen, pencil-holder and needle pt.	4,00
6. The same, without the needle point, - -	3,00

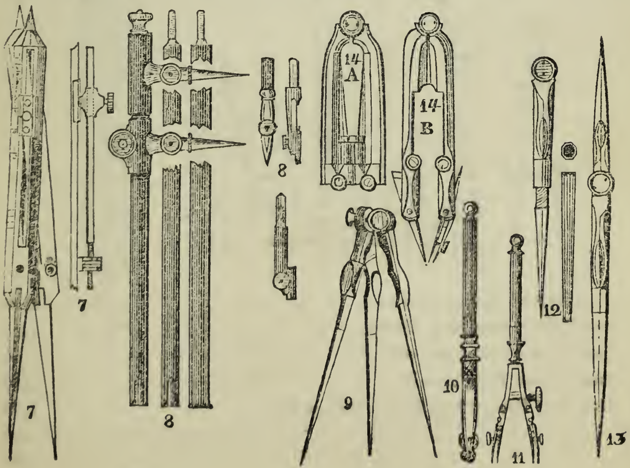
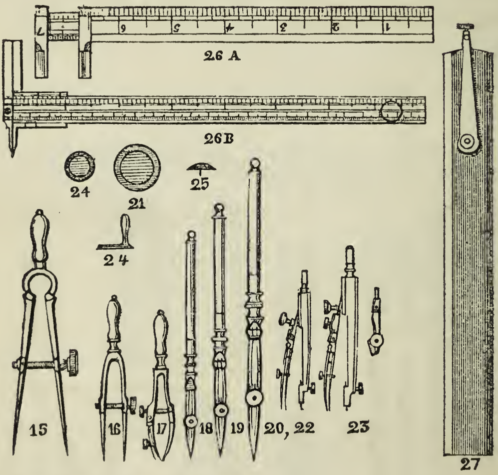
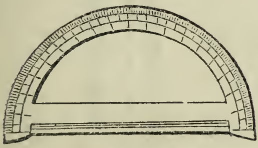


FIGURE.		PRICE.
7.	Proportional Compass, with full divisions for lines and circles,	$8,00
7.	The same, with Micrometer Screw,	9,00
8.	Beam Compass, 19–20 inches long, in 2 German Silver bars,	8,00
8.	The same, 20 inches long, in 3 German Silver bars,	9,00
8.	" " 36 " " 4 " " "	10,00
8.	" " 48 " " 4 " " "	12,50
9.	Triangular Compass,	3,00
10.	Dotting Pen,	1,75
11.	Road Pen,	2,50
12.	Pocket Divider,	1,75
13.	Whole and Half Divider,	2,50
No. 14 A,	Universal Compass, with points to shift,	4,50
No. 14 B,	Universal Compass, with points to *turn*,	5,00



15.	Large Steel Spring Divider,	2,00
16.	Small Steel Stepping Divider,	1,25
17.	Small Steel Compass, with Pen,	1,50
17.	Small Steel Bow Pencil,	1,50
18.	Drawing Pen, with joint 4½ inches long,	1,00
19.	" " " 5½ "	1,25
20.	" " " 6 "	1,50

FIGURE,		PRICE.
21.	Horn Centre, with German Silver frame, -	$0,37
22.	Bow Pen, - - -	1,80
23.	Bow Pen, with pencil holder, - -	2,50
24.	German Silver Centre, with handle, -	,37
25.	German Silver Paper Pins, per doz., - -	,60
25.	Steel " " " -	,75
A No. 26,	Calliper, - - - -	4,00
B "	" English pattern, with two verniers, -	7,00
27.	Eccentric Rule, - - -	1,80



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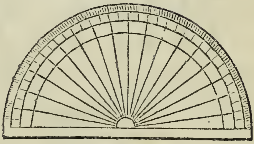

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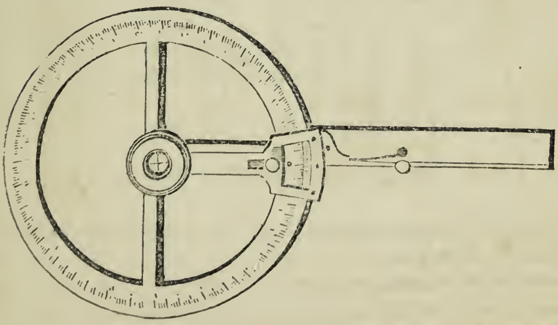
28.	Protractor, 4½ inch diameter, whole degrees, -	1,25
28.	" 5¼ " half " - -	1,50
28.	" 6 " half " -	1,62
28.	" 6¼ " quarter, " - -	2,50
28.	Horn Protractors, from 25 to - -	,50
28.	Circular Protractor with arm, 8 inch diameter, quarter degrees,	8,00
28.	" " " 10 " " "	10,50



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29.	Circular Protractor with vernier, 8 inch diam., quarter deg.,	12,00
29.	" " " 10 " "	13,00

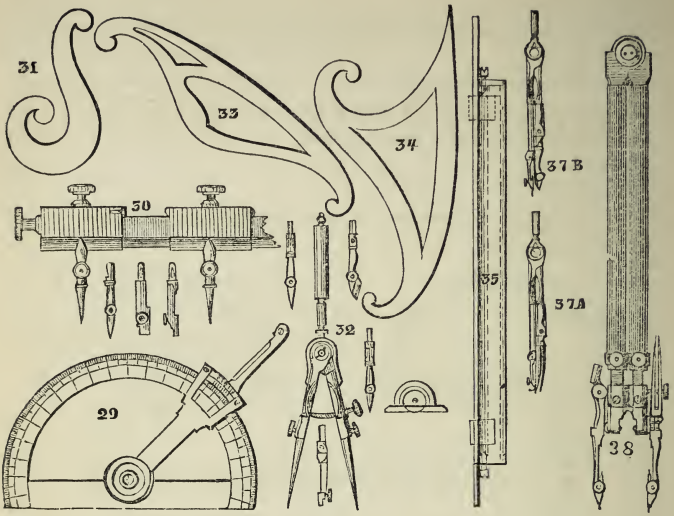

FIGURE.		PRICE.
29.	Half Circle Protractor with vernier, 5½ inch diam., half deg.	$7,50
29.	" " " 8 " quarter "	9,00
30.	Beam Compass furniture, for wood beams, -	6,00
31, 33 and 34.	Horn Curves, each - -	,50
32.	Drawing Compass, 4 inches, with long Ivory handle, spring, and micrometer, with 2 pens, pencil-holder and needle pt.,	5,00
35.	Parallel Rule, with rollers, - -	2,00
36.	Protractor Scale, divided to ½°, - - -	2,75
36.	" " " ¼°, - -	3,75
A No. 37.	Bow Compass, fast needle point and pen, with joints in both legs, - - - -	2,00
B No. 37.	Bow Compass, fast needle point and pencil-holder, with joints in both legs, - - -	2,00
38.	Lengthening Compass, - - -	12,00

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Elephant,	28x22	do	do	3,37
Columbier,	34x23	do	do	5,25
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Purple,
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Raw Umber,
Red Lead,
Roman Ochre,
Sap Green,
Yellow Lake,
Burnt Sienna,
Flake White,
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Black or Yellow Gilt, Round, 1, 2, 3, 4, small, ... do .... ,37
One Box containing 7 Pencils, for Engineers, sliding ends to box,.... ,62
do do 7 do BB to HHH,........................ ,56
do do 4 do Nos. 1 to 4,........................ ,25

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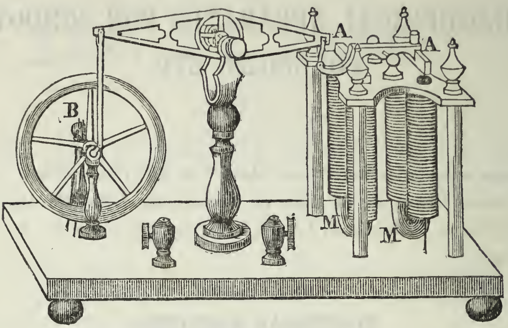

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