ESTABLISHED IN NEW YORK, 1834

ESTABLISHED IN SAN FRANCISCO, [illegible]

ILLUSTRATED CATALOGUE AND MANUAL

OF

CIVIL ENGINEERS'

AND

SURVEYORS' INSTRUMENTS

(With Useful Tables, Illustrations and Descriptions of the Latest Improvements on the Most Recent Instruments of Precision.)

MANUFACTURED BY

J. C. SALA

SUCCESSOR TO

JOHN ROACH

429 MONTGOMERY STREET, Cor. Sacramento

SAN FRANCISCO, CAL.

1899

PRICE, FIFTY CENTS

TESTIMONIALS . . .

I do not deem it necessary to print testimonials. The instruments made by this house have been used for over forty years on the Pacific Coast, and for a long time were the only ones made here; they are their own recommendation, and the endeavor is to have them embody all the latest improvements and keep fully abreast of the times.

This house manufactured the large transit reading to five seconds of an arc, used in 1862 to re-survey the City of San Francisco. This same instrument of precision is still in use to-day, showing neither eccentricity nor any signs of wear in points of minor importance! Since 1865, the **Mechanics' Institute of San Francisco** has awarded me

8 Gold Medals

4 Grand Silver Medals

1 Grand Bronze Medal

8 Silver Medals

and 12 Diplomas

for the best Surveying and Engineering Instrument, Altitude Barometers and Drawing Instruments.

I also received

3 Gold Medals and 1 Diploma of Honor

at the

California International Midwinter Exposition, 1894

There are on file in my office, hundreds of unsolicited testimonials which all parties interested in such matters are free to read at any time.

ESTABLISHED IN NEW YORK, 1831 — ESTABLISHED IN SAN FRANCISCO, 1853

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SUBDIVISIONS

PAGE

J. C. SALA

429 Montgomery Street, San Francisco, Cal.

TO CORRESPONDENTS

This catalogue and price list supersedes all former editions.

The prices in this catalogue are net cash, and instruments are not sold on the installment plan.

Every instrument is carefully packed, and the responsibility of the house ceases when instruments leave the factory. In case of damage, the express companies must be held liable.

Instruments are not sent on trial but will be sent C. O. D. for purposes of examination.

Goods sent C. O. D. only when order is accompanied by a deposit sufficient to pay expressage both ways.

The engravings in this catalogue give a good idea of the instruments at the present time; as improvements however, are being constantly made, customers will always receive the latest improved instruments.

My aluminum instruments weigh from 40 to 50% less than the regular ones, and the price is 15% higher.

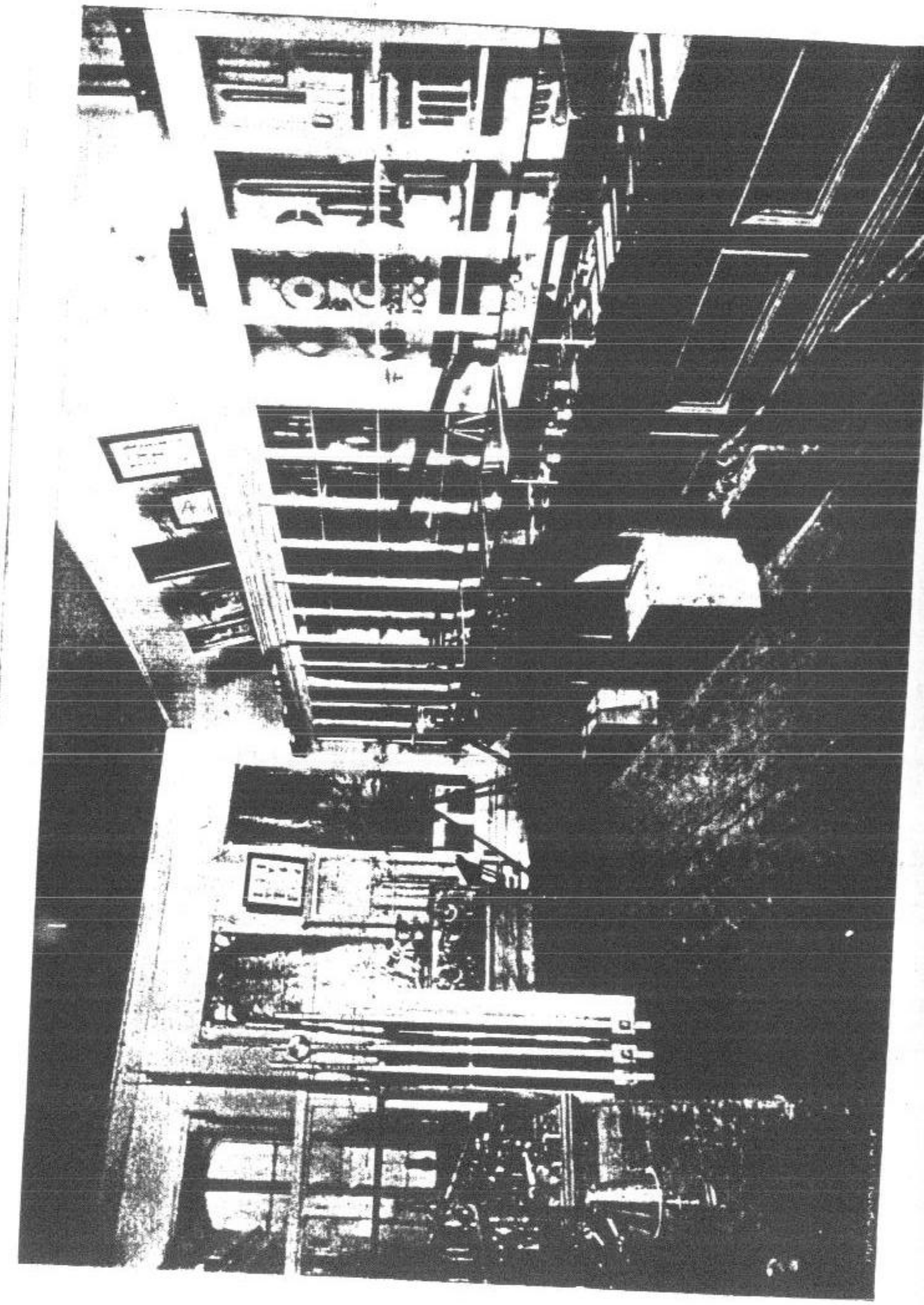
Weight of regular instruments are as follows:

Transits, No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
	14½ lbs.	**15**	**16**	**17**	**11**	**10**	**17½**
Tripods	**8½**	**8½**	**8½**	**8½**	**7**	**7**	**8½**
Levels	**8 lbs.**	**9**	**10**	**11**			
	15	**12½**	**10**	**8**			
Tripods	**8½**	**8½**	**8¼**	**8**			

Any extras to transits and levels supplied at the lowest rates.

The illustrations of transits, levels and other surveying instruments in this catalogue, represent instruments made exclusively in my shop.

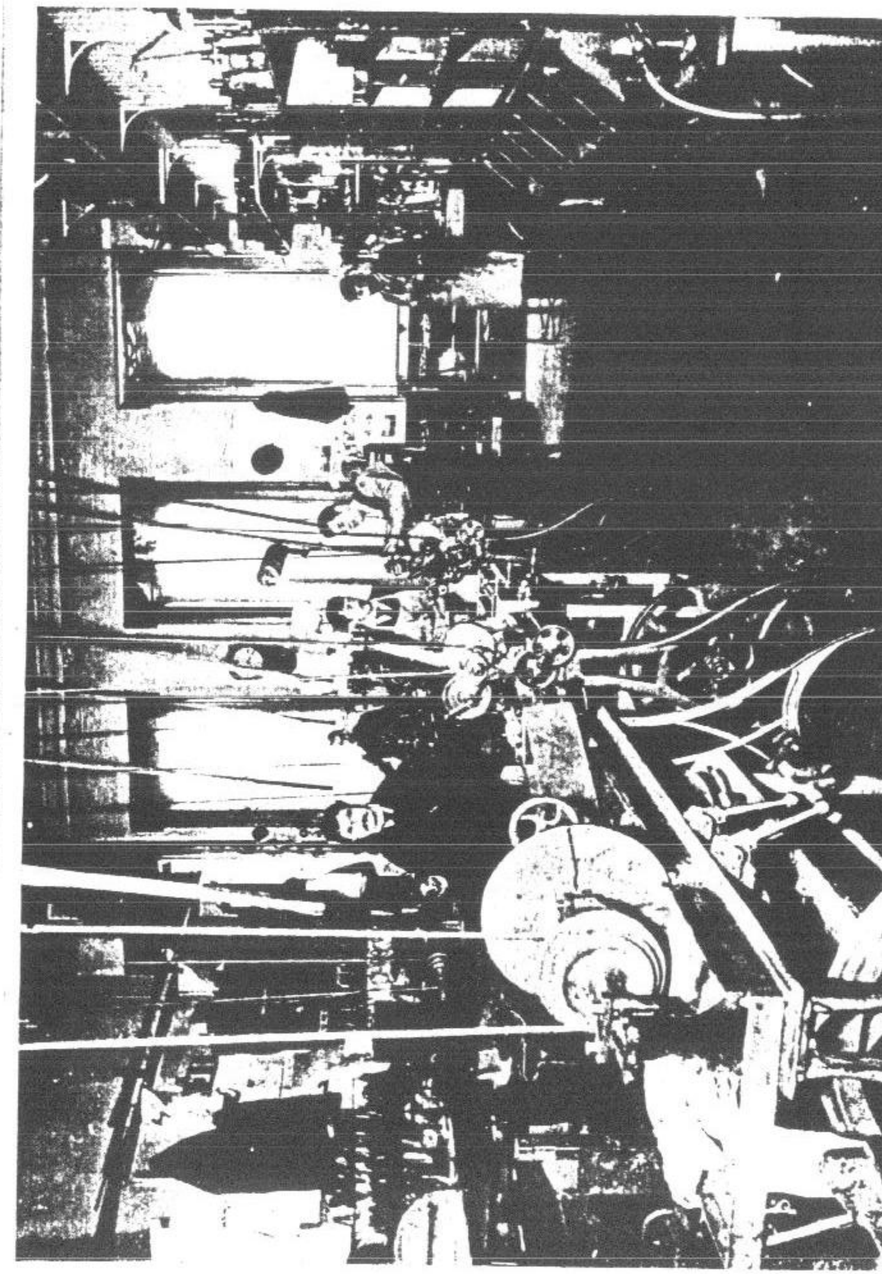
Standard astronomical instruments and other instruments not illustrated in this catalogue, are kept in stock and can be furnished upon application. Having made arrangements with foreign makers of such instruments, I can supply them upon the most reasonable terms.



INTRODUCTION

In addition to the long personal experience, indispensable to the manufacturer, and the trained staff of workmen engaged in the delicate task of building surveying and engineering instruments, and automatic machinery of precision, it is absolutely necessary to build such instruments so as to conform with the mathematical exactions required to perform correct work in the field and office.

The following illustrations will give an idea of the most prominent ones amongst those in use in my well-supplied workshop.



PARTIAL VIEW OF WORK-SHOP.

. . PREFACE . .

. . WHEN JOHN ROACH, the founder of this house, commenced business in New York City in 1834, the American Transit was only three years old. Proper castings were difficult to obtain, and the instrument-maker at that time worked under many disadvantages. There were no lenses made in the United States suitable for surveying instruments, and until about 1850, when an instrument was ordered, the telescope had to be made to suit the glasses obtainable. About the latter date, good glasses of American make commenced to appear, and there was a noticeable improvement in the making of transits; something like uniformity in size and make was obtainable.

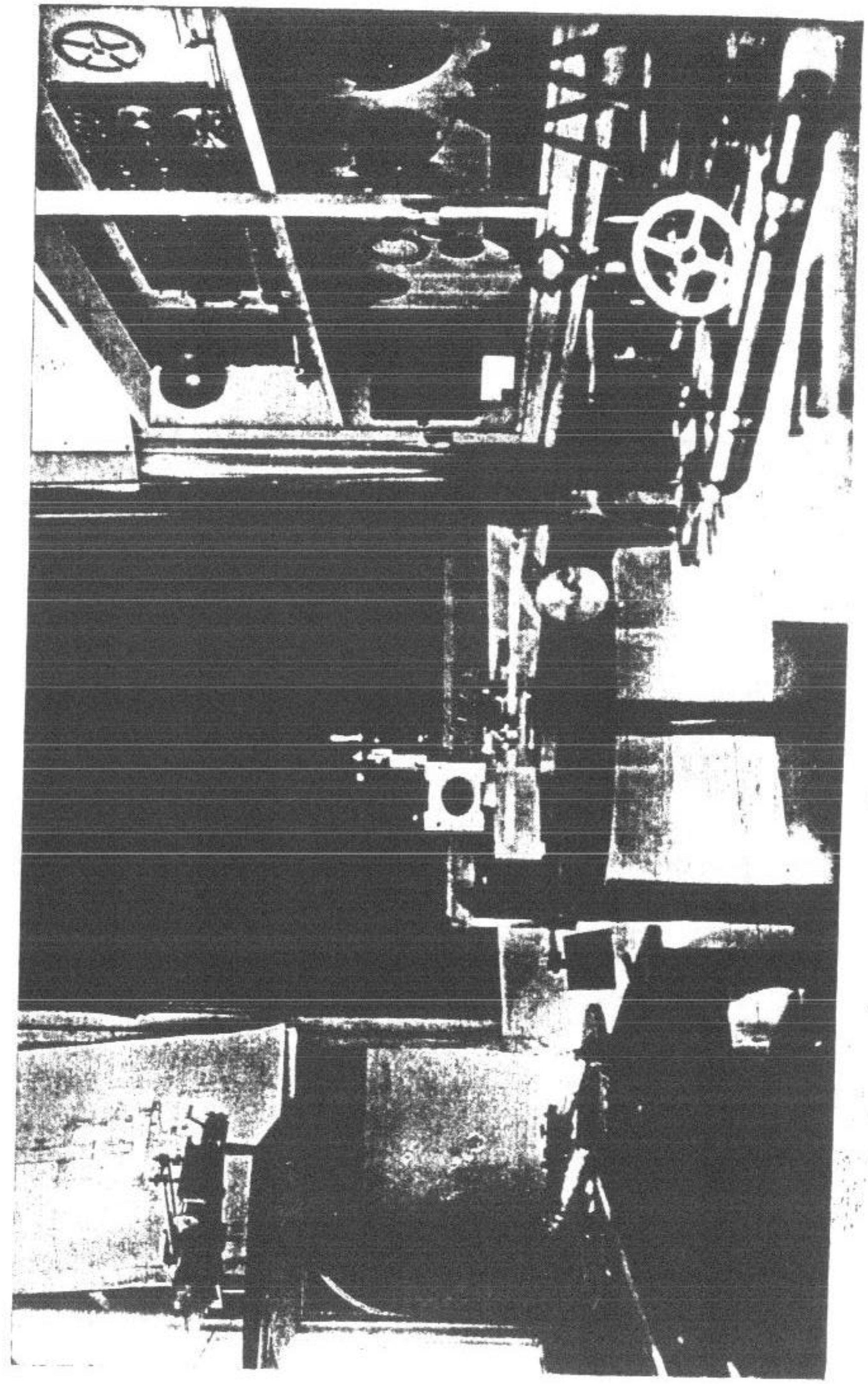
In 1855 Mr. Roach established himself in San Francisco, and the "Roach Instruments" became known in the West wherever the surveyor pitched his camp. Some of the first made are in use to this day and there is no sign of breaking down yet; they have naturally an aged appearance, but their joints are in fairly good order, their graduations clear, and the glasses nearly perfect.

Instruments in the early days were not handled always by the most competent men and received harder usage than modern instruments are called upon to stand; as a consequence, metal was not spared in their construction. While lightness was always a desideratum, still strength was more important, and the early instruments were strong. They had also an appearance of strength and solidity which favorably impressed members of the engineering profession.

The modern instrument, made by this house, while changed in appearance somewhat to suit the eyes of the present day user, still preserves the sturdy, well-made, substantial appearance which did so much to render popular the "Roach Instrument." Although it has a strong appearance, and is in fact as strong as any instrument need to be, it weighs no more than one of the same size made by any other maker. Strength is secured by a system of bracing and ribbing, which enables a saving in much material. Lightness is secured by this same system of ribbing and also by the use of aluminum alloy in all places where it is of undoubted benefit.

In examining this catalogue the reader's attention is directed to the sturdy appearance of the instruments and to the weight of each. He must remember also that they represent an evolution, the result of a growth of over forty years of experience on the Pacific Coast in all classes of work.

J. C. SALA.



ADJUSTING ROOM.

MAKING AND REPAIRING OF INSTRUMENTS

The first essential for accurate work with any kind of an instrument is that it be carefully made of the best materials and that the workmanship be the best obtainable.

These desirable results have been reached in my instruments. Only the best materials are used, and the workmen are all first-class men of long experience and special training. The tools used are of the strongest and most modern construction. The instruments for precise work are automatic and of the most approved types.

The illustrations give a good idea of the various departments of the establishment, and a visit to the works will well repay those who are sufficiently interested to call. I am always pleased to see my patrons and friends.

Attention is called to the cuts of the dividing engine and other tools I use.

As remarked in the preface, my instruments are strong and as light as is consistent with proper strength. The dead weight is removed wherever not necessary for stiffness; at the same time, stiffness is secured by properly shaping the parts. Each part is shaped to withstand the strains it will be called upon to bear, and wherever possible to remove extra metal it has been done, but ribs have been left. A judicious employment of aluminum alloy having a great tensile strength helps to decrease the weight materially, and all bearing parts are of the hardest metals. Joints have been avoided largely by combining as many parts as possible in a single casting. This, while an increased expense in making, is of great value, for it reduces the number of joints and therefore the weak places.

Aluminum.—A great popular demand has of late years arisen for instruments made of aluminum, and in response to the demand, I make instruments with a very large percentage of aluminum when

ordered. These instruments are lighter than the regular make, and the dull silver-like finish is very pleasing. The workmanship on them is of the same high class as on my other instruments, and the customer secures a good instrument subject however to the advantages and disadvantages mentioned below.

The disadvantages of aluminum are its softness, the difficulty of soldering to other metals and its wearing. On the other part there are incontestable advantages for certain parts of instruments where lightness is especially desired.

The aluminum bronze is now considered one of the best materials entering into the manufacture of tubes for telescopes, on account of the great rigidity of this alloy. Alloy of silver and aluminum is certainly a valuable material for graduation, allowing an easier reading than on pure silver. I have been building such parts of aluminum or aluminum alloys on transits, levels and plane tables where the metal and its alloys are of recognized advantage, and have such instruments on hand, but am opposed to an indiscriminate use of this metal in the construction of instruments of precision.

In regard to aluminum for surveying instruments, a great many unwarranted statements are made every day and engineers should understand fully this question. Aluminum while a very light metal, is not a non-friction metal by any manner of means. The co-efficient of friction is very high, therefore for all the finer bearing parts a bushing of hard metal must be used, otherwise the close fitting of parts so necessary to the instrument of precision is lacking. A transit containing enough aluminum to reduce the weight very considerably, is composed of too many parts to be a satisfactory instrument. I use enough aluminum alloy in my instruments to lighten some of the more unimportant parts, but it is confined to such parts.

An instrument must be steady and should have enough weight to secure such steadiness as will enable it to stand wind well. The surface exposed to the wind is considerable, and the wind exercises much force upon it. If the instrument is therefore very light it will tremble in a breeze. Instruments made of extreme lightness must have heavy tripods and it is difficult to see where the advantage of the light top comes in in such case. If an engineer really desires to carry a light instrument it will be better to purchase a small sized transit than a large one so light that it will be an annoyance to use it.

I have carefully experimented with the various alloys of aluminum, and as a result of these experiments believe it is not of such value as to justify its very extensive use in surveying instruments.

The best alloys of metals are used, and such as have nearly the same co-efficient of expansion as glass are the preferable, as the optical parts of instruments are of such importance. The co-efficient of glass per linear foot for one degree Fahrenheit is 0.000054 inches; of steel it is 0.000076; brass, 0.000125; aluminum, 0.000148. It may be readily seen that when an instrument is so made that all its parts have the same, or nearly the same, co-efficient of expansion, that it will retain its adjustments under decided changes of temperature much better than one which has various metals with widely differing co-efficients. Aluminum is the least desirable of metals in use for such purpose. Iron and steel of course would be better than brass were it not for the needle and also the liability to rust in exposed positions. Steel centers for levels are much used now and have their advantages. I put them in when ordered in place of ordinary centers without extra charge.

FINISH.—The finish of my instruments is of a pleasing brown color, unless ordered otherwise. I finish the instruments in any manner ordered.

The natural finish of bronze or any other alloy or metal has a glaring effect upon the eye of the observer, and is therefore objectionable. The black finish is not to be recommended on account of its great affinity for absorbing heat and consequently expanding the more exposed parts of the instrument very rapidly to the detriment of the adjustments. To obviate these inconveniences I have adopted two styles of finish which have given the best possible results.

My bright finish, somewhat the color of antique bronze, is not glaring and stands well any wear. My cloth finish on such parts of the instruments as are apt to absorb the heat more rapidly on account of their exposure, is of a pleasant greenish color, and feels to the touch as a soft piece of cloth. It secures a very gradual and uniform expansion and contraction in sudden changes of temperature. The durability of this finish is not equal to the bright finish, but lasts about as

On page eleven of the catalogue issued by me in 1896 the statement was made that after careful experiments with various alloys of aluminum I thought the metal was not of such value as to justify its very extensive use in surveying instruments.

This opinion might have been taken as an expression of the extreme of conservatism and a dislike to change, but the contrary was the truth. Early after the demand first came in for instruments of aluminum the experiments were commenced and have been continued to the present day. While the result of the experiments up to that time was as stated they were not stopped, as there is a constantly increasing demand for aluminum instruments.

This house made its reputation by furnishing none but the best instruments and keeping fully abreast of the times and in many cases antedating other makers in improvements. So bearing this fact in mind I have continued experimenting and beg to announce that instruments are now made by me of a new aluminum alloy which possesses all the good properties which can be demanded of it and has none of the defects heretofore found.

The alloy is one of my own composition and used by no other maker.

It is with considerable satisfaction that I am now able to assure my customers and friends that my aluminum instruments are as good in every respect as those made of the old standard metals, and those who prefer a light instrument can secure one of aluminum alloy from me which will give perfect satisfaction.

J. C. SALA.

long as the black finish would. As it is not necessary to finish or polish an instrument so finely when cloth-finished, the cost is less than for the ordinary bright finish. In neither of my finishes enter any material having effect upon the magnetic needle.

My instruments do not separate above the levelling screws but are placed in the case directly and in an upright position. The cases have rubber cushions on the bottom to ease all jarring motion in transportation.

It may be seen that the constant endeavor of this house is to maintain its old reputation for furnishing the engineer with an instrument he can rely upon. I desire to make at all times an instrument which will need no special puffing or advertising, but will be its own recommendation.

To secure these desirable ends, special attention is paid to secure:

1st—Careful workmanship and design.

2d—Accuracy of division.

3d—High powered achromatic telescopes.

4th—Equable adjustments.

5th—Lightness, stiffness and strength.

6th—Simplicity in parts.

These all conduce to ease in manipulation and certainty in results.

Every instrument sent from the factory is carefully adjusted and packed in a manner which should insure safe transportation. My experience in packing instruments for so many years when they were exposed to all sorts of usage in transportation, has developed skill in packing, and very few instruments sent by me arrive at their destination with the adjustments impaired in the slightest degree.

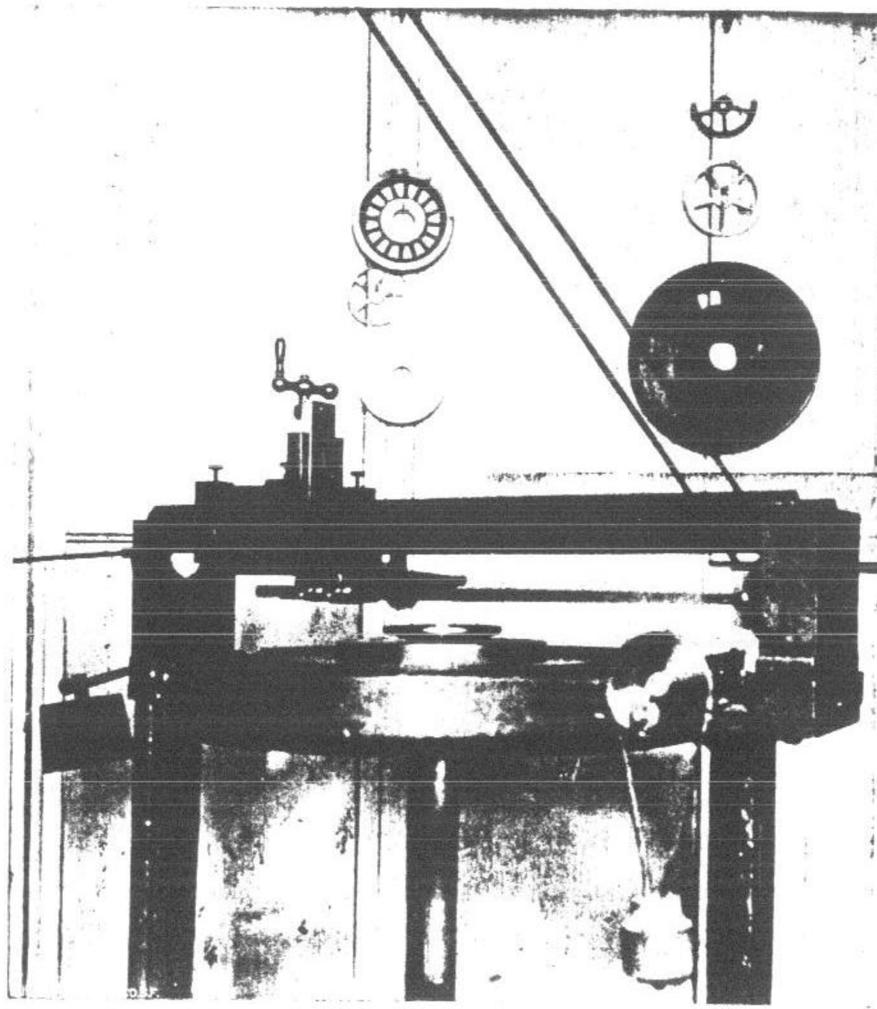
Repair of Instruments.—My facilities for repair work of all kinds are unsurpassed. Having been for years the only house on the Coast in this line, and the freight rates to the East being very high, I have repaired instruments of nearly every known make. I am therefore as familiar with the construction and workmanship of the leading instrument makers of this country as with my own make, and can guarantee satisfaction in repairing. My shop is especially well fitted for such work.

The most satisfactory way to obtain first-class work in repairs is to send the instrument to me with instructions to put it in thorough order and adjustment. I will give an estimate of the cost if desired, before doing the work. Of course this is the most expensive way of doing the work but it is the cheapest in the end. If it is not thought best to do this, the instrument can be sent with a clear description of the repairs or other work desired, and I will follow instructions. I will do as good work as can be done, taking into account the make, material, workmanship and general state of the instrument as regards condition and extent of the damage done. The cost will be as low as is consistent with good work and will be according to the time consumed and material used.

The packing of instruments sent for repairs should be carefully attended to. Place the instrument in its own case and then the case into a packing box with the space between filled with excelsior or straw. This will enable it to be sent safely and at the same time enables it to be shipped at regular rates. Usually higher rates are charged for surveying instruments than for ordinary express packages.

I will guarantee as good work as it is possible to put on the job, but reserve the right to decline a job if I believe it impossible to put the instrument into such shape as will warrant the owner spending the money on it.

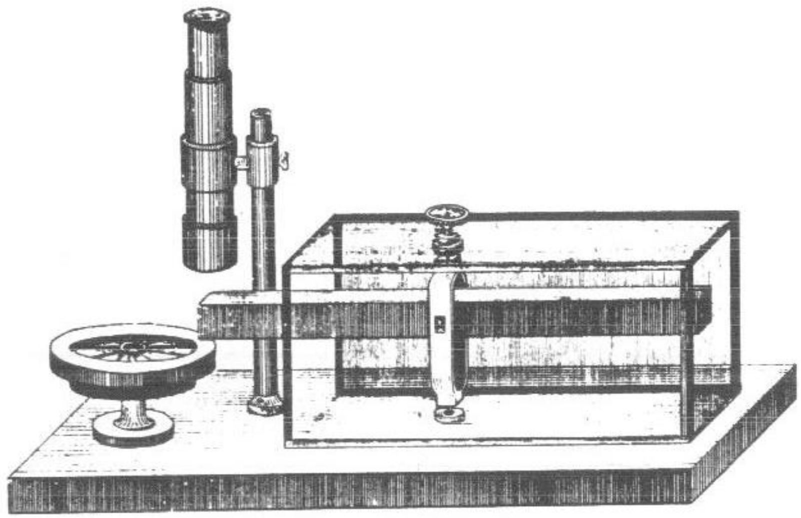
My own instruments should always be sent to me for repairs, as by so doing, considerable expense may be saved. I am in a position to duplicate all parts from stock on hand and can therefore repair instruments of my own make quickly and cheaply.



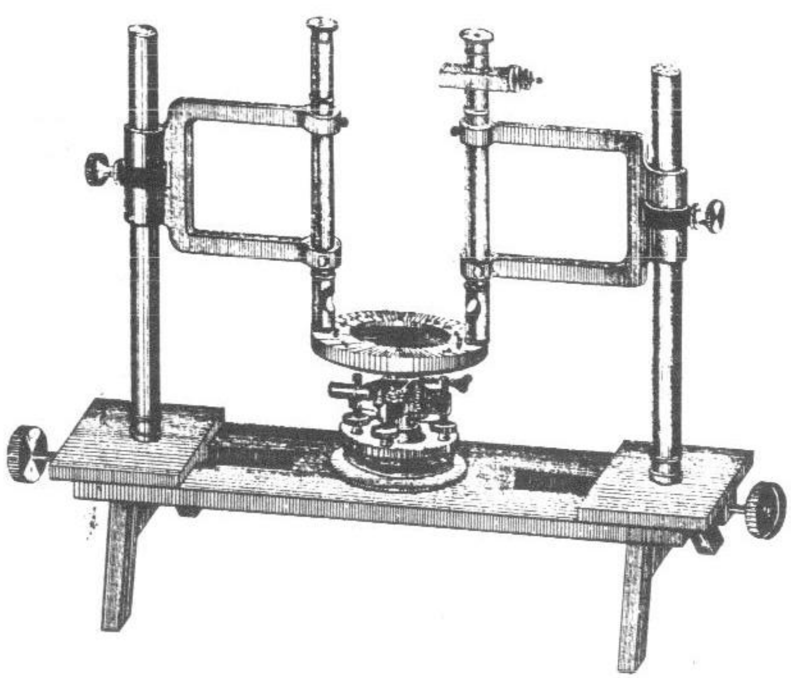
THE AUTOMATIC DIVIDING ENGINE.

30-INCH CIRCLE

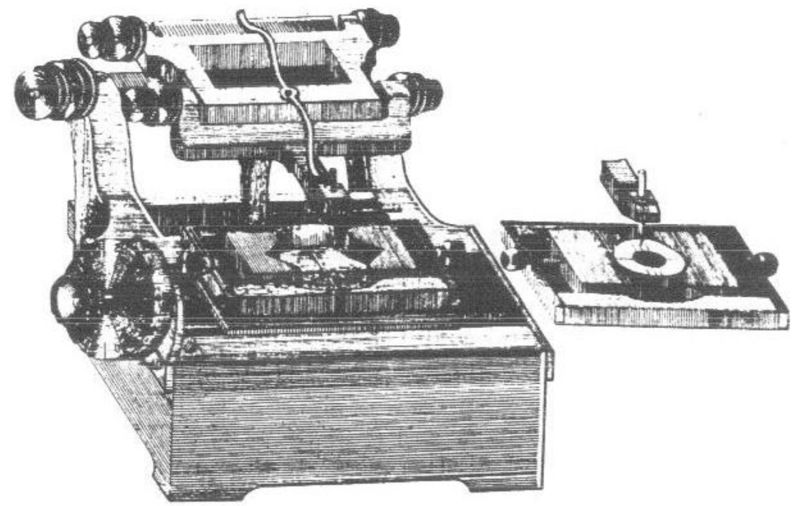
This Engine is Used to Make Graduations on Limbs, Verniers, Etc., and is One of the Best ever Built in this Country or Europe.



APPARATUS FOR TESTING MAGNETIC INFLUENCE OF METAL.

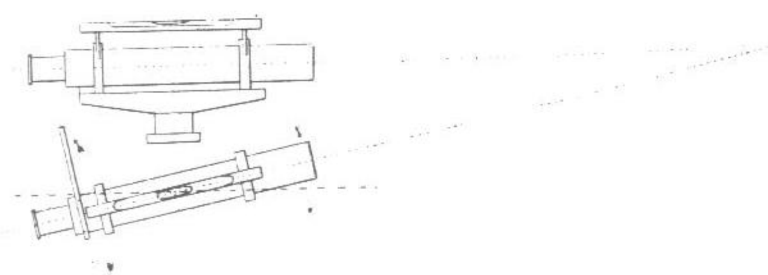


CENTERING APPARATUS—USED FOR TESTING GRADUATIONS.



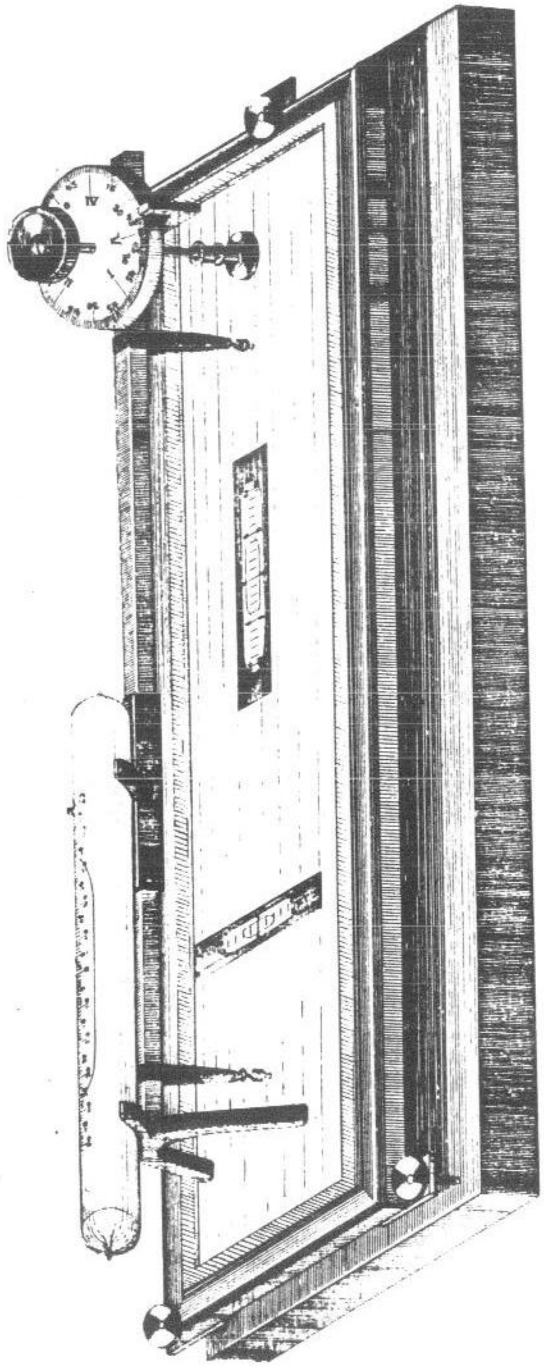
THE LONGITUDINAL DIVIDING ENGINE.

Apparatus for Graduating the Grooves for Cross and Stadia Wires on the Diaphragm of Telescopes.



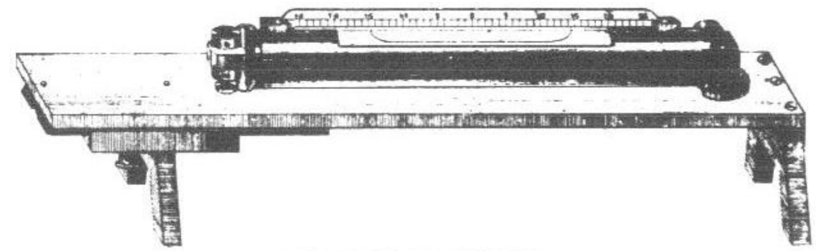
THE COLLIMATOR APPARATUS.

For Adjusting the Line of Collimation of Surveying Instruments.



THE LEVEL-TRIER.

Apparatus Used in the Manufacture of Spirit-Levels to Try the Character and Approximate Sensitiveness of the Curvature Ground in the Glass Tubes before they are Finally Filled and Sealed. Also to Accurately Determine the Value of One Division of Level in Seconds of Arc.



THE COLLAR TESTER.

Used in the Construction of Levels, to Ascertain the Uniformity of Collars on Telescopes.

CARE OF INSTRUMENTS.

In the care of instruments, common sense should play a great part.

The tripod legs should never be permitted to become loose, but the nuts and bolts should fit snugly. Before carrying the instrument, care should be taken that it is screwed firmly to the tripod and in no danger of falling off. It is well also to see that it is tight before using the instrument.

Before carrying the instrument, the levelling screws should be screwed to a firm seat and the instrument slightly clamped in order to prevent any movement or wear of the centers.

The needle should always be clamped, except of course when in use. It is also thought well to permit the needle to swing freely when the instrument is in its case, as it will swing at once into the meridian in which position it is supposed to retain magnetism best.

All unnecessary movement on the pivot should be avoided, and when swinging, the motion should be gently checked by the lifter in order to reduce the play to as small an arc as possible. The needle should always be gently let down on the pivot.

A silk handkerchief should never be used to clean the glass or lenses of a transit.

Buttons, knives, keys, wire hat brims, cheap watch chains, etc., have a great effect on the needle of an instrument.

Screws should never be turned more than necessary to obtain a firm seat. The slightest movement more will strain them and impair the accuracy of the instrument and reliability of adjustment. A screw should never be so tight that any great effort will be necessary to start it. When the threads of a screw work hard, they should be cleaned with a stiff bristle brush. A tooth brush is excellent. After cleaning the threads with the brush, oil the screw and work it in to its full length and then out again; the oil should be wiped off with a clean chamois skin and more oil put on and the screw again worked in and out. This operation should be repeated again and again until the screw is clean and works smooth and free. When this result is accomplished, the screw should be run in and out several times without oil and wiped each time to remove all oil. No oil should be left on exposed portions of levelling or tangent screws, as it will collect dust.

A gossamer or silk water-proof bag should be carried in the field for the purpose of covering the instrument in case of rain or dust storms coming up.

The only oil to be used on an instrument is the very best quality of watch oil and as little of that as is necessary to cause a smooth motion of the parts lubricated; too much will cause the parts to become sticky and gum up. Sometimes marrow is used for lubricating, but it is objectionable because it is liable to become rigid and bind in cold weather. Vaseline is very good, as it is less rigid than watch oil and somewhat softer and less liable to bind than marrow, but it requires renewal often. As an instrument should be as little disturbed as possible in its adjustments, the best lubricating material is that which requires little attention and contains no grit. Watch oil is the best and is the only thing to use on centers and the finer grade of instruments.

Sea air has a tendency to destroy the finish of the surface of an instrument; a good plan to follow when working near the seashore is to cover the entire surface with a thin coating of oil.

All exposed surfaces moving in contact, such as the object slide, etc., must be kept free from oil, as it will collect dust and sooner or later cause fretting. When any surface begins to fret, it should be carefully examined and a piece of hard wood rubbed on the spot to smooth off the roughness. If this does not improve the matter, the surface should be slightly scraped with a sharp knife or touched with a very fine flat file and burnished with a polished piece of steel. A little oil can then be applied and the movement tested. If all fretting has disappeared the oil should be very thoroughly wiped off and the parts replaced in position.

If any powder is used to reduce the roughness instead of employing a scraper, care should be taken that it is not emery, as that is the worst possible thing to use. Only powdered pumice or some rouge should be used.

The telescope glasses should be left in their places as long as it is possible to use them, as any unscrewing will destroy their seat and the adjustment will be impaired. When the glasses however become greatly soiled and it is hard to get a good sight through them they should be washed with alcohol. Chamois skin and soft flannel are the best things with which to wipe lenses. Too much rubbing of lenses will destroy the fine polish of the faces which it is important to preserve and all unnecessary rubbing is to be avoided.

When the graduations become greasy, coat them with a thin covering of watch oil and let it stand for an hour or two; then wipe it gently with a piece of soft cloth or chamois and be careful to take off all the oil. Try and avoid as much as possible, touching the edges of the graduations.

If an instrument falls, and the centers become bent, it should be sent at once to the maker for repairs, as every turn after the accident only makes the condition of affairs worse

The few hints here given it is hoped will be of service to users of instruments, and familiarity in their use will be found to suggest many other things which the man possessed of common sense will be able to adopt and find of service.

An instrument is a finely made and delicate machine, but to one who thoroughly understands it, the limit of its delicacy can be understood, and some men can do a great deal more to one in the way of repairs than others. The old maxim of "every man to his trade" is however a good one to follow; the efforts of the owner should be confined to the keeping of his instrument clean and ready for service.

LOOK OUT FOR YOUR NEEDLE.

On account of the great number of strong electric currents over the country, the magnetism of needles is more apt to be disturbed than in days "gone by."

Never take a transit into an electric power house.

Keep a respectable distance away from dynamos and other electric machinery when carrying a transit.

Do not ride on electric cars when carrying a transit, if possible to avoid it.

If compelled to ride on an electric car with a transit, let the needle swing freely, and carry the instrument on your lap. Never under any circumstances allow the transit to rest on the floor of an electric car.

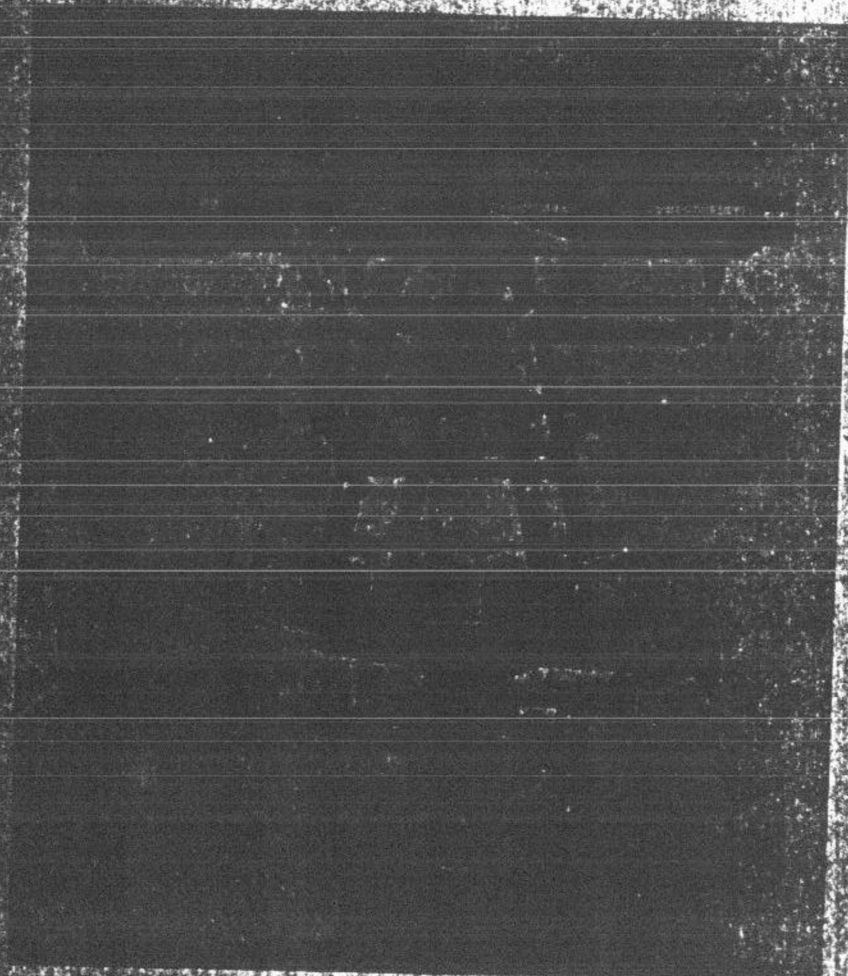
If using a transit near strong electric currents or near electrical machinery, allow the needle to swing freely.

If your office is in an upper story of a high office building, have a piece of thick rubber to place the transit box on and always allow the needle to swing freely.

Surveyors and Engineers

Instruments

Field Work



THE TRANSIT

THE TRANSIT

The most important instrument used in engineering work is the transit, and its invention marked a great advance in the doing of accurate work. It can, with its various modifications, do the work of the compass, the level, and, with more or less accuracy, the work of the chain in measuring distances. It is in fact, a universal instrument and an American invention. Its essential parts will be briefly explained.

GRADUATIONS. The object for which the transit was invented was to obtain closer results in the reading of angles than was possible with the compass. The graduations therefore, by which close reading is obtained, must be very carefully and accurately cut. Those cut on automatic dividing machines are the only ones to be depended upon, as every line is uniform. The lines must be clear and perfectly straight: to obtain this, only silver should be used, as it is of uniform density, and there is no danger of blowholes or defects in the casting such as are encountered in brass or other materials sometimes used for the purpose and silver-plated afterwards. All graduations on transits made by this house are on solid silver.

The graduations on the horizontal plate read in opposite directions from 0 to 360 degrees and are inclined in the direction of the reading.

I especially invite a comparison of the graduations on the limbs and verniers made by my automatic dividing engine mentioned under another heading, and the graduations as now existing on a good many instruments of other makes, and am satisfied that the practiced eye of the connoisseur will at once observe that notwithstanding the extreme fineness of the lines, this advantage is obtained without impairing their distinctness.

VERNIERS. A vernier is a device whereby finer readings may be obtained than by any other method. It is in fact an auxiliary scale and is so made that a certain number of divisions on it will equal one more or less on the plate, or limb. If for instance a plate is graduated into degrees and quarters, no angle can be read which is less than fifteen minutes. It can be estimated a little closer, but such a proceeding is only refined guesswork. To obtain a reading say to half minutes, a vernier must be used; this is a scale so divided that thirty divisions on it will equal twenty-nine on the plate. Now by placing the vernier in contact with the plate so that the lines on each end are coincident with two lines on the plate, it may be seen that the line next to the end is not exactly coincident with any line. The next line has an increased space between it and the line nearly opposite on the plate, and that this difference grows uniformly greater until it gets to the middle of the scale when the middle line is exactly half way between two lines on the scale; then the lines begin again to approach until the end line at the other end is coincident with a line on the plate. A little reflection will show that each graduation on the vernier is one-thirtieth smaller than one of the graduations on the plate. As the graduations on the plate are fifteen minutes each, the vernier must be able to show a difference equal to one-thirtieth of fifteen minutes, or thirty seconds. Therefore, to find how closely any vernier will read, it is only necessary to divide the value of a division on the plate by the number of divisions on the vernier. It makes no difference whether the graduations on plate and vernier are straight or on circles, the rule holds good; the vernier may be so graduated to enable a finer reading of the foot or of degrees or any other unit.

To read a vernier on a transit, read the degrees on the plate and in the direction indicated by the numbering. The zero of the vernier will indicate the number of degrees, and if it coincides with one of the lines, it gives the exact reading; if it does not coincide with any line, then when the zero point is reached the reading must be on the vernier until a line is reached which coincides with a line on the plate. The number of spaces the line on the vernier is from the zero, indicates the number of units of the "smallest reading" to be added to the reading on the plate as indicated by the zero mark.

The graduations on the horizontal plate of the transit are in a circle, and the vernier is on a small plate attached to a circular ring outside the graduated plate. To obtain close readings, the line dividing the two plates should be very fine and hardly distinguishable; it

can only be so if the two plates are in precisely the same plane. If there is a wide space between the graduated plates or one is a trifle higher than the other, the transit is not capable of doing as accurate work as is necessary. The verniers on my transits are placed directly in front where they can be most easily read.

THE CENTERS. The centers of a surveying instrument are the fundamental part of such instrument. Upon the axis and bearings depends in the first place the accuracy of measuring either horizontal or vertical angles, and also on their trueness depends the closeness of the line between the horizontal or vertical limb and its vernier. Since my predecessor started in business, the instruments built by this firm have been renowned for the trueness and unsurpassed wearing qualities of the centers of their instruments.

The fineness of the line between the vernier and the plate depends to a great extent upon the perfect fitting of the centers. No matter how well graduated the plates or how excellent the workmanship in other parts of the instrument, if the centers are not truly fitted, no good work can be done. The centers support all the vital parts of the transit, and for steadiness should be long and fit perfectly at all points so as to insure firm and steady bearings; they must be well turned in order to move freely without binding and to require as little lubricating material as possible. There must be just enough lubricating material on the centers to enable the surfaces to move on each other without grinding; the least additional amount prevents a perfect fit. Any bending of the centers introduces errors and sets up a grinding motion which soon renders the instrument useless.

The centers on all my instruments are long and made of the very hardest bell metal. The center of gravity is brought down as low as possible and steadiness thus insured.

THE PLATE LEVELS. To obtain correct readings of horizontal angles, the instrument must be level; to make it so, there are two level tubes on the plate at right angles to each other. One is parallel to the line of sight. The one parallel to the line of sight is sometimes placed on the standards supporting the telescope and the other on the plate.

It was formerly stated that it did not matter much if the level on the side was a little out of adjustment, as the angles were read from an imaginary vertical line through the center of the telescope tube; it was thought that if the level at right angles was perfectly level, angles could be correctly read even if the other level was out slightly. This idea is no longer entertained, for it may be easily perceived that if the plate is not truly horizontal, all the angles will be too small. The repeated clamping, unclamping and turning of the instrument while making observations, has a tendency to throw the plate slightly out of level, and it is therefore necessary that the plate levels should be extremely sensitive in order that the least amount of deviation may be ascertained and corrected before much harm is done.

All levels for close work are ground to a true arc of a circle and must be uniformly ground or they are of no use. A very good idea can be formed of the quality of work put in an instrument by noticing the sensitiveness of the levels; unless all fittings are good, the levels will always be unsteady and a source of annoyance. A maker puts on his instruments as sensitive levels, as he thinks will be good for them to have, and if the bubble is sluggish, it is a pretty sure indication that the workmanship generally is not first-class. If the metal in the centers is soft, a sensitive level will soon tell when any wearing begins. To insure good work and peace of mind it is well to have sensitive levels on an instrument and the value of the graduations known; if the level gets out a little on the work, the operator will know just how much his work is likely to be affected and can govern himself accordingly.

THE LEVELING SCREWS. These parts of an instrument are more used than any other, and therefore require to be made of hard metal, and the threads must be even and deep; the heads should be broad, in order that a firm hold may be obtained and the screws turned easily. The leveling arrangements of my instruments are fully in accord with the best modern ideas. The parts are strong and the motion easy and uniform.

A caution to be remembered in using an instrument is, that when a screw has been brought to a firm bearing, all turning should stop. An extra effort, however slight, will have a tendency to jam the screw and interfere with easy motion, or bend a thread, and thus open the way for future trouble and expense.

The instruments ordinarily used have four leveling screws arranged in opposing pairs. To level the plate, one pair at a time is turned, each screw in an opposite direction. When the thumbs move towards each other, the bubble goes towards the right; when they move from each other, the bubble goes to the left. Before the operation is commenced, the levels must be parallel with the pairs of screws.

Four screws are most convenient for ordinary instruments, but transits graduated to read angles of 10″ or less, generally have only three leveling screws. The objections to three screws are that they make necessary a little increase in the size of the tripod head, and consequently larger tripod legs and a larger carrying case. The advantages of three leveling screws are that the instrument is made steadier, the centers are relieved of some strain and a perfect horizontal adjustment is obtained, thus insuring a high degree of accuracy. Instruments can be supplied with three or four screws as desired.

All my leveling screws are capped and so constructed as to prevent dust getting on the threads. The transits are also supplied with shifting centers, which permit of a small lateral movement of the upper part of the transit after the tripod is set, and thus enables an accurate setting over a point.

TRIPOD ATTACHMENT. Several devices are in use for securing the instrument to the tripod, but none are so satisfactory as the screw. By the screw the fastening is secure, and timely warning is given before the hold loosens to an extent which will cause a severance of the parts. The only real objection urged against the screw, is the time it takes to attach the instrument by means of it; this objection I have overcome by providing the bottom plate with a double-threaded screw. One single turn and a half will fasten the instrument firmly in place.

THE TELESCOPE. We now come to a part of the transit which is of not much less importance than the graduations. The telescope should have a large field and give a clear definition; it should be achromatic. It is not necessary here to give any description of the principle of the telescope, as all good works on optics sufficiently deal with the subject. It is sufficient to state that my telescopes combine all the latest improvements. The question of power has been carefully considered, and with forty-two years' experience to guide me, the telescopes placed on my transits are equal to all demands which will ever be made upon them. The glasses are ground to special formula, and the best quality of glass used. The telescope tubes are castings, and carefully finished; this insures rigidity and prevents a warping of the telescope. This is the invention of the present head of this house, and was never used by any maker before my instruments were thus fitted. The advantages over drawn brass tubes are apparent.

The axis of the telescope is large, and of hard solid bell metal; the ends are corrugated where they rest in the uprights, thus giving a large bearing with steadiness of motion and securing the line of collimation. The telescope is so placed on the axis that it is perfectly balanced when the sun shade is on.

The object end is furnished with a slide *protector* which prevents dust and grit from injuring the slide, upon which the perfection of the collimation depends.

The eye piece is provided with an improved screw adjustment, permitting the cross hairs to be accurately brought into focus without shaking or jarring the instrument. The telescope swings freely and in a full circle. The eye piece is erecting but can be made inverting if so ordered. An erect eye piece intercepts more light than an inverting one, but is convenient to use. With a little practice, an inverting eye piece offers no great inconvenience, and for stadia work, where brilliancy of the object observed is desirable, it is to be recommended.

STANDARDS. The standards, or uprights, are of the form best calculated to do the work required, of supporting the telescope and its various attachments. An expanded base is well secured to the upper plate and an adjustment is provided for securing the revolution of the telescope in a vertical plane.

COMPASS. As the graduations only occupy a narrow ring on the edge of the plate, there is a vacant space inside the ring and between the standards which is utilized by placing a compass box therein. The needle is as long in all cases as it is possible to put in. The utility of the compass as a portion of the transit is too apparent to require any special remarks. The compasses on my transits are as carefully made as any other part of the instrument, and especial care is taken that the

graduations will coincide exactly with the graduations on the horizontal limb; this, if not done, sometimes causes wide differences in bearings of lines when observed with different instruments. The line of collimation of the telescope must exactly coincide with the north and south line engraved on the compass ring, and the line through the 0° and 180° graduations on the horizontal limb.

As to what is embodied in a good compass, see chapter on compasses.

CLAMP AND TANGENT SCREWS. The clamp and tangent screws are of German silver or aluminum alloys, either metal being used where it is deemed best. For clamping the whole instrument, the tangent screws are either of the improved spring pattern or have two opposing screws of the old pattern. While this latter form requires the use of both hands in setting the sight, it has the advantage of being firmly set and requiring no further attention. With an opposing spring, the screw works as it were, against a cushion, and is liable to derangement if the instrument is standing for any length of time over one point as frequently happens. The upper tangent screw controlling the movement of the plates, is of the improved spring pattern, as it is placed where it is under easy control and is convenient to use, requiring only one hand. The heads of all screws are broad and easy to grasp and turn.

TRIPOD. The tripod legs are made round, but split leg tripods are furnished when ordered; the upper ends of the legs are pressed firmly on each side of a strong tenon on the solid bronze head by a bolt and thumb screw on opposite sides of the leg. To set the tripod up easily, the legs should move freely but not loosely on this tenon; when they become loose they may be tightened by means of the thumb screw—this obviates the necessity for carrying a screw driver or wrench for the purpose. A strap with buckle is fastened to one of the legs near the lower end for the purpose of fastening the legs together for shipment. The lower end of the leg has a brass shoe with iron point, securely fastened and riveted to the wood.

Extension tripods can be furnished if desired; they are convenient when using the transit in confined spaces, as on very steep hillsides.

ATTACHMENTS OF THE TRANSIT.

The foregoing description is of what is known as the plain transit: with it, lines can be ranged and angles turned to right or left of the lines. To increase its range of usefulness, there are certain attachments which are termed "extras." The first generally added, is a level tube beneath the telescope and a clamp and tangent screw on the standards to control it; by adding this level tube, the transit can then be used for leveling. A vertical circle, or arc, added to the telescope axis with a vernier on the standard, makes it possible to take vertical angles. Two extra hairs (called stadia hairs) placed inside the telescope enable distances to be measured by rod readings. A graduated head placed on the tangent screw of the telescope makes what is termed a gradienter; by its means, *grades* can be established, and *horizontal distances, vertical angles* and *differences of level* can be measured with great rapidity.

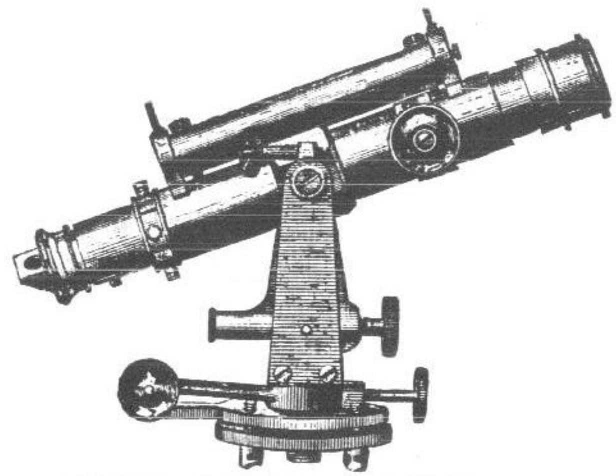
THE GRADIENTER. The head of the screw on the clamp for the telescope is divided into one hundred equal parts; over it is a scale which is divided into spaces, each of which is equal to one revolution of the screw, so that by comparing the edge of the head with the scale, the number of revolutions made can be ascertained. If the telescope is clamped and the screw turned, it will be seen that the end of the telescope will be moved vertically, and as one complete revolution of the screw will move the horizontal cross wire over a space of one foot on the rod held at a distance of one hundred feet, it may be easily seen that distances can be read by means of the gradienter with the same facility as with the stadia.

Grades can be established as follows: First level the instrument and then bring the bubble under the telescope to the center of the tube, move the gradienter screw until the zero is opposite the zero on the scale, and clamp the telescope; then turn off as many spaces on the head as there are hundredths of feet to the hundred in the grade to be

established. Sometimes there are fewer graduations on the screw than stated above, but the principle and method are the same.

For setting off the variation of the needle, an adjustable arc is often placed inside the compass box. In my transits, the variation arc is placed outside the compass ring, thus obtaining a large radius, and being graduated to minutes, the engineer is enabled to read and set the variation with ease.

SAEGMULLER SOLAR ATTACHMENT. As the transit is sometimes used to retrace lines which have been previously run with a needle, or to run lines the bearing of which it is necessary to correct by observations on the sun in order to obtain the true bearing, there have been various forms of solar attachments invented. The best known and most widely used are the Burt and the Saegmuller; I keep both makes and put them on any transit to order. Directions for their use are given in all standard works on surveying, and the makers get out special directions for use, with tables, etc. The Saegmuller has the advantage over the Burt of having a telescope, and a transit fitted with it can be used for sighting down shafts like a mining transit.

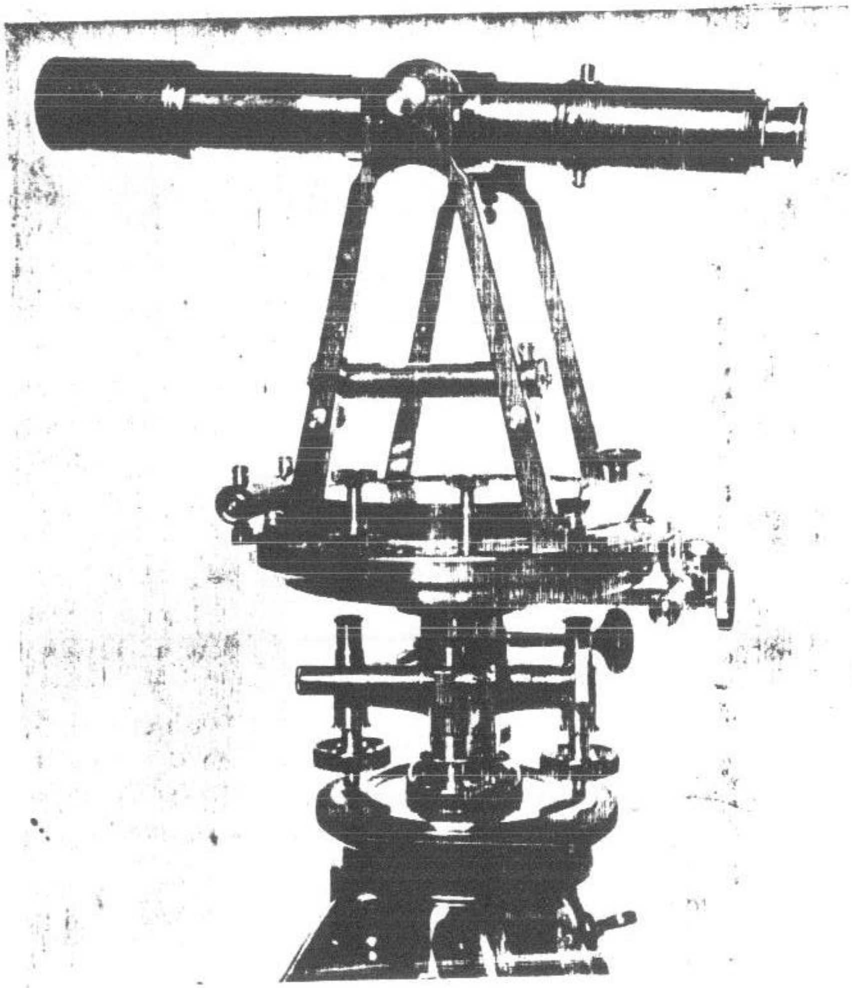


SAEGMULLER SOLAR ATTACHMENT.

The transit can be provided with open sights attached to the standards to make offsets at right angles to the line of collimation of the telescope, if such sights are desired.

A transit with all the attachments mentioned, is called a complete transit.

All transits are furnished with a carrying case supplied with a leather strap, rubber supports, good lock and hooks, and contains plumb bob, sun shade, adjusting pins and magnifying glass.



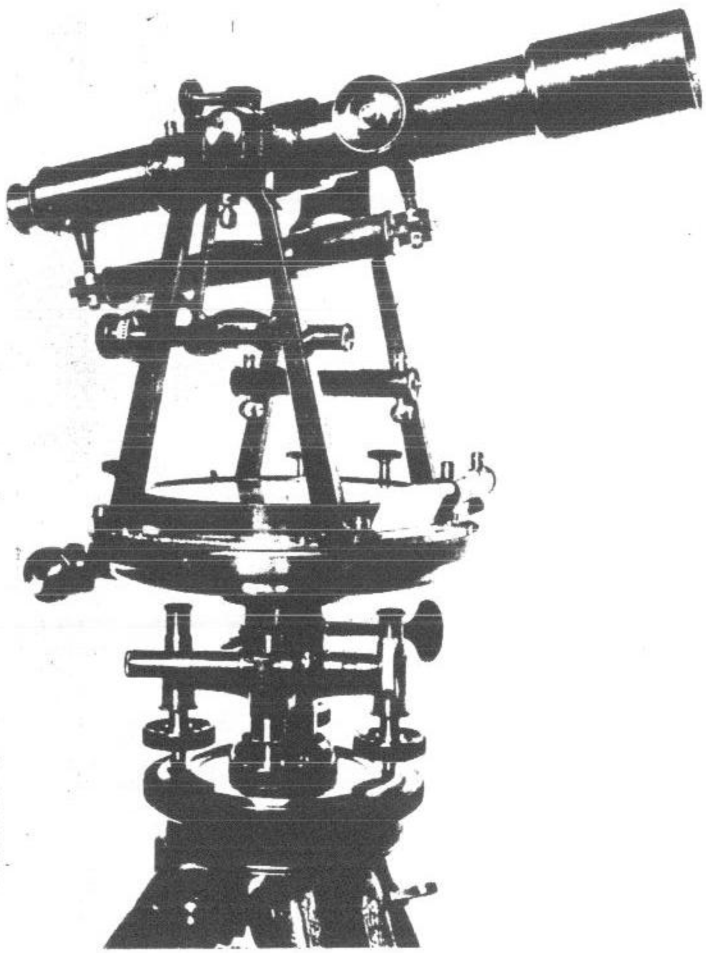
TRANSIT No. 1—PRICE $185.

TRANSIT No. I.

The engineers' plain transit as manufactured by J. C. Sala, has an 11-inch telescope, which is provided with achromatic lenses of high power, slide protector, sun and dust shades. The telescope reverses at both ends. The object glass of the telescope has an aperture of 1¼ inches; its eye piece is provided with a screw adjustment. The axis of the telescope is large and of solid hard bell metal. The horizontal plate is of seven inches diameter, with double verniers graduated on solid silver, reading to thirty seconds. The circle of the compass box is graduated to thirty minutes, the needle is 4⅜ inches long, with agate bearing; the compass box has on its outside, a variation plate with vernier reading to single minutes.

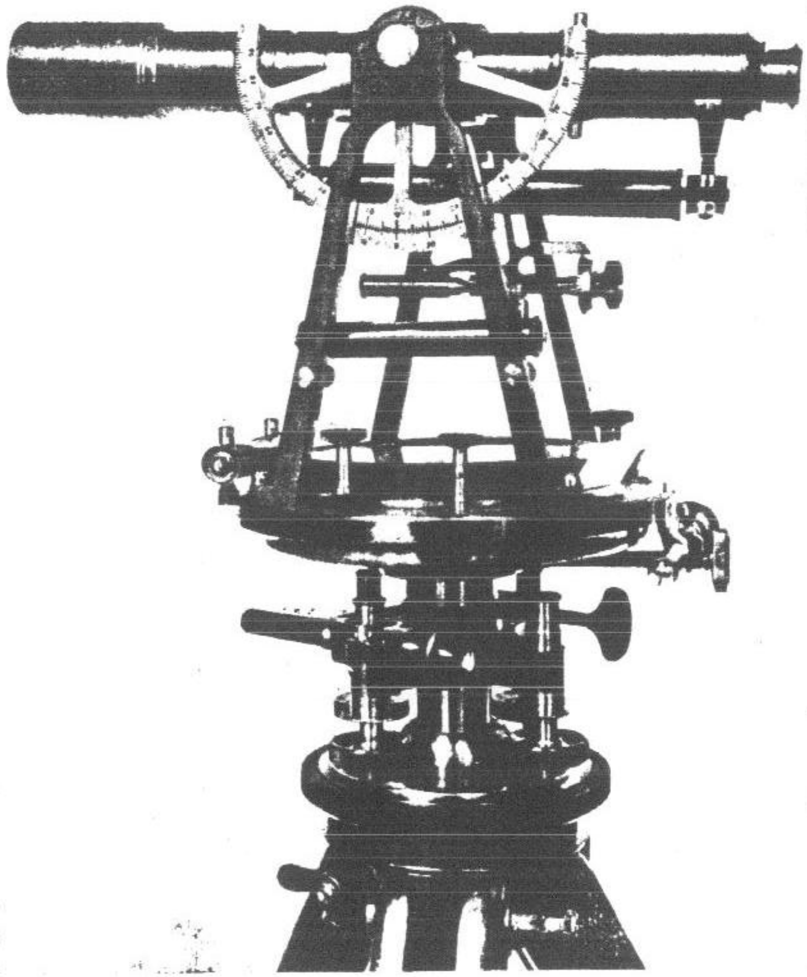
The small graduated bubbles of the levels on the horizontal plate are ground and graduated to the greatest accuracy; the tangent screw of the horizontal plate is provided with a compensating spring; the tangent screw to the center of the instrument is also provided with a compensating spring. The leveling screws are protected with a dust and grit cap covering the whole of the thread of these screws; they rest upon a shifting plate which moves upon the bottom plate screwed to the tripod; this allows the instrument to be shifted accurately over any given point, and when the leveling screws are set, the shifting plate becomes fixed. The center upon which most of the efficacy and accuracy of the instrument depends, has a bearing length of 4½ inches.

The tripod is made with either split, solid or extension legs, as desired. The case is furnished with a leather strap, rubber supports, good lock and hooks, and contains plumb bob, sun shade, adjusting pins and magnifying glass.



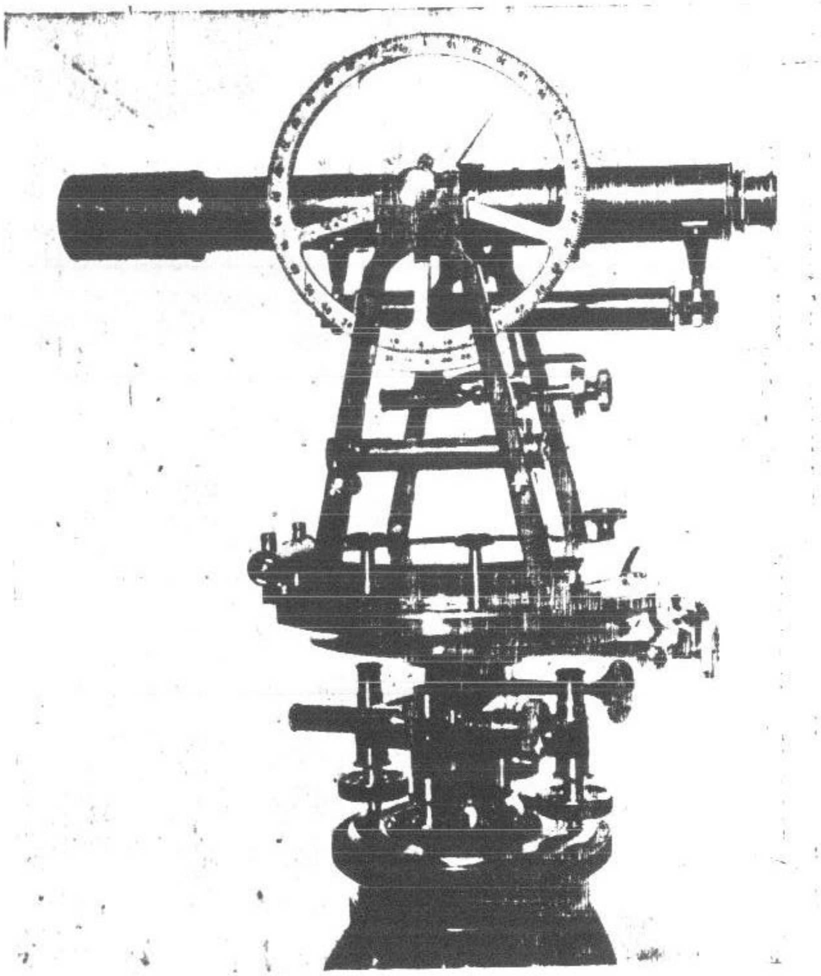
ENGINEERS' TRANSIT, No. 2—PRICE $210.

The description of this instrument is the same in size and particulars as No. 1, with the addition of clamp and tangent attachment to axis, and level to telescope, with a finely ground and graduated bubble.



ENGINEERS' COMPLETE TRANSIT, No. 3—PRICE $235.

This instrument is the same in size and particulars as No. 1, with the addition of clamp and tangent attachment to axis and level to telescope, with a finely ground and granulated bubble: vertical arc with vernier reading to thirty seconds; (all graduations on **solid silver**) this instrument is the most desirable, having all the necessary attachments for general work, being of good size, strong and yet not too heavy to carry.



SURVEYORS' TRANSIT, No. 4—PRICE $250.

Has a horizontal plate 8 inches in diameter, with two verniers reading to thirty seconds. Length of needle 5 inches. Clamp and tangent attachment to axis and level to telescope, with a finely ground and graduated bubble; vertical circle, 5 inches in diameter, and vernier reading thirty seconds. For other particulars, see description of No. 1.

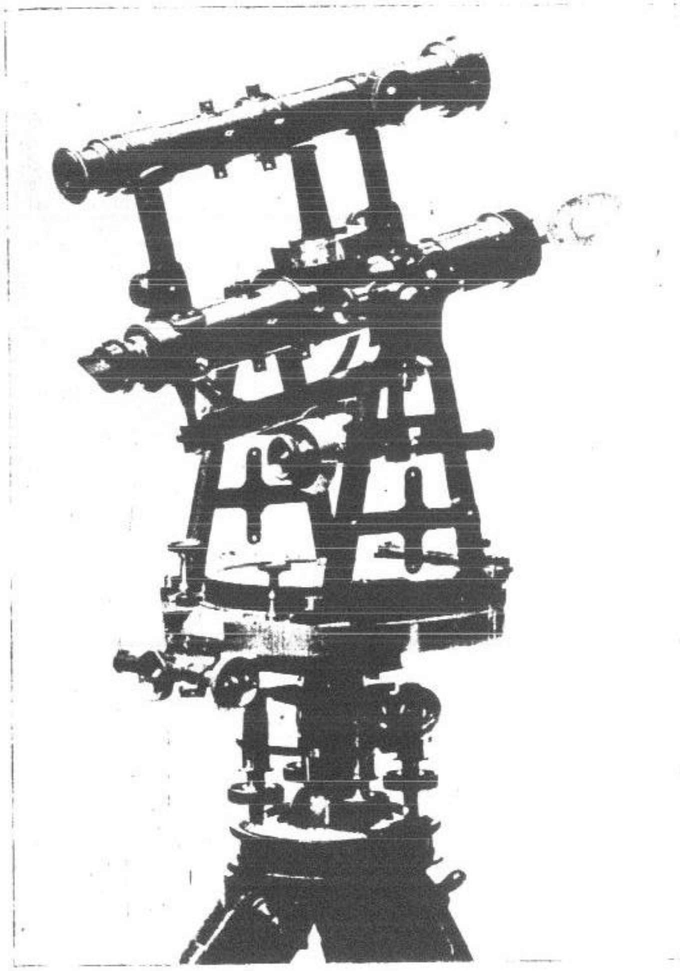
COMBINED MINING, MOUNTAIN AND SOLAR TRANSIT.

I manufacture a combined mining and mountain transit with two telescopes parallel to each other; the upper one, although detachable, is securely fastened to the one revolving in the standards, by supports and thumb screws. The telescopes are supplied with achromatic lenses of twenty magnifying power, rack movement for the object glass, fixed or adjustable stadia hairs, movable prism to fit the eye pieces of either telescope. To the telescope revolving in the standards is attached an hour arc and center column for a solar attachment, and under it a level of precision; the divisions of its bubble reading to ten seconds of arc. Both telescopes are provided with a slide protector and a sun shade, also with a silver reflector for illuminating cross hairs in mining or night work. The vertical circle attached to the axis of the telescope and its vernier are graduated on solid silver, and read to either thirty seconds or one minute, as desired.

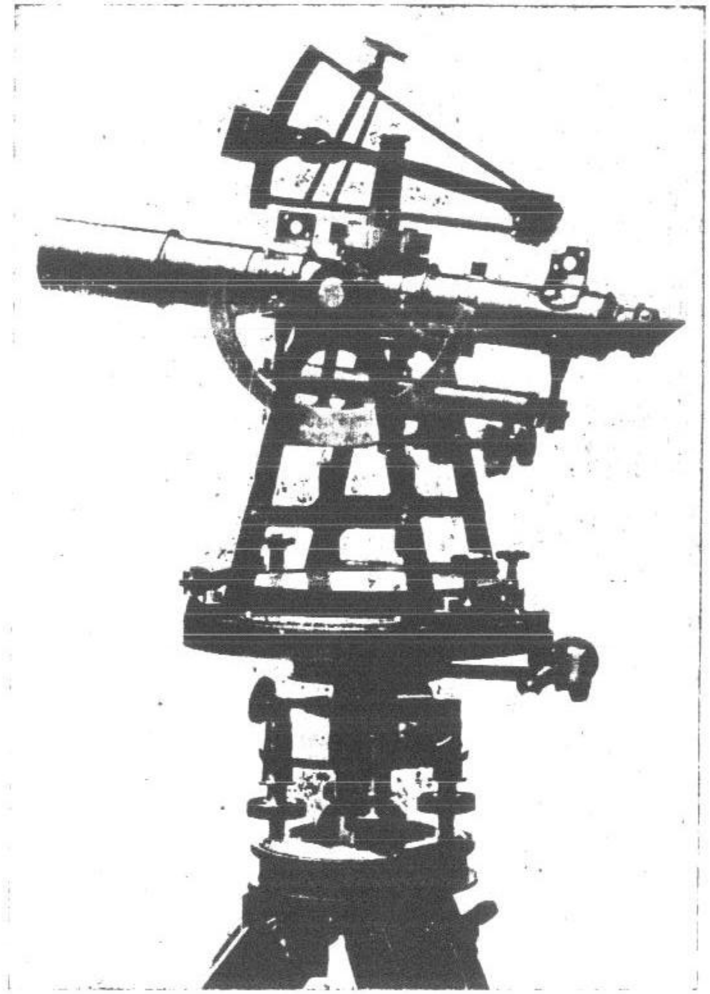
The micrometer tangent screw with compensating spring on the upright, is provided with a gradienter attachment. The standards are also furnished with open sights giving a line of 90° to the line of collimation of the telescopes. The circle of the compass box is graduated to thirty minutes, the needle being 3¾ inches long, with agate bearing. The compass box has on its outside, a variation plate with vernier reading to minutes.

The small graduated bubbles of the levels on the horizontal plate are ground and graduated to the greatest accuracy. The horizontal limb and verniers are graduated on solid silver, and read directly under the eye piece and object glass of the telescope to thirty seconds on a beveled surface at an angle of 30°. The tangent screw is provided with a compensating spring.

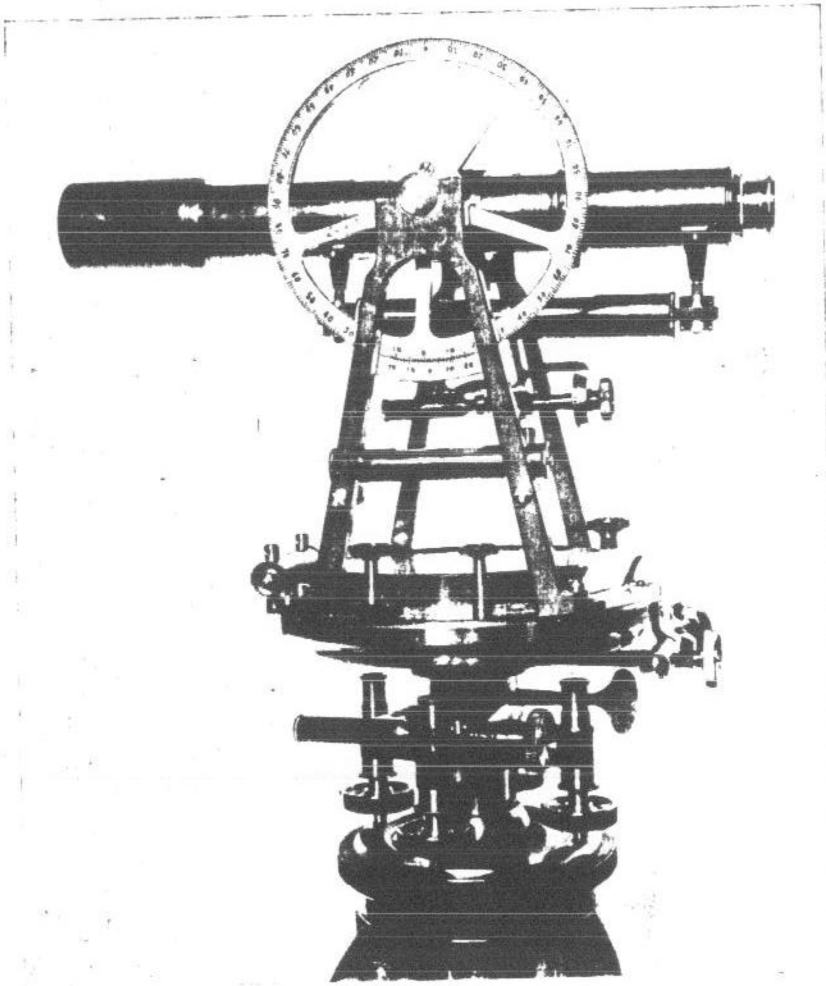
The leveling screws are protected by caps and rest upon a shifting plate which moves upon the bottom plate screwed to the tripod; this allows the instrument to be shifted accurately over any given point, and when the leveling screws are set, the shifting plate becomes fixed. The center, upon which most of the efficiency of the instrument depends, has a bearing length of four inches. The tripod is made with either split, solid or extension legs, as desired.



COMBINED MINING, MOUNTAIN AND SOLAR TRANSIT, No. 5, WITH DOUBLE TELESCOPE TO TAKE VERTICAL ANGLES—PRICE $335.

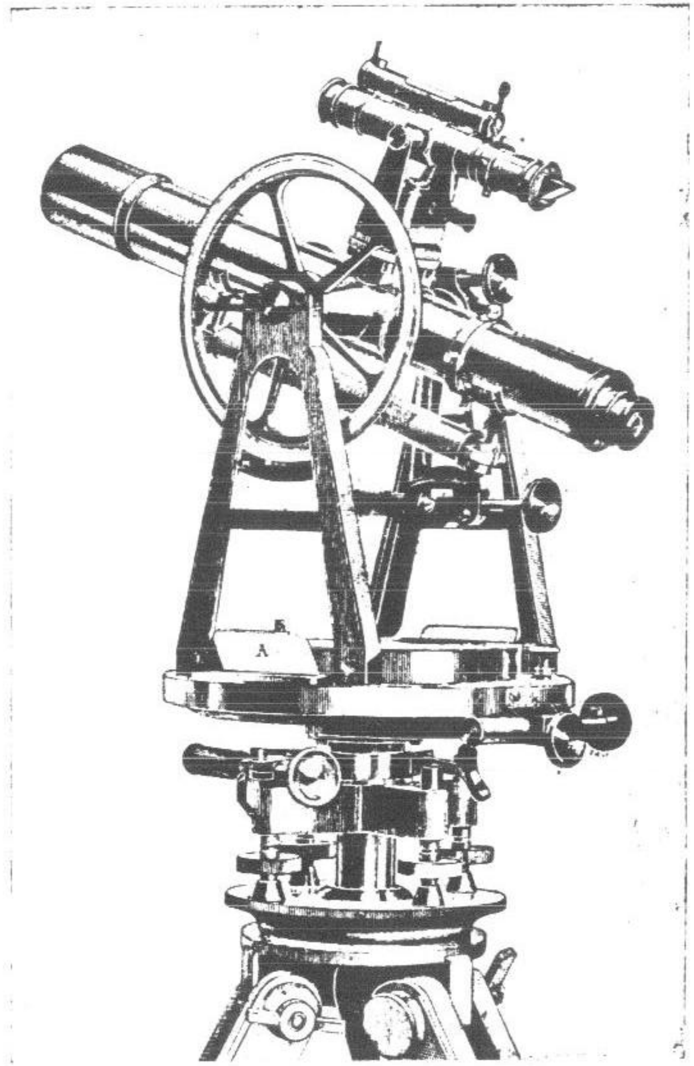


COMBINED MINING, MOUNTAIN AND SOLAR TRANSIT, No. 5—SHOWING SOLAR ATTACHMENT.



LIGHT MOUNTAIN TRANSIT, No. 6—PRICE $220.

Having a horizontal plate 6 inches in diameter, with double verniers reading thirty seconds; improved spring tangent screws, magnetic needle 3¾ inches long, with adjustable variation arc, 4-inch *vertical circle*. A telescope 8 inches in length, with high magnifying power, aperture of object glass 1 inch; erect eye-piece, and reversing at both ends. To the tangent screw of the vertical arc is attached a gradienter, and by its means, grades, horizontal distances, vertical angles and differences of level can be obtained.



COMBINED MINING AND SOLAR TRANSIT, No. 7—PRICE, $290.

This instrument is the same as No. 4, only differing from it in having the Saegmuller attachment; this answers all the purposes of a side telescope in taking perpendicular sights in mining work. The Saegmuller Solar Attachment to this instrument enables the engineer to establish accurately the astronomical meridian The advantages of this solar attachment are:—It is more accurate, it is simpler and easier of adjustment, it can be used when the sun is partly occsured by the clouds, it can be used where the sun is quite close to the meridian, the time can be obtained with it reliable to within a few seconds with perfect ease, and as stated above, it can be used as a vertical telescope in mining surveying.

HOW TO ADJUST THE TRANSIT.

Every transit should be properly adjusted by the maker before leaving his hands, they are however liable to derangement by transportation, and a few remarks on the adjustments will not prove useless. These are the levels, the standards, the line of collimation, the vertical circle and the level to telescope.

TO ADJUST THE LEVELS. Set the instrument upon its tripod as nearly level as possible, unclamp the plates and bring the levels in line with the leveling screws, and by these bring the bubbles between the lines, and when both are in place, turn the instrument half-way around; if the bubbles stay in the center, they will need no correction, but if not, turn the small screw at the ends of the levels with the adjusting pin until the bubbles are moved half the error, then bring the bubbles in center by the leveling screws, and repeat the operation until the bubbles remain in the center, and the adjustment will be complete.

Care should be taken to loosen one end of the level screw before tightening the other, so as to not strain the tube.

TO ADJUST THE STANDARDS. Set up the instrument in a place where a very steep point can be obtained, giving a long vertical line. Carefully level the instrument and bring the wires on some high object, clamp the plates, then bring the telescope down until the wires strike some well defined point at the base, turn the instrument half round, fix the wires on the same high point, clamp the plates and bring the telescope down; if the wires strike the same point as before, the vertical adjustment is correct, if not, by means of the adjusting screw, placed in one of the standards, raise or lower the adjusted piece half the difference found, and repeat until the adjustment is correct.

TO ADJUST THE LINE OF COLLIMATION. 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 200 to 500 feet; determine if the vertical wire is plumb, by clamping the instrument firmly 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 head 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.

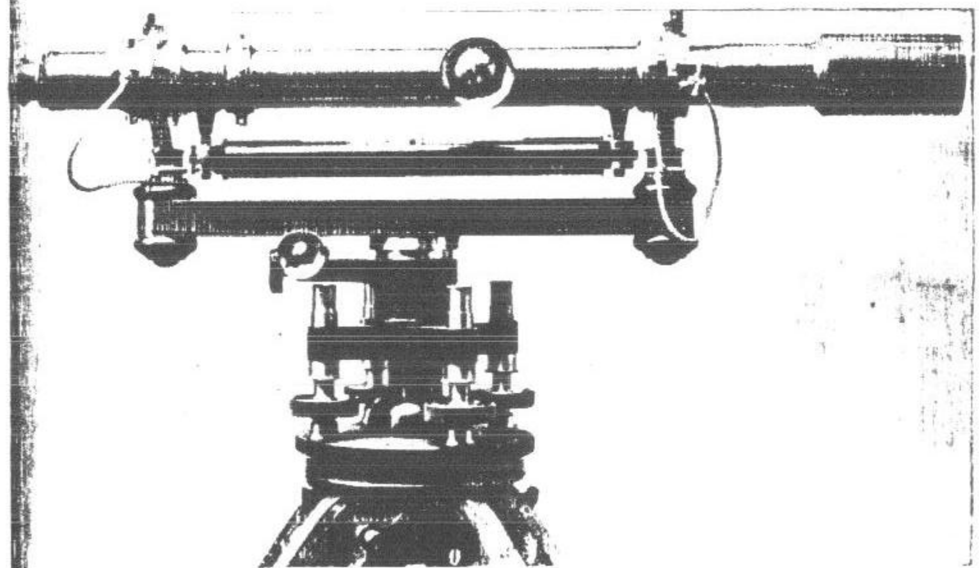
Now, having found or placed an object which the vertical wire bisects, unclamp the instrument, turn it half way around and direct the telescope to the first object selected; having bisected this with the wires, again clamp the instrument, revolve the telescope, and note if the vertical wire bisects the second object observed. Should this happen, it will indicate that the wires are in adjustment, and the points bisected are with that of the center of the instrument, in the same straight line; if not, then move one-quarter of the difference, using the two capstan head screws on the sides of the telescope, these being the ones which affect the position of the vertical wire, and repeat until the line of collimation is adjusted.

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.

TO ADJUST THE VERTICAL CIRCLE. Having the instrument firmly set up and carefully leveled, bring into line the zeros of the circle and vernier, and with the telescope find or place some well defined point or line, from 100 to 500 feet distant, which is cut by the horizontal wire. Turn the instrument half way 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 capstan head screws, which fasten the vernier, and move the zero of the vernier over half the error; bring the zeros again into coincidence, and proceed precisely as at first, until the error is entirely corrected, when the adjustment will be complete. A slight error may be most readily removed by putting the zeros in line and then moving the wire itself over half the interval.

The level is adjusted by bringing the bubble carefully into the center by the nuts at each end, and when there is a vertical circle on the instrument, this should be done when the zeros of the circle and vernier are in line and in adjustment.

To Adjust the Level on Telescope. 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, drive a stake at a convenient distance, say from 100 to 300 feet, and note the height cut by the horizontal wire upon a staff set on the top of the stake. Fix another stake in the opposite direction, and at the same distance from the instrument, and without disturbing the telescope, turn the instrument upon its spindle, set the staff upon the stake and drive in the ground until the same height is indicated as in the first observation; the top of the two stakes will then be in the same horizontal line, however much the telescope may be out of level. Now remove the instrument from fifty to one hundred feet to one side of either stakes, and in line with both; again level the instrument, clamp the telescope as nearly horizontal as may be, and note the heights indicated upon the staff placed first upon the nearest and then upon the most distant stake. If both agree, the telescope is level; if they do not agree, then with the tangent screw move the wire over nearly the whole error, as shown at the distant stake, and repeat the observation as described. Proceed thus until the horizontal wire will indicate the same height at both stakes, when the telescope will be truly horizontal. Taking care not to disturb its position, bring the bubble into the center by the little leveling nuts at the end of the tube, when the adjustment will be completed.



THE LEVEL.

The level is an instrument of precision for ascertaining the difference in elevation between points. There are two different forms in general use. The Dumpy level is of simple construction and excellent for working; it retains its adjustments much longer than a Y level, but once out, the adjustments are not so easily made as in the latter, and for this reason many prefer the Y level. Both forms are made by this house.

The remarks about the telescope, centers, leveling screws, clamp and tangent screws, level tubes, tripods, and general workmanship in the chapter on the transit, apply also to our levels. The workmanship is the best and the latest improvements are adopted.

ENGINEERS' Y LEVEL, No. 8

PRICE $150.

The telescope is 21 inches long, has a power of 50 diameters, aperture of object glass 1⅝ inches, clear; erect eye piece, achromatic perfect, defines sharply, has a flat field with great penetrating power, which is essential in good leveling. The eye piece is provided with a semi-circular movement, very convenient for focussing the cross wires without shaking the instrument. The telescope has two extra wires for stadia measurements. The collars are of the hardest metal, with clamp screws to keep the cross wires in horizontal position. The spirit level is 8¼ inches long; the bubble is very sensitive and finely graduated. The object end is provided with a slide protector, which prevents dirt or dust from injuring the slide upon which perfect adjustment depends. The center is 3¾ inches long, stout and of the hardest *bell metal or steel*. The four large leveling screws are perfectly covered. It has an improved spring tangent screw and a clamp to the center. The bar is 13 inches long, very heavy, and it is attached to the tripod in the same manner as transit No. 1.

The case is furnished with heavy leather straps, rubber supports, good lock, adjusting pins and sun shade.

ENGINEERS' Y LEVEL, No. 9

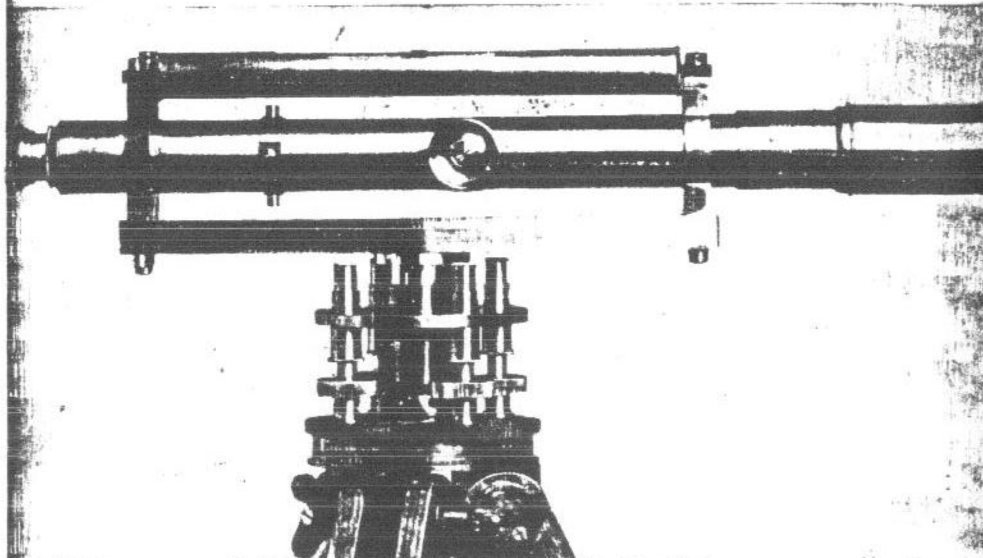
PRICE $140.

Telescope 19 inches, (description same as No. 8) bar 11 inches long, heavy; length of spirit level 7½ inches. Center and leveling screws (as described in No. 8).

ENGINEERS' Y LEVEL, No. 10

PRICE $130.

Telescope 17 inches long, aperture of object glass 1¼ inch, (for description see No. 8) bar 10 inches long, spirit level 6½ inches, with a fine graduated bubble. Center and leveling screws (as described in No. 8). This instrument is the most convenient size for general work.



DUMPY LEVEL, No. 11—PRICE $90.

This level is expressly designed for irrigation, having an erecting telescope 16 inches long, with a magnifying power of thirty diameters, and a large sensitive bubble, with the level tube enclosed in a revolving protecting tube, thus allowing the bubble to be perfectly covered when not in use.

This level has been approved by competent irrigation engineers, as being the most suitable for their use.

No. 12—Architects' or builders' level, with a telescope 12 inches long, erect eye piece, ground graduated bubbles. Price $60.

No. 13—Farmers' or drainage levels of all description, from $15 to $40.

HYDROGRAPHIC Y LEVEL.

On special order I make a superior Y level with three leveling screws in place of four, and a reflecting mirror to enable a quick and accurate setting of the bubble without rendering necessary a change of position by the observer. Price upon application.

REVERSION LEVELS.

Sometimes the wyes in which the level telescope rest or the collars of the telescope wear unequally, and the bubble underneath the telescope if desired can be so ground that the telescope can be revolved in its collars and the bubble thus brought on the upper side, and indicate in that position also a level line (thus correct levels can be taken when the collars are badly worn). While this is an ingenious idea, it is based upon the same principle as the repeating of angles in transit work. If the engineer desires to go to all the trouble necessary, he can do as good work with his instrument supplied with an ordinary bubble.

I grind bubbles for reversion levels to order.

HOW TO ADJUST THE LEVEL.

To Adjust the Level Bubble. Clamp the instrument over either pair of leveling screws and bring the bubble into the center of the tube; now turn the telescope in the wyes, so as to bring the level tube on either side of the center of the bar. Should the bubble run to the end, it would show that the vertical plane, passing through the center of the bubble, was not parallel to that drawn through the axis

of the telescope rings. To correct the error, bring the bubble entirely 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 center of the bar, and the bubble to the center; 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 center of the bar. The necessity of 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 a 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 center 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 center 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 position at right angles to the vertical axis, so that the bubble will remain in the center during an entire revolution of the instrument. To do this, bring the level tube directly over the center 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 center and proceed precisely as previously 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 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 in any position.

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 100 to 500 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, bring the wires in the center of the field of view by the other capstan screws. The inverting property 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 be here 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.

THE SURVEYORS' COMPASS.

One of the oldest of instruments for ranging lines, the compass has at last come to be regarded as of little value in accurate work. In running old lines however, and for work of a preliminary nature, it is safe to say the compass will never be supplanted. There are certain classes of work, requiring speed rather than accuracy, which are very satisfactorily performed by means of the compass, and to supply the demand, I keep a good stock of all kinds.

The Needle. All compass work depends upon the accuracy with which the needle reads. It is essential therefore that the needle be of hard steel and tempered throughout to retain its magnetism. It should be thin and at the same time have enough surface to be strongly magnetic.

The needle should be perfectly straight and the two points should read precisely 180° different in any part of the box. It should be so sensitive that when drawn away from its pointing by a piece of metal, it will always return to the same reading when the attraction is withdrawn. Four things affect the sensitiveness of a needle: the form of the pivot on which it swings, the sharpness of the pivot, the strength of the magnetism, and the bearing on the jeweled pivot.

When a needle is sluggish it should be lifted off the pivot and the point of the pivot examined with a glass; if it is dull or bent, take a fine oil stone and holding it against the point at an angle of about 25°, turn the compass slowly on its center. This will grind a good point if carefully done. If, after ascertaining that the point is sharp, the needle is still not sensitive, it may then need to be remagnetized. If the pivot point is bent or not truly ground, the two ends of the needle will not read 180° different; to preserve it, the needle should always be screwed up when the instrument is carried.

As the generally accepted theory is that a needle retains its magnetism longer when lying in the meridian, it is well to always let the needle swing freely when the instrument is not in use, taking care to keep the instrument level so the needle can not bend the pivot. A quivering motion in the needle when swinging freely, is a very good indication that it is well made, the center of gravity being low.

REMAGNETIZING. To remagnetize a needle, take it off the pivot and hold the south end in the left hand; take a good magnet in the other hand and place the positive end on the needle. Draw the magnet slowly toward the north end and clear off the needle. Return it in a large circle back to the starting point and repeat the operation until the work is done.

Never rub a magnet back and forward on a needle.

ERRORS IN THE INSTRUMENT. To determine whether the compass itself has iron in it, set three stakes in the ground in the form of a triangle. Set on one and read the angle (preferably 10 or 15 degrees) between the other two. Take this angle on different parts of the graduated circle, and if the reading is the same at all points there is no local attraction in the instrument.

In a compass attached to a transit, it is a good plan after setting the instrument so that both compass needle and vernier read 0, to go round the circle, setting the vernier ten degrees ahead each time, and noting whether the compass needle also describes an arc of precisely ten degrees; if it does not, there is some attraction in the instrument.

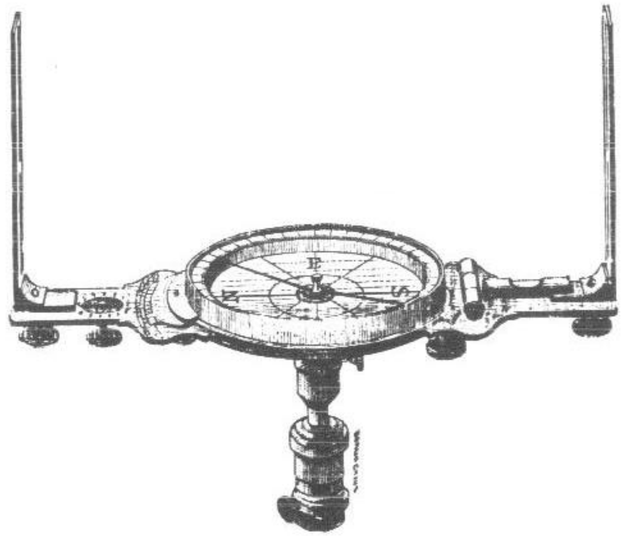
A fine coil of wire is placed on the south end of needles used in the northern hemisphere to balance them; this wire must be shifted as the compass is changed to another latitude, and in the southern hemisphere must be placed on the north end of the needle.

GRADUATIONS. The graduations on the compass box should begin at the north point, and run 90° in both directions; then decrease to 0 again at the south point. In order that the needle reading may indicate the direction of the telescope, the lines joining the zeros of the ordinary compass ring must be in the same vertical plane with the line of collimation of the telescope, and the letters denoting the cardinal points, east and west, must be transposed; *i. e.*, when the letter N is towards the north, the letter W should be towards the east.

The needle always indicates magnetic north, and in the case of

instruments unprovided with means of setting off the local variation of the needle, all the readings of the needle must be corrected for this local deviation.

In some compasses the graduations begin at 0 at the north end and run to 360 in the direction of the movements of the hands of a clock; this guards against reading N for S, E for W, and vice versa.



VERNIER COMPASS, No. 14—PRICE $50.

Surveyors' compass, 5½-inch needle, 14-inch plate, vernier to set off the magnetic variation of the needle, two levels with ground bubbles. Open sights, which enable more accurate observations to be taken than with the ordinary sights. Brass head tripod. Cherry box, with strap.

No. 15—Plain compass, plate 12 inches long, open sight, needle 4¾ inches long, two levels, Jacob staff mountings. Cherry box, with strap. Price $35.00.

CLINOMETER COMPASS, No. 16—PRICE $55.

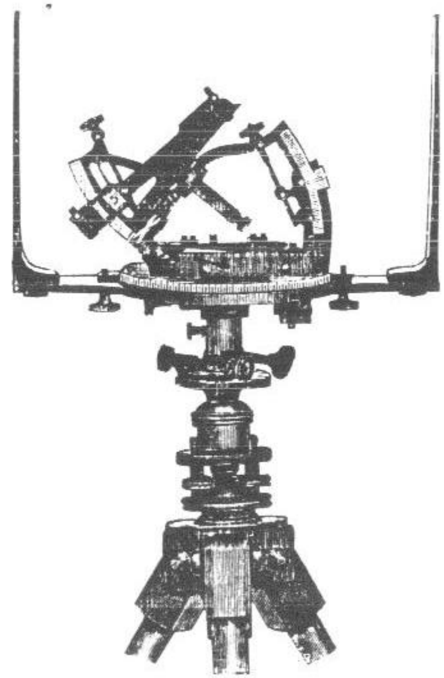
This instrument is very useful for mining and for road-making: the sights are placed 9 inches apart, having a slot for straight lines, a cross and a pin hole at each end for leveling purposes, a quadrant divided into half degrees, with pointer and clamp to hold it in any position. Perpendicular angles can be taken with this instrument. Compass divided in half degrees, needle 3⅜ inches long. Ball and socket with brass head tripod. The instrment is packed in a small portable box, with strap.

SURVEYORS' POCKET COMPASS, No. 17—PRICE $25.

With extra plate to set off variation of the needle, two spirit levels, needle 4½ inches long, with Jacob staff. In my compasses, the variation is put on top of the ring, which allows it to be read more easily.

The same, with brass head tripod, price $30.00.

No. 18—The same, but one inch smaller, with Jacob staff. Price $20.00.



SOLAR COMPASS, No. 19—PRICE $220.

The horizontal plate of this instrument is 6¼ inches in diameter, and the lower plate is 12 inches long. The plate has one double vernier reading single minutes, the declination and latitude arcs are also provided with verniers reading single minutes. The length of needle is 4 inches. The instrument is furnished with ball and socket, and with leveling screws which can be used separately or together. All the graduations are on **Solid Silver.** The instrument is small, compact and very strong, and obviates the necessity of carrying a much heavier instrument.

A telescope can be attached to this instrument if desired.

THE SOLAR COMPASS.

As the principal objections to the magnetic needle arise from the fact that the needle is easily attracted from its true direction by the near presence of metal, the solar compass was invented; by it, true lines are run from observations on the sun, but its use is restricted to sunshiny days and certain hours of the day.

The first practical solar compass was invented by William A. Burt of Michigan, and patented by him in 1836. The principle consists in a practical scientific application of the principles which govern the motion of the sun, that when the instrument is placed in adjustment, and the sun's image brought to a certain place, the instrument must necessarily be in the meridian. This is indicated by the zeros of the horizontal plates, and any other angle can be read off by graduated plates. As solar work can only be performed in clear weather, the instrument is furnished with needle and graduated plates.

As first made, the solar was without tangent screws, and with ordinary ball and socket motion, being made as simple as possible for use in the wooded brush country where the government surveys were then made. Since then, and with the progress of surveys into more open country, the tangent screws and the transit tripod have been added.

When the weather is clear, the solar compass works with much greater rapidity than either compass or transit. With ordinary care, and instrument in adjustment, its result should not vary in rapid work more than from one to two minutes from the correct line, a result unattainable in the ordinary compass, and requiring careful work to ensure in long continued lines with transit.

MOUNTINGS. Compasses are mounted on a Jacob staff, which is a single sharp-pointed leg to thrust into the ground, or on tripods.

The larger compasses generally have telescopes instead of open sights.

ADJUSTMENTS OF THE SOLAR COMPASS.

1. *To make the plane of the bubbles perpendicular to the vertical axis.* This is done by reversals about the vertical axis, whereby the error is doubled, and at the same time made apparent.

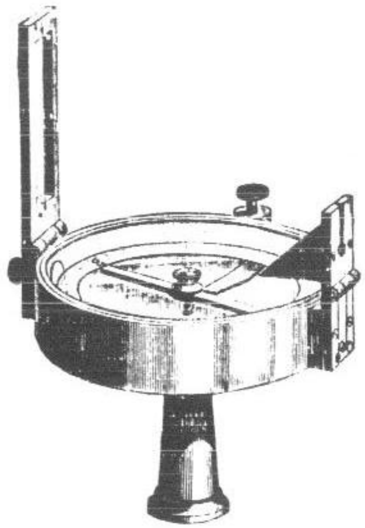
2. *To adjust the lines of collimation.* The declination arm has two lines of collimation established by a lens and a graduated disk at either end of the arm. The lens at the arc and vernier end is for the north declination from March 20th to September 20th, for the south declination, September 20th to March 20th, the declination arm is revolved 180°. This adjustment consists in making the two lines of collimation parallel to each other; to accomplish this, an adjuster is necessary, and therefore this part of the adjustment is generally left to the instrument maker.

3. *To make the declination arc read zero when the line of collimation is at right angles to the polar axis.* Set the vernier on the declination arc to read zero; by the latitude arc bring the line of collimation upon the sun. When carefully centered on the disk, revolve the arm quickly 180° about the polar axis, and observe if the image now falls exactly on the other disk; if not, move the declination arm by means of the tangent screw until the image falls exactly on the disk. Read the declination arc, loosen the screws in the vernier plate and move it back one-half its distance from the zero reading. Center the image again, reverse 180° and test. Repeat until by reversing, the image falls in the center. If the vernier scale is not adjustable *one-half*, the total movement is the error of the declination arc. Make this adjustment when the sun is near the Zenith.

5. *To adjust the vernier of the latitude arc.* Find the latitude of the place either from a good map, compound it from table No. XI by a sextant or transit observation. Set up the compass a few minutes before noon, with the true declination (compounded for that day from the Ephemeris) set off. Bring the line of collimation upon the sun,

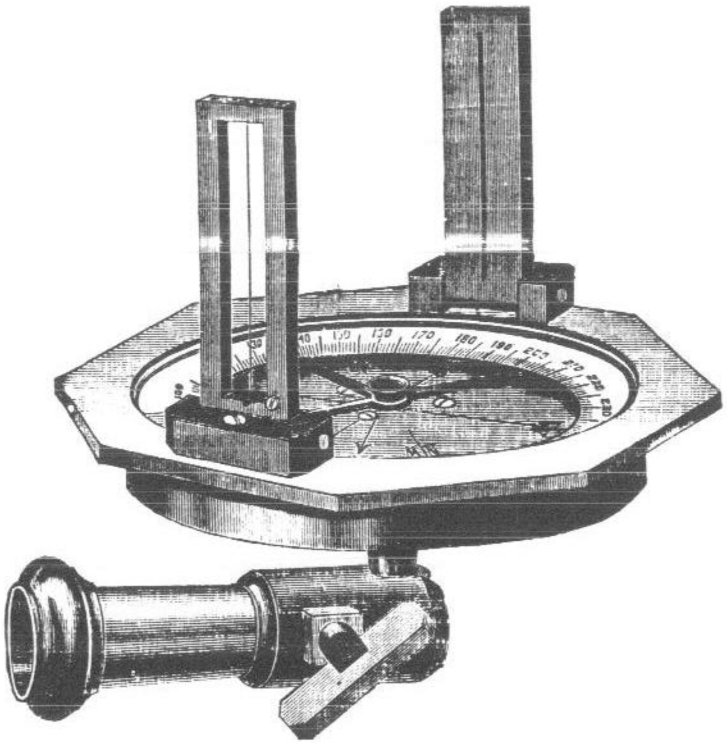
having it clamped in the plane of the sights or at the twelve-hour angle, and follow it by moving the latitude arc by means of the tangent screw, and by turning the instrument on its vertical axis. When the sun has attained its highest altitude, read the latitude arc; compare this with the known latitude, correct on the vernier if possible, if not, record the error.

Other adjustments being either the same as in the limbs of the transit or belonging entirely to the instrument maker's resort, I omit them here.



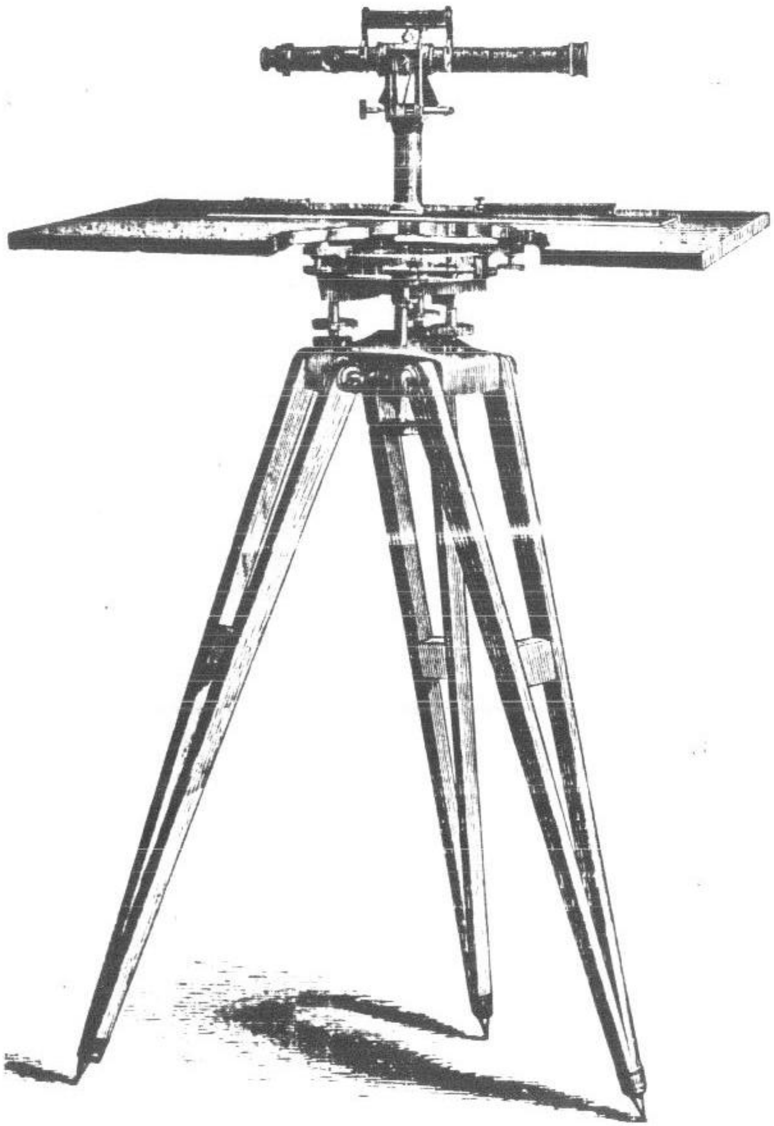
PRISMATIC COMPASS, No. 20—PRICE $15.

This compass is 3 inches in diameter, with divided ring on needle and folding sights; packed in neat case, very convenient for reconnoissance. Prices range between $15 and $18.



POCKET COMPASS, No. 21.

These compasses have folding sights. Prices range between $6.00 and $25.00.



THE PLANE TABLE—No. 22.

THE PLANE TABLE.

This instrument is made by me in two sizes. Size 1 has a larger base for the table to rest on than is usual in plane tables, and therefore is particularly adapted for the more accurate work in topographical surveying. For work of a more general character, where greater portability is required, I make this base of the ordinary size, like those used in the U. S. Coast Survey, but with all the improvements of the larger base. One tangent screw is attached to the lower part, and this, as well as the alidade, is built on the skeleton plan, so as to make them light and stiff. The alidade is provided with a powerful telescope, striding level, vertical arc, small round level and stadia wires, and is so arranged that lines can be ruled in the vertical plane of the line of collimation of the telescope.

Price of plane table No. 1, including table, detached compass, 2 cases, screw-drivers, clamps, etc.,	$275.00
Price of plane table No. 2 (size usually made),	250.00

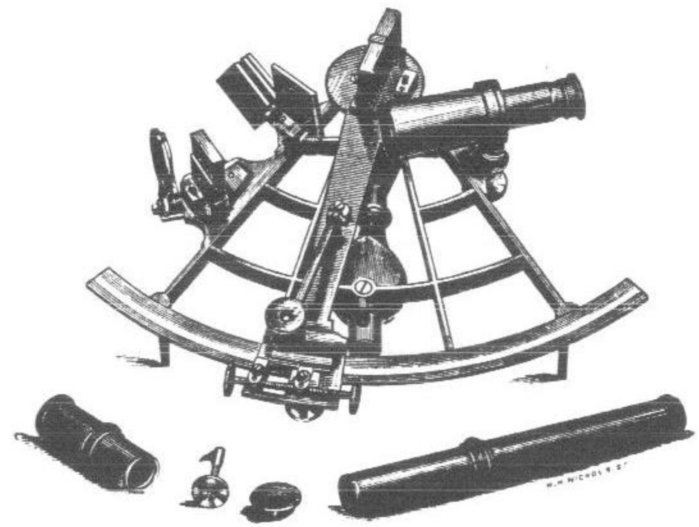
The plane table is the instrument used almost exclusively by the U. S. Coast and Geodetic Surveyors for filling in of the topographical charts.

Plane table complete with achromatic telescope 11 inches long, with sunshade, object glass 1⅛-inch, with rack movement; spiral adjustment to eye piece, magnifying about twenty-four times. The telescope revolves on axis mounted in standards 6½ inches high, with arc graduated to half degrees, vernier reading to one minute. Alidade 18 inches long, two inches wide, one edge beveled. Detachable table 18x24 inches, mounted on tripod by a large plate, resting on three leveling screws. Either compass with 3-inch or 4½-inch needle, plumb bob, plumbing bar and universal level.

ADJUSTMENTS OF THE PLANE TABLE.

The adjustment of the alidade being the same as the adjustment of the telescope and vertical arc in the transit, I refer to the adjustment of the transit for these adjustments. There is only one other adjustment.

To make the axis of the plate-bubbles parallel to the plane table. Level the table with the alidade in any position, noting the readings of the bubbles, mark the exact position of the alidade on the table, take it up carefully and reversing it end for end, replace it by the same marks. If the bubbles now have the same reading as before, with reference to the table, they are parallel to the plane of the table: if not, adjust the bubbles for *one-half* the movement and try again.



THE SEXTANT, No. 23.

The radius of the sextant is 7 inches, 145°: four sun-glasses between the large and the small reflecting mirror, and three sun-glasses behind the small reflecting mirror, all of which can be turned on their axis 180°. Graduation on **Solid Silver**, reading to 10″; telescope ¾-inch aperture: two astronomical eye pieces with powers of 6 and 10 dia. One Galilean telescope with extra large objective, power 3 dia.; one fixed reading glass; two sights for examination and correction of the large reflecting mirror. All complete in box. Best quality, imported.

Price, as above,	$130.00
" " radius 10 inches,	150.00

ARTIFICIAL HORIZON.

Mercury Horizon, of boxwood, with silver-plated copper bowl; bottle of boxwood for mercury; brass rectangular roof with glass covers made of parallel glass. All complete; packed in box. Best quality, imported.	50.00

SEXTANTS.

In addition to the ordinary sextant in general use on board ships, I keep on hand the pocket sextant, especially designed for the use of civil engineers in hydrographic surveying, locating of buoys or soundings, also in reconnoissance work, explorations and preliminary surveys. This sextant is made of brass, is about 3 inches in diameter, 1½-inch deep, and has a brass lid which entirely covers it when not in use. It reads angles to half a minute. Price $43.00.

ADJUSTMENTS OF THE SEXTANT.

1. *To make the index glass perpendicular to the plane of the sextant.* Bring the vernier to read about 30°, and examine the arc and its image in the index glass to see if they form a continuous curve. If the glass is not perpendicular to the plane of the arc, the image will appear above or below the arc, according as the mirror leans forward or backward. It is adjusted by slips of thin paper under the projecting points and corners of the frame.

2. *To make the horizon glass parallel to the index glass for a zero-reading of the vernier.* Set the vernier at zero and see if the direct and reflected images of a well defined distant object as a star, comes into exact coincidence; if not, adjust the horizon glass until they do.

3. *To make the plane of sight of the telescope parallel to the plane of the sextant.* The recticule in the sextant carries four wires forming a square in the center of the field; the center of this square is in the line of collimation of the instrument. Rest the sextant on a plane surface, pointing the telescope upon a well defined point some

twenty feet distant. Place two objects of equal height upon the extremities of the limb that will serve to establish a line of sight parallel to the limb; two lead pencils of same diameter will serve, but they had better be of such height as to make this line of sight even with that of the telescope. If both lines of sight come upon the same point to within half an inch or so at a distance of twenty feet, the resulting maximum error in the measurement of an angle will be only 1″.

OPTICAL SQUARE.

The optical square is a small hand instrument to set off right angles in full in setting off offsets.

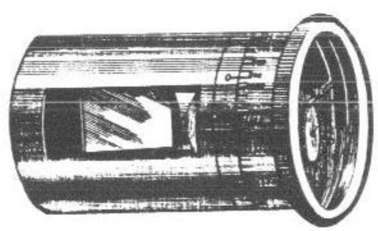


FIG. 25.

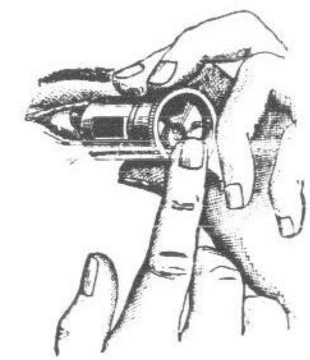


FIG. 26.

THE TELEMETER, No. 24—PRICE $18.

This is an exceedingly clever little instrument, invented by Labbez, and is designed to give, without any calculation whatever, the distance of objects from 250 to 3,000 yards. It is most simple in construction, easily understood, very accurate, and not likely to get out of order. The chief merits claimed for it are, that it does not require much training to use it, nor is it necessary that an absolute right angle be laid out. and it is not dependent on seeing a definite-sized object (such as a man standing erect.)

The following are the directions for using the instrument:

1. Open the slide at end of cylinder.

2. Set the small-toothed wheel so that the zero is opposite zero-line, also set the revolving part of the cylinder so that the zero on it is exactly on the zero-line of fixed portion of cylinder.

3. To find the distance of A (Fig. 27), stand at D, face to the left, E, and notice an object (say B) of a prominent nature (known hereafter as the mark) as near as possible at right angles to the object A of which the range is required. Hold the instrument with the thumb and finger of the left hand, as shown at Fig. 26, in such a way that the oblong opening is quite free, and place it to the eye; look through the hole at the small end of the instrument at mark B, and with the forefinger of the right hand turn the small-toothed wheel until coincidence between the range object A and the mark B is obtained—in other words, A is reflected on B.

4. Fasten the end of the line into the ground at D by passing one of the arrows through the loop and walk to the other end (C) of the 30-yard line in the direction of B. Let someone standing exactly over D dress the observer exactly with B (by calling out quarter or half pace, &c., right or left, until the right side of head of observer covers the mark B.)

5. The observer, facing the same way as in previous operation, now looks at B revolving the end of cylinder until the object A is reflected on B.

Directly this is done the line opposite the fixed zero will represent the distance of the object A in yards.

Should it so happen (and the occurrence would be very rare) that no natural or other prominent object is to be found somewhere near at right angles to A to use as a mark, then a man can run out with a lance, rifle, &c., and place himself at any position near the right angle at any distance over 60 yards.

The observation may be made the reverse of above if no suitable object is found to the left (see Fig. 28). The only thing is to turn

the instrument over and follow the same instructions as previously given, reading "right" for "left."

The base may be paced, instead of measured, when approximate accuracy is sufficient, and time is of consequence.

The length of base may be half (viz. 15 yards) or double (60 yards), and the results will be half and double respectively of the distances shown on the drum of instrument.

Observations may be checked by stopping at 15 when using the 30 base, and taking an observation there.

If no second person is at hand to dress the observer with the mark B, and greater accuracy is required than can be obtained by walking straight by the eyesight in the direction of B, the following plan may be resorted to:—

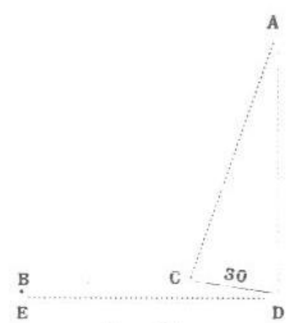


FIG. 27.

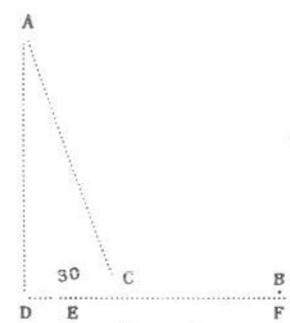


FIG. 28.

For laying out the base.—Note the object you intend taking as a mark about at right angles to the object, then walk about 33 paces in the direction of it, see that nothing obscures the object or mark, and place a sword or picket through loop of line; now return, unwinding the 30 yards of line as you go, and when at the end move right or left until the picket is aligned on mark. Then proceed as in previous directions, paragraphs 1, 2, 3, at this point (D), and on going to C turn cylinder until object and mark coincide. Read off the distance in yards opposite zero.

When time is of consequence very good results can be obtained by walking the equivalent number of paces to 30 yards in the direction of mark, placing the picket or sword, and pacing the same number back, taking mean of error in doing so, and aligning picket as before.

Another plan for use by one person only:

(This illustration, Fig. 28, is shown the reverse way to that generally adopted; that is, looking right instead of left.)

1. Use a line 15 yards long, and place an arrow or picket through the loop of it at E. Set the instrument to zero as before, and looking through it in direction of B see what object will coincide nearest with the reflection of A.

2. Walk to end of the line at D, and, moving right or left, stop when E is aligned with B, and place a mark or picket in that position, then look through the instrument and turn small-toothed wheel until A is exactly reflected on mark B.

3. Now take the line, and walking past D stop at extremity of it (C), when E and D are aligned, right about turn very exactly so as not to shift the position.

4. Face B, and on looking through the telemeter rotate the end of cylinder until A is reflected on B. The range can now be set off opposite the zero.

In rotating the cylinder it is better to stop exactly at the point where the object aligns the mark; and if it goes beyond, then it should be turned back and gradually brought up to the mark again. This precaution, although not absolutely necessary, ensures greater accuracy.

If time permits, a second observation can be taken, and the mean of the two readings taken as the distance of object A.

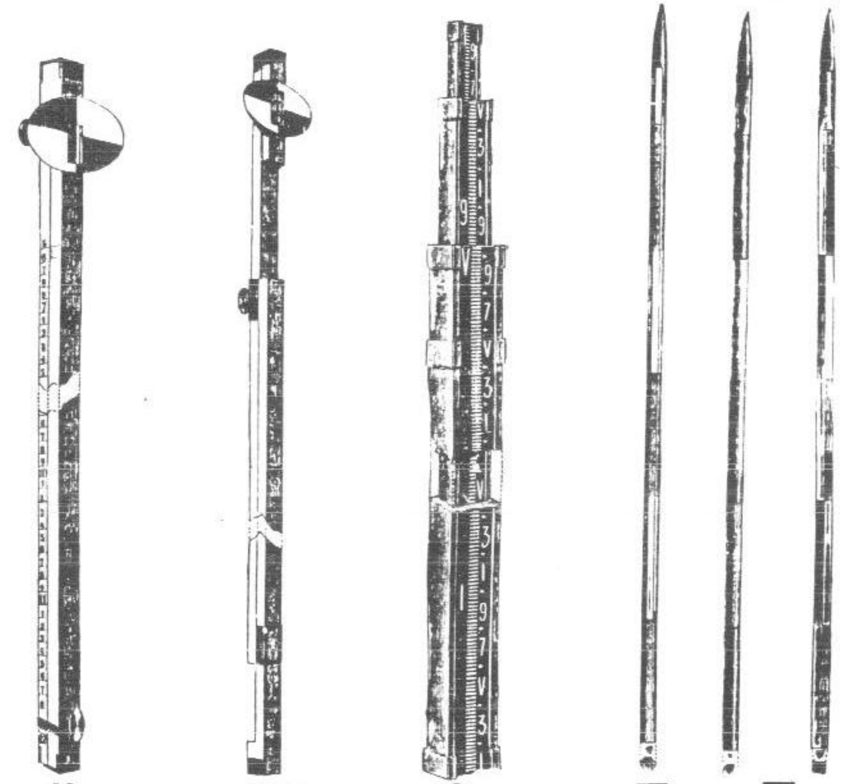
The use of the Labbez telemeter as a surveying instrument.—The instrument will determine the distance apart of two inaccessible objects by laying out a triangle as follows:

Let A and B be two points inaccessible from point C. Having measured with the telemeter the distance C A and C B, carry on in these two directions proportional lengths C B′ and C A′.

The triangle A′ B′ C being similar to the triangle A B C, one has

$$AB = A'B' \times \frac{CB}{CB'}.$$

A′ B′ is known as it can be measured directly, and the product $\frac{CB}{CB'}$ is an equality of it.



29 30-31 31 33 34 35

LEVELING RODS.

No. 29. NEW YORK ROD, with my improved clamp, preventing the defacing of the divisions, target provided with good rim protecting the painted face. Target vernier reading to 1000ths. Satinwood, sliding out to 12 feet. Price $14.00.

No. 30. PHILADELPHIA ROD, made of the best cherrywood, thoroughly seasoned; the face is accurately divided by machine to 100ths of a foot, with improved target divided to read to 1000ths of a foot. Price $17.00.

No. 31. PHILADELPHIA ROD, as above, but divided in 10ths of a foot, with vernier reading to 200ths of a foot. Price $14.00.

No. 32. ENGLISH SELF-READING ROD, telescoping with strong brass mounting, 5 feet long, slides out to 14 feet. Price $27.00.

No. 33. LINE RODS of best wood, 8 ft. long with steel-pointed shoe, and divided red and white alternately, each $2.50; 10 feet long, $3.00.

No. 34. STEEL LINE RODS 7 feet long, size ⅝ of an inch, painted red and white, each $3.00.

No. 35. IRON TUBULAR ROD, ⅞ inch diameter steel shoes, painted red and white alternately every foot. Price $3.00.

No. 36. Sala's Self-Reading Rod, 8 feet long; divided in feet, 10ths and 100ths of a foot, with red numbers at each foot, no target, very convenient for quick work. Price $4.00.

No. 37. The same, but double, sliding out to 15 feet, $10.00.

FLYNN'S COMBINED TRANSIT AND LEVEL ROD, No. 38—PRICE $5.00.

This rod is merely a combination of two old rods into one. I am making these rods after a pattern supplied to me by P. J. Flynn, civil engineer, who has used it on railroad construction and found it very useful for that work. By its use one rod can be dispensed with under certain circumstances, as in railroad construction, running contour and grade lines, etc., by transit with level attachment.

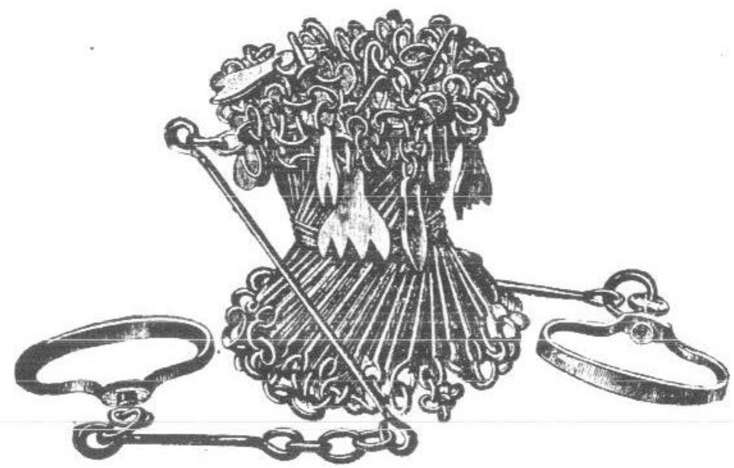
This rod is 1½ inches wide, ¾ inch thick, and 8 feet or more in length, as may be required. One end is shod with iron like an ordinary level rod; the other end is tapered to a point and has a steel shoe pointed at one end secured to it. From the point of this steel shoe to the middle of the other end of the rod, a straight line is drawn, and on each side of this line the rod is painted alternately red and white at every foot; this side forms the transit rod. On the back of rod, that is on the face of the level rod, and about 3½ feet from the steel point a small level is held, to show when the center line of the rod is vertical, and by this level the rodman can keep his rod-plumb even when he is so situated that he cannot see the transit-man; and the transit-man, if he is able to see two feet of the rod above an obstruction, can fix a point and take an observation with precision.

The other side of the rod is graduated as a self-reading level rod from the shoe upwards into feet and tenths, half-tenths and hundredths, as may be required. This rod can then be used with either transit or level, and can also be used when chaining on steep ground as a plumb.

No. 39. Flexible Pocket Leveling Rod, 10 feet long, 3 inches wide, divided like self-reading rod to 10ths and 100ths of a foot. Made of pliable, strong, rubber canvas. Can be coiled up and carried in pocket. For use, it is fastened to a board or stick with thumb tacks. Price $3.25; 12 feet long, $4.00; 14 feet long, $4.50; 3 meters long, $3.25; 4 meters long, $4.00.

The above rods are also divided in inches and ⅛ inch at same price.

METRIC RODS ALWAYS ON HAND.



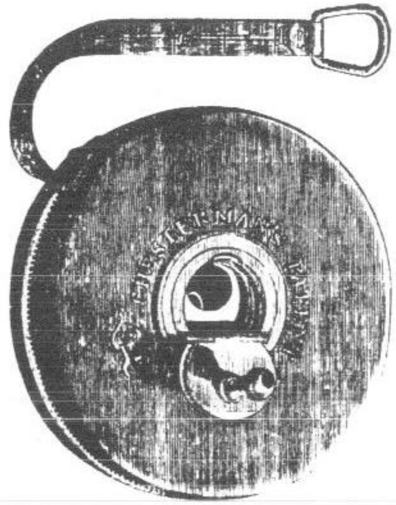
SURVEYORS' CHAINS, No. 40.

These are all standard chains with three oval rings.

Iron Chain, Brass Handles,	No. 8 wire,	33 feet	....	$ 2 60
" " "	" 8 "	50 "	....	3 25
" " "	" 8 "	66 "	....	4 00
" " "	" 8 "	100 "	....	5 25
Steel Chains, " "	" 10 "	33 "	....	3 50
" " "	" 10 "	50 "	....	4 25
" " "	" 10 "	66 "	....	6 50
" " "	" 10 "	100 "	....	8 00
" **brazed** links and ring,	No. 12 wire,	33 feet	....	5 50
" " "	" 12 "	50 "	....	6 00
" " "	" 12 "	66 "	....	10 00
" " "	" 12 "	100 "	....	11 50

Meter Chains always on hand. Iron Arrows, No. 8 wire, 11 in set, 18 inches........ 1 25

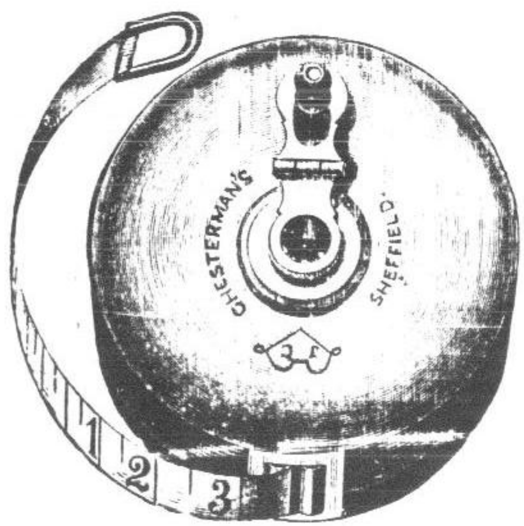
Steel Arrows, No. 10 wire, 11 in set, 12 inches, 50 cts., 75 cts., $1.00 and $1.25.



CHESTERMAN'S STEEL TAPES, No. 41.

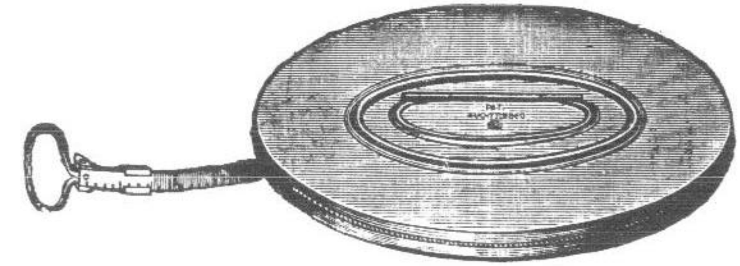
In leather case, with flush handles.

25 feet	$ 4 50	66 feet	$ 8 00
33 "	5 00	75 "	9 00
50 "	6 00	100 "	10 00



CHESTERMAN'S METALLIC TAPES, No. 42.

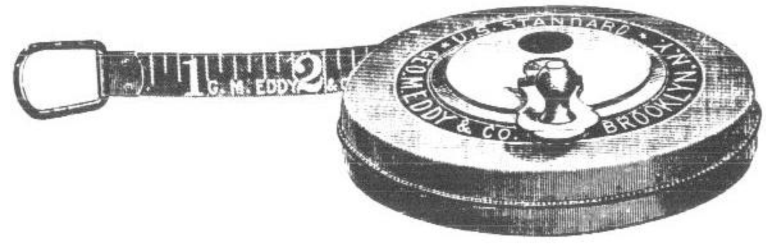
33 feet	$2 25	75 feet	$3 75
50 "	2 75	100 "	4 50
66 "	3 00		



PAINE'S PATENT STEEL TAPES, No. 43.

In leather case, with flush handles.

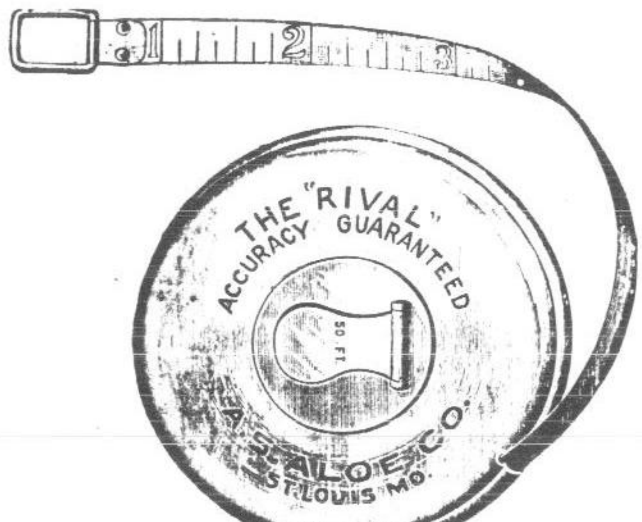
33 feet	$5 00	75 feet	$ 9 00
50 "	6 00	100 "	11 25
66 "	7 50		



EDDY'S IMPROVED STANDARD STEEL TAPES, No. 44.

Metal lined with flush handles, in leather-covered case, graduated in 10ths or 12ths of a foot or metric measure.

Feet	33	50	66	75	100
Price, each	$5.50	6.75	8.25	9.75	12.00

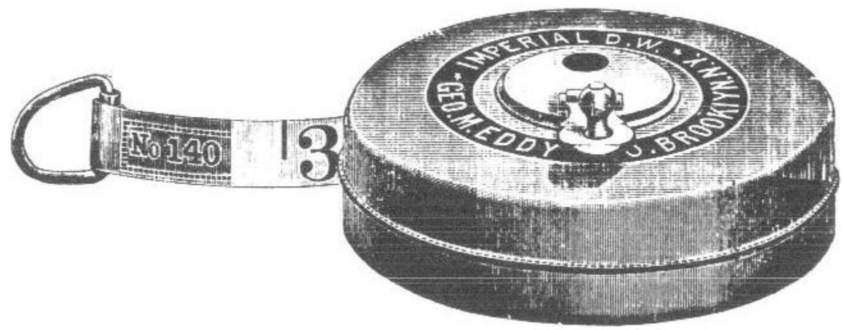


THE RIVAL STEEL TAPE, No. 45.

The Rival is made of the best steel ribbon of sufficient width (3/8 inches) and thickness to insure strength and durability, yet light enough not to require a cumbersome case. The steel ribbon is etched to such a depth as to let the marks appear as if embossed, thus guaranteeing their distinctness after years of hard service. The case is made of stout brass, nicely nickel plated and is more durable than any other used; it is compact in form, and the handle folds nearly flush with the case. I respectfully invite a critical comparison of the Rival steel tape with the cheaper grades extensively advertised and quoted at a similar price. A comparison will show that the Rival rests upon its intrinsic merits as a reliable, low-priced tape.

Rival Steel,	50 feet long, in 10ths or 12ths	$4 00
" "	75 " " " "	5 50
" "	100 " " " "	7 00

STEEL TAPES OF ANY DESIRED LENGTH MADE TO ORDER.

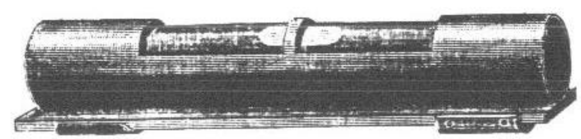


METALLIC WARP TAPES, No. 46.

These tapes are made of the best linen tape with wire threads to prevent stretching, and by our process of making are always soft and pliable. The ends are reinforced with leather to prevent wearing, and all the cases have our new improved flush handle. Graduated in 10ths, with links on opposite side.

Metallic Tape, 5/8 inch wide.

Feet	25	33	40	50	66	75	100
Price, each	$1.30	1.50	1.75	2.00	2.30	2.75	3.10



Invented by Ernest McCullough, Civil Engineer.

PATENT TAPE LEVEL, No. 47—PRICE $1.00.

This little device, a California production, is meeting with deserved favor wherever used. The above cut is full size; the weight of the level is only one ounce. It is used by clamping to the tape, about one foot from the handle, by means of the two springs shown, and can be attached and detached instantly.

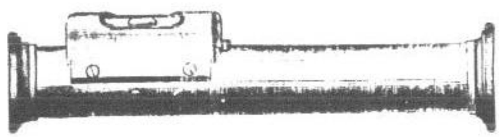
POCKET LEVEL, No. 48.

Bubble mounted in lacquered brass tube upon brass base.

3	6	9	12 inch.
$ .50	1.00	1.75	2.50

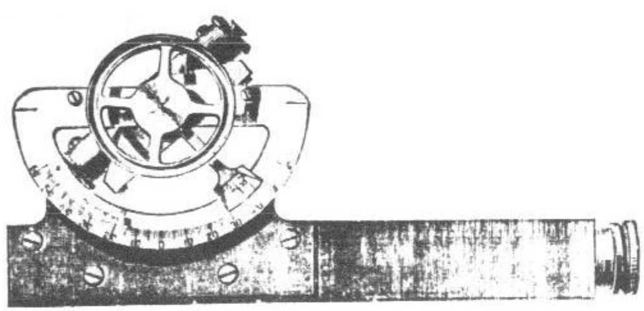
Extra fine ground spirit-level, mounted in bell-metal tube and rendered adjustable to the base by capstan screws; very delicate.

6	9	12 inches.
$7.50	9.00	10.50



LOCKE'S HAND LEVEL, No. 49.

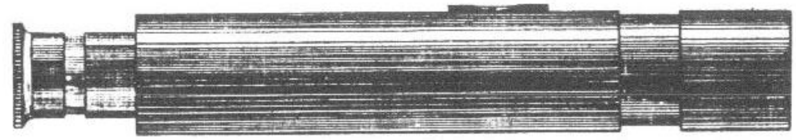
Bronze, in good leather case..$7 00



ABNEY'S REFLECTING LEVEL, No. 50—PRICE $13.50.

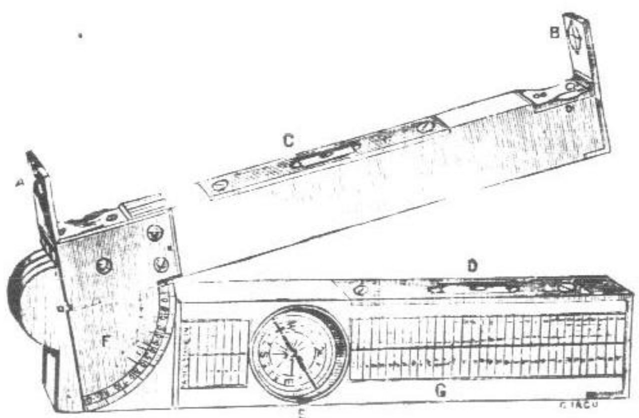
Abney's Reflecting Level or Pocket Altimeter, improved, combining the uses of both "Locke's Hand Level" and "Clinometer," in leather or mahogany box.

No. 51. Same as above, but with compass and socket for Jacob staff. Price, $16.00.



SALA'S TELESCOPIC HAND LEVEL, No. 52.

The Sala Hand Level is an entirely new instrument, and consists of a telescope magnifying six times. The tube is provided with the level and prism usual in other hand levels. In the tube is fixed a diaphragm with stadia wires adjusted to the ratio of one foot to fifty feet, thus enabling an engineer to quickly measure distances in preliminary surveying. The eye piece and object glass are adjustable as in ordinary transit telescopes. Price, with leather case, $15.00.



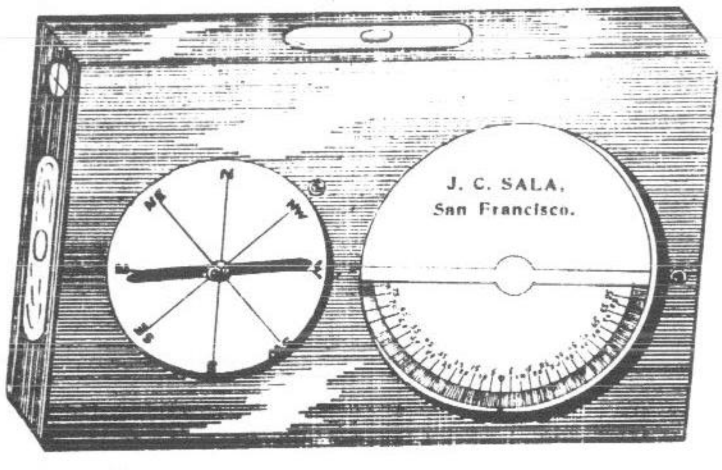
BOXWOOD CLINOMETER RULE, No. 53—PRICE $11.50.

Superior 12 inch, attached compass E, two bubbles C and D, folding sights A B, and arc F of 90°, for each degree of which the corresponding rates between horizontal distance and rise or fall is found upon the inclination scale G; in morocco case.

THE ATTWOOD CLINOMETER.

No. 54.

This is a very useful and practical instrument for the use of the miner, prospector, millman and foreman of mines. It is light and can be carried in the pocket. With the aid of a small straight-edge, any inclination or angle can be determined. It is admirably adapted for the arranging of sluices and setting of amalgamating plates or timbering in drifts or inclines in a mine.



SALA'S ALUMINUM CLINOMETER, No. 55.

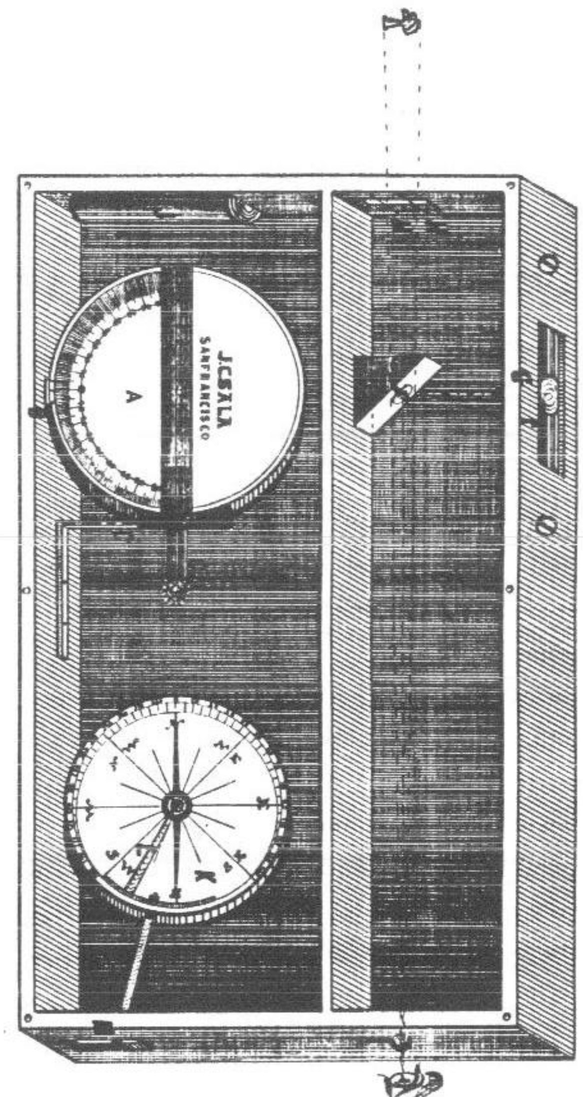
My Aluminum Clinometer is an improvement on the Attwood Clinometer in so far as it is lighter and not liable to warp when alternately exposed to damp and very dry atmospheres. Another peculiarity consists in the disposition of the sights, which are inserted in the short narrow upright sides, which disposition affords them greater protection; also the adaptation of the dial and the compass box of the same, on the face of the instrument, is novel. The horizontal and vertical levels are inserted in the top and side faces as they are in the Attwood Clinometer. The size of the instrument is 6x3½x¾ inches, making it small enough to be carried in the pocket. Price, in leather case, $15.00.

J. C. SALA'S

NEW ALUMINUM MINING CLINOMETER

combined with Level, Compass and Telemeter.

DIAGRAM (front plate removed)



Dimensions: 6" x 3½" x ¾" Weight: 11 ozs.

Price $15.00

- A—Metallic Clinometer Dial
- B—Metallic Indicator.
- C—Metallic Stop for Clinometer.
- C'—Metallic Stop Lever for Clinometer.
- D—Level Sights.
- E—Prismatic Reflector.
- F—Level Bubble.
- G—Center Wire.
- HH—Telemeter Wires set 1-25.
- I—Eye Piece.
- J—Vertical Bubble.
- K—Compass.
- L—Stop Bar for Compass.
- M—Stop Button for Compass

J. C. SALA'S

NEW ALUMINUM MINING CLINOMETER

Combined with Level, Compass

and Telemeter.

Former Clinometers, such as Attwood's and others, consisted of a clinometer dial, and a compass box only.

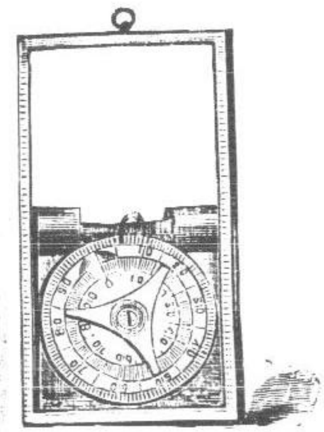
For the convenience of the mining engineer and the foreman of mills and underground work, I have in my new instrument added a hand level and distance measurer which has met with the fullest approval of the mining fraternity at large, saving the carrying of many instruments.

This instrument made of Aluminum is extremely light, very compact and solid, and will do the work of four separate instruments.

It is especially adapted for taking the dip and course of any mineral vein, the rise or fall of any incline or drainage ditch, etc.

In mill work its applications are as multifold as in underground work, such as giving desired angles to sluice boxes, concentrating blankets, trays or amalgamating plates.

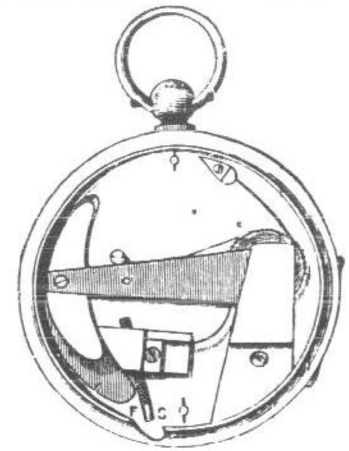
In surface work the hand level and the stadia wires set 1-25 will be of great use for approximate work in prospecting for the grade of water works to be established in connection with the mine.



SALA'S ODOMETER, No. 56—

PRICE $17.00.

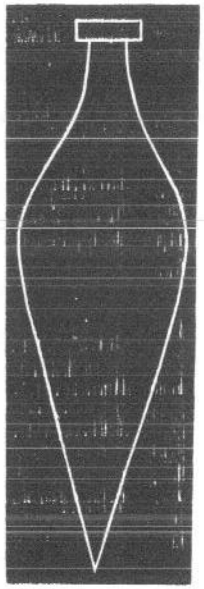
For measuring distances by a wagon. It is enclosed in a brass box, 4½ inches diameter, furnished with leather case with double straps to fasten to the center of the wheel. It is the most correct Odometer in practical use.



PEDOMETERS, No. 57.

Pedometers are pocket instruments for measuring the distance traversed in walking, the number of miles being registered by a mechanism, inclosed in a nickel-plated watch casing, and operated by the motion of the body. Directions accompany each instrument.

Watch size, registering 20 miles and divided in ¼ of mile........	$ 5 00
The same, with three faces and hands, registering single steps...	9 00
Passometer, watch pattern, nickel case, with three hands, registering 25,000 steps..........	10 00



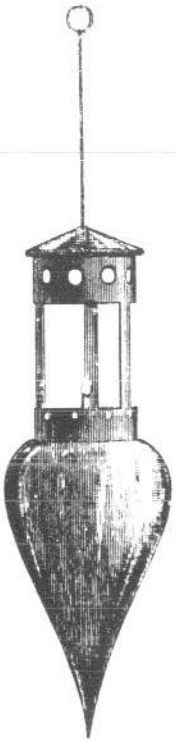
PLUMB BOBS, No. 58.

Plumb Bobs of the most improved shape with steel point, from $1.00 to $5.00, according to size and weight.

J. C. SALA'S ILLUMINATED PLUMB BOB,

No. 59—Price $10 and $12.

Patented October 30th, 1883.



This simple instrument, which supplies a long felt want among civil and mining engineers, contains within itself, lamp and lantern combined. The Plummet, which is chambered for the purpose at the top, is the lamp, and all the parts are firmly secured together, giving an absolute solidity to the whole.

All the work, being done upon the lathe, is concentric, securing a perfectly vertical line through the point, the lamp and the point of suspension. The difficulties of protecting the flame from flaring and those arising from the non-adjustment of the point and the flame, which are experienced in the best lamps heretofore constructed, wherein the lamp is suspended by chains, are entirely obviated.

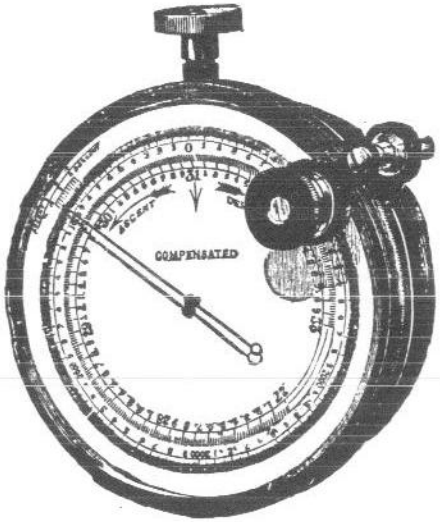
To light the lamp it is only necessary to slide up the glass which forms the lantern and apply the match.

The conical top of the lantern protects the light against water dropping from the roof of the mine or tunnel.

It is admirably adapted for use in mills and manufactories where shafting is laid.

Special diploma awarded by the Mechanics' Institute, San Francisco, 1883.

Size No. 1, weighs 2¾ lbs.; size No. 2, weighs 1½ lbs.



SURVEYING ANEROID BAROMETERS, WITH VERNIER READING TWO FEET.

No. 60—Surveying Barometer, brass case, 5 inch diameter, silvered dial, division on raised ring, fixed altitude scale 15,000 feet, vernier scale operated by rack and pinion, reading to one foot, compensated for temperature, adjustable reading lens, in leather sling case........ each, $50 00

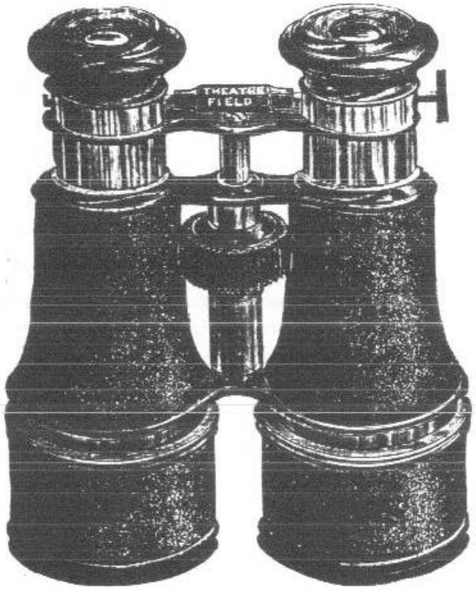
No. 61—Surveying Barometer, brass case, 3 [redacted] inch diameter, silvered dial, division on raised ring, fixed altitude scale 10,000 feet, vernier scale operated by rack and pinion, reading to five feet, compensated for temperature, adjustable reading lens, in leather sling case...... " 47 00

ANEROID BAROMETERS.

For Measuring Heights and Atmospheric Pressure.

No. 62—Pocket pattern, bronzed case, 2¾ inch diameter, silvered dial, revolving altitude scale from 8000 to 16,000 feet. Revolving altitude scale compensated for temperature. In morocco case, price..........................from $20 to $30

No. 63—Pocket pattern, gilt case, 1¾ inch diameter, silvered dial, revolving altitude scale 8000 feet, compensated for temperature. In morocco case, price ....from $10 to $20



ACHROMATIC FIELD AND MARINE GLASSES.

Manufactured by the Societe d'Optique, Paris.

No. 64. Field or Marine Glasses, black kid body with sun-shades, finely japanned or oxidized draw-tubes, cross-bars, tops and trimmings; in sole leather sling case:

21	24	26 lignes.
$14.00	16.00	18.00

Manufactured by Bardou, Paris.

No. 65. Field or Marine Glasses, black morocco body with sun-shades, oxidized draw-tubes, cross-bars, tops and trimmings; in sole leather sling case:

24	26 lignes
$21.00	24.00

No. 66. Field or Marine Glasses, as above, with 12 lenses:

24	26 lignes.
$25.00	28.00

ACHROMATIC FIELD AND MARINE GLASSES—Continued.

No. 67. Field or Marine Glasses, with *jointed* cross-bars, affording adjustment for pupillary distance:

24	26 lignes.
$25.00	28.00

Manufactured by Lemaire, Paris.

No. 68. Field or Marine Glasses, *superior*, U. S. Signal Service, black morocco body with sun-shades, finely black japanned or oxidized draw-tubes, cross-bars, tops and trimmings; in sole leather sling case:

24	26 lignes.
$18.00	20.00

No. 69. Field or Marine Glasses, as above, with *jointed* cross-bars, affording adjustment for pupillary distance, 26 lignes.........$28.00

No. 70. Field or Marine Glasses, black morocco body with sun-shades, black japanned or oxidized draw-tubes, cross-bars, tops and trimmings in morocco sling case:

15	17	19	21	24	26	28 lignes.
$9.00	10.00	11.00	12.00	13.00	14.00	25.00

No. 71. Field or Marine Glasses, as above, with 12 lenses; sole leather case, 26 lignes...$21.00

No. 72. Field or Marine Glasses, black morocco body with sun-shades, black japanned or oxidized draw-tubes, tops and trimmings; *jointed* cross-bars, affording adjustment for pupillary distance; in sole leather sling case:

24	26 lignes.
$21.00	22.50

No. 73. Field or Marine Glasses, black morocco body with sun-shades, finely black japanned or oxidized draw-tubes, cross-bars and *low* tops, compact model, designed to afford large field, in morocco sling case:

15	17	19	21	24	26 lignes.
$11.00	12.00	13.00	14.00	15.00	16.00

BINOCULAR TELESCOPES, No. 74.

These glasses have great power, and where objects are fully illuminated, they are unequaled. They are provided with hinge or joint, and can be adjusted to the different widths of eyes, thereby securing a perfectly even field, and avoiding, when looked through, all strain to the ocular muscles.

The performance of a glass of this kind is equal to a spy-glass of very much greater power, because, by the use of both eyes, the field of vision or amount of scenery which a person sees at one time is wonderfully increased. Complete with sun-shades, case, strap, etc.

Binocular Telescope, as above, 11 lignes........................$ 50 00
" " " 13 " 55 00
" " " 15 " 65 00

ALUMINUM BINOCULAR TELESCOPES, No. 75.

11 lignes, same as above........................$ 75 00
13 " " " 85 00
15 " " " 100 00
17 " " " 115 00

SPY-GLASSES, No. 76.

First Quality. 11 Lignes, Equal to One Inch

Spy-glasses 3 draws, black morocco body, stitched, burnished brass draw tubes.

DIMENSIONS. Full Length, Inches.	Closed, Inches.	Diameter of Object Glass, Lignes.	Magnifying Power, Times.	Range, Miles.	PRICE.
14¾	5¼	10	10	5	$2 50
16¼	6	11	15	6	3 00
16¼	6	12	15	6	3 50
17	6¼	13	20	7	4 00
17½	6¾	14	20	8	4 50
23	8	16	25	9	6 00
30	10	10	30	10	8 00

Spy-glasses, 4 draws, with sun-shade to extend over object glass; black morocco body, burnished draw tubes.

DIMENSIONS. Full Length, Inches.	Closed, Inches.	Diameter of Object Glass, Lignes.	Magnifying Power, Times.	Range, Miles.	PRICE.
36	10½	22	40	14	$16 50
45½	12¾	25	45	18	23 50

The above are very superior glasses for terrestrial observations, and afford excellent views of the sun, moon, Satellites of Jupiter, etc. To produce the best results, they should be used on a tripod stand.

Tripods for any spy-glass, nicely made $5 00

POCKET MAGNIFIERS, No. 77.

Rubber case, size of lens 1 inch diameter........................$0 50
" " " 1¼ " " 75
" " " 1½ " " 1 00
" " lenses 1⅛ and 1¼ inch diameter........................ 1 25
Shell case, size of lens 1¼ inch diameter 1 30
" " lenses 1⅛ and 1¼ inch diameter........................ 1 80

GOSSAMER AND SILK BAGS.

Gossamer or water-proof bag, to cover transit or level in case of rain or dust.......... $ 1 00

Silk bag, to cover transit, with solid graduations.......... 1 00

LUBRICANTS.

Bottle of fine watch oil, for lubricating transit centers, etc.........$0 25

" vaseline for lubricating level centers, leveling and tangent screws, etc.......... 25

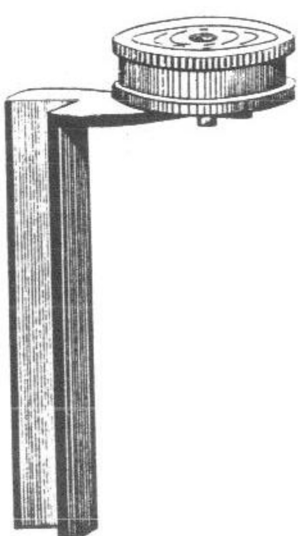
UTENSILS FOR CLEANING INSTRUMENTS.

Camel's hair brush..........$0 40

Stiff brush for cleaning screw-threads.......... 40

Chamois-skin for cleaning lenses, centers, etc.......... 50

Stick for cleaning centers.......... 50



ROD LEVEL.

ROD LEVEL, No. 78—PRICE $3.50.

This contrivance consists of a Universal level and a V shaped handle. The shape of the handle permits one to use the rod level on any round, prismatic or angular pole.

TIMBER SCRIBER, No. 79—PRICE $1.25.

Tool for surveyors to mark stakes, bearing trees, etc.

STEPHENS' COMBINATION RULE, No. 80—PRICE $2.00.

IMPROVED CAMERA LUCIDA, No. 81—PRICE $10.00.

With double sliding tubes and clamp; in mahogany case.

Surveyors' Engineers' Architects and Draughtsmen's Office Requisites

PART B

DRAWING MATERIALS.

Drawing boards from 75 cents each, for small work, to any size and price desired. Constructed of sound, seasoned wood.

Trestles and horses for drawing boards furnished to order. Folding trestles and cases of drawers also furnished. Send for plans and prices.

Drawing papers of all standard makes and names, in sheets and rolls. Detail papers, tracing papers, tracing cloth, profile and cross-section paper in sheets and rolls, kept on hand and sent upon order at regular catalogue prices of all dealers.

Sample books, with prices, 15 cents.

BLUE PRINT PAPERS.

Any make of the standard blue print papers can be furnished at the catalogue price of the maker. Also blue print frames and all appliances for the work.

To make blue print copies of tracings. As some customers off in the country are called upon for blue print copies occasionally and cannot wait for the supplies to arrive from San Francisco, and besides may not have enough calls for such work to warrant them in keeping a supply on hand at all times, the following directions for making their own paper may be useful.

1st. The paper should be a good quality of book paper.

2d. *The Mixture.* This consists of equal parts, by weight, of citrate of iron and ammonia, and red prussiate of potash. These may be procured from any druggist. They are mixed in the proportion of one ounce of citrate of iron and ammonia and one ounce of red prussiate of potash to eight ounces of water. Put in a stone bottle (to keep from the light) and shake well. In ten minutes they will be dissolved.

3d. Lay the paper which is to be treated, on a smooth table or board. Pour some of the sensitizing solution in a shallow dish, as a plate or saucer, and with a broad brush like a soft copying-press brush, apply a good even coating of the solution to the paper. When the paper is coated, tack it to a board and put it in a dark place to dry, an operation which will take about an hour.

4th. *To Print.* Upon a smooth board tack two or three thicknesses of flannel or blanket, and be careful that they are not wrinkled. Lay on the cloth the sheet of sensitized paper with the coated surface up; upon this lay the tracing, and great care must be exercised that the paper and tracing are also very smooth, as a wrinkle will spoil the work. Upon the tracing, lay a piece of heavy plate glass. The foregoing operations must be conducted in a dark room. The glass must be heavy to keep the paper smooth. After the glass is in position, bring the board out to the light and put it in the place it is to remain while printing.

5th. Within an hour or two of noon during the summer time, from six to ten minutes will suffice for an exposure. Earlier or later in the morning it will take longer to make a good print, and if the day is cloudy or the drawing cannot be exposed directly to the sun, it may take from half an hour to one or two hours to secure a good print. Experience will soon enable one to do good work.

6th. *Washing.* After the print has been exposed a sufficient time, take it from under the glass and place in a sink or shallow box filled with cold water. Let it soak for a few minutes and then wash it thoroughly. The lines of the drawing, faintly visible up to this time, will appear in clear white lines upon a blue ground. After washing, tack it up against a wall or hang by the corners from a line to dry. The operation is then finished.

7th. To write with a white line upon a blue print, use a solution of common soda with an ordinary pen.

Papers and material also kept for positive black printing processes, which some prefer to blue prints.

Engineers' Field Books for transit, level, topography and stadia work, kept on hand or made to order at regular catalogue prices.

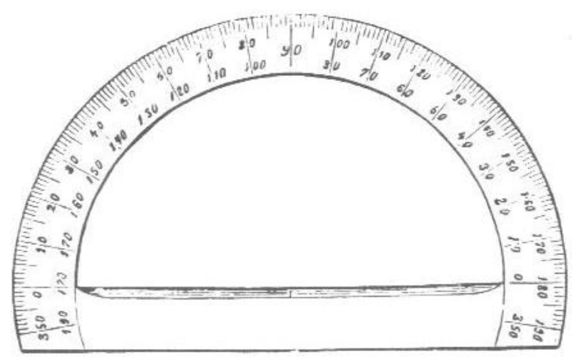
Lead Pencils of all the best makes furnished when called for.

THE PLANIMETER, No. 82.

The polar planimeter is used for computing with rapidity and accuracy, the area of any figure, how irregular it ever may be, such as railroad profiles, indicator diagrams, plots of ground, etc., etc., and is of great value to engineers and others on account of its saving in time and labor.

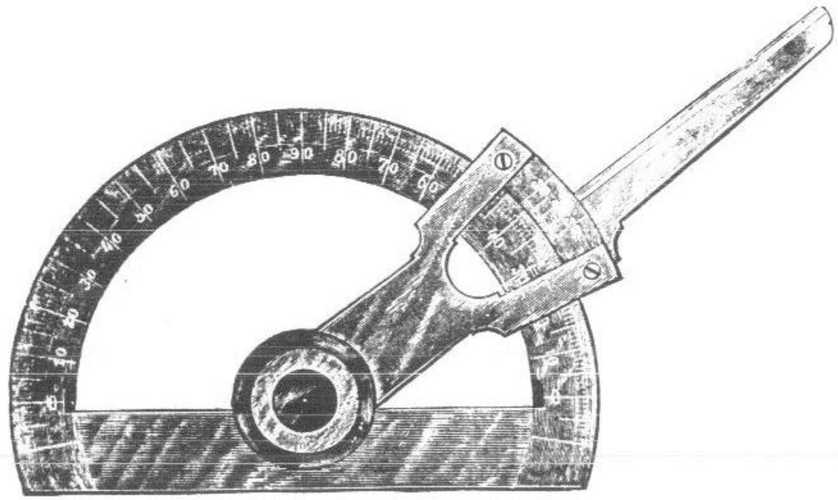
Amsler's polar planimeter, German silver, in case.................... $27 50

Pantographs of any make can be furnished to order at regular prices.



PROTRACTORS, No. 83—PRICE FROM $1.00 to $6.00.

Plain circular and semi-circular protractors, German silver, brass or horn, divided to ¼, ½, and single degree.



KERN'S SWISS PROTRACTORS, WITH ARM AND VERNIER, No. 84.

Semi-circular German silver Protractor, 5½-inch, divided to ½ degrees, with arm and vernier, reading to 3 minutes...	$11 00
Semi-circular German silver Protractor, 8-inch, divided to ¼ degrees, with arm and vernier, reading to 1 minute........	14 00
Semi-circular German silver Protractor, 10-inch, divided to ¼ degrees, with arm and vernier, reading to 1 minute........	17 00
Circular German silver Protractor, 5½-inch, divided to ½ degrees, with arm and vernier, reading to 3 minutes........	14 00
Circular German silver Protractor, 8-inch, divided to ¼ degrees, with arm and vernier, reading to 1 minute........	16 00
Circular German silver Protractor, 10-inch, divided to ¼ degrees, with arm and vernier, reading to 1 minute........	19 00

Morocco silk velvet-lined cases for above, $3.50 to $4.50.

DRAUGHTSMEN'S PROTRACTORS, No. 85.

This Protractor is made from 1/16-inch sheet steel and is light and durable. The length of the blade is 8½ inches. The graduations read to degrees and the vernier reads to 5 minutes.

This Protractor is chiefly used in connection with a T square or straight edge. It can be quickly and accurately set by hand to any

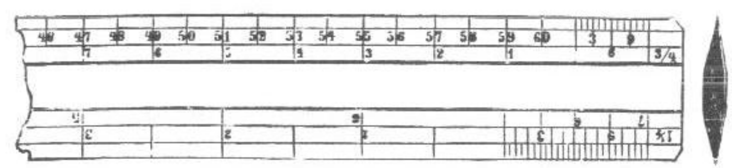
angle. A lever is, however, provided as of possible advantage in obtaining very fine settings.

There are no projections on either face of the Protractor, and, consequently, it can be used on either edge of the blade or either side up. This makes it particularly convenient in dividing circles, transferring angles, drawing oblique lines at right angles to each other, or laying off given angles each side of a vertical or horizontal line without changing the setting.

In many instances the Protractor takes the place of the ordinary 45-degree and 60-degree triangle, and it is also used as an extension to the T square when the work is beyond the end of the blade of the square.

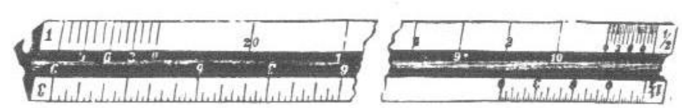
Draughtsmen's Protractor, in morocco case, velvet-lined...........	$9 00
" " no case..	7 50

Boxwood and Ivory Protractors. Any make at regular catalogue prices.



FLAT SCALES, No. 86.

Ivory and boxwood flat chain scales, for engineers and architects, from $1.00 to $3.00. Special divided scales made to order.



TRIANGULAR SCALES, No. 87.

Patent Metallic Scales, 12 inches long, for architects or engineers, price $3.00.

Boxwood Scales, for architects or engineers, 12-inch $1.50; 18-inch $2.50; 24-inch $4.25.

Triangular Scale Guard, 25 cents.

MANNHEIM SLIDE RULE, No. 88—PRICE $4.50.

10-inch long, divided on celluloid facing, with brass indicator, also directions for using.

STADIA SLIDE RULE, No. 89—PRICE $13.50.

20-inch, celluloid face.

STRAIGHT EDGES, No. 90.

Steel nickel plated:

24	30	36	42	48	60	72 inches
$2.00	3.00	4.00	5.00	6.00	8.50	12.00

Celluloid edged:

24	30	36	42	48 inches
$1.00	1.25	1.50	1.80	2.20

T SQUARES, WOOD, No. 91.

According to size, from..25cts. to $1.50
With shifting head, according to size, from.................$1.25 " 3.00

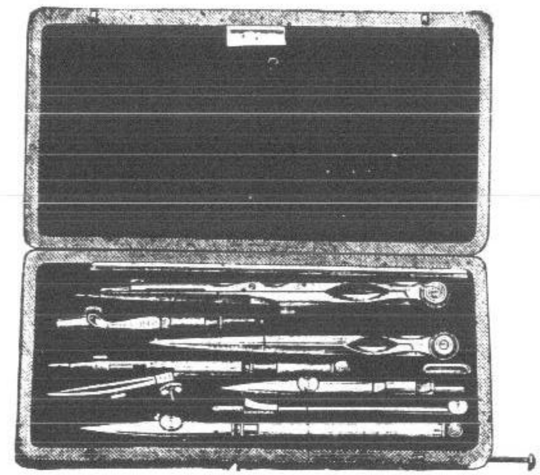
TRIANGLES, No. 92.

Steel nickel plated, 45°:	8	10	12 inches
	$4.25	5.50	6.50
Steel nickel plated, 30° and 60°:	8	10	15 inches
	$3.85	4.25	6.50

PARALLEL RULERS, No. 93.

Ebony folding:	6	9	12	15	18	24 inches
	30c	55c	75c	90c	$1.10	2.20

Rolling brass:	12	15	18 inches
	$9.00	10.50	12.00
Rolling ebony:	12	15	18 inches
	$5.00	6.50	7.50



Drawing instruments, colors, brushes, and all the one thousand and one little office necessities for engineers', surveyors' and draughtsmen's use, kept constantly on hand and furnished on demand.

Prices the same as all dealers' catalogues.

Mention name of dealer, date of catalogue, name and number of article wanted when ordering.

NOTICE

I am prepared to manufacture on short notice, to order, any scientific instruments applied to astronomy, navigation, physics, or chemistry appertaining to my line of business.

J. C. SALA.

Miscellaneous Scientific Instruments

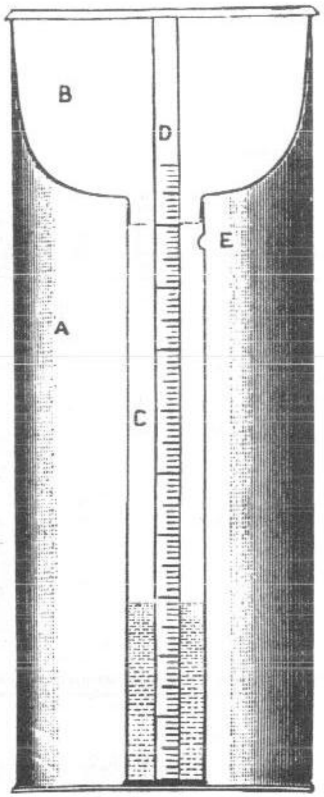
PART C

ASTRONOMICAL TELESCOPE, No. 94—PRICES $50 to $200.

Body with finder and movements of highly finished lacquered brass, rack and pinion for adjustment of focus; object-glass 3¼ inches in diameter, two terrestrial eye-pieces with sun-glass powers of 75, 100 and 150 diameters; packed in strong walnut case, with lock and key. The telescope is mounted upon a very fine polished, firm mahogany tripod stand, with folding legs, and can be adjusted to any desired height by a rack and pinion operated by a crank.

Heliographs for signaling by day or night, complete........$45.00

SALA'S STANDARD RAIN GAUGE, No. 95—PRICE $3.00.



The utility of knowing the rainfall of any locality is sufficiently obvious, and little need be said upon the subject. The rain gauge should be in the hands of every gardener and farmer.

In the management of out-door plants and crops, as well as in the maintenance of cisterns and tanks for the supply of water, a rain gauge is a valuable assistant. By its use the gardener will be guided in judging how far the supply of moisture to the earth is needed, and he will also see how beneficial is even a hasty shower to growing plants when he considers that a fall of rain measuring the tenth of an inch in depth corresponds to the deposit of about forty hogshead per acre.

The study of the rainfall of a country is of considerable interest to agriculturalists. The health and increase of domestic animals, the development of the productions of the land, as well as the daily labors of the farmer are dependent upon the excess or deficiency of rain. The **statistics** of rainfall are not only valuable and interesting, from a meteorological point of view and for agricultural purposes, but are also highly important in connection with sanitary arrangements for towns and engineering operations; this is especially evident to the hydraulic engineer.

As rain is an important source of water supply to rivers, canals and reservoirs, it is evident that a knowledge of the probable fall of any season or month at a given place, as furnished by **averages** of the observations of former years, will be the data upon which the engineer will base his plans for providing for floods or droughts, while the measurement of the actual quantity which has just fallen, as gathered

J. C. SALA'S

IMPROVED EXTENSION TRIPOD.

(See cut on next page.)

I have been manufacturing extension tripods for years, and repairing those of other manufacturers. All these tripods have the common defect, that the clamping surface is only on two plane faces of the extension part of the leg, and such part after being extended to its limit, is especially liable to move lateraly, thereby causing the instrument to be out of the level.

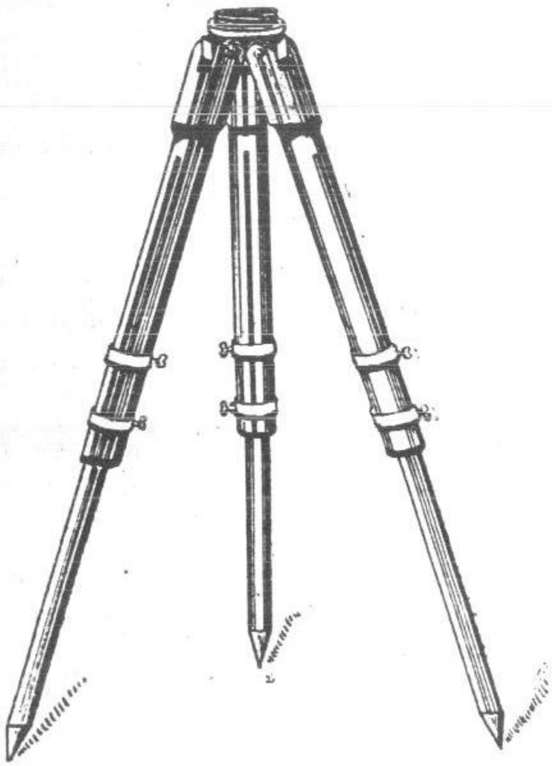
To remedy this I now build all my extension tripods of hollow wooden cylinders, firmly pressed to the tenon on the brasshead, by a bolt and thumb screw. This wooden cylinder has a sawcut of $\frac{1}{8}$ inch in width length ways, so as to give all the play necessary for clamping the two clamps on to the extension core, and upon releasing the clamps allow of a free and easy sliding of the core.

It will be easily understood that the tripod legs being hollow cylinders, and the core a solid cylinder the clamps must necessarily force the tripod halves to perfectly fit the core, and therefore there will be no chance for any slipping or lateral movement.

The cylindrical form being the most rigid of all, these tripods will surpass any other construction in stability.

The cylindrical form of the legs adds much comfort to the carrier of the instrument.

J. C. SALA'S
IMPROVED EXTENSION TRIPOD.



from indications of a series of gauges, will suggest to him the precautions to adopt, either to economize or to conduct away the inflowing waters.

This rain gauge is made of metal, is simple, and cannot get out of order. It consists of four pieces:

a. The overflow, a galvanized iron cylinder 12 inches long and 3 inches in diameter, holding 10 inches of rain.

b. The copper receiver, which catches all the rain to be measured.

c. The brass measuring cylinder connecting with the copper receiver.

d. The black walnut measuring rod having ten inches divided into one hundred parts; measuring as one inch the rainfall to that degree of accuracy.

e. The outlet.

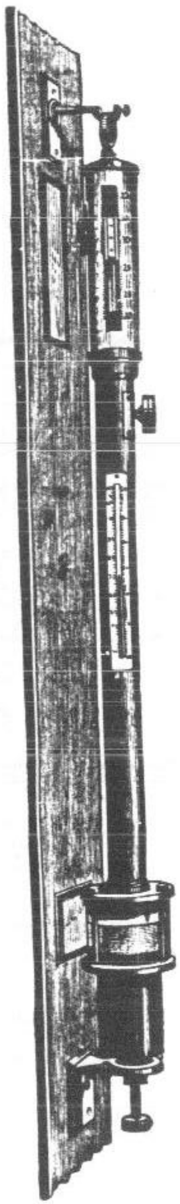
Directions for use. In an unsheltered open level space, sink the overflow to half its depth and support it so it will not get upset. If more than one inch of rain falls, it runs into the overflow. Insert the measuring rod which wets up to 10, that is one inch, the surplus escaping into the overflow; if less, the rod will be wet to 40 or 70 as the case may be, showing so many hundreds of an inch. Pour the water out from the brass cylinder and pour in from overflow one inch, or parts of the inch, and add all together, which gives total fall from last observation, which should be made every twenty-four hours.

GROUND BUBBLES, No. 96.

Ground Bubbles of all sizes for engineers, millwrights, machinists and carpenters.

SALA'S IMPROVED EXTENSION TIRPOD, No. 97—PRICE $14.

This tripod is the best for stability, and the legs being round, obviate the trouble of carrying a bulky tripod, with sharp corners. It can be opened to 5 feet and closed within 34 inches.



U. S. Signal Service Mercurial Standard Barometer.

U. S. SIGNAL SERVICE MERCURIAL STANDARD BAROMETER, No. 98.

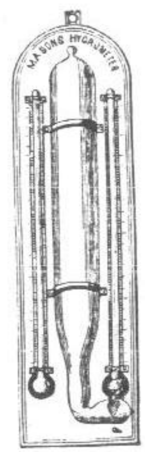
Price, in sling case........................$40 to $75

WEATHER ANEROID BAROMETERS, No. 99.

In brass cases, best quality, brass dial:

5	7	8	10 inches
$12.00	17.00	25.00	35.00 With double thermometer

MASON'S HYGROMETER, No. 100—PRICE $5.50.



With wet and dry bulb thermometers and cistern, mounted and graduated on solid boxwood, with hygrometic tables.

THERMOMETERS, No. 101.

Vacuum gauges and thermometers for sugar pan, made to order.

Maximum thermometers..........................$3.50

Minimum " 2.00

Six's combined maximum and minimum thermometer, 10-inch, mounted and graduated on neatly carved, solid boxwood back 5.50

Thermometers and Hydrometers of all description and sizes.

Papers and Tables

PART D.

... Tables, I have omitted
... the
... pub-
... Land Office
... those
... Nautical Almanacs.

J. C. SALA.

THE SAEGMULLER SOLAR ATTACHMENT.

Patented May 3, 1881.

J. C. SALA, AGENT.

This attachment to the regular engineer's transit, by means of which the astronomical meridian may be obtained in a few minutes with an accuracy scarcely thought to be possible, has met with such success that it bids fair to supersede all other methods for the determination of the meridian by means of engineering instruments.

The transit has come to be the universal instrument for the engineer, and will be for the surveyor sooner or later, and the attachment of the solar apparatus to the transit has thus become a necessity. Since its first introduction, this attachment has been greatly improved, and as now made, is well nigh perfect. Attached to any transit which possesses a telescope, level and a vertical circle, it will give the meridian within the nearest minute. By using instruments which have a finer graduated vertical circle and better levels than are usually found on transits, the meridian can be determined with greater accuracy still.

Advantages of the "Saegmuller Solar Attachment" over the old form:

First. It is more accurate.

Second. It is simpler and easier of adjustment.

Third. It can be used when the sun is partly obscured by clouds, when the ordinary "solar" fails altogether.

Fourth. It can be used where the sun is quite close to the meridian.

Fifth. The time can be obtained with it reliable to within a few seconds with perfect ease.

Sixth. It can be used as a vertical sighting telescope.

It is as superior to all forms hitherto used, as the transit is to the ordinary compass, or as a telescope is to common sights.

The sights of an ordinary solar compass consist merely of a small lens and a piece of silver with lines ruled on it placed in its focus. This is simply a *very primitive* telescope, since the exact coincidence of the sun's image with the lines has to be determined by the unaided eye, or at best with a simple magnifying glass. That far greater precision can be attained by means of a suitable telescope is obvious; in fact, the *power* of the solar telescope is in keeping with the transit telescope, as it should be.

A glance at the cut will show that the "Saegmuller Solar Attachment" is far simpler than the ordinary form. By raising or depressing, it can be set to north or south declination. To effect this with the ordinary solar compass, *two* sets of *primitive telescopes*—one answering for north, the other for south declination—are required, which are difficult to adjust. The addition of the level on the solar telescope dispenses with the declination arc altogether, the arc or circle on the transit also serving for that purpose in conjunction with it. The "Saegmuller Solar Attachment" is in fact the only one which should be used in connection with a transit instrument. *It solves the solar problem*, as has been attested by leading astronomers and engineers who have used it.

Prof. J. B. Johnson, of Washington University, St. Louis, Mo., has given it a thorough test, and writes as follows:

"In order to determine just what accuracy was possible with a Saegmuller Solar Attachment, I spent two days in making observations on a line whose azimuth had been determined by observations on two nights on Polaris at elongation, the instrument being reversed to eliminate errors of adjustment. Forty-five observations were made with the solar attachment on Oct. 24, 1885, from 9 to 10 A. M., and from 1.30 to 4 P. M., and on Nov. 7, forty-two observations between the same hours.

"On the first day's work the latitude used was that obtained by an observation on the sun at its meridian passage, being 38° 39′, and the mean azimuth was 20 seconds in error. On the second day, the instrument having been more carefully adjusted, the latitude used was 38° 37′, which was supposed to be about the true latitude of the point of observation, which was the corner of Park and Jefferson avenues in this city. It was afterwards found this latitude was 38° 37′ 15″, as referred to Washington University Observatory, so that when the mean azimuth of the line was corrected for this 15″ error in latitude it agreed exactly with the stellar azimuth of the line, which might have been 10″ or 15″ in error. On the first day all the readings were taken without a reading glass, there being four circle readings to each result. On the second day a glass was used.

"On the first day the maximum error was 4 minutes, the average error was 0.8 minute, and the 'probable error of a single observation' was also 0.8 minute. On the second day the maximum error was 2.7 minutes, the average

error was 1 minute, and the 'probable error of a single observation' was 0.86 minute. The time required for a single observation is from three to five minutes.

"I believe this accuracy is attainable in actual practice, as no greater care was taken in the adjustment or handling of the instrument than should be exercised in the field.

"The transit has come to be the universal instrument for the engineer, and should be for the surveyor; so it is more desirable to have the solar apparatus attached to the transit than to have a separate instrument. The principal advantages of this attachment are:

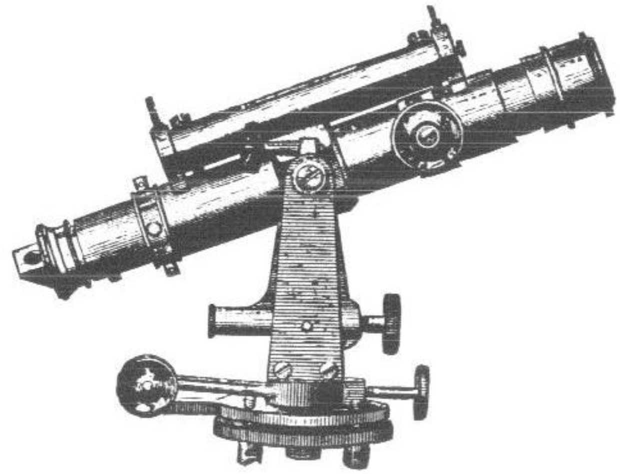
"1. Its simplicity.

"2. Its accuracy of pointing, being furnished with a telescope which is accurately set on the sun's disk.

"3. In its providing that all angles be set off on the vertical and horizontal limbs of the transit, thus eliminating the eccentricity and other inaccuracies usually found in attachment circles or arcs.

"4. Its small cost.

"It is also readily removed and replaced without affecting its adjustments, and is out of the way in handling and reversing the telescope. It may be attached to any transit."



SAEGMULLER SOLAR ATTACHMENT.

The above cut represents the improved "Saegmuller Solar Attachment" as now made. It consists essentially of a small telescope and level, the telescope being mounted in standards, in which it can be elevated or depressed. The standard revolves around an axis, called the polar axis, which is fastened to the telescope axis of the transit instrument. The telescope called the "Solar Telescope" can thus be moved in altitude and azimuth. Two pointers attached to the telescope to approximately set the instrument are so adjusted that when the shadow of the one is thrown on the other the sun will appear in the field of view.

Adjustment of the Apparatus.

1. The transit must be in perfect adjustment, especially the levels on the telescope and the plates; the cross axis of the telescope should be exactly horizontal, and the index error of the vertical circle carefully determined.

2. *The Polar axis must be at right angles to the line of collimation and horizontal axis of main telescope.*

To effect this, level the intstrument carefully and bring the bubble of each telescope level to the middle of its scale. Revolve the solar around its polar axis, and if the bubble remains central the adjustment is complete. If not, correct half the movement by the adjusting screws at the base of the polar axis, and the other half by moving the solar telescope on its horizontal axis.

3. *The line of Collimation of the solar telescope and the axis of its level must be parallel.*

To effect this, bring both telescopes in the same vertical plane and both bubbles to the middle of their scales. Observe a mark through the transit telescope, and note whether the solar telescope points to a mark above this, equal to the distance between the horizontal axis of the two telescopes. If it does not bisect this mark, move the cross wires by means of the screws until it does. Generally the small level has no adjustments and the parallelism is effected only by moving the cross hairs.

The adjustments of the transit and the solar should be *frequently* examined, and kept as nearly perfect as possible.

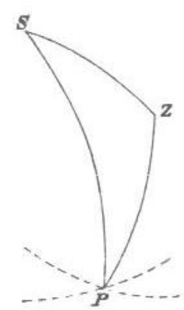
Directions for Using the Attachment.

First. Take the declination of the sun as given in the Nautical Almanac for the given day, and correct it for refraction and hourly change. Incline the *transit telescope* until this amount is indicated by

its vertical arc. If the declination of the sun is north, depress it; if south, elevate it. Without disturbing the position of the transit telescope, bring the solar telescope into the vertical plane of the large telescope and to a horizontal position by means of its level. The two telescopes will then form an angle which equals the amount of the declination, and the inclination of the solar telescope to its polar axis will be equal to the polar distance of the sun.

Second. Without disturbing the *relative* positions of the two telescopes, incline them and set the vernier to the co-latitude of the place.

By moving the transit and the "Solar Attachment" around their respective *vertical* axis, the image of the sun will be brought into the field of the solar telescope, and after accurately bisecting it the *transit telescope must be in the meridian, and the compass-needle indicates its deviation at that place.*



The vertical axis of the "Solar Attachment" will then point to the pole, the apparatus being in fact a small equatorial.

Time and azimuth are calculated from an observed altitude of the sun by solving the spherical triangle formed by the sun, the pole, and the zenith of the place. The three sides, S P, P Z, Z S, complements respectively of the declination, latitude, and altitude, are given, and we hence deduce S P Z, the hour angle, from apparent noon, and P Z S, the azimuth of the sun.

The "Solar Attachment" solves the same spherical triangle by construction, for the second process brings the vertical axis of the solar telescope to the required distance, Z P, from the zenith, while the first brings it to the required distance, S P, from the sun.

Observation for Time.

If the two telescopes, both being in position—one in the meridian, and the other pointing to the sun—are now turned on their *horizontal* axis, the vertical remaining undisturbed, until each is level, the angle between their directions (found by sighting on a distant object) is S P Z, the time from apparent noon.

This gives an easy observation for correction of time-piece, reliable to within a few seconds.

To Obtain the Latitude with the "Saegmuller Solar Attachment."

Level the transit carefully and point the telescope toward the south and elevate or depress the object end, according as the declination of the sun is south or north, an amount equal to the declination.

Bring the solar telescope into the vertical plane of the main telescope, level it carefully and clamp it. With the solar telescope observe the sun a few minutes before its culmination; bring its image between the two horizontal wires by moving the *transit telescope* in *altitude* and *azimuth*, and keep it so by the slow motion screws until the sun ceases to rise. Then take the reading of the vertical arc, correct for refraction due to altitude by the table below. Subtract the result from 90°, and the remainder is the latitude sought.

Mean Refraction.

Barometer 30 inches, Fahrenheit Thermometer 50°.

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

The following table, computed by Prof. Johnson, C. E., Washington University, St. Louis, will be found of considerable value in solar compass work:

"This table is valuable in indicating the errors to which the work is liable at different hours of the day and for different latitudes, as well as serving to correct the observed bearings of lines when it afterwards appears that a wrong latitude or declination has been used. Thus on the first day's observations I used a latitude in the forenoon of 38° 37′, but when I came to make the meridian observation for latitude I found the instrument gave 38° 39′. This was the latitude that should have been used, so I corrected the morning's observations for two minutes error in latitude by this table.

"It is evident that if the instrument is out of adjustment the latitude found by a meridian observation will be in error; but *if this observed latitude be used* in setting off the co-latitude the instrumental error is eliminated. Therefore always use for the co-latitude that given by the instrument itself in a meridian observation."

Errors in Azimuth (by Solar Compass) for 1 min. Error in Declination or Latitude.

Hour.	For 1 Min. Error in Declination.			For 1 Min. Error in Latitude.		
	Lat. 30°	Lat. 40°	Lat. 50°	Lat. 30°	Lat. 40°	Lat. 50°
	MIN.	MIN.	MIN.	MIN.	MIN.	MIN.
11.30 A.M. / 12.30 P.M.	8.85	10.00	12.90	8.77	9.92	11.80
11.00 A.M. / 1.00 P.M.	4.46	5.05	6.01	4.33	4.87	5.80
10.00 A.M. / 2.00 P.M.	2.31	2.61	3.11	2.00	2.26	2.70
9.00 A.M. / 3.00 P.M.	1.63	1.85	2.20	1.15	1.30	1.56
8.00 A.M. / 4.00 P.M.	1.34	1.51	1.80	0.67	0.75	0.90
7.00 A.M. / 5.00 P.M.	1.20	1.35	1.61	0.31	0.35	0.37
6.00 A.M. / 6.00 P.M.	1.15	1.30	1.56	0.00	0.00	0.00

NOTE.—Azimuths observed with erroneous declination or co-latitude may be corrected by means of this table by observing that for the line of collimation set *too high* the azimuth of any line *from the south point* in the direction S. W. N. E. is found *too small* in the *forenoon* and *too large* in the *afternoon* by the tabular amounts for each minute of error in the altitude of the line of sight. The reverse is true for the line set too low.

Correction for Refraction.

This correction is applied to the **declination** of the sun, and is equal to the refraction-correction of the sun's observed altitude multiplied by the cosine of the angle which the sun makes between the declination-circle and the vertical.

In order to reduce the refraction-correction to the simplest possible form, we have added a separate column to the ephemeris containing them, which we publish every year. They are thus brought in immediate juxtaposition with the declination angle, and we think the arrangement will be appreciated by those who use the Solar Attachment.

Latitude Coefficients.

LAT.	COEFF.	LAT.	COEFF.	LAT.	COEFF.	LAT.	COEFF.
15°	.30	27°	.56	39°	.96	51°	1.47
16	.32	28	.59	40	1.00	52	1.53
17	.34	29	.62	41	1.04	53	1.58
18	.36	30	.65	42	1.08	54	1.64
19	.38	31	.68	43	1.12	55	1.70
20	.40	32	.71	44	1.16	56	1.76
21	.42	33	.75	45	1.20	57	1.82
22	.44	34	.78	46	1.24	58	1.88
23	.46	35	.82	47	1.29	59	1.94
24	.48	36	.85	48	1.33	60	2.00
25	.50	37	.89	49	1.38		
26	.53	38	.92	50	1.42		

Refraction Correction, Lat. 40°.

January.

Day	′ ″
1	1h.1 58
2	2 2 16
	3 3 04
3	4 6 23
4	1 1 54
5	2 2 11
6	
7	3 2 59
8	4 6 01
9	1 1 51
10	2 2 07
11	
12	3 2 51
13	4 5 40
14	1 1 46
15	2 2 01
16	
17	3 2 40
18	4 5 00
19	1 1 42
20	
21	2 1 56
22	3 2 31
23	4 4 35
24	1 1 37
25	2 1 58
26	
27	3 2 22
28	4 4 07
29	1 1 32
	2 1 44
30	3 2 13
31	4h.3 41

February.

Day	′ ″
1	
2	
3	1h.1 26
4	2 1 37
5	
6	3 2 04
7	4 3 21
8	1 1 21
9	
10	2 1 31
11	3 1 56
12	4 3 04
13	1 1 16
14	2 1 25
15	3 1 48
16	4 2 47
17	5 8 39
18	1 1 12
19	2 1 20
20	3 1 40
21	4 2 31
22	5 6 49
23	1 1 07
24	2 1 15
25	3 1 33
26	4 2 18
27	5h.5 28
28	

March.

Day	′ ″
1	1h 1 03
	2 1 10
2	3 1 27
3	4 2 06
4	5 4 39
5	1 0 59
6	2 1 06
7	3 1 21
8	4 1 56
9	5 4 04
10	1 0 55
11	2 1 02
12	3 1 15
13	4 1 47
14	5 3 34
15	1 0 52
16	2 0 58
17	3 1 10
18	4 1 39
19	5 3 08
20	1 0 48
21	2 0 54
22	3 1 05
23	4 1 32
24	5 2 51
25	1 0 45
26	2 0 50
27	3 1 01
28	4 1 25
29	5 2 34
30	1 0 42
31	2h 0 47

April

Day	′ ″
1	3h 0 57
2	4 1 19
3	5 2 18
4	1 0 39
5	2 0 44
6	3 0 54
7	4 1 14
8	5 2 08
9	1 0 36
10	2 0 41
11	3 0 51
12	4 1 10
13	5 1 58
14	1 0 34
15	2 0 38
16	3 0 48
17	4 1 06
18	5 1 49
19	1 0 32
20	2 0 36
21	3 0 45
22	4 1 02
23	5 1 42
24	1 0 30
25	2 0 34
26	3 0 42
27	4 0 58
28	5 1 36
29	1 0 28
30	2h 0 32

May.

Day	′ ″
1	1h 0 28
	2 0 32
2	3 0 39
	4 0 55
3	5 1 30
4	1 0 26
5	2 0 30
6	3 0 37
7	4 0 53
8	5 1 26
9	1 0 25
10	2 0 29
11	3 0 36
12	4 0 51
13	5 1 22
14	1 0 23
15	2 0 27
16	3 0 34
17	4 0 49
18	5 1 18
19	1 0 22
20	2 0 26
21	3 0 33
22	4 0 47
23	5 1 15
24	1 0 21
25	2 0 25
26	3 0 32
27	4 0 46
28	5 1 13
29	1 0 20
	2 0 24
30	3 0 31
	4 0 44
31	5h.1 11

June

Day	′ ″
1	5h 1 11
2	
3	1 0 19
4	2 0 23
5	3 0 30
6	4 0 43
7	5 1 10
8	1 0 18
9	2 0 22
10	3 0 29
11	4 0 43
12	5 1 09
13	1 0 18
14	2 0 22
15	3 0 29
16	4 0 42
17	5 1 08
18	1 0 18
19	2 0 22
20	3 0 28
21	4 0 42
22	5 1 08
23	1 0 18
24	2 0 22
25	3 0 29
26	4 0 42
27	5 1 08
28	1 0 18
29	2 0 22
	3 0 29
30	4h 0 43

July

Day	′ ″
1	5h.1 09
2	
3	1 0 19
4	2 0 23
5	3 0 30
6	4 0 43
7	5 1 10
8	1 0 20
9	2 0 24
10	3 0 31
11	4 0 44
12	5 1 11
13	1 0 21
14	2 0 25
15	3 0 32
16	4 0 46
17	5 1 13
18	1 0 22
19	2 0 26
20	3 0 33
21	4 0 47
22	5 1 15
23	1 0 23
24	2 0 27
25	3 0 34
26	4 0 49
27	5 1 18
28	1 0 25
29	2 0 29
	3 0 36
30	4 0 51
31	5h 1 22

August

Day	′ ″
1	
2	1h 0 26
3	2 0 30
4	3 0 37
5	4 0 53
6	5 1 26
7	1 0 28
8	2 0 32
9	3 0 39
10	4 0 55
11	5 1 30
12	1 0 30
13	2 0 34
14	3 0 42
15	4 0 58
16	5 1 36
17	1 0 32
18	2 0 36
19	3 0 45
20	4 1 02
21	5 1 42
22	1 0 34
23	2 0 38
24	3 0 48
25	4 1 06
26	5 1 49
27	1 0 36
28	2 0 41
29	8 0 51
30	4 1 10
31	5h.1 58

September.

Day	′ ″
1	1h.0 39
2	2 0 44
3	3 0 54
4	4 1 14
5	5 2 08
6	1 0 42
7	2 0 47
8	3 0 57
9	4 1 19
10	5 2 18
11	1 0 45
12	2 0 50
13	3 1 01
14	4 1 25
15	5 2 34
16	1 0 48
17	2 0 54
18	3 1 05
19	4 1 32
20	5 2 51
21	1 0 52
22	2 0 58
23	3 1 10
24	4 1 39
25	5 3 08
26	1 0 56
27	2 1 02
28	3 1 15
29	4 1 47
30	5h.3 34

October.

Day	′ ″
1	1h.0 59
2	2 1 06
3	3 1 21
4	4 1 56
5	5 4 04
6	1 1 03
7	2 1 10
8	3 1 27
9	4 2 06
10	5 4 39
11	1 1 07
12	2 1 15
13	3 1 33
14	4 2 18
15	5 5 39
16	1 1 12
17	2 1 20
18	3 1 40
19	4 2 31
20	5 6 29
21	1 1 16
22	2 1 25
23	3 1 48
24	4 2 47
25	5 8 39
26	1 1 21
27	2 1 31
28	3 1 56
29	4 3 04
30	6 11 01
	1h.1 26
31	1 37
	2 04

November.

Day	′ ″
1	2h.3 21
2	3 13 57
3	4
4	5
5	1 1 32
6	2 1 44
7	3 2 13
8	4 3 41
9	5
10	1 1 37
11	2 1 50
12	3 2 22
13	4 4 07
14	5
15	1 1 42
16	2 1 56
17	3 2 31
18	4 4 35
19	5
20	1 1 46
21	2 2 01
22	3 2 40
23	4 4 59
24	5
25	1 1 50
26	2 2 06
27	3 2 49
28	4 5 33
29	5h.
30	

December.

Day	′ ″
1	1h 1 54
	2 2 11
2	3 2 59
3	4 6 01
4	5
5	1 1 58
6	2 2 16
7	3 3 04
8	4 6 23
9	5
10	1 2 00
11	2 2 19
12	3 3 09
13	4 6 38
14	5
15	1 2 01
16	2 2 20
17	3 3 11
18	4 6 47
19	5
20	1 2 01
21	2 2 20
22	3 3 11
23	4 6 49
24	5
25	1 2 00
26	2 2 19
27	3 3 09
28	4 6 43
29	5h.
30	
31	

The Preparation of the Declination Settings for a Day's Work.

The Solar Ephemeris gives the declination of the sun for the given day, for Greenwich mean noon. Since all points in America are west of Greenwich, by 5, 6, 7, or 8 hours, the declination found in the ephemeris is the declination at the given place at 7, 6, 5, or 4 o'clock A. M., of the same date, according as the place lies in the "Eastern," "Central," "Mountain," or "Western Time" belts respectively.

The column headed "Refraction Correction" gives the correction to be made to the declination, for refraction, for any point whose latitude is 40°. If the latitude is more or less than 40° these corrections are to be multiplied by the corresponding coefficients given in the table of "Latitude Coefficients," p. 116. Thus the refraction corrections in latitude 30° are 65 hundredths, and those of 50° 142 hundredths of the corresponding ones in latitude 40°. There is a slight error in the use of these latitude coefficients, but the maximum error will not amount to over 15″, except when the sun is very near the horizon, and then any refraction becomes very uncertain. All refraction tables are made out for the mean, or average, refraction, whereas the actual refraction at any particular time and place may not be more than one-half, or as much as twice the mean refraction, with small altitudes. The errors made in the use of these latitude coefficients are, therefore, very small as compared with the errors resulting from the use of the mean, rather than unknown actual refraction which affects any given observation.

Example I.

Let it be required to prepare a table of declinations for a point whose latitude is 38° 30′, and which lies in the "Central Time" belt, for April 5, 1890.

Since the time is 6 hours earlier than that at Greenwich, the declination given in the ephemeris is the declination here at 6 A. M. of same date. This is found to be + 6° 9′ 57″. To this must be added

the hourly change, which is also plus, and equal to 56″.83. The latitude coefficient is 0.94. The following table may now be made out:

Declination Settings for April 5, 1890, Lat. 38° 30′, Central Time.

Hr.	Declination	Ref. Cor.	Setting.	Hr.	Declination	Ref. Cor.	Setting.
7	+6° 10′ 54″	+ 2′ 00″	6° 12′ 54″	1	6° 16′ 35″	+ 37″	6° 17′ 12″
8	6 11 51	1 10	6 13 01	2	6 17 31	41	6 18 12
9	6 12 47	51	6 13 38	3	6 18 28	51	6 19 19
10	6 13 44	41	6 14 25	4	6 19 25	1 10	6 20 35
11	6 14 41	37	6 15 18	5	6 20 22	2 00	6 22 22

Example II.

Let it be required to prepare a declination table for a point in latitude 45°, in the "Eastern Time" belt, for Oct. 10, 1890.

The time now is 5 hours earlier than that of Greenwich, hence the declination given in the ephemeris for Greenwich mean noon is the declination at our point at 7 A. M. The declination found is—6° 43′ 56″, and the hourly change is—56″.87. The latitude coefficient is 1.20. The table then becomes:

Declination Setting for Oct. 10, 1890, Lat. 45°, Eastern Time.

Hr.	Declination	Ref. Cor.	Settings.	Hr.	Declination	Ref. Cor.	Settings.
7	−6° 43′ 56″	+ 5′ 35″	−6° 38′ 21″	1	−6° 49′ 37″	+ 1′ 16″	−6° 48′ 21″
8	6 44 53	2 31	6 42 22	2	6 50 34	1 24	6 49 10
9	6 45 50	1 44	6 44 06	3	6 51 31	1 44	6 49 47
10	6 46 47	1 24	6 45 23	4	6 52 28	2 31	6 49 57
11	6 47 44	1 16	6 46 28	5	6 53 25	5 35	6 47 50

If the date be between June 20 and Sept. 20 the declination is positive and the hourly change negative, while if it be between Dec. 20 and March 20 the declination is negative and the hourly change positive. The refraction correction is always positive; that is, it always increases numerically the north declinations and diminishes numerically the south declinations. The hourly refraction corrections given in the ephemeris are exact for the middle day of the five-day period corresponding to that set of hourly corrections. For the extreme days of any such period an interpolation can be made between the adjacent hourly corrections, if desired.

By using standard time instead of local time a slight error is made, but the maximum value of this error is found at those points where the standard time differs from the local time by one-half hour, and in the spring and fall when the declination is changing rapidly. The greatest error, then, is less than 30″, and this is smaller than can be set off on the vertical circle or declination arc. Even this error can be avoided by using the true difference of time from Greenwich in place of the standard meridian time.

TOPOGRAPHICAL SURVEYING

— BY —

ERNEST McCULLOUGH, C. E.

I. Surveying by Camera.
II. Stadia Surveying.

I. Surveying by Camera.*

The principle depends upon the art of projecting perspective views upon a horizontal plane.

Any camera may be used provided it is perfectly level when the view is taken, and the smallest size adapted for the work is one with a 5×8-inch plate. Although an ordinary camera may be used, it is better to have one for the purpose, provided with two levels and four leveling screws. The box should be solid, and focusing done by means

*Written in 1891 and revised in 1896 for this manual.

of the objective slide. If the camera has a compass, or a horizontal limb and a vertical limb, it will be complete.

Glass negatives are the most accurate to use, but paper negatives on account of portability are more convenient.

The several adjustments of the camera must not be neglected. The first is called "the test for register." The film on the sensitive plate must exactly replace the surface of the ground glass. To do this set the instrument up and focus for a distant view. Make a scratch to show the relative positions of the plate and tube. Take out the ground glass, and put in one with a transparent film. Focus on this, and make

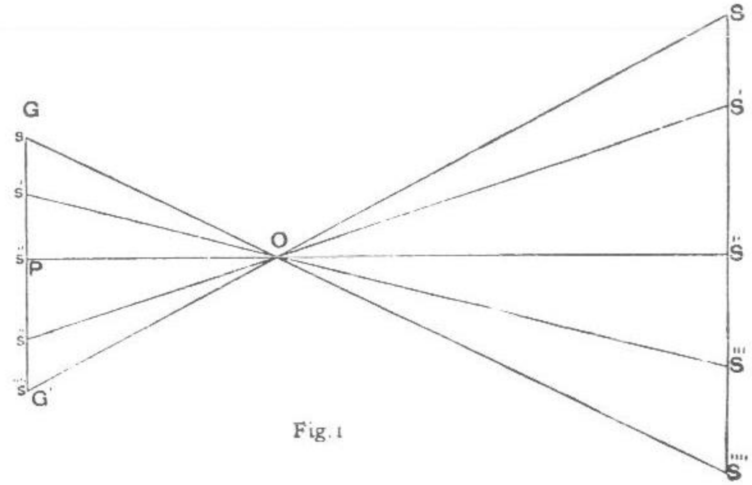


Fig. 1

another mark. In actual work this difference must be allowed for by changing the focus after the removal of the ground glass, so the film on the plate will be in the right position. The instrument maker should see to the register.

The focal distance must be accurately determined. Lens makers usually state the focal distance, but as it is liable to vary, the operator had better determine it himself. For simple convex lens, double or plano convex lens, measure from optic center to surface of ground glass. For double compound lenses proceed as follows: (Fig. 1.)

Set up several stakes in the ground distant from O about two or three hundred feet, as $S\ S'\ S''\ S'''\ S''''$. With transit at O, measure angles $S\ O\ S''$, etc. Set up the camera at O, level it carefully, make the image S'' coincide with a vertical line through the center of the plate, and photograph the stakes. The greater the distance apart on the plate of the stakes, the more accurate will be the determination of the focal length. $G\ G'$ represents the plate, $O\ P$ the focal length. Measure $s''\ s''''$ on plate, then

$$O\ P = \frac{s''\ s''''}{\text{tan. a}} = s''\ s''''\ \text{cot. a}$$

$$S\ O\ S'' = \text{a}$$

For a test of distortion of the lens, with $O\ P$ just found, compute the angles $S\ O\ S'\ S\ O\ S''$, etc., and if they agree with angles taken with the transit the lens is free from distortion.

Next, the horizon of the view must be found. Find the center of the ground glass and draw a vertical and horizontal line through it. Level the instrument carefully, and set beside it an engineer's level, with the telescope at same height as the lens of the camera. With the level find some object in the distance. Turn the camera to this object and move the object slide up and down until the object is exactly at the intersection of the lines on the ground glass, the object slide is then in its normal position, and a scratch on the slide will determine that position for all time. This scratch should be marked zero, and graduations should extend above and below it. The lower graduations should have a minus sign before their numbers. The plate holder should have four fine needles so inserted in the frame that their shadows will be photographed. When the picture is developed, lines scratched on the plate and connecting these points will occupy the same positions as the lines drawn on the ground glass.

The horizontal line represents the horizon of the picture, and is the trace of a line on a level with the center of the instrument. The object of graduating the vertical movement of the object slide is to provide for a changing of the horizon when necessary to limit sky views. By noting the number on this index when the view is taken, the actual horizon of the picture is set off from the horizon of the instrument when plotting.

To measure the field of view, half the length of the plate divided by the focal length gives the tangent of half the horizontal angle. The

horizontal angle is the field of view, and dividing 360° by this angle, gives the number of views needed to go around the circle.

Half the width of the plate, divided by the focal length, gives the tangent of half the vertical angle. As a general proposition it may be stated that the greater the focal length, the smaller the field of view and the greater the accuracy in the work. The smaller the focal length, the greater the field of view, greater rapidity (because fewer views) and less accuracy.

Set up the camera and level it carefully. Adjust to focal length and set object slide to most favorable position and note index number for fixing horizon. Adjust stop, set the plate holder and verify the leveling. The levels are apt to get a little out during all the handling. When all is ready take the picture. The camera must be rigid and the plate truly vertical.

The Plotting.

On the plate draw the horizontal line (the horizon) and the vertical line, from the shadows of the points of the needles. If the objective was above or below the horizon, then instead of drawing it draw a line parallel to it above or below, as indicated by the index number observed. From the vertical line measure to the right or left to the object you wish to locate, and divide this distance by the focal length, this will give the tangent of the horizontal angle from the line of sight. From the horizontal line, which is a trace of the plane of the optic center, measure up or down, as the case may be, to the object, and divide this distance By the focal length to obtain the tangent of the vertical angle.

Every point located on the map must show in at least two views. These views are taken from points previously fixed by triangulation or by direct measurement. The points from which the views are taken must be plotted, and from these points lines drawn on the bearings given in the field notes when the view was taken. On these bearings lay off the focal distance, and at the end of this line draw one at right angles to represent the plate. On the line representing the plate, lay off on either side the distances from the vertical to the object, and from the point of view draw lines through these points. The lines through two plates produced to an intersection locate the objects.

Figure 2 illustrates the method of plotting. O O' represent the points from which the views were taken. G G' and G'' G''' the plates, O P and O' P' the line of direction of sight. A B C etc. and A' B' C' etc. represent on the plate the objects to be located and their positions on the maps are shown by the points of intersection.

To fix the elevation, measure the distance from point of sight to object, and multiply into tangent of vertical angle already found; add to the elevation of the point from which the sight was taken, the

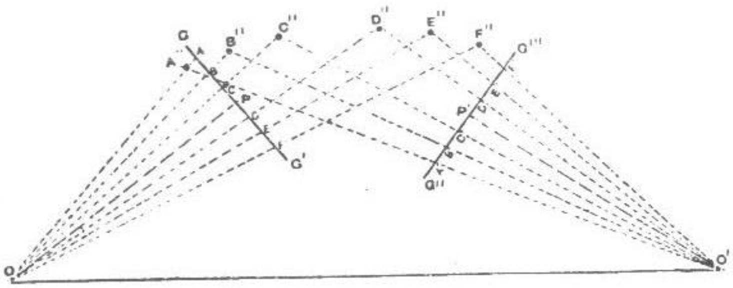


Fig. 2

height of instrument, and add or subtract, according to whether the point is above or below the horizon, the height above ascertained. This will give the elevation of the object above datum.

Spherical aberration does not interfere with the accuracy of the work, provided the focal length is ascertained by means of a point near the extremity of the plate in the horizon. (See Fig. 1.)

Field Work.

1. The ground may be triangulated with the transit and views taken from the triangulation points with the camera, the direction of the views to be ascertained by azimuths from the lines between stations. These azimuths to be taken by a compass, or by means of a horizontal limb.

2. The camera may be used in connection with a pocket compass, the work starting from a measured base.

3. The work may be done with a camera alone, fitted with a compass, horizontal limb and vertical circle. In this case the triangulation is carried on with the work.

Below is a form of record.

Station.	View.			Remarks.
	Number.	Index No.	Bearing.	
A.........	1	0	195½°	
	2	0	227°	
B	1	— 2	84°	

The index number may be the same or different for all views at the same station. Any time of the year is good for this work, and any hour of the day when the air is clear. Long distances between stations should be chosen, as short bases increase error. A few views only are necessary, as sketches may be made of unimportant places, and these views should be well chosen. A little care exercised in selecting positions will save much office work.

Office Work.

Upon the scale used depends the accuracy of the plotting. If the scale is large, then very long sights should not be attempted, but if the scale is small, then of course the range can be longer. The error in height is in proportion to the distance.

When the plates are prepared for plotting, the office notes are placed in a book in seven columns as follows:

Form of Record to Reduce Ht. to Common Datum.

View.	Distance.	Point.	Ref. ft.	Ref. of Sta. ft.	True Elev. ft.	Remarks.
Va.		1	+102	+460	+562	
		2	+ 90		550	
		3	− 25		435	

The first column is for the views.

The second column contains the distances to the points.

The third column the names or numbers of the points.

The fourth column the height above or below station.

The fifth column elevation of station.

The sixth column elevation of point.

The seventh column for remarks.

For drawing in contours, the fixing of natural and artificial objects on the plan, with their heights noted, will give all the data necessary, together with a close inspection of the proofs as the work proceeds. In the case of a bare country, with no buildings, fences or trees, a few painted stakes or flags put in at salient points will serve.

It is best to work directly from the negatives, as the paper positives are too much affected by atmospheric changes. Blue prints are as easy to work from as silver prints if positives are used.

II. Stadia Surveying.

A stadia survey consists of three operations:

1. The triangulation, or fixing of points to base the stadia work upon.
2. The leveling for benchmarks.
3. The stadia work.

The stadia work proper, is merely the filling in work of the topographical survey, and depends for its accuracy upon the care with which the triangulation has been done and the benchmarks fixed.

In surveying, a stadia line is run from one fixed point to another and all errors distributed on that line between those two points, so that if there are many points, the total error may be brought within very close limits. Whenever a benchmark is met, a reading is taken on it and errors in elevation distributed between adjacent benchmarks.

The fixed points may be located by triangulation or by any method the surveyor prefers so that enough points are taken and accurately determined. They should occupy elevated sites, and from any one a clear sight should be had to two others. Each point can also be a benchmark, but in running levels from one to the other, a number of other points can have their elevation determined and be properly marked.

The instrument is set on one of the fixed points and a sight taken to another with the plate clamped at zero or at the azimuth of that line, the azimuth being reckoned from true north. All readings are taken from 0 to 360, instead of "right" and "left." The angles are not double-centered or repeated, and the telescope is not reversed on any sights.

One or more rodmen may be employed. The instrument being oriented, the rodmen go to the points to be located and also hold at each change of slope, the rods being held vertical. The instrument man measures the height of the telescope center above the ground at the station, and directs the middle wire to that reading on the rod. He then takes and records his readings, which are:

1. The horizontal angle.
2. The vertical angle. (Plus or minus.)
3. The readings on the upper and lower wire.

The readings are recorded, each in its proper column in the order set forth, but in practice the rod readings may be first set down and as the instrument is clamped, the angles may be read while the rodman is moving to a new position.

When all the sights which can be taken from one point are taken, the right hand rodman is motioned forward and he proceeds to select a point favorably situated for sights. The left hand rodman comes to the instrument.

The point selected and the readings taken, the instrument is moved forward, the left hand, or "rear" rodman holding his rod on the peg just left. The instrument being set up, vernier "B" is set to the reading last taken, so that vernier "A" reads 180° different. The telescope is directed to the rear rod and the readings taken. This affords a check on the forward reading and should never be neglected. The rod reading should be the same as previously and the angle should be the same with different sign.

The rodmen again hold their rods where necessary, and the former operations are repeated.

When a fixed point is arrived at, a new start is taken from it so that each stadia line is thus independent of any other.

The Triangulation.

Sometimes the triangulation may be carried forward with the survey by a method akin to the "three-point problem," where three well located points may be sighted to from each instrument station or, as in a river survey or preliminary survey for an irrigating ditch line, a line of stakes may be set parallel to the stadia line and distant several hundred feet. Each of these points are sighted from two stations, and at every tenth station a new base line is measured with a tape. The writer has used this plan with good results. The calculations of the sides of the triangles are checked by the stadia readings and errors are distributed between base lines. An article describing the method very fully appeared in the *Engineering News* Oct. 12th, 1893, a reprint from the transactions of "The Eng. Assoc. of the South," of a paper by W. G. Kirkpatrick, C. E.

The Leveling.

The leveling cannot be dispensed with. Elevations taken by vertical angles are not as reliable as spirit-leveling, owing to the many adjustments and to the fact that vertical circles seldom read less than minutes. A man is more liable also to misread an angle than a rod.

Having frequent points at which to stop and renew, stadia elevations introduces an element of certainty, and frequent practice will show to what extent the vertical angles may be reliable.

GENERAL REMARKS.

There is no need of an engineer making his own stadia rods, for if the wires are adjusted to read one foot when the rod is one hundred feet distant, (plus constant) an ordinary self-reading leveling rod is sufficient.

A constant must be added to all sights, as the rod reading is not from the center of the instrument but from a point in front of the telescope. Measure the distance from the center of the telescope to the object glass; then focus on a distant point and measure the distance from the stadia wires to the object glass. Add the two measurements together and the result is a constant to be added to all rod readings.

All readings are to be reduced to the horizontal, so it is not advisable to read any vertical angles greater than 12° on the line or greater than 20° on the side sights.

Although the greater the length of sight, the greater the degree of accuracy, still the limiting length should be about six hundred feet, except in rather rough work on account of atmospheric conditions.

Office Work.

As a result of the field operations, four columns in the field book have been filled and three remain to be filled in the office.

The columns are:

1. Horizontal angles.
2. Vertical angles. (Plus or Minus.)
3. Reading on upper wire.
4. Reading on lower wire.
5. Bearings.
6. Distance from station.
7. Elevation referred to datum.

No sketches are necessary, as each sight is described on the page for remarks.

In the book a line is reserved for the number of the station, the direction to the fore or backsight, and its elevation referred to datum if the station be one of the triangulation points. If it be a stadia station the line tells its number and the height of the telescope above the ground. Below this line the records are placed, and when all the sights are taken from one point, a line is drawn across the page to separate the spaces used for the records for each station. Some men use a page for each station but no useful purpose is gained, and if few sights are taken much space is wasted.

The following formulas should be used for reducing stadia readings on the line:

$$d = Ka \ Cos^2 \ n.$$

$$e = Ka \ \tfrac{1}{2} \ Sin \ 2n.$$

n = Vertical reading.

k = A constant representing the wire spacing which is generally 100.

a = The reading on the rod, being the difference between the readings on the upper and lower wire, plus constant added to all rod readings.

d = The true distance.

e = Difference in elevation.

By these formulas, colums 6 and 7 can be filled for stations. If the horizontal angles were azimuths from true north, column 5 can be filled for all readings.

Columns 6 and 7 should be filled by formula for all sights on the line. That is, for all sights which carry the line forward, the formula should be used for reduction of distance and elevation.

For side sights which are for the purpose of merely obtaining contour points, the columns may be filled from diagram readings.

A form of diagram for distances is illustrated in Fig. 1. The vertical line at the end is divided for the vertical angles. A line is set off perpendicularly from a horizontal line, and the horizontal line may be ten or twenty inches long. In the diagram it is supposed to be twenty inches long.

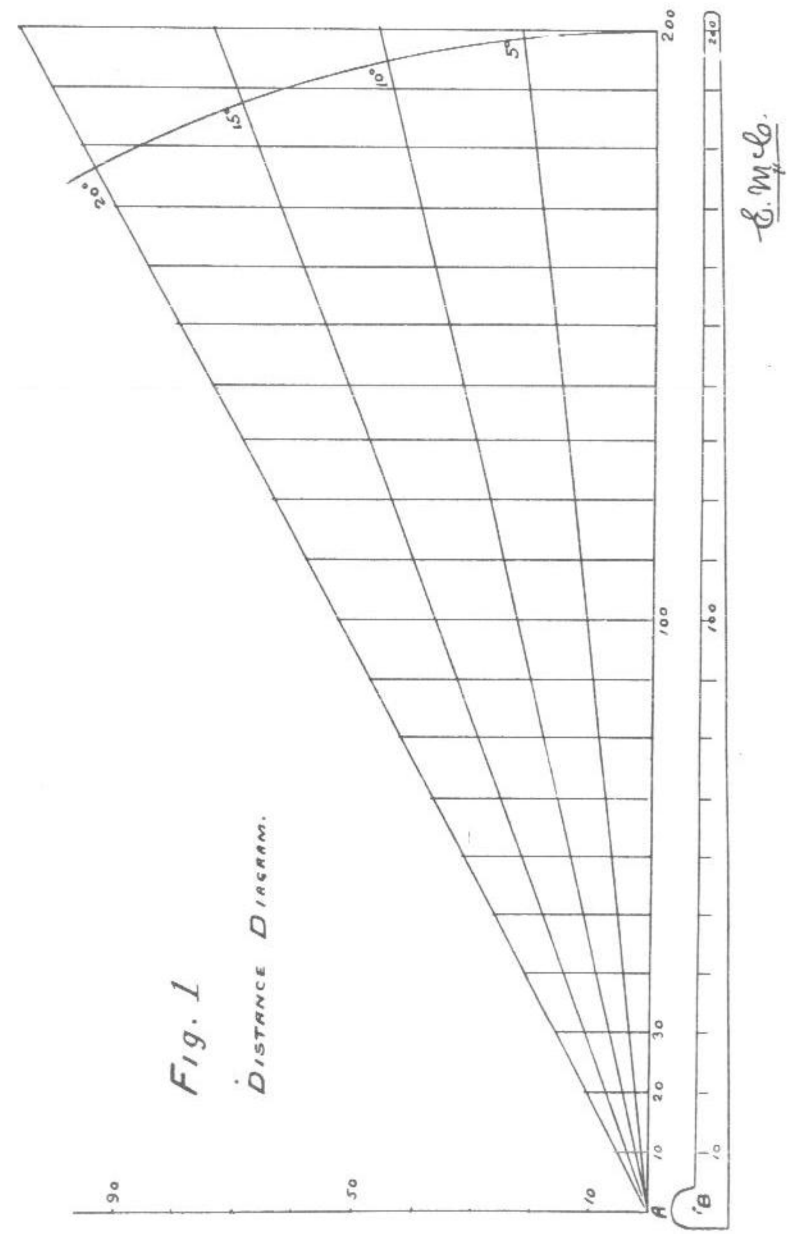


Fig. 1
Distance Diagram.

The vertical line is a tangent to the horizontal line, and if there was no co- ection to make on account of the rod being held vertical, it would be fficient to set off on that line the natural tangent of the distance whatever angle is selected. The formula for distance must however used, and in place of setting off on the vertical line the natural ent of the distance there should be set off the cos².

On vertical line there should be a point made for every five minute ngle. For instance in the distance two hundred and for angle f minutes, the cos² of five minutes into two hundred would give the istance, on the vertical line, from the horizontal on which a point sl d be made.

I ler to set off on the vertical line the points mentioned, it is necessa to describe an arc of a circle commencing at the end of the horizon al line, with center at A. The radius of the circle will therefore be 200.

he correct distance is to be calculated by the formula and set off on the orizontal line. From this point a vertical line should be drawn to int ect the arc. Through this point of intersection draw the lines from to the vertical line. On Fig. 1 an arc is drawn to represent the arc n ntioned. It does not have to be inked in on the diagram.

These points should be made for every five minutes up to ten degr s, and from ten degrees to fifteen for each ten minutes. From fifte twenty degrees the angles can be set off for each fifteen min f desired.

ht black lines can connect the point A with the degree marks an ght red lines may be used for the smaller subdivisions.

Fig. No. 2 is of the scale for obtaining the distances. A needle is ut through the points A and B, and the scale is then swung around as the angle is called off. The rod reading is read on the scale and the true horizontal reading is read off on the horizontal line at the bottom of the diagram. For example, it is required to know the horizontal distance for a rod reading of 175 feet for a vertical angle of ten degrees and four minutes. The distance scale is attached and laid on the line leading from A to the required angle. The distance of 175 feet is then read on the scale and at the point where it intersects with the diagram

an imaginary vertical line is dropped to the base, and the true horizontal distance is then read off.

It is convenient to divide the diagram by vertical line e inch apart in black, and divide each inch into tenths in red. Th agram

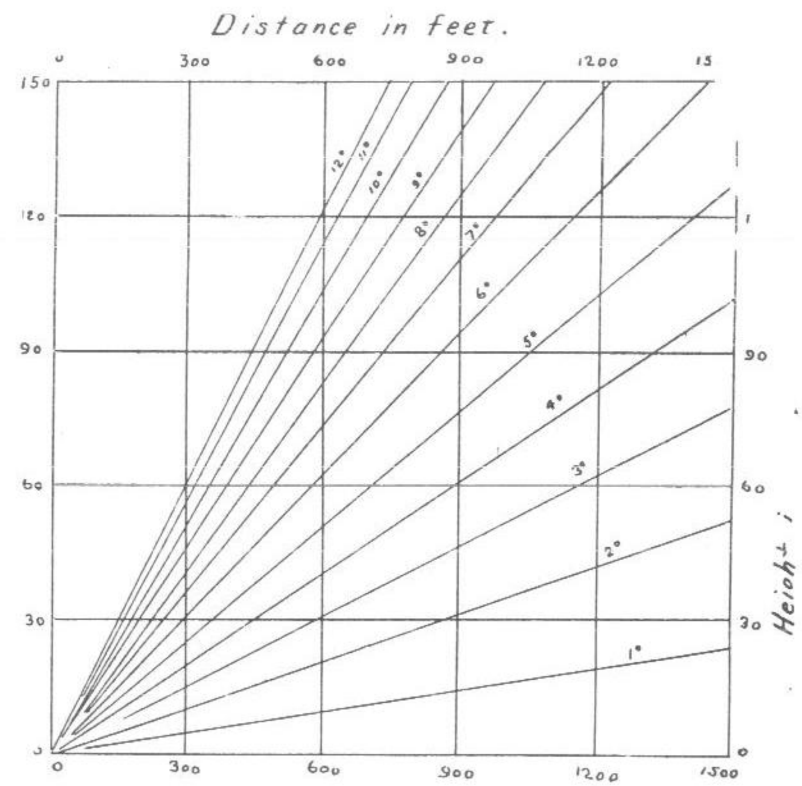


Fig 2.

Elevation Diagram.

being twenty inches long, it follows that horizontal distances may be read to the nearest foot and estimated closer for readings of less than 200 feet. A doubling of the scale will secure readings of two feet for rod readings of less than 400 feet, etc. The accuracy is about equal to the accuracy of the rod readings themselves.

The paper under the point A must be reinforced with cardboard or strong paper to prevent the needle wearing too large a hole, and the scale should also be protected where the needle goes through. To insure a correct setting of the scale there should be a vertical line drawn from the point A, and when the scale is attached for work, its edge should be laid along the two rectangular lines starting from A. It is plain to see that when the readings for zero and ninety degrees are correct, the intermediate readings will be correct if the hole does not wear too large. The vertical and horizontal lines are graduated the same as the scale, so it is an easy matter to make the scale coincide both for angle and distance.

By the use of the preceding diagram, all distances may be calculated quickly. One man can call off the angle and rod reading, and the other can call off the true distance. When the true distances are all found, the differences in elevation are next to be found. For this purpose Fig. 2 is used. It may be from ten to twenty inches square. In the cut it is supposed to be fifteen inches. The diagram is ruled into one-inch squares and each square into tenths. The horizontal lines are the true distances and the vertical line B-C is used for the differences in elevation. It will be noticed that one foot on the vertical line is equal to ten feet horizontally.

On the vertical line the angles are set off and a line drawn for each five minutes for every degree to six, and for each ten minutes to ten degrees, after which the interval may be for fifteen minutes or thirty, at the option of the man using the scale. To obtain the difference in elevation for any rod reading, the angle is called off and the line followed until it intersects with a vertical line showing the true horizontal distance. This point will show the difference in elevation between the instrument and the point where the rod was held. On account of the exaggeration in scale, it may be seen that close readings are possible.

A diagram may be made which is a combination of the two described, and which will give the distance and difference in elevation at the same time. To construct it there must first be drawn a diagram for calculating elevations. The true distance should be calculated for each degree and for each one hundred feet (counting one inch on the

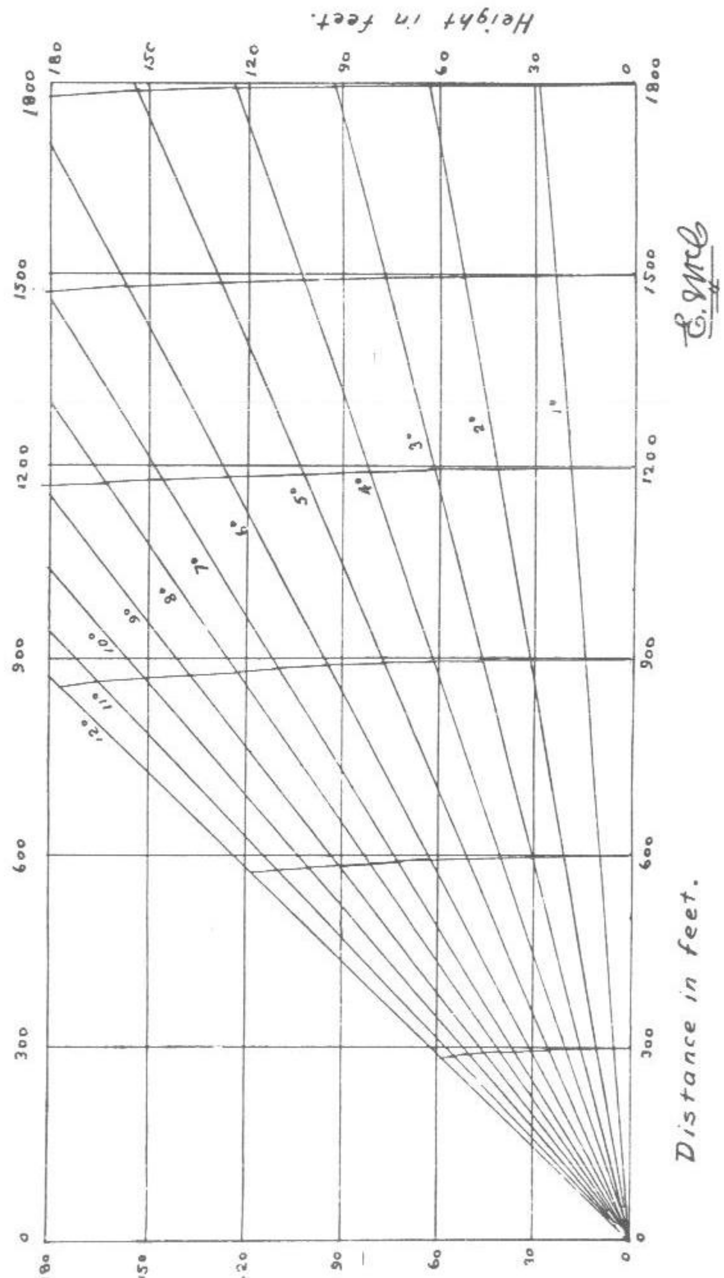


Fig. 3 DISTANCES & ELEVATIONS.

horizontal line as one hundred feet). The true distances should then be laid off on the lines connecting point A (Fig. 2) with the degrees.

There will then be on all the lines, points about one inch apart. Commencing at the first inch on the bottom line, a spline can be bent to connect all the points which show the distance for a rod reading of 100 feet on all the angles. A line can then be drawn connecting these points. The same process can be followed at 200, 300, etc. The result will be curved lines starting from the points on the lower horizontal line and the divisions can be as close as the maker of the diagram likes.

It being desired to know the true distance and difference of elevation for a certain rod reading, it is only necessary to place the pencil on the bottom horizontal line at the distance given in the rod reading and follow the curved line, which begins at that point, until it intersects the given angle. The horizontal line at that point gives the distance and the vertical line at that point gives the difference of elevation.

Edward P. Adams, C. E., described two excellent stadia charts in the May 1893 number of the journal of the Association of Engineering Societies. Any engineer can make them and they do not depend upon scaling for accuracy. The charts themselves need to be accurately made, but once made the scale of the chart cuts no figure.

Plotting.

When all the readings have been reduced and the columns in the field book properly filled, the plotting is commenced.

First all the triangulation points are plotted and then the stadia lines connecting the points. These stadia lines are adjusted for errors, if any, and then the work of plotting the side sights begins.

To adjust the errors in the stadia lines the following is a good practical method: Plot the lines and if they do not meet the point properly, scale the distance by which they strike to one side or the other and divide it by the total distance to find the natural tangent of the amount of change in the meridian which must be made to plot in the side sights correctly. For instance, if the angle is five minutes, the

meridian must be changed five minutes from the true meridian at each point where side shots are taken. The bearings of the sights may be read off as set down, but in plotting, the meridian must be varied.

The angle found, the lines as plotted may be traced on a piece of tracing paper and fitted on the triangulation points. Each station is pricked through, and through each station must be drawn two lines at right angles, one due north and south, and the other due east and west. On these lines fit the protractor.

A large paper protractor is used for plotting side sights. The center is cut out close to the graduations which are numbered from 0° to 360°. Place it on the lines drawn at right angles through the stations so that the lines pass through 0°, 90°, 180°, 270°, and 360°.

Take a triangular scale and paste on it at the point where measurements commence, a piece of paper about a quarter of an inch square or smaller. It should be a tough paper. Directly opposite the zero mark put a fine needle through this paper and through the station on the map. The scale may then be swung around in a circle.

The angle is first read and the scale points to it. The distance is then read off on the scale and set on the map. It may be seen that the process is a duplicate of that by which the sights were taken. The instrument station is the center of the protractor, and the angles are read off the same as on the instrument. The true distance is read on the scale and plotted on the map. The elevation is marked on it, and when ready for contour work, the man who did the field work can draw in the contours. Any draughtsman may plot the notes, but only the original surveyor can correctly put in the contours. The draughtsman may make contours if he likes from the original notes as plotted, but the contours should not be inked in until the field man has had an opportunity to verify them.

Accuracy of Stadia Work.

Instances are on record of stadia lines closing with an error of less than one in five thousand, which is a better result than can be obtained by other methods of topographical surveying and certainly is closer than many farm surveys. Such close results are however, exceptional, and there must have been present conditions which cannot always be expected.

For careful work, the error may be from one in seven hundred to one in fifteen hundred. It may be made very much less as experience with the work increases. It is closer than can be scaled on a map of the scale to which topographical maps are usually made, so it is as accurate as is necessary.

In plane table work the plotting is accurate only for the scale to which the first map is made or for a smaller map reproduced from the original. Every enlargement increases the amount of error if any error is in the work. With stadia surveying it is not so. The work may be plotted to any scale and the error is of equal amount in each plat. If the reading was one foot wrong it is only one foot wrong whether the scale is one thousand feet to an inch or fifty feet.

Uses of the Map.

A survey of a piece of country thirty miles long was made by the stadia method with running triangulation, and topography taken with stadia rod for a distance of a quarter of a mile on either side of the line. The line was run approximately on the grade of the proposed canal. The work was plotted and contours with one foot intervals drawn. Upon this was located the canal line and when staked in the field the agreement was remarkable. The complete notes were made in the office from the map and very little change was necessary.

A canyon in the interior of this State was surveyed for a short line of railroad and the location made on the map. This location was followed on construction without change.

A tract of land was surveyed at small cost and on the map was planned the subdivision. All the roads and streets were laid out, a sewer system designed and grades established. A few monuments were set in and all future subdivision of that piece of land will be made from the map which was filed, and the measurements will be taken from the monuments as starting points. Parks and cemeteries were also laid out on this map.

It is possible to make surveys from which to calculate quantities for grading. Many such surveys have been made and the results are

as good as when the land is staked out in small squares. The work can of course be made as close as desired, depending entirely upon the care taken.

A survey has recently been made in a town where the original field notes had entirely disappeared. The roads were all winding, and in many places the owners of property had encroached on the street. A careful tape survey was made to connect monuments which were set in, and the fences and buildings were located with stadia rods from each station. The work was plotted on a large scale (forty feet to an inch). The taped lines were plotted by latitude and departures and the side sights plotted in as described before. All original maps, etc., were plotted on, and the original lines recovered as well as possible. Then a set of field notes were made from the map and run in on the ground.

In making a set of notes from the map, it is necessary to rule it off into latitude and departure squares as accurately as they can be plotted, and when all the points have been set on the map, their position may be scaled and the latitude and departure of each point set down. The bearing and distance between two points can then be calculated.

GRADIENTER SCREW TABLE.

(COPYRIGHTED)

This Table has been computed by
A. BARION, C. E.
Expressly for this Catalogue.

Multiples, for the space on the leveling rod, expressed in feet and decimals, obtained by two revolutions of the gradienter screw.

Angles of Elevation.	Multiples for Direct Distance.	Multiples for Horizontal Distance.	Angles of Elevation.	Multiples for Direct Distance.	Multiples for Horizontal Distance.
° ′			° ′		
0.	100.000	100.000	**8.00**	98.888	97.926
0.15	99.995	99.993	8.15	.822	.799
0.30	.987	.984	8.30	.754	.669
0.45	.979	.970	8.45	.684	.536
1.00	.967	.954	**9.00**	.613	.399
1.15	.954	.930	9.15	.539	.257
1.30	.939	.906	9.30	.465	.113
1.45	.923	.877	9.45	.387	96.966
2.00	.905	.843	**10.00**	.307	.814
2.15	.884	.807	10.15	.227	.659
2.30	.862	.768	10.30	.143	.500
2.45	.837	.722	10.45	.059	.338
3.00	.811	.674	**11.00**	97.972	.172
3.15	.785	.623	11.15	.883	.003
3.30	.753	.566	11.30	.794	95.830
3.45	.721	.506	11.45	.701	.654
4.00	.687	.444	**12.00**	.607	.474
4.15	.651	.377	12.15	.511	.291
4.30	.614	.306	12.30	.414	.104
4.45	.575	.231	12.45	.313	94.915
5.00	.534	.154	**13.00**	.212	.722
5.15	.492	.070	13.15	.109	.524
5.30	.444	98.986	13.30	.004	.323
5.45	.397	.897	13.45	96.896	.121
6.00	.348	.803	**14.00**	.788	93.913
6.15	.297	.707	14.15	.677	.703
6.30	.246	.606	14.30	.565	.489
6.45	.188	.503	14.45	.450	.272
7.00	.133	.395	**15.00**	.334	.052
7.15	.075	.285	15.15	.216	92.829
7.30	.015	.167	15.30	.096	.601
7.45	98.952	.049	15.45	95.975	.369

GRADIENTER SCREW TABLE.

(CONTINUED)

Angles of Elevation.	Multiples for Direct Distance.	Multiples for Horizontal Distance.	Angles of Elevation.	Multiples for Direct Distance.	Multiples for Horizontal Distance.
° ′			° ′		
16.00	95.850	92.137	**23.00**	91.660	84.374
16.15	.725	91.902	23.15	.484	.056
16.30	.598	.662	23.30	.307	83.735
16.45	.469	.421	23.45	.128	.411
17.00	.338	.173	**24.00**	90.948	.086
17.15	.205	90.923	24.15	.766	82.757
17.30	.071	.671	24.30	.583	.427
17.45	94.935	.417	24.45	.396	.092
18.00	.797	.158	**25.00**	.208	81.757
18.15	.657	89.896	25.15	.019	.419
18.30	.515	.632	25.30	89.829	.078
18.45	.372	.364	25.45	.636	80.735
19.00	.227	.093	**26.00**	.441	.390
19.15	.080	88.819	26.15	.246	.042
19.30	93.930	.543	26.30	.047	79.692
19.45	.780	.264	26.45	88.848	.340
20.00	.627	87.980	**27.00**	.646	78.986
20.15	.473	.696	27.15	.444	.629
20.30	.317	.409	27.30	.242	.270
20.45	.160	.117	27.45	.035	77.909
21.00	.000	86.823	**28.00**	87.826	.546
21.15	92.839	.527	28.15	.616	.180
21.30	.676	.228	28.30	.405	76 .813
21.45	.511	85.926	28.45	.192	.444
22.00	.343	.621	**29.00**	86.977	.073
22.15	.175	.313	29.15	.761	75.700
22.30	.005	.002	29.30	.544	.324
22.45	91.833	84.690	29.54	.324	.947
			30.00	.102	.568

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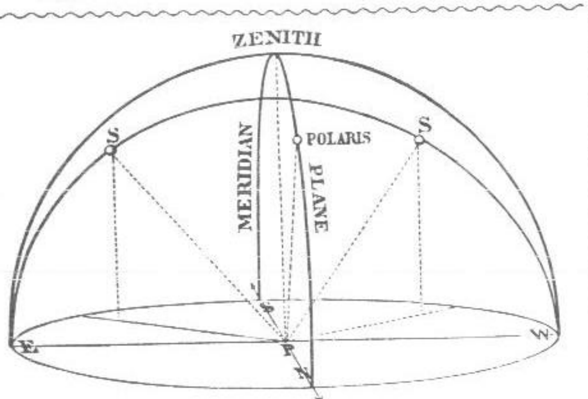
INSTRUCTIONS.

To determine the true Meridian by two equal Altitudes of the Sun.



Set up the transit instrument at the place of observation, P; see that there is no dead motion in the tangent-screws and tripod-legs; slide the Solar Reflector into the eye-piece cap; put the cover with the small hole over the object-glass; clamp the vernier of the horizontal plate to zero; then level up the instrument, turn it on the lower plate center toward the sun, and raise the telescope till the sun's image appears on the reflector. Clamp the telescope axis and the lower plate center, and bring with the vertical axis tangent screw and with the lower plate tangent screw the image of the sun exactly within the graduated lines of the reflector. Note the time, and make it so that the forenoon observation will correspond nearly in time with one of the columns of the correction table. Be careful that the position of the instrument is not disturbed, and that the vernier of the horizontal plate remains at zero; because zero is the starting-point for the afternoon observation.

The afternoon observation will be sooner or later, as the case may be, on account of the declination of the sun; and it is important that the observer should be aware of this, so that he may not put any reliance on exact corresponding meridian distance as to time for the afternoon observation. The second observation, or the double-equal altitude of the sun, is fast or slow: but the observer must not lose confidence in the accuracy of his established true meridian line on account of this irregularity, as the table will afterwards make the necessary correction. Taking it for granted that the instrument has remained undisturbed in the same position during the time since the forenoon observation was taken, and as the time for the afternoon equal altitude of the sun is approaching, the observer has to loosen carefully the horizontal vernier clamp, and slowly turn the instrument on the horizontal circle in the direction the sun has moved. As soon as the sun's image begins to appear on the reflector, the observer has to fasten the clamp of the horizontal vernier, and make the final motion with the horizontal vernier tangent screw alone. The utmost precaution has to be taken not to move the lower clamp and tangent-screw, or the telescope axis tangent screw, as any motion on either of those parts will make the observation worthless.

The sun is moving very fast; two seconds of time can be distinctly seen on the reflector; the observer must therefore be very attentive and quick; he must follow with the horizontal vernier tangent screw the oblique course of the sun on the reflector till the image is precisely in the same place between the graduated lines as by the former observation. When this is satisfactorily done, then the observer has to find correctly the horizontal angle, and make the necessary corrections for the true meridian line, as shown hereafter.

DIRECTIONS

For the Use of the Table of Corrections.

Find in the ephemeris of the sun the hourly difference of the sun's declination in seconds, for the date of observation; and find in the correction table the number which corresponds to the latitude of the place and to the time of morning observation, multiply the number in the correction-table with the hourly difference of the sun's declination, and the product will be the correction in minutes of arc.

The actual or abstract multiplier to give the result in seconds of arc is sixty times the number given in the table below; but we have divided by sixty, so as to give minutes of arc at once, as not less than a minute of arc can be read on the division of a transit instrument.

Between Dec. 22d and June 22d the sun is moving North, or the north polar distance is decreasing, and the correction found by the multiplier must be SUBSTRACTED from the angle as found on the horizontal plate between the fore and afternoon observations, and the line bisecting the remaining angle will be the true meridian. But between June 22d and Dec. 22d, when the sun is moving South or the north polar distance is increasing, ADD the correction to the horizontal angle, as found in the reading of the instrument, and the line bisecting the sum of these two angles will be the true meridian.

TABLE OF CORRECTIONS.

Lat.	8 A. M.	8½ A. M.	9 A. M.	9½ A. M.	10 A. M.	10½ A. M.	11 A. M.	11½ A. M.
32°	0.18	0.17	0.17	0.16	0.16	0.15	0.15	0.14
33°	0.18	0.18	0.17	0.16	0.16	0.16	0.15	0.15
34°	0.19	0.18	0.17	0·17	0.16	0.16	0.16	0.15
35°	0.19	0.18	0.17	0.17	0.16	0.16	0.16	0.15
36°	0.19	0·18	0.17	0.17	0.16	0.16	0.16	0.15
37°	0·19	0.18	0.18	0.17	0.17	0.16	0.16	0.16
38°	0.20	0.19	0.18	0.17	0.17	0.17	0.16	0.16
39°	0.20	0.19	0.18	0.18	0.17	0.17	0.17	0.16
40°	0.20	0.19	0.18	0.18	0.17	0.17	0·17	0.16
41°	0.20	0.19	0.19	0.18	0.18	0.17	0.17	0.17
42°	0.21	0.20	0.19	0.18	0.18	0.18	0·17	0.17
43°	0.21	0.20	0.19	0.19	0.18	0.18	0.18	0.17
44°	0.21	0.20	0.20	0.19	0.19	0.18	0.18	0.18
45°	0.22	0.21	0.20	0.19	0.19	0.18	0.18	0.18
46°	0.22	0.21	0.20	0.20	0.19	0.19	0.19	0.18
47°	0.23	0.22	0.21	0.20	0.20	0.19	0.19	0.19
48°	0.23	0.22	0.21	0.20	0.20	0.20	0.19	0.19
49°	0.23	0.22	0.22	0.21	0.20	0.20	0.20	0.19

☞ Substract the product of the multiplication between December 22d and June 22d.

☞ Add the product of the multiplication between June 22d and Dec. 22d.

EXAMPLE I. May 24th, 1881, 8:30 A.M., at San Francisco, in lat. 37 deg. 48 min. north, I took the altitude of the sun's image; and seven hours afterwards, at 3:30 P.M. I had the same altitude. The horizontal angle between the two observations measured 168 deg. 33 min., and the hourly differences in the sun's declination in the ephemeris was 27·46 seconds. The tabular number for lat. 38deg. and 8:30 A.M. is 0,19; hence correction is: 27.46 x 0,19 gives 5 minutes; horizontal angle is 168 deg. 33 min., from which deduct 5 min., leaving 168 deg. 28 min., which divided by two gives 84 deg. 14 min. for the true meridian.

EXAMPLE II. Sept. 10th, 1881, at 11 o'clock A.M., at the same place of observation, the horizontal angle measured at 1 P.M. 52 deg 41 min.; the hourly difference in the sun's declination was 56.93 seconds. The tabular number for 38 deg. and 11 A.M. is 0,16; hence correction is: 56.93 x 0.16 gives 9 minutes; horizontal angle is 52 deg 41 min., to which add 9 min., making 52 deg. 50 min., which divided by two gives 26 deg. 25 min. for the true meridian.

After establishing the line on the ground, the whole manipulation is finished.

TABLE

Of Refractions in Declination for Solar-Compasses and Solar-Transits.

By Sun's Declinations North,
From March 22d to Sept. 22d, *add:*

For Latl.	Hours from Merid.	Sun's Declinations in Nautical Alm. + 20°	+ 15°	+ 10°	+ 5°
		′ ″	′ ″	′ ″	′ ″
30°	1.	10	15	21	27
"	2.	14	19	25	31
"	3.	20	26	32	39
"	4.	32	39	46	52
35°	1.	15	21	27	33
"	2.	20	25	32	38
"	3.	26	33	39	47
"	4.	39	47	56	1 06
40°	1.	21	27	33	40
"	2.	25	32	39	46
"	3.	33	40	48	57
"	4.	47	55	1 05	1 18
45°	1.	27	33	40	48
"	2.	32	39	46	52
"	3.	40	47	56	1 06
"	4.	54	1 02	1 14	1 32
50°	1.	33	40	48	57
	2.	38	46	55	1 06
"	3.	47	56	1 06	1 20
"	4.	1 00	1 45	2 00	3 00

By Sun's Declinations South,
From Sept. 22d to March 22d, *substract:*

For Latl.	Hours from Merid.	Sun's Declinations in Nautical Alm. − 5°	− 10°	− 15°	− 20°
		′ ″	′ ″	′ ″	′ ″
30°	1.	40	48	56	1 00
"	2.	46	54	1 10	1 18
"	3.	55	1 06	1 18	1 36
"	4.	1 19	1 35	1 57	2 29
35°	1.	48	57	1 06	1 20
"	2.	55	1 04	1 18	1 34
"	3.	1 06	1 20	1 40	2 00
"	4.	1 40	2 00	2 30	3 30
40°	1.	1 00	1 08	1 30	1 40
"	2.	1 08	1 20	1 36	2 00
"	3.	1 20	1 40	2 00	2 40
"	4.	2 00	2 30	3 20	5 00
45°	1.	1 08	1 30	1 40	2 00
"	2.	1 20	1 40	2 00	2 30
"	3.	1 40	2 00	2 36	3 30
"	4.	2 20	3 00	4 40	8 00
50°	1.	1 30	1 40	2 00	2 40
"	2.	1 36	2 00	2 30	3 15
"	3.	2 30	2 45	3 30	5 00
"	4.	3 00	4 30	7 00	15 00

TABLE.

Of the increase or decrease of the Sun's Declination for hourly Differences, from 5 seconds to 60 seconds, and from three to twelve hours of time.

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

TABLE.

AZIMUTHS OF POLARIS,

At the time of greatest elongation, from the year 1881 to 1900, and from latitude 30deg. to 49deg. north.

COMPUTED BY W. J. LEWIS, C. E.

year.	L. 30°	L. 31°	L. 32°	L. 33°	L. 34°	L. 35°	L. 36°	L. 37°	L. 38°	L. 39°	year.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	
1881.	1 32	1 33	1 34	1 35	1 36	1 37	1 38	1 40	1 41	1 42	1881.
1882.	1 31	1 32	1 33	1 34	1 36	1 37	1 38	1 39	1 41	1 42	1882.
1883.	1 31	1 32	1 33	1 34	1 35	1 36	1 38	1 39	1 40	1 42	1883.
1884.	1 31	1 32	1 33	1 34	1 35	1 36	1 37	1 38	1 40	1 41	1884.
1885.	1 30	1 31	1 32	1 33	1 34	1 36	1 37	1 38	1 39	1 41	1885.
1886.	1 30	1 31	1 32	1 33	1 34	1 35	1 36	1 38	1 39	1 40	1886.
1887.	1 30	1 31	1 32	1 33	1 34	1 35	1 36	1 37	1 39	1 40	1887.
1888.	1 29	1 30	1 31	1 32	1 33	1 34	1 36	1 37	1 38	1 39	1888.
1889.	1 29	1 30	1 31	1 32	1 33	1 34	1 35	1 36	1 38	1 39	1889.
1890.	1 29	1 29	1 30	1 31	1 32	1 34	1 35	1 36	1 37	1 39	1890.
1891.	1 28	1 29	1 30	1 31	1 32	1 33	1 34	1 36	1 37	1 38	1891.
1892.	1 28	1 29	1 30	1 31	1 32	1 33	1 34	1 35	1 37	1 38	1892.
1893.	1 27	1 28	1 29	1 30	1 31	1 32	1 34	1 35	1 36	1 37	1893.
1894.	1 27	1 28	1 29	1 30	1 31	1 32	1 33	1 34	1 36	1 37	1894.
1895.	1 27	1 28	1 29	1 30	1 31	1 32	1 33	1 34	1 35	1 37	1895.
1896.	1 26	1 27	1 28	1 29	1 30	1 31	1 32	1 34	1 35	1 36	1896.
1897.	1 26	1 27	1 28	1 29	1 30	1 31	1 32	1 33	1 35	1 36	1897.
1898.	1 26	1 27	1 27	1 29	1 29	1 31	1 32	1 33	1 34	1 35	1898.
1899.	1 25	1 26	1 27	1 28	1 29	1 30	1 31	1 32	1 34	1 35	1899.
1900.	1 25	1 26	1 27	1 28	1 29	1 30	1 31	1 32	1 33	1 34	1900.

	L. 40°	L. 41°	L. 42°	L. 43°	L. 44°	L. 45°	L. 46°	L. 47°	L. 48°	L. 49°	
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	
1881.	1 44	1 45	1 47	1 49	1 51	1 52	1 54	1 57	1 59	2 01	1881.
1882.	1 43	1 45	1 47	1 48	1 50	1 52	1 54	1 56	1 58	2 01	1882.
1883.	1 43	1 45	1 46	1 48	1 50	1 52	1 54	1 56	1 58	2 00	1883.
1884.	1 43	1 44	1 46	1 47	1 49	1 51	1 53	1 55	1 57	2 00	1884.
1885.	1 42	1 44	1 45	1 47	1 49	1 51	1 53	1 55	1 57	1 59	1885.
1886.	1 42	1 43	1 45	1 47	1 48	1 50	1 52	1 54	1 56	1 59	1886.
1887.	1 41	1 43	1 44	1 46	1 48	1 50	1 52	1 54	1 56	1 58	1887.
1888.	1 41	1 42	1 44	1 46	1 47	1 49	1 51	1 53	1 56	1 58	1888.
1889.	1 41	1 42	1 44	1 45	1 47	1 49	1 51	1 53	1 55	1 57	1889.
1890.	1 40	1 42	1 43	1 45	1 47	1 48	1 50	1 52	1 55	1 57	1890.
1891.	1 40	1 41	1 43	1 44	1 46	1 48	1 50	1 52	1 54	1 56	1891.
1892.	1 39	1 41	1 42	1 44	1 46	1 48	1 50	1 52	1 54	1 56	1892.
1893.	1 39	1 40	1 42	1 44	1 45	1 47	1 49	1 51	1 53	1 55	1893.
1894.	1 38	1 40	1 41	1 43	1 45	1 47	1 49	1 51	1 53	1 55	1894.
1895.	1 38	1 40	1 41	1 43	1 44	1 46	1 48	1 50	1 52	1 54	1895.
1896.	1 38	1 39	1 41	1 42	1 44	1 46	1 48	1 50	1 52	1 54	1896.
1897.	1 37	1 39	1 40	1 42	1 44	1 45	1 47	1 49	1 51	1 54	1897.
1898.	1 37	1 38	1 40	1 41	1 43	1 45	1 47	1 49	1 51	1 53	1898.
1899.	1 36	1 38	1 39	1 41	1 43	1 44	1 46	1 48	1 50	1 53	1899.
1900.	1 36	1 37	1 39	1 41	1 42	1 44	1 46	1 48	1 50	1 52	1900.

TABLES.

The following Tables give the greatest Eastern and Western Elongation of the North Star (Polaris), in common clock time, for every third day in the year when the star is visible.

EASTERN ELONGATION.

Day of Month	April.	May.	June.	July.	August.	September.
	h. min.	h. min.	h. min.	h. min.	h. min.	h. min.
1	6 39 A.M	4 41 A.M	2 39 A.M	0 41 A.M	10 35 P.M	8 32 P.M
4	6 27 "	4 29 "	2 28 "	0 30 "	10 23 "	8 20 "
7	6 15 "	4 17 "	2 16 "	0 18 "	10 12 "	8 08 "
10	6 03 "	4 05 "	2 04 "	0 06 "	10 00 "	7 56 "
13	5 52 "	3 53 "	1 52 "	11 49 P.M	9 48 "	7 45 "
16	5 40 "	3 41 "	1 40 "	11 37 "	9 36 "	7 33 "
19	5 28 "	3 30 "	1 28 "	11 25 "	9 24 "	7 21 "
22	5 16 "	3 18 "	1 17 "	11 14 "	9 12 "	7 09 "
25	5 04 "	3 06 "	1 05 "	11 02 "	9 01 "	6 57 "
28	4 52 "	2 54 "	0 53 "	10 50 "	8 49 "	6 46 "
31	——	2 42 "	——	10 38 "	8 37 "	——

WESTERN ELONGATION.

Day of Month	October.	November.	December.	January.	February.	March.
	h. min.	h. min.	h. min.	h. min.	h. min.	h. min.
1	6 27 A.M	4 24 A.M	2 26 A.M	0 27 A.M	10 21 P.M	8 31 P.M
4	6 15 "	4 13 "	2 14 "	0 15 "	10 09 "	8 18 "
7	6 03 "	4 01 "	2 02 "	12 00 P.M	9 58 "	8 06 "
10	5 51 "	3 49 "	1 51 "	11 48 "	9 46 "	7 55 "
13	5 39 "	3 37 "	1 39 "	11 36 "	9 34 "	7 44 "
16	5 27 "	3 25 "	1 27 "	11 24 "	9 22 "	7 32 "
19	5 16 "	3 13 "	1 16 "	11 12 "	9 10 "	7 20 "
22	5 04 "	3 02 "	1 04 "	11 01 "	8 59 "	7 08 "
25	4 52 "	2 50 "	0 52 "	10 49 "	8 47 "	6 56 "
28	4 40 "	2 38 "	0 41 "	10 36 "	8 35 "	6 44 "
31	4 28 "	——	0 30 "	10 25 "	——	6 33 "

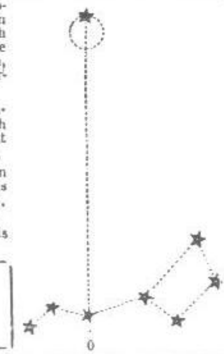
An approximation to the true meridian might be obtained by sighting on the Pole Star at the instant when it is on the same vertical plane with Alioth. The North Star is exactly in the true meridian 26 minutes in time after it has been in the same vertical plane with Alioth, and may be sighted after that interval of time with perfect accuracy.

On the first day of January, 1882, the right ascension of Polaris will be: 1 h. 15 m. 30 sec., and of Alioth 13 h. 42 m. 53 sec. When therefore Polaris arrives at the meridian, Alioth will be 27 m. 23 sec. to the East.

Hence when Alioth is directly under Polaris, or in the same vertical plane, the pole is to the West of this plumb line, ranging from 10 min. 38 sec. in arc in lat. 30 deg. north to 14 min. 2 sec. in lat. 49 deg. north.

The azimuth for every second degree of latitude is shown in the following table:

Lat.	m. s.	Lat.	m. s.	Lat.	m. s.
28°	10 27	36°	11 23	44°	12 48
30°	10 38	38°	11 41	46°	13 15
32°	10 51	40°	12 01	48°	13 46
34°	11 06	42°	12 23	49°	14 02



EXPLANATORY NOTES.

EXPLANATION OF THE TABLES.

Tables I and II.

Table I gives the length of a degree of latitude, in chains, for every minute of latitude between 29 and 49 degrees, calculated by the Formula $Dm = 5528,8724 - 27,7425 \cos 2l + ,0592 \cos 4l$, in which Dm represents a degree of the meridian, and l, the middle latitude.

Table II gives the length of a degree of longitude, in chains, for every minute of latitude between 29 and 49 degrees, calculated by the formula $Dp = 5537,7439 \cos l - 4,6337 \cos 3l + ,0058 \cos 5l$, in which Dp represents a degree of the parallel and l, the latitude.

These tables are useful for converting linear into angular, and angular into linear measure, as well as for determining the convergencies and divergencies of the meridians, on the spheroidal surface of the earth.

PROBLEMS AND EXAMPLES.

1. *Given the latitudes of any two places on the same meridian, to find the distance between them.*

RULE.—Find, from Table I, the length of a degree of the meridian at each latitude, and take half their sum for the mean length of a degree. Then say, as 60 minutes is to the difference of latitude, so is the mean length of a degree to the distance required.

The latitude of the Monte Diablo Base Line, is 37 deg. 52 min. 47 sec., and that of the 1st Standard North, 38 deg. 18 min. 53 sec.; what is the meridional distance between them?

chains. chains.
As 60 min.: 26 min. 6 sec. : : 5517.205 : 24.00 the distance required.

2. *Given the distance between any two places on the same meridian, and the latitude of one of them to find their difference of latitude.*

RULE.—Find, from Table I, the length of a degree of the meridian, in the given latitude, and also in that differing from it, by the meridional distance, converted into an arc at the rate of 52 seconds per mile, and take half their sum for the mean length of a degree. Then say, as the mean length of a degree is to the meridional distance, so is 60 minutes to the difference of latitude required.

The latitude of the Monte Diablo Base Line, is 37 deg. 52 min. 47 sec.: what is the latitde of the 1st Standard North, the meridional distance being 30 miles?

chains. chains.
As 5517.205 : 2400 : : 60 min. : 26 min. 6 sec, the difference of latitude required.

3. *Given the longitudes of any two places, on the same parallel, in a given latitude, to find the distance between them.*

RULE.—Find, from Table II, the length of a degree of longitude in the given latitude: and say, as 60 minutes is to the difference of longitude, so is the length of the degree of longitude to the distance required.

The longitude of Monte Diablo Meridian is 121 deg. 54 min. 49 sec., and that of Range 1 East, 121 deg. 21 min. 53 sec.; what is the distance between them, on the Base Line, in latitude 37 deg. 52 min. 47 sec.?

chains chains
As 60 min. : 32 min. 56 sec. : : 4372.51 : 2400, the distance required.

EXPLANATORY NOTES.

4. *Given the distance between any two places on the same parallel, in a given latitude, to find their difference of longitude.*

RULE.—Find from Table II, the length of degree of longitude in the given latitude; and say, as the length of the degree of longitude is to the given distance, so is 60 minutes to the difference of longitude.

The longitude of the Monte Diablo Meridian, is 121 deg. 54 min. 49 sec.: what is the difference of longitude to Range 5 East, the distance on the Base Line, in latitude 37 deg. 52 min. 47 sec., being 30 miles?

chains. chains.
As 4373 51: 2400: 60 min.: 32 min. 56 sec, the difference of longitude required.

5. *Given the distance between two meridians, on any parallel, in a given latitude, to find the convergency of the meridians for any distance north of that parallel.*

RULE.—Find the length of a degree of longitude, at each latitude, by the foregoing rules; and say, as the greater of the two lengths is to their difference, so is the given distance to the convergency required.

The distance between Ranges 1 and 2 on the 1st Standard South, is 6 miles, what is the convergency of the two range lines at the 2d Standard North, the meridional distance being 30 miles?

chains. chains. chains. chains.
As 4346.66 : 26.07 : : 480 : 2.88, the convergency required.

6. *Given the distance between two meridians, on any parallel in a given latitude, to find the divergency of the meridians for any distance south of that parallel.*

RULE.—Find the length of a degree of longitude, at each latitude, by the foregoing rules; and say, as the less of the two lengths is to their difference, so is the given distance to the divergency required.

The distance between Ranges 1 and 2, on the 1st Standard South, is 6 miles; what is the divergency of the two range lines at the 2d Standard South, the meridional distance being 24 miles?

chains. chains. chains. chains.
As 4393.00 : 20.34 : : 480 : 2.22, the divergency required.

Table III.

This table gives the divergency of the Parallel of Latitude from the Prime Vertical,* or perpendicular to the meridian, on the spheroidal surface of the earth at every second degree of latitude, from 28 to 48 degrees, for any number of miles from 1 to 36; and is useful in running a parallel of latitude by fore and back sighting.

*The length of a degree of the Prime Vertical may be calculated by the Formula $Dv = 5551,6748 - 18,6536 \cos 2l + ,0940 \cos 4l$; in which Dv represents a degree of the Prime Vertical, in chains, and l the latitude.

EXAMPLE.

If a line commenced on the parallel of 37 degrees north latitude, be extended east or west, 27½ miles, by fore and back sighting, what distance will its terminus be south of that parallel?

	chains.
The table gives for 27 miles in latitude 37 deg.	5.52
" " 28 " "	5.94
The mean of which is	5.73 the distance required.

TABLE I.

Length of a Degree of Latitude.

′	29°	30°	31°	32°	33°	34°	35°	36°	37°	38°	′
	chains.	chains.	chains.	chains.	chains.	chains.	chains.	chains.	chains.	chains.	
0	5509·15	5509·97	5510·82	5511·67	5512·55	5513·44	5514·34	5515·25	5516·18	5517·11	0
1	09·16	09·99	10·83	11·69	12·56	13·45	14·35	15·27	16·19	17·13	1
2	09·17	10·00	10·84	11·70	12·58	13·47	14·37	15·28	16·21	17·14	2
3	09·19	10·01	10·86	11·72	12·59	13·48	14·38	15·30	16·22	17·16	3
4	09·20	10·03	10·87	11·73	12·61	13·50	14·40	15·31	16·24	17·17	4
5	09·21	10·04	10·89	11·75	12·62	13·51	14·42	15·33	16·25	17·19	5
6	09·23	10·06	10·90	11·76	12·64	13·53	14·43	15·34	16·27	17·20	6
7	09·24	10·07	10·91	11·78	12·65	13·54	14·45	15·36	16·28	17·22	7
8	09·25	10·08	10·93	11·79	12·67	13·56	14·46	15·38	16·30	17·23	8
9	09·27	10·10	10·94	11·81	12·68	13·57	14·48	15·39	16·32	17·25	9
10	09·28	10·11	10·96	11·82	12·70	13·59	14·49	15·41	16·33	17·27	10
11	09·30	10·13	10·97	11·83	12·71	13·60	14·51	15·42	16·35	17·28	11
12	09·31	10·14	10·99	11·85	12·73	13·62	14·52	15·44	16·36	17·30	12
13	09·32	10·15	11·00	11·86	12·74	13·63	14·54	15·45	16·38	17·31	13
14	09·34	10·17	11·01	11·88	12·76	13·65	14·55	15·47	16·39	17·33	14
15	09·35	10·18	11·03	11·89	12·77	13·66	14·57	15·48	16·41	17·34	15
16	09·36	10·19	11·04	11·91	12·79	13·68	14·58	15·50	16·42	17·36	16
17	09·38	10·21	11·06	11·92	12·80	13·69	14·60	15·51	16·44	17·38	17
18	09·39	10·22	11·07	11·94	12·81	13·71	14·61	15·53	16·46	17·39	18
19	09·41	10·24	11·09	11·95	12·83	13·72	14·63	15·54	16·47	17·41	19
20	09·42	10·25	11·10	11·96	12·84	13·74	14·64	15·56	16·49	17·42	20
21	09·43	10·26	11·11	11·98	12·86	13·75	14·66	15·57	16·50	17·44	21
22	09·45	10·28	11·13	11·99	12·87	13·77	14·67	15·59	16·52	17·45	22
23	09·46	10·29	11·14	12·01	12·89	13·78	14·69	15·61	16·53	17·47	23
24	09·47	10·31	11·16	12·02	12·90	13·80	14·70	15·62	16·55	17·49	24
25	09·49	10·32	11·17	12·04	12·92	13·81	14·72	15·64	16·56	17·50	25
26	09·50	10·33	11·19	12·05	12·93	13·83	14·73	15·65	16·58	17·52	26
27	09·51	10·35	11·20	12·07	12·95	13·84	14·75	15·67	16·60	17·53	27
28	09·53	10·36	11·21	12·08	12·96	13·86	14·76	15·68	16·61	17·55	28
29	09·54	10·38	11·23	12·10	12·98	13·87	14·78	15·70	16·63	17·56	29
30	09·56	10·39	11·24	12·11	12·99	13·89	14·79	15·71	16·64	17·58	30
31	09·57	10·41	11·26	12·12	13·01	13·90	14·81	15·73	16·66	17·60	31
32	09·58	10·42	11·27	12·14	13·02	13·92	14·82	15·74	16·67	17·61	32
33	09·60	10·44	11·29	12·15	13·04	13·93	14·84	15·76	16·69	17·63	33
34	09·61	10·45	11·30	12·17	13·05	13·95	14·86	15·77	16·70	17·64	34
35	09·63	10·46	11·31	12·18	13·07	13·96	14·87	15·79	16·72	17·66	35
36	09·64	10·48	11·33	12·20	13·08	13·98	14·89	15·81	16·74	17·67	36
37	09·65	10·49	11·34	12·21	13·10	13·99	14·90	15·82	16·75	17·69	37
38	09·67	10·50	11·36	12·22	13·11	14·01	14·92	15·84	16·77	17·71	38
39	09·68	10·52	11·37	12·24	13·13	14·02	14·93	15·85	16·78	17·72	39
40	09·69	10·53	11·39	12·26	13·14	14·04	14·95	15·87	16·80	17·74	40
41	09·71	10·55	11·40	12·27	13·16	14·05	14·96	15·88	16·81	17·75	41
42	09·72	10·56	11·42	12·29	13·17	14·07	14·98	15·90	16·83	17·77	42
43	09·74	10·57	11·43	12·30	13·18	14·08	14·99	15·91	16·84	17·78	43
44	09·75	10·59	11·44	12·31	13·20	14·10	15·01	15·93	16·86	17·80	44
45	09·76	10·60	11·46	12·33	13·21	14·11	15·02	15·94	16·88	17·82	45
46	09·78	10·62	11·47	12·34	13·23	14·13	15·04	15·96	16·89	17·83	46
47	09·79	10·63	11·49	12·36	13·24	14·14	15·05	15·98	16·91	17·85	47
48	09·80	10·65	11·50	12·37	13·26	14·16	15·07	15·99	16·92	17·86	48
49	09·82	10·66	11·52	12·39	13·27	14·17	15·08	16·01	16·94	17·88	49
50	09·83	10·67	11·53	12·40	13·29	14·19	15·10	16·02	16·95	17·89	50
51	09·85	10·69	11·54	12·42	13·30	14·20	15·11	16·04	16·97	17·91	51
52	09·86	10·70	11·56	12·43	13·32	14·22	15·13	16·05	16·98	17·93	52
53	09·87	10·72	11·57	12·45	13·33	14·23	15·15	16·07	17·00	17·94	53
54	09·89	10·73	11·59	12·46	13·35	14·25	15·16	16·08	17·02	17·96	54
55	09·90	10·74	11·60	12·48	13·36	14·26	15·18	16·10	17·03	17·97	55
56	09·92	10·76	11·62	12·49	13·38	14·28	15·19	16·11	17·05	17·99	56
57	09·93	10·77	11·63	12·51	13·39	14·29	15·21	16·13	17·06	18·00	57
58	09·94	10·79	11·65	12·52	13·41	14·31	15·22	16·15	17·08	18·02	58
59	09·96	10·80	11·66	12·53	13·42	14·32	15·24	16·16	17·09	18·04	59
60	09·97	10·82	11·67	12·55	13·44	14·34	15·25	16·18	17·11	18·05	60

TABLE I.

Length of a Degree of Latitude.

′	39°	40°	41°	42°	43°	44°	46°	46°	47°	48°	′
	chains.	chains.	chains.	chains.	chains.	chains.	chains.	chains.	chains.	chains.	
0	5518·05	5519·00	5519·96	5520·92	5521·88	5522·85	5523·81	5524·78	5525·75	5526·72	0
1	18·07	19·02	19·97	20·93	21·90	22·86	23·83	24·80	25·77	26·73	1
2	18·08	19·03	19·99	20·95	21·91	22·88	23·85	24·82	25·78	26·75	2
3	18·10	19·05	20·00	20·96	21·93	22·89	23·86	24·83	25·80	26·76	3
4	18·11	19·06	20·02	20·98	21·94	22·91	23·88	24·85	25·82	26·78	4
5	18·13	19·08	20·04	21·00	21·96	22·93	23·90	24·86	25·83	26·80	5
6	18·15	19·10	20·05	21·01	21·98	22·94	23·91	24·88	25·85	26·81	6
7	18·16	19·11	20·07	21·03	21·99	22·96	23·93	24·90	25·86	26·83	7
8	18·18	19·13	20·08	21·04	22·01	22·98	23·94	24·91	25·88	26·84	8
9	18·19	19·14	20·10	21·06	22·02	22·99	23·96	24·93	25·90	26·86	9
10	18·21	19·16	20·12	21·08	22·04	23·01	23·98	24·94	25·91	26·88	10
11	18·22	19·18	20·13	21·09	22·06	23·02	23·99	24·96	25·93	26·89	11
12	18·24	19·19	20·15	21·11	22·07	23·04	24·01	24·98	25·94	26·91	12
13	18·26	19·21	20·16	21·12	22·09	23·06	24·02	24·99	25·96	26·92	13
14	18·27	19·22	20·18	21·14	22·11	23·07	24·04	25·01	25·98	26·94	14
15	18·29	19·24	20·20	21·16	22·12	23·09	24·06	25·03	25·99	26·96	15
16	18·30	19·25	20·21	21·17	22·14	23·10	24·07	25·04	26·01	26·97	16
17	18·32	19·27	20·23	21·19	22·15	23·12	24·09	25·06	26·02	26·99	17
18	18·34	19·29	20·24	21·20	22·17	23·14	24·11	25·07	26·04	27·00	18
19	18·35	19·30	20·26	21·22	22·19	23·15	24·12	25·09	26·06	27·02	19
20	18·37	19·32	20·28	21·24	22·20	23·17	24·14	25·11	26·07	27·04	20
21	18·38	19·33	20·29	21·25	22·22	23·19	24·15	25·12	26·09	27·05	21
22	18·40	19·35	20·31	21·27	22·23	23·20	24·17	25·14	26·10	27·07	22
23	18·41	19·37	20·32	21·29	22·25	23·22	24·19	25·15	26·12	27·09	23
24	18·43	19·38	20·34	21·30	22·27	23·23	24·20	25·17	26·14	27·10	24
25	18·45	19·40	20·36	21·32	22·28	23·25	24·22	25·19	26·15	27·12	25
26	18·46	19·41	20·37	21·33	22·30	23·27	24·23	25·20	26·17	27·13	26
27	18·48	19·43	20·39	21·35	22·31	23·28	24·25	25·22	26·19	27·15	27
28	18·49	19·45	20·40	21·36	22·33	23·30	24·27	25·23	26·20	27·17	28
29	18·51	19·46	20·42	21·38	22·35	23·31	24·28	25·25	26·22	27·18	29
30	18·53	19·48	20·44	21·40	22·36	23·33	24·30	25·27	26·23	27·20	30
31	18·54	19·49	20·45	21·41	22·38	23·35	24·32	25·28	26·25	27·21	31
32	18·56	19·51	20·47	21·43	22·40	23·36	24·33	25·30	26·27	27·23	32
33	18·57	19·53	20·48	21·45	22·41	23·38	24·35	25·32	26·28	27·25	33
34	18·59	19·54	20·50	21·46	22·43	23·40	24·36	25·33	26·30	27·26	34
35	18·60	19·56	20·52	21·48	22·44	23·41	24·38	25·35	26·31	27·28	35
36	18·62	19·57	20·53	21·49	22·46	23·43	24·40	25·36	26·33	27·29	36
37	18·64	19·59	20·55	21·51	22·48	23·44	24·41	25·38	26·35	27·31	37
38	18·65	19·60	20·56	21·53	22·49	23·46	24·43	25·40	26·36	27·33	38
39	18·67	19·62	20·58	21·54	22·51	23·48	24·44	25·41	26·38	27·34	39
40	18·68	19·64	20·60	21·56	22·52	23·49	24·46	25·43	26·39	27·36	40
41	18·70	19·65	20·61	21·57	22·54	23·51	24·48	25·44	26·41	27·37	41
42	18·72	19·67	20·63	21·59	22·56	23·52	24·49	25·46	26·43	27·39	42
43	18·73	19·68	20·64	21·61	22·57	23·54	24·51	25·48	26·44	27·41	43
44	18·75	19·70	20·66	21·62	22·59	23·56	24·52	25·49	26·46	27·42	44
45	18·76	19·72	20·68	21·64	22·60	23·57	24·54	25·51	26·47	27·44	45
46	18·78	19·73	20·69	21·65	22·62	23·59	24·56	25·52	26·49	27·45	46
47	18·79	19·75	20·71	21·67	22·64	23·60	24·57	25·54	26·51	27·47	47
48	18·81	19·76	20·72	21·69	22·65	23·62	24·59	25·56	26·52	27·49	48
49	18·83	19·78	20·74	21·70	22·67	23·64	24·61	25·57	26·54	27·50	49
50	18·84	19·80	20·76	21·72	22·69	23·65	24·62	25·59	26·56	27·52	50
51	18·86	19·81	20·77	21·74	22·70	23·67	24·64	25·61	26·57	27·53	51
52	18·87	19·83	20·79	21·75	22·72	23·69	24·65	25·62	26·59	27·55	52
53	18·89	19·84	20·80	21·77	22·73	23·70	24·67	25·64	26·60	27·57	53
54	18·91	19·86	20·82	21·78	22·75	23·72	24·69	25·65	26·62	27·58	54
55	18·92	19·88	20·84	21·80	22·77	23·73	24·70	25·67	26·64	27·60	55
56	18·94	19·89	20·85	21·82	22·78	23·75	24·72	25·69	26·65	27·61	56
57	18·95	19·91	20·87	21·83	22·80	23·77	24·73	25·70	26·67	27·63	57
58	18·97	19·92	20·88	21·85	22·81	23·78	24·75	25·72	26·68	27·65	58
59	18·98	19·94	20·90	21·86	22·83	23·80	24·77	25·73	26·70	27·66	59
60	19·00	19·96	20·92	21·88	22·85	23·81	24·78	25·75	26·72	27·68	60

TABLE. II.

Length of a Degree of Longitude.

′	29°	30°	31°	32°	33°	34°	35°	36°	37°	38°	′
	chains.	chains.	chains.	chains.	chains	chains.	chains.	chains.	chains.	chains.	
0	4843·17	4795·82	4747·01	4696·75	4645·06	4591·96	4537·45	4481·56	4424·29	4365·68	0
1	42·40	95·02	46·19	95·90	44·19	91·06	36·53	80·61	23·33	64·69	1
2	41·62	94·22	45·36	95·05	43·32	90·16	35·61	79·67	22·36	63·70	2
3	40·84	93·42	44·53	94·20	42·44	89·26	34·69	78·73	21·40	62·72	3
4	40·06	92·61	43·71	93·35	41·57	88·37	33·77	77·78	20·43	61·73	4
5	39·28	91·81	42·88	92·50	40·69	87·47	32·84	76·84	19·46	60·74	5
6	38·50	91·01	42·05	91·65	39·82	86·57	31·92	75·89	18·49	59·75	6
7	37·72	90·20	41·22	90·80	38·94	85·67	31·00	74·95	17·53	58·76	7
8	36·94	89·40	40·39	89·94	38·06	84·77	30·08	74·00	16·56	57·77	8
9	36·16	88·59	39·56	89·09	37·19	83·87	29·15	73·05	15·59	56·77	9
10	35·38	87·79	38·73	88·24	36·31	82·97	28·23	72·11	14·62	55·78	10
11	34·60	86·98	37·90	87·38	35·43	82·07	27·30	71·16	13·65	54·79	11
12	33·82	86·18	37·07	86·53	34·55	81·17	26·38	70·21	12·68	53·80	12
13	33·04	85·37	36·24	85·67	33·68	80·26	25·46	69·26	11·71	52·81	13
14	32·26	84·56	35·41	84·82	32·80	79·36	24·53	68·32	10·74	51·81	14
15	31·47	83·76	34·58	83·96	31·92	78·46	23·60	67·37	09·77	50·82	15
16	30·69	82·95	33·75	83·11	31·04	77·56	22·68	66·42	08·80	49·83	16
17	29·91	82·14	32·92	82·25	30·16	76·65	21·75	65·47	07·82	48·83	17
18	29·12	81·33	32·08	81·40	29·28	75·75	20·83	64·52	06·85	47·84	18
19	28·34	80·52	31·25	80·54	28·40	74·85	19·90	63·57	05·88	46·84	19
20	27·55	79·71	30·42	79·68	27·52	73·94	18·97	62·62	04·91	45·85	20
21	26·77	78·90	29·58	78·82	26·64	73·04	18·04	61·67	03·93	44·85	21
22	25·98	78·09	28·75	77·97	25·75	72·13	17·11	60·72	02·96	43·85	22
23	25·20	77·28	27·92	77·11	24·87	71·23	16·19	59·77	01·98	42·86	23
24	24·41	76·47	27·08	76·25	23·99	70·32	15·26	58·81	01·01	41·86	24
25	23·62	75·66	26·25	75·39	23·11	69·41	14·33	57·86	00·04	40·86	25
26	22·83	74·85	25·41	74·53	22·22	68·51	13·40	56·91	4399·06	39·87	26
27	22·05	74·04	24·57	73·67	21·34	67·60	12·47	55·96	98·08	38·87	27
28	21·26	73·22	23·74	72·81	20·45	66·69	11·54	55·00	97·11	37·87	28
29	20·47	72·41	22·90	71·95	19·57	65·78	10·61	54·05	96·13	36·87	29
30	19·68	71·60	22·06	71·09	18·69	64·88	09·67	53·09	95·16	35·87	30
31	18·89	70·78	21·22	70·22	17·80	63·97	08·74	52·14	94·18	34·87	31
32	18·10	69·97	20·39	69·36	16·91	63·06	07·81	51·19	93·20	33·87	32
33	17·31	69·16	19·55	68·50	16·03	62·15	06·88	50·23	92·22	32·87	33
34	16·52	68·34	18·71	67·64	15·14	61·24	05·94	49·27	91·25	31·87	34
35	15·73	67·53	17·87	66·77	14·26	60·33	05·01	48·32	90·27	30·87	35
36	14·94	66·71	17·03	65·91	13·37	59·42	04·08	47·36	89·29	29·87	36
37	14·15	65·89	16·19	65·05	12·48	58·51	03·14	46·41	88·31	28·87	37
38	13·35	65·08	15·35	64·18	11·59	57·60	02·21	45·45	87·33	27·87	38
39	12·56	64·26	14·51	63·32	10·70	56·68	01·28	44·49	86·35	26·87	39
40	11·77	63·44	13·67	62·45	09·81	55·77	00·34	43·53	85·37	25·86	40
41	10·98	62·52	12·82	61·59	08·93	54·36	4499·40	42·57	84·39	24·86	41
42	10·18	61·81	11·98	60·72	08·04	53·95	98·47	41·62	83·41	23·86	42
43	09·39	60·99	11·14	59·85	07·15	53·03	97·53	40·66	82·42	22·85	43
44	08·59	60·17	10·30	58·99	06·26	52·12	96·59	39·70	81·44	21·85	44
45	07·80	59·35	09·45	58·12	05·36	51·21	95·66	38·74	80·46	20·85	45
46	07·00	58·53	08·61	57·25	04·47	50·29	94·72	37·78	79·48	19·84	46
47	06·21	57·71	07·76	56·38	03·58	49·38	93·78	36·82	78·49	18·84	47
48	05·41	56·89	06·92	55·51	02·69	48·46	92·84	35·86	77·51	17·83	48
49	04·61	56·07	06·07	54·65	01·80	47·55	91·91	34·89	76·53	16·82	49
50	03·82	55·25	05·23	53·78	00·90	46·6	90·97	33·93	75·54	15·82	50
51	03·02	54·43	04·3	52·91	00·01	45·71	90·03	32·97	74·56	14·81	51
52	02·22	53·60	03·54	52·04	4599·12	44·80	89·09	32·01	73·57	13·80	52
53	01·42	52·78	02·69	51·17	98·22	43·88	88·15	31·04	72·59	12·80	53
54	00·62	51·96	01·84	50·30	97·33	42·96	87·21	30·08	71·60	11·79	54
55	4799·82	51·13	01·00	49·42	96·44	42·04	86·27	29·12	70·62	10·78	55
56	99·02	50·31	00·15	48·55	95·54	41·13	85·32	28·15	69·63	09·77	56
57	98·22	49·49	4699·20	47·68	94·64	40·21	84·38	27·19	68·64	08·76	57
58	97·42	48·66	98·45	46·81	93·75	39·29	83·44	26·22	67·66	07·75	58
59	96·62	47·84	97·60	45·94	92·85	38·37	82·50	25·26	66·67	06·74	59
60	95·82	47·01	96·75	45·06	91·96	37·45	81·56	24·29	65·68	05·73	60

TABLE. II.

Length of a Degree of Longitude.

′	39°	40°	41°	42°	43°	44°	45°	46°	47°	48°	′
	chains.	chains.	chains.	chains.	chains	chains.	chains.	chains.	chains.	chains.	
0	4305.73	4244·47	4181·91	4118·06	4052·96	3986·62	3919·05	3850·28	3780·33	3709·22	0
1	04·72	43·45	80·85	16·99	51·87	85·50	17·91	49·12	79·15	08·02	1
2	03·71	42·41	79·80	15·91	50·77	84·38	16·78	47·97	77·98	06·83	2
3	02·70	41·37	78·75	14·84	49·67	83·27	15·64	46·81	76·80	05·63	3
4	01·69	40·34	77·69	13·76	48·58	82·15	14·50	45·65	75·63	04·44	4
5	00·68	39·31	76·64	12·69	47·48	81·03	13·36	44·50	74·45	03·24	5
6	4299·67	38·27	75·58	11·61	46·38	79·91	12·23	43·34	73·27	02·05	6
7	98·65	37·21	74·52	10·53	45·28	78·79	11·09	42·18	72·09	00·85	7
8	97·64	36·20	73·47	09·46	44·19	77·68	09·95	41·02	70·92	3699·65	8
9	96·63	35·17	72·41	08·38	43·09	76·56	08·81	39·86	69·74	98·46	9
10	95·61	34·13	71·36	07·30	41·99	75·44	07·67	38·70	68·56	97·26	10
11	94·60	33·10	70·30	06·22	40·89	74·32	06·53	37·54	67·38	96·06	11
12	93·59	32·06	69·24	05·14	39·79	73·20	05·39	36·38	66·20	94·86	12
13	92·57	31·02	68·18	04·07	38·69	72·08	04·25	35·22	65·02	93·66	13
14	91·56	29·99	67·12	02·99	37·59	70·96	03·11	34·06	63·84	92·46	14
15	90·54	28·95	66·07	01·91	36·49	69·84	01·97	32·90	62·66	91·26	15
16	89·52	27·91	65·01	00·83	35·39	68·72	00·83	31·74	61·48	90·06	16
17	88·51	26·87	63·95	4099·75	34·29	67·59	3899·69	30·58	60·30	88·86	17
18	87·49	25·84	62·89	98·67	33·19	66·47	98·54	29·42	59·12	87·66	18
19	86·48	24·80	61·83	97·58	32·09	65·35	97·40	28·26	57·94	86·46	19
20	85·46	23·76	60·77	96·50	30·98	64·23	96·26	27·09	56·76	85·26	20
21	84·44	22·72	59·71	95·42	29·88	63·11	95·12	25·93	55·57	84·06	21
22	83·42	21·68	58·65	94·34	28·78	61·98	93·97	24·77	54·39	82·86	22
23	82·40	20·64	57·58	93·26	27·67	60·86	92·83	23·60	53·21	81·66	23
24	81·39	19·60	56·52	92·17	26·57	59·73	91·68	22·44	52·02	80·46	24
25	80·37	18·56	55·46	91·09	25·47	58·61	90·54	21·28	50·84	79·25	25
26	79·35	17·52	54·40	90·01	24·36	57·49	89·40	20·11	49·66	78·05	26
27	78·33	16·48	53·44	88·92	23·26	56·36	88·25	18·95	48·47	76·85	27
28	77·31	15·43	52·27	87·84	22·15	55·24	87·11	17·78	47·29	75·64	28
29	76·29	14·39	51·21	86·75	21·05	54·11	85·96	16·62	46·10	74·44	29
30	75·27	13·35	50·14	85·67	19·94	52·98	84·81	15·45	44·92	73·24	30
31	74·24	12·31	49·08	84·58	18·84	51·86	83·67	14·29	43·73	72·03	31
32	73·22	11·26	48·02	83·50	17·73	50·73	82·52	13·12	42·55	70·83	32
33	72·20	10·22	46·95	82·41	16·62	49·60	81·37	11·95	41·36	69·62	33
34	71·18	09·18	45·89	81·33	15·52	48·48	80·23	10·79	40·18	68·42	34
35	70·16	08·13	44·82	80·24	14·41	47·35	79·08	09·62	38·99	67·21	35
36	69·13	07·09	43·75	79·15	13·30	46·22	77·93	08·45	37·80	66·01	36
37	68·11	06·04	42·69	78·07	12·19	45·09	76·78	07·28	36·62	64·80	37
38	67·09	05·00	41·62	76·98	11·09	43·96	75·63	06·11	35·43	63·59	38
39	66·06	03·95	40·55	75·89	09·98	42·83	74·48	04·95	34·24	62·39	39
40	65·04	02·90	39·49	74·80	08·87	41·71	73·34	03·78	33·05	61·18	40
41	64·01	01·86	38·42	73·71	07·76	40·58	72·19	02·61	31·86	59·97	41
42	62·99	00·81	37·35	72·62	06·65	39·45	71·04	01·44	30·67	58·76	42
43	61·96	4199·76	36·28	71·53	05·54	38·32	69·89	00·27	29·48	57·56	43
44	60·93	98·72	35·21	70·44	04·43	37·18	68·74	3799·10	28·30	56·35	44
45	59·91	97·67	34·14	69·35	03·32	36·05	67·58	97·93	27·11	55·14	45
46	58,88	96·62	33·08	68·26	02·21	34·92	66·43	96·76	25·92	53·93	46
47	57·85	95·57	32·01	67·17	01·10	33·79	65·28	95·59	24·73	52·72	47
48	56·83	94·52	30·93	66·08	3999·98	32·66	64·13	94·41	23·53	51·51	48
49	55·80	93·47	29·86	64·99	98·87	31·53	62·98	93·24	22·34	50·30	49
50	54·77	92·42	28·79	63·90	97·76	30·39	61·82	92·07	21·15	49·09	50
51	53·74	91·37	27·72	62·81	96·65	29·26	60·67	90·90	19·96	47·88	51
52	52·71	90·32	26·65	61·71	95·53	28·13	59·52	89·72	18·77	46·67	52
53	51·68	89·27	25·58	60·62	94·42	26·99	58·36	88·55	17·58	45·46	53
54	50·66	88·22	24·51	59·53	93·31	25·86	57·21	87·38	16·38	44·25	54
55	49·63	87·17	23·43	58·43	92·19	24·73	56·06	86·20	15·19	43·03	55
56	48·59	86·12	22·36	57·34	91·08	23·59	54·90	85·03	14·00	41·82	56
57	47·56	85·07	21·29	56·25	89·96	22·46	53·75	83·86	12·80	40·61	57
58	46·53	84·02	20·21	55·15	88·85	21·32	52·59	82·68	11·61	39·40	58
59	47·50	82·96	19.14	54·06	87·73	20·19	51·44	81·51	10·41	38·18	59
60	44·47	81·91	18·06	52·96	86·62	19·05	50·28	80·33	09·22	36·97	60

TABLE III.

Divergency of the Parallel of Latitude and the Prime Vertical.

Dist	28°	30°	32°	34°	36°	38°	40°	42°	44°	46°	48°	Dist
mile	chns	chns	chns	chns	chns	chns	chns	chns	chns	chns.	chns.	mile
1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	1
2	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	2
3	0.05	0.05	0.06	0.06	0.07	0.07	0.08	0.08	0.09	0.09	0.10	3
4	0.09	0.09	0.10	0.11	0.12	0.13	0.13	0.14	0.16	0.17	0.18	4
5	0.13	0.14	0.16	0.17	0.18	0.20	0.21	0.23	0·24	0.26	0.28	5
6	0.19	0.21	0.23	0.24	0.26	0.28	0.30	0.33	0.35	0.37	0.40	6
7	0.26	0.28	0.31	0.33	0.36	0.38	0.41	0.44	0.48	0.51	0.55	7
8	0.34	0.37	0.40	0.43	0 47	0.50	0.54	0.58	0.62	0.67	0.71	8
9	0.43	0.47	0.51	0·55	0.59	0.64	0.68	0.73	0.79	0.84	0.90	9
10	0.53	0.58	0.63	0.68	0.73	0.78	0.84	0.90	0.97	1.04	1.11	10
11	0.65	0.70	0.76	0.82	0.88	0.95	1.02	1.09	1.17	1.26	1.35	11
12	0.77	0.83	0.90	0.97	1.05	1.13	1.21	1.30	1.40	1.50	1.61	12
13	0 90	0.98	1.06	1.14	1.23	1·33	1.42	1.53	1.64	1.76	1.88	13
14	1.05	1.14	1.23	1.33	1.43	1.54	1.65	1.77	1.90	2.04	2.19	14
15	1.20	1.30	1.41	1.52	1.64	1.76	1.90	2.03	2.18	2.34	2.51	15
16	1.36	1.48	1.60	1.73	1.87	2.01	2.16	2.32	2.48	2.66	2.85	16
17	1.54	1.67	1.81	1.96	2.11	2.27	2.44	2.61	2.80	3.00	3.22	17
18	1.73	1.88	2.03	2.19	2.36	2.54	2.73	2.93	3.14	3.37	3.61	18
19	1.92	2.09	2.26	2.44	2.63	2.83	3.04	3.26	3.50	3.75	4.03	19
20	2.13	2.32	2.51	2.71	2.92	3·14	3.37	3.62	3.88	4.16	4.46	20
21	2.35	2.55	2.76	2.98	3.22	3.46	3.72	3.99	4.28	4.59	4.92	21
22	2.58	2.80	3.03	3.28	3.53	3·80	4.08	4.38	4.69	5.03	5.40	22
23	2.82	3.06	3.32	3.58	3.86	4.15	4.46	4.78	5.13	5.50	5.90	23
24	3.07	3.34	3.61	3·90	4·20	4.52	4.85	5.21	5.59	5.99	6.42	24
25	3.33	3.62	3.92	4.23	4.56	4.90	5.27	5.65	6.06	6.50	6.97	25
26	3.60	3.91	4.24	4.57	4.93	5.30	5.70	6.11	6.56	7.03	7.54	26
27	3·89	4.22	4.57	4.93	5·32	5.72	6.14	6.59	7.07	7.58	8.13	27
28	4.18	4.54	4.91	5·31	5.72	6.15	6.61	7.09	7.60	8.15	8.74	28
29	4.48	4.87	5.27	5.69	6.13	6.60	7.09	7.61	8.16	8.74	9.38	29
30	4.80	5.21	5.64	6.09	6.56	7.06	7.58	8.14	8.73	9.36	10.04	30
31	5.12	5.57	6.02	6.50	7.01	7.54	8.10	8.69	9.32	9.99	10.72	31
32	5.46	5.93	6.42	6.93	7.47	8.03	8.63	9.26	9.93	10.65	11.42	32
33	5.81	6.31	6.83	7.37	7.94	8.54	9.18	9.85	10.56	11.32	12.14	33
34	6.16	6.69	7.25	7.82	8.43	9.07	9.74	10.45	11.21	12.02	12.89	34
35	6.53	7.09	7.63	8.29	8·93	9.61	10.32	11.08	11.88	12.74	13.66	35
36	6.91	7.51	8.12	8.77	9.45	10.16	10.92	11.72	12.57	13.47	14.45	36

Table showing the Difference of Latitude and Departure in running 80 chains, at any course from 1 to 60 minutes.

Min's	Links.	Min's	Links.	Min's	Links.	Min's	Links.	Min's	Links.	Min's	Links.
1	2⅓	11	25⅔	21	49	31	72⅓	41	95⅔	51	119
2	4⅔	12	28	22	51⅓	32	74⅔	42	98	52	121⅓
3	7	13	30⅓	23	53⅔	33	77	43	100⅓	53	123⅔
4	9⅓	14	32⅔	24	56	34	79⅓	44	102⅔	54	126
5	11⅔	15	35	25	58⅓	35	81⅔	45	105	55	128⅓
6	14	16	37⅓	26	60⅔	36	84	46	107⅓	56	130⅔
7	16⅓	17	39⅔	27	63	37	86⅓	47	109⅔	57	133
8	18⅔	18	42	28	65⅓	38	88⅔	48	112	58	135⅓
9	21	19	44⅓	29	67⅔	39	91	49	114⅓	59	137⅔
10	23⅓	20	46⅔	30	70	40	93⅓	50	116⅔	60	140

TABLES.

Table for reducing Chains to Feet, and Feet to Chains.

Chains or Links.	Feet.	Chains or Links.	Feet.	Chains or Links.	Feet.	Chains or Links.	Feet.	Chains or Links.	Feet.
1	66	21	1386	41	2706	61	4026	81	5346
2	132	22	1452	42	2772	62	4092	82	5412
3	198	23	1518	43	2838	63	4158	83	5478
4	264	24	1584	44	2904	64	4224	84	5544
5	330	25	1650	45	2970	65	4290	85	5610
6	396	26	1716	46	3036	66	4356	86	5676
7	462	27	1782	47	3102	67	4422	87	5742
8	528	28	1848	48	3168	68	4488	88	5808
9	594	29	1914	49	3234	69	4554	89	5874
10	660	30	1980	50	3300	70	4620	90	5940
11	726	31	2046	51	3366	71	4686	91	6006
12	792	32	2112	52	3432	72	4752	92	6072
13	858	33	2178	53	3498	73	4818	93	6138
14	924	34	2244	54	3564	74	4884	94	6204
15	990	35	2310	55	3630	75	4950	95	6270
16	1056	36	2376	56	3696	76	5016	96	6336
17	1122	37	2442	57	3762	77	5082	97	6402
18	1188	38	2508	58	3828	78	5148	98	6468
19	1254	39	2574	59	3894	79	5214	99	6534
20	1320	40	2640	60	3960	80	5280	100	6600

Table of Acres required per Mile, and per 100 Feet, for different widths.

width. Feet.	Acres per Mile.	Acres per 100 feet.	width. Feet.	Acres per Mile.	Acres per 100 feet.	width. Feet.	Acres per Mile.	Acres per 100 feet.
1	.121	.002	23	2.79	.053	45	5.45	.103
2	.242	.005	24	2.91	.055	46	5.58	.106
3	.364	.007	24¾	3.00	.057	47	5.70	.108
4	.485	.009	25	3.03	.058	48	5.82	.110
5	·606	.011	26	3.15	.060	49	5.94	.112
6	.727	.014	27	3.27	.062	49½	6.00	.114
7	.848	.016	28	3.39	.064	50	6.06	.115
8	.970	.018	29	3.52	.067	51	6.18	.117
8¼	1.00	.019	30	3.64	.069	52	6.30	.119
9	1.09	.021	31	3.76	.071	53	6.42	.122
10	1.21	.023	32	3.88	.073	54	6.55	.124
11	1.33	.025	33	4.00	.076	55	6.67	.126
12	1.46	.028	34	4.12	.078	56	6.79	.129
13	1.58	.030	35	4.24	.080	57	6.91	.131
14	1.70	.032	36	4.36	.083	57¾	7.00	.133
15	1.82	.034	37	4.48	.085	58	7.03	.134
16	1.94	.037	38	4.61	.087	59	7.15	.135
16½	2.00	.038	39	4.73	.090	60	7.27	.138
17	2.06	.039	40	4.85	.092	61	7.39	.140
18	2.18	.041	41	4.97	.094	62	7.52	.142
19	2.30	.044	41¼	5.00	.095	63	7.64	.145
20	2.42	.046	42	5.09	.096	64	7.76	.147
21	2.55	.048	43	5.21	.099	65	7.88	.149
22	2·67	.051	44	5.33	.101	66	8.00	.151

MISCELLANEOUS.

APPROXIMATE RULES CONVENIENT IN PRACTICE.

I. FOR CORRECTING RANDOM LINES.*

1. ***Given the error of latitude or departure for any distance, to find the error of the course.***

RULE.—Three-sevenths of the error of latitude or departure, per mile, in links, will be the error of the course, in minutes.

EXAMPLE.

What is the error of the course for an error of 210 links of latitude or departure, in 6 miles?

Here the error, per mile, is 35 links, three-sevenths of which is 15 minutes, the error required.

2. ***Given the error of the course, to find the corresponding error of latitude or departure for any distance.***

RULE.—Seven-thirds of the error of the course, in minutes, will be the error of latitude or departure, per mile, in links.

EXAMPLE.

What is the error of latitude or departure, in 6 miles, for an error of 15 minutes in the course?

Here seven thirds of 15 is 35 links, the error per mile, or 210 links in 6 miles, the error required.

II. FOR RUNNING A PARALLEL OF LATITUDE.†

Given the distance run, east or west, on a great circle, to find the divergency from the parallel of latitude.

RULE.—Multiply the square of the distance in miles, by the natural tangent of the latitude, and the product will be the divergency, in links.

EXAMPLE.

After running 6 miles, east or west, on the arc of a great circle, from latitude 38 degrees, what will be the meridional distance south of the parallel?

Here we have $.781 \times 6^2 = 28$ links, the divergency required.

TRIGONOMETRICAL SERIES

$$\sin A = A - \frac{A^3}{2.3} + \frac{A^5}{2.3.4.5} - \frac{A^7}{2.3.4.5.6.7} + \text{etc.}$$

$$\cos A = 1 - \frac{A^2}{2} + \frac{A^4}{2.3.4} - \frac{A^6}{2.3.4\,5.6} + \text{etc.}$$

$$\tan A = A + \frac{A^3}{3} + \frac{2A^5}{3.5} + \frac{17A^7}{3^2.5.7} + \text{etc}$$

$$\cot A = \frac{1}{A} - \frac{A}{3} - \frac{A^3}{3^2.5} - \frac{2A^5}{3^3\,5.7} - \text{etc.}$$

$$\text{Arc } A = \sin A + \frac{\sin^3 A}{2.3} + \frac{3\sin^5 A}{2.4.5} + \frac{3.5\sin^7 A}{2.4.6.7} + \text{etc.}$$

$$\text{Arc } A = \tan A - \frac{1}{3}\tan^3 A + \frac{1}{5}\tan^5 A - \frac{1}{7}\tan^7 A + \text{etc.}$$

* This approximation is true to the nearest minute for all angles up to 3 deg.; and to the nearest quarter of a degree for all angles up to 11½ degrees.

† This approximation may be considered practically correct for any distance not exceeding 30 miles.

MISCELLANEOUS

Rules for Solving all Cases of Plane Trigonometry.

CASE 1.

Given all the Angles and One Side, to find the other Side.

RULE.—As sine of the angle opposite the given side, is to sine of the angle opposite the required side, so is the given side to the required side.

CASE 2.

Given two Sides and an Angle opposite one of them, to find the other Angles and Side.

RULE.—As the side opposite the given angle, is to the other given side, so is sine of the angle opposite the former, to sine of the angle opposite the latter.

CASE 3.

Given two Sides and the included Angle, to find the other Angles and Side.

RULE.—Subtract the given angle from 180 degrees and the remainder will be the sum of the two unknown angles; then say, as the sum of the two given sides is to their difference, so is tangent of half sum of unknown angles, to tangent of half their difference. Add this half difference of the unknown angles to their half sum for the angle opposite the greater side, and subtract it from the half sum for the angle opposite the less side.

CASE 4.

Given the Three Sides to find the Angles.

RULE—Upon the longest side let fall a perpendicular from the opposite angle. This perpendicular will divide the base into two segments and the triangle into two right-angled triangles; then say, as the given base is to the sum of the two other sides, so is the difference of those sides, to the difference of the segments of the base. To half the base add half the difference of the segments for the greater segment, and subtract it from half the base for the less side; then proceed as in Case 2.

RULE 2.—Add together the arith. comp. of the logarithms of the two sides, containing the required angle, the log. of the half sum of the three sides and the log. of the difference of the half sum and the side opposite the required angle. The half sum of these four logarithms will be the logarithmic cosine of half the required angle.

FOR FINDING THE DIAMETER OF A TREE.

RULE.—Annex a cipher to the number of links around the tree, and one fourth of the result will be the diameter, in inches.

EXAMPLE.

What is the diameter of a tree whose circumference is 16 links?

Here we have ¼ of 160 = 40 inches, the diameter required.

TABLE FOR RUNNING ON SLOPES.

In the following table the first column shows the angle, the second the number of links to be added to a chain on the slopes, to make 1 chain horizontal measurement.

Angle.	Cor. in links	Angle.	Cor. in links	Angle.	Cor. in links	Angle.	Cor. in links
°		°		°		°	
4	0.24	11	1.88	18	5.14	25	10.54
5	0.38	12	2.24	19	5.76	26	11.26
6	0.55	13	2.63	20	6.42	27	12.24
7	0.76	14	3.06	21	7.11	28	13.37
8	0.98	15	3.53	22	7.85	29	14.34
9	1.24	16	4.02	23	8.64	30	15.47
10	1.55	17	4.56	24	9.47	35	22.07

TABLES.

Position of the Principal Lines of the United States Surveys in the State of California.

MONTE DIABLO Merid., Mt. Diablo. Lat. 37° 52′ 47″, Long. 121° 54′ 49″ W.

Parallel.	Latitude.			Distance.	Longitude per Range.			Converg.
	°	′	″	Miles.	°	′	″	Chains.
Monte Diablo	37	52	47	0	0	0	35.2	0.00
I Standard North	38	18	53	30	0	6	37.5	2.84
II " "	38	44	58	60	0	6	39.9	2.88
III " "	39	11	4	90	0	6	42.4	2.93
IV " "	39	37	10	120	0	6	44.9	2.97
V " "	40	3	15	150	0	6	47.5	3.02
VI " "	40	29	21	180	0	6	50.1	2.06
VII " "	40	55	26	210	0	6	52.8	3.11
VIII " "	41	21	31	240	0	6	55.5	3.16
IX " "	41	47	54	270	0	6	58.3	3.21
Oregon Boundary	42	0	0	284	0	6	59.6	1.48
I Standard South	37	31	54	24	0	6	33.4	2.25
II " "	37	11	1	48	0	6	31.6	2.22
III " "	36	50	8	72	0	6	29.8	2.19
IV " "	36	29	14	96	0	6	28.0	2.17
V " "	36	8	21	120	0	6	26.3	2.14
VI " "	35	47	28	144	0	6	24.6	2.11
VII " "	35	26	35	168	0	6	22.9	2.09
VIII " "	35	5	41	192	0	6	21.3	2.06
IX " "	34	44	48	216	0	6	19.7	2.03
X " "	34	23	55	240	0	6	18.1	2.00

HUMBOLDT MERID., Mt. Pierce. Lat. 40° 24′ 56″, Long. 124° 07′ 03″ W.

Parallel.	Latitude.			Distance.	Longitude per Range.			Converg.
	°	′	″	Miles.	′	′	″	Chains.
Mount Pierce	40	24	56	0	0	6	49.6	0.00
I Standard North	40	51	1	30	0	6	52.3	3.09
II " "	41	17	6	60	0	6	55.0	3.15
III " "	41	43	12	90	0	6	57.9	3.20
Oregon Boundary	42	0	0	109.32	0	6	59.6	2.09
								Diverg.
I Standard South	40	4	4	24	0	6	47.5	2.48

SAN BERNARDINO Merid., Mt. San Bern. Lat. 34° 07′ 25″, Long. 116° 56′ W.

Parallel.	Latitude.			Distance.	Longitude per Range.			Converg.
	°	′	″	Miles.	°	′	″	Chains.
Mount San Bernardino	34	7	25	0	0	6	16.9	0.00
I Standard North	34	33	32	30	0	6	18.8	2.47
II " "	34	59	39	60	0	6	20.8	2.51
III " "	35	25	46	90	0	6	22.8	2.56
IV " "	35	51	53	120	0	6	24.9	2.60
V " "	36	18	0	150	0	6	27.1	2.64
VI " "	36	44	6	180	0	6	29.2	2.68
								Diverg.
I Standard South	33	46	31	24	0	6	15.3	1.95
II " "	33	25	38	48	0	6	13.8	1.93
III " "	33	4	34	72	0	6	12.3	1.90
IV " "	32	43	50	96	0	6	10.9	1.87
V " "	32	22	56	120	0	6	9.5	1.85

TABLES.

POSITION OF THE PRINCIPAL LINES OF THE UNITED STATES SURVEYS IN THE STATE OF NEVADA.

The principal Base and Standard Parallels in this State are precisely the same as those of California. All the townships are numbered from the Monte Diablo meridian and base line. The Fourth Standard Parallel base line commences at the California and Nevada State lines, run by A. W. von Schmidt, at the line between Ranges 17 and 18, and extends to the Utah boundary line, in Range 70.

There are four Guide Meridians, viz.:

CARSON GUIDE MERIDIAN, running north from the Fourth Standard North, between Ranges 20 and 21 E. M. D. M.

HUMBOLDT RIVER GUIDE MERIDIAN, running north from the Fourth Standard North, between ranges 35 and 36 E. M. D. M.

REESE RIVER GUIDE MERIDIAN, running south from the Fourth Standard North, between Ranges 42 and 43 E. M. D. M.

RUBY VALLEY GUIDE MERIDIAN, running N. and S. from the Fourth Standard Parallel North, between Ranges 55 and 56 of the Monte Diablo meridian.

Position of the Principal Lines of the United States Surveys in UTAH

Initial Point, Salt Lake Base and Meridian,
Latitude, 40° 46′ 08″ North; Longitude 111° 53′ 47″ West.

Surveys North of the Base Line.

Parallel.	Latitude.			Distance.	Longitude. per Range.			Converg.
	°	′	″	Miles.	°	′	″	Chains.
Initial Point	40	46	08	0	0	6	51.8	0 0
I Standard North	41	07	00	24	0	6	53.9	2.51
II " "	41	27	52	48	0	6	56.1	2.54
III " "	41	48	44	72	0	6	58.4	2.58
Oregon Line	42	00	00	84.95	0	6	59.6	1.40

Surveys South of the Base Line.

Parallel.	Latitude.			Distance.	Longitude. per Range.			Converg.
	°	′	″	Miles.	°	′	″	
Initial Point	40	46	08	0	0	6	51.8	Chains. 0 0
I Standard South	40	20	03	30	0	6	49.1	3.09
II " "	39	53	57	60	0	6	45.6	3.05
III " "	39	27	51	90	0	6	44.0	2.99
IV " "	39	01	46	120	0	6	41.5	2.95
V " "	38	35	40	150	0	6	39.1	2.91
VI " "	38	09	34	180	0	6	36.7	2.86
VII " "	37	43	28	210	0	6	34.3	2.82
VIII " "	37	17	22	240	0	6	32.1	2.78
Arizona Line	37	00	00	259.95	0	6	30.1	2.37

COLORADO BASE LINE.

Latitude of Initial Point, 33 deg. 51 min.;....Longitude, 114 deg. 22 min.

Meridian runs north 12 miles to Lat. 34 deg. 1 min. 27 sec.

Convergency, 0.97 chains.

TABLES

Position of the Principal Lines of the U. S. Surv. in ARIZONA TER.
Initial Point, junct. of Salt & Gila rivers, Lat. 33° 22′ 57″, Long. 112° 15′ 46″

Surveys north of Gila and Salt River Base Line.

Parallel.	Latitude.			Distance.	Longitude per Range.			Converg.
	°	′	″	Miles.	°	′	″	Chains.
Initial Point..............	33	22	57	0	0	6	13.6	0 0
I Standard North.....	33	43	51	24	0	6	15.1	1.92
II " "	34	04	45	48	0	6	16.6	1.95
III " "	34	25	38	72	0	6	18.2	1.97
IV " "	34	46	32	96	0	6	19.8	2.00
V " "	35	07	25	120	0	6	21.4	2.02
VI " "	35	28	18	144	0	6	23.0	2.05
VII " "	35	49	12	168	0	6	24.7	2.08
VIII " "	36	10	05	192	0	6	26.4	2.10
IX " "	36	30	58	216	0	6	28.1	2.13
X " "	36	51	52	240	0	6	29.9	2.16
North Boundary.........	37	00	00	249.35	0	6	30.6	0.85

Surveys south of Gila and Salt River Base Line.

Parallel.	Latitude.			Distance.	Longitude per Range.			Converg.
	°	′	″	Miles.	°	′	″	Chains.
Initial Point..............	33	22	57	0	0	6	13.6	0 0
I Standard South......	32	56	50	30	0	6	11.8	2·37
II " "	32	30	42	60	0	6	10.0	2.33
III " "	32	04	35	90	0	6	8.2	2.29
IV " "	31	38	27	120	0	6	6.5	2.26

Initial Point of Williametta Meridian, WASHINGTON
Base Line, Lat. 45° 31′ 13″ North, Long. 122° 30′ [illegible]″ W.

Parallel.	Latitude.			Distance.	Longitude per Range.			Converg.
	°	′	″	Miles.	°	′	″	Chains.
Initial Point..............	45	31	13	0	0	7	25.0	0 0
I Standard North.....	45	52	04	24	0	7	27.7	2.96
II " "	46	12	55	48	0	7	30.6	3.00
III " "	46	33	46	72	0	7	33.4	3.04
IV " "	46	54	37	96	0	7	36.3	3.07
V " "	47	15	28	120	0	7	39.3	3.11
VI " "	47	36	19	144	0	7	42.4	3.15
VII " "	47	57	09	168	0	7	45.4	3.19
VIII " "	48	18	00	192	0	7	48.6	3.23
IX " "	48	38	51	216	0	7	51.8	3.27
X " "	48	59	41	240	0	7	55.1	3.30

Position of the Principal Lines of the U.S. Surveys in MONTANA
Initial Point, intersec. prin. base & mer., lat. 45°46′27 N.; Long. 111°27′11″ W

Parallel.	Latitude.			Distance.	Longitude per Range.			Converg.
	°	′	″	Miles.	°	′	″	Chains.
Principal Base............	45	46	27	0	0	7	27.8	0 0
I Standard North......	46	07	15	24	0	7	28.2	3.01
II " "	46	28	03	48	0	7	28.5	3.03
III " "	46	48	51	72	0	7	28.8	3.06
IV " "	47	09	39	96	0	7	29.2	3.11
V " "	47	30	27	120	0	7	29.6	3.15
VI " " ..	47	51	15	144	0	7	29.9	3.19
VII " "	48	12	03	168	0	7	30.3	3.22
								Diverg.
I Standard South......	45	20	27	30	0	7	27.3	3.71
II " "	44	54	27	60	0	7	27.8	3.67

TABLES

Position of the Principal Lines of the U. S. Surveys in the

STATE OF OREGON.

Initial Point, intersection of Willamette meridian and base line.

Lat. 45° 31′ 13″ North; Long. 122° 30′ 26″ West,

Surveys north of the Willamette Base Line.

Parallel	Latitude.			Distance	Longitude per Range.			Converg.
	°	′	″	Miles.	°	′	″	Chains.
Willamette Base Line.....	45	31	13	0	0	7	25.0	0 0
I Standard North ...	45	52	04	24	0	7	27.7	2.96
II " " ..	46	07	42	42	0	7	29.8	2.25

Surveys south of the Willamette Base Line.

Parallel	Latitude.			Distance	Longitude per Range.			Converg.
	°	′	″	Miles.	°	′	″	Chains.
Willamette Base Line	45	31	13	0	0	7	25.0	0 0
I Standard South....	45	05	09	30	0	7	21.6	3.62
II " "	44	39	05	60	0	7	18.3	3.59
III " " ...	44	23	26	78	0	7	16.3	2.15
IV " "	43	57	22	108	0	7	13.1	3.51
V " " .	43	36	30	132	0	7	10.6	2.76
VI " "	43	10	26	162	0	7	07.7	3.41
VII " " ..	42	44	21	192	0	7	04.6	3.38
VIII " " .	42	28	42	210	0	7	02.8	2.00
IX " " ..	42	07	50	234	0	7	00.4	2.63
North Bound. of Calif'a..	42	00	00	243	0	6	59.5	0.99

TABLES.

TABLES OF GRADES,

Per Mile and per 100 Feet, measured horizontally and corresponding to different Angles of Elevation.

° '	Feet per mile.	Feet per 100 ft.	° '	Feet per mile.	Feet per 100 ft.	° '	Feet per mile.	Feet per 100 ft.	° '	Feet per mile.	Feet per 100 ft.
	1.	0.01894	0 18	27.64	0.5237		54.	1.02273		81.	1.53409
0 1	1.536	0.02091		28.	0.53030		55.	1.04167	0 53	81.40	1.5419
	2.	0.03788		29.	0.54924	0 36	55.30	1.0472		82.	1.55303
	3.	0.05682	0 19	29.17	0.5528		56.	1.06061	0 54	82.94	1.5710
0 2	3.072	0.0582		30.	0.56818	0 37	56.83	1.0763		83.	1.57197
	4.	0.07576	0 20	30.72	0.5818		57.	1.07955		84.	1.59091
0 3	4.608	0.0873		31.	0.58712		58.	1.09848	0 55	84.47	1.6000
	5.	0.09470		32.	0.60606	0 38	58.37	1.1054		85.	1.60985
	6.	0.11364	0 21	32.26	0.6109		59.	1.11742		86.	1.62879
0 4	6.144	0.1164		33.	0.62500	0 39	59.90	1.1345	0 56	86.01	1.6291
	7.	0.13258	0 22	33.80	9.6400		60.	1.13636		87.	1.64773
0 5	7.680	0.1455		34.	0.64394		61.	1.15530	0 57	87.54	1.6583
	8.	0.15152		35.	0.66288	0 40	61.44	1.1636		88.	1.66666
	9.	0.17045	0 23	35.33	0.6691		62.	1.17424		89.	1.68561
0 6	9.216	0.1746		36.	0.68182	0 41	62.97	1.1927	0 58	89.08	1.6873
	10.	0.18939	0 24	36.86	0.6982		63.	1.19318		90.	1.70455
0 7	10.75	0.2037		37.	0.70076		64.	1.21212	0 59	90.62	1.7164
	11.	0.20833		38.	0.71970	0 42	64.51	1.2218		91.	1.72348
	12.	0.22727	0 25	38.40	0.7273		65.	1.23106		92.	1.74242
0 8	12.29	0.2328		39.	0.73864		66.	1.25000	1 0	92.16	1.7455
	13.	0.24621	0 26	39.94	0.7564	0 43	66.04	1.2509		93.	1.76136
0 9	13.82	0.2619		40.	0.75758		67.	1.26894		94.	1.78030
	14.	0.26515		41.	0.77652	0 44	67.57	1.2800		95.	1.79924
	15.	0.28409	0 27	41.47	0.7855		68.	1.28788	1 2	95.23	1.8038
0 10	15.36	0.2909		42.	0.79545		69.	1.30682		96.	1.81818
	16.	0.30303		43.	0.81439	0 45	69.11	1.3090		97.	1.83712
0 11	16.90	0.3200	0 28	43.01	0.8146		70.	1.32576		98.	1.85606
	17.	0.32197		44.	0.83333	0 46	70.64	1.3381	1 4	98.30	1.8620
	18.	0.34091	0 29	44.54	0.8436		71.	1.34470		99.	1.87500
0 12	18.43	0.3491		45.	0.85227		72.	1.36364		100.	1.89394
	19.	0.35985		46.	0.87121	0 47	72.18	1.3672		101.	1.91288
0 13	19.96	0.3782	0 30	46.08	0.8727		73.	1.38258	1 06	101.1	1.9202
	20.	0.37879		47.	0.89015	0 48	73.72	1.3963		102.	1.93182
	21.	0.39773	0 31	47.62	0.9018		74.	1.40152		103.	1.95076
0 14	21.50	0.4073		48.	0.90909		75.	1.42045		104.	1.96969
	22.	0.41667		49.	0.92803	0 49	75.26	1.4254		147.	2.78409
	23.	0.43561	0 32	49.16	0.9309		76.	1.43939	1 36	147.4	2.7932
0 15	23.04	0.4361		50.	0.94697	0 50	76.80	1.4545		148.	2.80303
	24.	0.45455	0 33	50.69	0.9600		77.	1.45833		149.	2.82197
0 16	24.58	0.4655		51.	0.96591		78.	1.47727		150.	2.84091
	25.	0.47348		52.	0.98485	0 51	78.33	1.4837	1 38	150.5	2.8514
	26.	0.49242	0 34	52.23	0.9891		79.	1.49621		151.	2.85985
0 17	26.11	0.4946		53.	1.00379	0 52	79.87	1.5128		152.	2.87879
	27.	0.51136	0 35	53.76	1.0182		80.	1.51515	1 40	153.6	2.9097

TABLE.

TABLE OF RADII, MIDDLE ORDINATES, &c., OF CURVES.

CHORD 100 FEET.

☞ The Tangential Angle is always one-half of the Angle of Deflection.

Angle of Deflec. ° '	Radii in feet.	Deflec. distance, in ft.	Tang. dist. in feet.	Mid. Ordin.	Angle of Deflec. ° '	Radii in feet.	Deflec. dist. in feet.	Tang. dist. in feet.	Mid. Ordin.
1	343775	.029	.014	.004	2 6	2729	3.665	1.832	.458
2	171887	.058	.029	.008	" 12	2604	3.839	1.919	.480
4	85944	.116	.058	.014	" 18	2491	4.014	2.007	.502
6	57296	.174	.087	.022	" 24	2387	4.188	2.094	.523
8	42972	.232	.116	.028	" 30	2292	4.363	2.182	.545
10	34378	.291	.145	.036	" 36	2204	4.538	2.269	.567
12	28648	.349	.174	.043	" 42	2122	4.712	2.356	.589
14	24556	.407	.203	.050	" 48	2046	4.886	2.443	.611
16	21485	.465	.232	.058	" 54	1976	5.060	2.530	.632
18	19098	.523	.261	.065	3 0	1910	5.235	2.618	.654
20	17189	.581	.290	.073	" 15	1763	5.666	2.836	.710
22	15627	.639	.319	.080	" 30	1637	6.108	3.054	.764
24	14324	.697	.348	.087	" 45	1528	6.544	3.272	.818
26	13222	.756	.378	.095	4 0	1433	6.980	3.490	.873
28	12278	.814	.407	.102	" 15	1348	7.416	3.708	.927
30	11459	.872	.436	.109	" 30	1274	7.853	3.927	.981
32	10743	.930	.465	.116	" 45	1207	8.289	4.145	1.036
34	10111	.988	.494	.123	5 0	1146	8.722	4.361	1.091
36	9549	1.046	.523	.131	" 15	1092	9.159	4.579	1.146
38	9046	1.104	.552	.138	" 30	1042	9.595	4.798	1.200
40	8594	1.162	.581	.145	" 45	996.8	10.03	5.015	1.255
42	8185	1.221	.610	.152	6 0	955.4	10.47	5.235	1.309
44	7814	1.279	.639	.159	" 15	917.0	10.90	5.450	1.364
46	7474	1.337	.668	.167	" 20	882.0	11·34	5.670	1.419
48	7162	1.395	.697	.174	" 45	849.3	11·78	5.890	1.473
50	6876	1.453	.726	.182	7 0	819.0	12.21	6.105	1.528
52	6611	1.511	.755	.189	" 15	790.8	12.64	6.320	1.582
54	6367	1.569	.784	.197	" 30	764.5	13.08	6.540	1.637
56	6139	1.627	.813	.204	" 45	739.9	13.51	6.755	1.692
58	5928	1.685	.842	.211	8 0	716.8	13.95	6.975	1.746
1 0	5730	1.745	.872	.218	" 15	695.1	14.38	7.190	1.801
" 4	5372	1.860	.930	.232	" 30	674.6	14.81	7.405	1.855
" 8	5056	1.976	.988	.246	" 45	655.5	15.25	7.625	1.910
" 12	4775	2.094	1.047	.261	9 0	637.3	15.68	7.840	1.965
" 16	4524	2.210	1.105	.275	" 15	620.2	16.12	8.060	2.019
" 20	4298	2.326	1.163	.290	" 30	603.8	16.55	8.275	2.074
" 24	4093	2.443	1.221	.306	" 45	588.4	16.99	8.495	2.128
" 28	3907	2.559	1.279	.320	10 0	573.7	17.43	8.715	2.183
" 32	3737	2.676	1.338	.334	" 15	559.7	17.87	8.935	2.238
" 36	3581	2.793	1.396	.349	" 30	546.4	18.30	9.150	2.292
" 40	3438	2.908	1.454	.364	" 45	533.8	18.73	9.365	2.347
" 44	3306	3.025	1.512	.378	11 0	521.7	19.17	9.585	2·401
" 48	3183	3.141	1.570	.393	" 15	510.1	19.61	9.805	2.456
" 52	3069	3.258	1.629	.407	" 30	499.1	20.05	10.03	2.511
" 56	2964	3.374	1.687	.422	" 45	488.5	20.50	10.25	2.566
2 0	2865	3.490	1.745	.436	12 0	478.3	20.94	10.47	2.620

TABLE.

TEMPERATURE OF BOILING WATER

Corresponding to the Height of Barometer and Altitude above Sea Level.

Thermo.	Baro.	Alti.	Thermo.	Baro.	Alti.	Thermo.	Baro.	Alti.
Deg.	Inch.	feet.	Deg.	Inch.	feet.	Deg.	Inch.	feet.
184.0	16.79	15221	194.0	20.82	9579	204.0	25.59	4169
.2	16.86	15112	.2	20.91	9466	.2	25.70	4057
.4	16.93	15003	.4	21.00	9353	.4	25.88	3945
.6	17.00	14895	.6	21.09	9241	.6	25.91	3344
.8	17.08	14772	.8	21.18	9130	.8	26.01	3742
185.0	17.16	14649	195.0	21.26	9031	205.0	26.11	3642
.2	17.23	14543	.2	21.35	8920	.2	26.22	3532
.4	17.31	14421	.4	21.44	8810	.4	26.33	3422
.6	17.38	14315	.6	21.53	8700	.6	26.43	3322
.8	17.46	14195	.8	21.62	8590	.8	26.54	3213
186.0	17.54	14075	196.0	21.71	8481	206.0	26.64	3115
.2	17.62	13956	.2	21.81	8361	.2	26.75	3007
.4	17.70	13837	.4	21.90	8253	.4	26.86	2899
.6	17.78	13718	.6	21.99	8145	.6	26.97	2792
.8	17.86	13601	.8	22.08	8038	.8	27.08	2685
187.0	17.93	13498	197.0	22.17	7932	207.0	27.18	2589
.2	18.00	13396	.2	22.27	7814	.2	27.29	2483
.4	18.08	13280	.4	22.36	7708	.4	27.40	2377
.6	18.16	13164	.6	22.45	7602	.6	27.51	2272
.8	18.24	13049	.8	22.54	7498	.8	27.62	2167
188.0	18.32	12934	198.0	22.64	7381	208.0	27.73	2063
.2	18.40	12820	.2	22.74	7266	.2	27.84	1959
.4	18.48	12706	.4	22.84	7151	.4	27.95	1856
.6	18.56	12593	.6	22.93	7048	.6	28.06	1753
.8	18.64	12480	.8	23.02	6945	.8	28.17	1650
189.0	18.72	12367	199.0	23.11	6843	209.0	28.29	1539
.2	18.80	12256	.2	23.21	6729	.2	28.40	1437
.4	18.88	12144	.4	23.31	6617	.4	28.51	1336
.6	18.96	12033	.6	23.40	6516	.6	28.62	1235
.8	19.04	11923	.8	23.49	6415	.8	28.73	1134
190.0	19.13	11799	200.0	23.59	6304	210.0	28.85	1025
.2	19.21	11690	.2	23.69	6198	.2	28.97	916
.4	19.29	11581	.4	23.79	6082	.4	29.09	808
.6	19.37	11472	.6	23.89	5972	.6	29.20	709
.8	19.45	11364	.8	23.98	5874	.8	29.31	610
191.0	19.54	11243	201.0	24.08	5764	211.0	29.42	512
.2	19.62	11136	.2	24.18	5656	.2	29.54	405
.4	19.70	11029	.4	24.28	5547	.4	29.65	308
.6	19.78	10923	.6	24.38	5440	.6	29.77	202
.8	19.87	10804	.8	24.48	5332	.8	29.88	105
192.0	19.96	10685	202.0	24.58	5225	212.0	30.00	sea level.
.2	20.05	10567	.2	24.68	5119	below	sea	level.
.4	20.14	10450	.4	24.78	5013	.2	30.12	− 104
.6	20.22	10346	.6	24.88	4907	.4	30.24	− 206
.8	20.31	10230	.8	24.98	4802	.6	30.35	− 304
						.8	30.47	− 405
193.0	20.39	10127	203.0	25.08	4697			
.2	20.48	10011	.2	25.18	4593	213.0	30.59	512
.4	20.57	9896	.4	25.28	4489	.2	30.71	613
.6	20.65	9794	.6	25.38	4386	.4	30.82	714
.8	20.73	9693	.8	25.49	4272	.6	30.93	813

TABLE.

THERMOMETERS.

Corresponding Temperatures by the Fahrenheit, Centigrade and Reaumur Scales.

Fahren.	Centi.	Reau.	Fahren.	Centi.	Reau.	Fahren.	Centi.	Reau.
Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.
212	100.0	80.0	128	53.3	42.6	44	6.7	5.3
210	98.9	79.1	126.	52.2	41.7	42	5.5	4.4
208	97.8	78.2	124	51.1	40.8	40	4.4	3.5
206	96.7	77.3	122	50.0	40.0	38	3.3	2.6
204	95.6	76.4	120	48.9	39.1	36	2.2	1.7
202	94.4	75.5	118	47.8	38.2	34	1.1	0.8
200	93.3	74.6	116	46.7	37.3	32	0.0	.0
198	92.2	73.7	114	45.6	36.4	30	- 1.1	- 0.8
196	91.1	72.9	112	44.4	35.5	28	2.2	1.7
194	90.0	72.0	110	43.3	34.6	26	3.3	2.6
192	88.9	71.1	108	42.2	33.7	24	4.4	3.5
190	87.8	70.2	106	41.1	32.8	22	5.5	4.4
188	86.7	69.3	104	40.0	32.0	20	- 6.7	− 5.3
186	85.6	68.4	102	38.9	31.1	18	7.7	6.1
184	84.4	67.5	100	37.8	30.2	16	8.9	7.3
182	83.3	66.6	98	36.7	29.3	14	10.0	8.0
180	82.2	65.7	96	35.6	28.4	12	11.1	8.8
178	81.1	64.9	94	34.4	27.5	10	12.2	9.7
176	80.0	64.0	92	33.3	26.6	8	- 13.3	10.6
174	78.9	63.1	90	32.2	25.7	6	14.4	11.5
172	77.8	62.2	88	31.1	24.8	4	15.5	12.4
170	76.7	61.3	86	30.0	24.0	2	16.7	13.2
167	75.0	60.0	84	28.9	23.1	− 0	17.7	14.1
166	74.4	59.5	82	27.7	22.1	2	18.9	15.1
164	73.3	58.6	80	26.6	21.2	− 4	- 20.0	−16.0
162	72.2	57.7	78	25.5	20.4	6	21.1	16.8
160	71.1	56.8	77	25.0	20.0	8	22.2	17.7
158	70.0	56.0	74	23.3	18.6	10	23.3	18.6
156	68.9	55.1	72	22.2	17.7	12	24.4	19.5
154	67.8	54.2	70	21.1	16.8	14	25.5	20.4
152	66.7	53.3	68	20.0	16.0	16	- 26.7	- 21.2
150	65.6	52.4	66	18.9	15.1	18	27.7	22.1
148	64.4	51.5	64	17.7	14.1	20	28.9	23.1
146	63.3	50.6	62	16.6	13.2	22	30.0	24.0
144	62.2	49.7	60	15.5	12.4	24	31.1	24.8
142	61.1	48.8	58	14.4	11.5	26	32.2	25.7
140	60.0	48.0	56	13.3	10.6	- 28	- 33.3	- 26.6
138	58.9	47.1	54	12.2	9.7	30	34.4	27.5
136	57.8	46.2	52	11.1	8.8	32	35.6	28.4
134	56.7	45.3	50	10.0	8.0	34	36.7	29.3
132	55.6	44.4	48	8.9	7.3	36	37.8	30.2
130	54.4	43.5	46	7.7	6.1	38	38.9	31.1

TABLES.

Equivalents of Lineal Measures.

Inches.	Links.	Feet.	Varas.	Yards.	Chains.	Miles.	Sp' Lea.	Eng. Lea.
1	0,126263	0.083333	0,029965	0,027778	0.001263	0.000016	0,000006	0,000005
7,92	1	0.66	0,237325	0.22	0.01	0,000125	0,000047	0,000042
12	1,515152	1	0,359583	0.333333	0.015152	0,000189	0,000072	0,000063
33,372	4,213636	2,781	1	0.927	0.042136	0,000527	0,0002	0,000176
36	4,545455	3	1.078749	1	0.045455	0,000568	0,000216	0,000189
792	100	66	23,73247	22	1	0,0125	0,004746	0,004167
63360	8000	5280	1898.598	1760	80	1	0,379720	0,333333
166860	21068,18	13905	5000	4635	210,6818	2,633523	1	0,877841
190080	24000	15840	5695,793	5280	240	3	1,139159	1

Equivalents of Square Measures.

Varas.	Yards.	Chains.	Acres.	Miles.	Sp. League	Eng. Lea.
1	0,859329	0,00177547	0,00017755	0,00000028	0,00000001	0,00000003
1,16369865	1	0,00206612	0,00020661	0,000000322	0,00000005	0,00000004
563,230148	484	1	0.1	0,00015625	0,00002253	0,00001736
5632,30148	4840	10	1	0,0015625	0,00022533	0,00017361
3604672,95	3097600	6400	640	1	0,14418692	0,11111111
25000000	21483225	44386,8285	4438,68285	6,93544195	1	0,77060466
32442056,5	27878400	57600	5760	9	1,29768226	1

French Units of Weights and Measures, &c.

METRE.	GRAMME.	LITRE.
MEASURES OF LENGTH.	WEIGHTS.	MEASURES OF VOLUME.
Myriametre....10000 meters	Millier ....1000000 Grammes	Kilolitre ....1000 litres
Kilometre...... 1000 "	Quintal.... 100000 "	Hectolitre.......... 100 "
Hectometre .... 100 "	Myriagram' 10000 "	Decalitre.......... 10 "
Dekametre..... 10 "	Kilogram'.. 1000 "	Litre.............. 1 "
Metre .... 1 "	Hectogram' 100 "	Decilitre ....one tenth "
Decimetre... one tenth "	Dekagram'. 10 "	Centillitre....one 100th "
Centimetre...one 100th "	Gramme... 1 "	Millilitre ....one 1000th "
Millimetre..one 1000th "	Decigram', one-tenth "	1 Fluid Dr'm..0,003967 "
1 Kilometre ....3280.833 feet	Centigram, one 100th "	1 Fl. Ounce...0,029739 "
1 Hectometre....328,083 feet	Milligram', one 1000th "	1 Fl. Pound, 0,3548656 "
MEASURE OF SURFACE.	CUBIC WEIGHT.	CUBIC MEASURE.
Hectare....10000 Sq. Meters	1 Cubic M...2204,6 lbs. A. D.	1 Cub. M. ...264,17 wine gal.
Hectare..........2,471 acres	1 Cub. Litre, 2,2046 " "	1 Cub. Litre 1,0567 wine gal.
Are.........119,6 Sq. Yards	1 Tonneau ..1000000 gr'mmes	1 Cub. Millilitre 0,0154 grains

TABLES.

Equivalents Lineal Measures

Inches.	Links.	Feet.	Yards.	Chains.	Miles.	Meters.
1	0.126263	0.083333	0.027778	0.001263	0.000016	0,0254005
7.92	1	0.66	0.22	0.01	0.000125	0,2011689
12	1.515152	1	0.333333	0.015152	0.000189	0.3048006
36	4.545455	3	1	0.045455	0.000568	0.9144018
792	100	66	22	1	0.0125	20.1168396
63360	8000	5280	1760	80	1	1609.347168
39.37	4.9710591	3.280899	1.093633	0.0497106	0.0006213	1

Equivalents of Square Measures.

Inches.	Feet.	Yards.	Chains.	Acres.	Meters.
1	0.0069444	0.0007716	0.0000016	0.00000016	0.00064516
144	1	0.333333	0.0002296	0.0000229	0.092903184
1296	9	1	0.00206612	0.00020661	0,836128656
627264	4356	484	1	0.1	404,671063
6272640	43566	4840	10	1	4046,71063
1550.0589477	10.7642982	1.1963331	0.0024711	0,00024711	1

Equivalents of Weights.

Grains.	Scruples.	Drachms.	Oz. Troy.	Oz. A. D.	P'd Troy.	P'd A. D.	Grammes.
1	0.05	0.016666	0.002083	0.002285	0.000173	0.000142	0.648004
20	1	0.333333	0.041666	0.045714	0.003472	0.002857	1.296008
60	3	1	0.125	0.139215	0.010416	0,008571	3,888024
480	24	8	1	0.990295	0,083333	0,0685702	31,10419
437.5	21,875	7.18311	1.0998	1	0.075941	0.0625	28,35017
5760	288	96,00	12	13,168	1	0.822857	373,2502
7000	350	116,66	14.5833	16	1.215278	1	453,6028
15.43316	0.771658	0.257219	0.032151	0.035275	0.002679	0.002203	1

Equivalents of Liquid Measures.

Gills.	Pints.	Quarts.	Gallons.	Liters.	Cubic Inches.
1	0.25	0.125	0.03125	0.1182955	7.21875
4	1	0.50	0.125	0.4737821	28,875
8	2	1	0.25	0.9463642	57.75
32	8	4	1	3.7854579	231.
8.4524	2.1131	1.05656	0.2641407	1	61.0165

A standard avoirdupois pound is the weight of 27,7015 cubic inches of distilled water, weighed in air at a temperature of 39.83 Fahrenheit, barometer at 30 inches. A cubic inch of such water weighs 252,6037 grains.

A cubic foot contains 7,48052 gallons liquid measure. A gallon is equal to a cylinder of 7 inches in diameter and 6 inches high.

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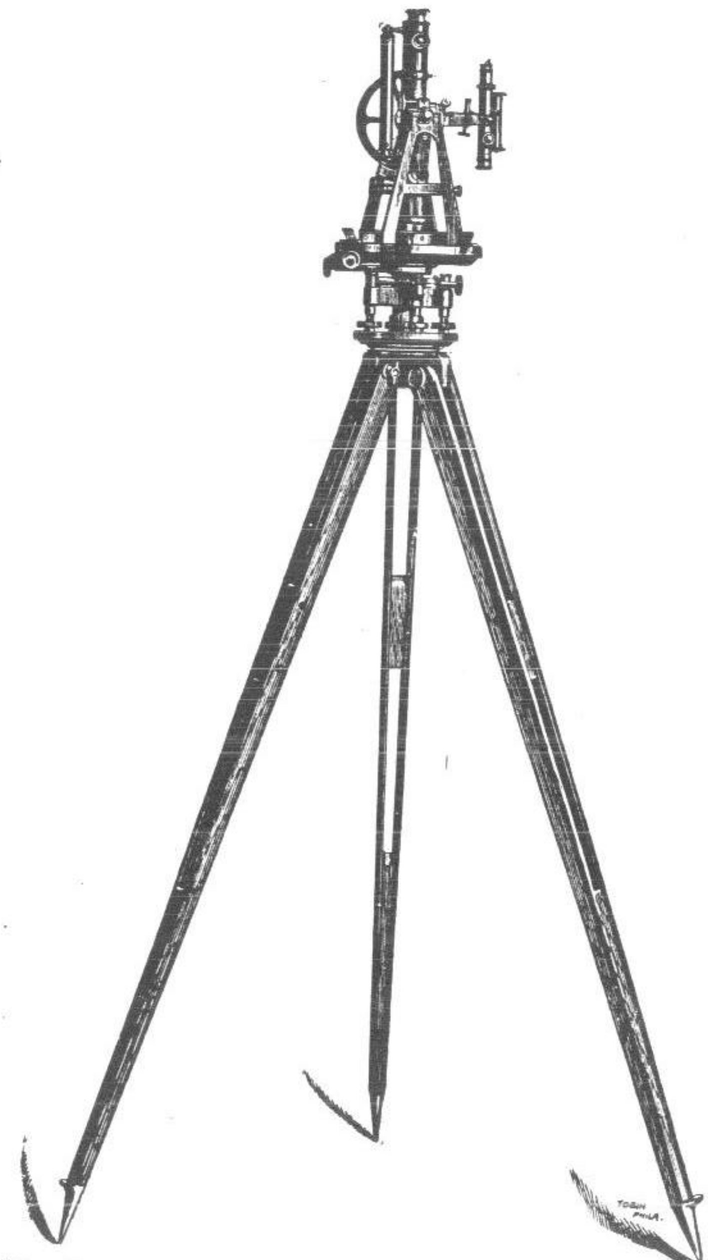

The Above Cut Represents the Mining Transit as Used with Saegmuller's Solar Attachment.

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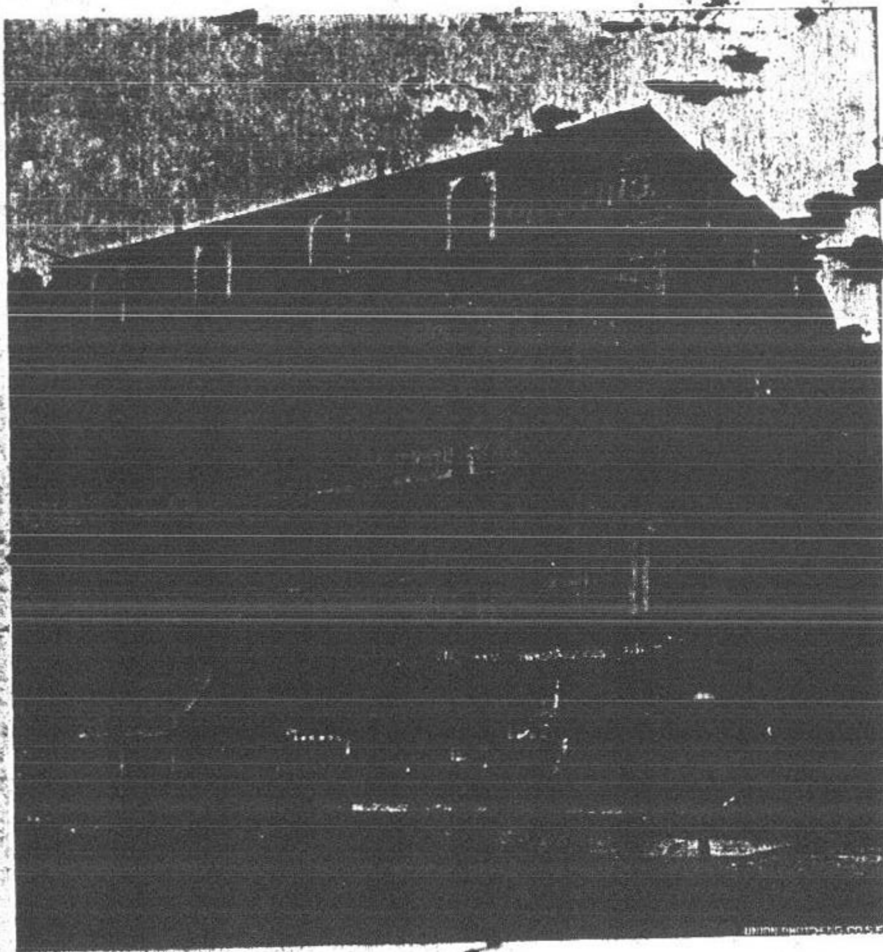

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