CATALOGUE

AND

PRICE LIST

OF

ENGINEERS' AND SURVEYORS'

INSTRUMENTS,

MADE BY

A. LIETZ & CO.

(Successors to Karl Rahsskopff,)

422 SACRAMENTO STREET,

SAN FRANCISCO, CAL.

PRICE, 25 CENTS.

SAN FRANCISCO:
JOS. WINTERBURN & CO., Printers and Electrotypers, 417 Clay Street.
Between Sansome and Battery Streets,
1888.

REMARKS

ON

ENGINEERS' SURVEYING INSTRUMENTS

BY

A. LIETZ & CO.

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PREFACE.

WE herewith present to the Engineering Profession our new Catalogue, giving a detailed description of our instruments and some information which may be of service to the reader.

The various improvements we have added to our instruments lately have led us to issue this publication. Our Coupling—a new method of rapidly and conveniently attaching or detaching the instrument to or from its tripod—is of great importance, and, undoubtedly, the most valuable improvement made during recent years in Surveying Instruments. Of almost equal value is our improved Telescope, having nearly double the power of ordinary ones. Our new Tangent Screw and Clamp; reduction in the weight of instruments with an increase of strength; their construction in such a manner as to bring the center of gravity nearer to the tripod head than any other make of instruments, thus making them more stable; the employment of composition and bell metal instead of common brass, and several minor improvements, have all contributed to the value of our instruments, and will, we trust, be appreciated by the profession.

We shall leave it to the intelligent reader to decide as to the superiority of our instruments over others. We shall only call attention to the different merits and points of ours, and invite comparison.

For the convenience of our customers, we will furnish any articles not on our list, but described in the catalogue of any American manufacturer or dealer in mathematical or optical instruments, at catalogue prices.

A. LIETZ & CO.

PART I.

NEW TRIPOD COUPLING.

This important improvement, which solves a problem that has occupied the attention of Instrument Makers and Engineers for years, and which has met the approbation of all who had occasion to either use or see it, was invented by us during the past year. Before describing it, we will mention the different methods of connecting the instrument to the tripod that have been employed, so far, and the defects they are all more or less possessed of.

There are known in general surveying two kinds of Transits, the Engineers' and the Surveyors'. The Engineers' Transit, as now made by almost every maker, is attached to the tripod by means of a screw at the base plate, and cannot be taken apart above the leveling screws. The Surveyors' Transit is attachable and detachable in the centre above the leveling screws. In most cases the parallel screws can also be detached from the tripod in the same manner as the Engineers' Transit, but in a great many they remain with the tripod.

To attach an Engineers' Transit by means of the screw at the base, is a very tedious and unsafe method, as probably most every engineer knows. Very often the screw will not catch, thus making the instrument liable to tip over. Besides, since its whole weight while turning rests on the screw, it naturally wears out the thread very soon.

The mode of attaching the Surveyors' Transit in the center is, though more safe, very defective. It is almost impossible to keep the center clean; a little dirt will often cause it to move very hard, and sometimes it commences to fret. But the greatest fault is its necessitating the construction of what is called "the flat center" for turning the upper plate. In such an instrument the plates stand too high above the leveling screws, and therefore cause unsteadiness. We believe it to be very difficult, if not impossible, to do accurate work with such an instrument, and will explain it more fully in our description of Transits.

The same reason which led to taking apart the Transit above the leveling screws, viz.: "The unsafety and inconvenience of attaching and detaching," also caused the different methods of taking apart levels. While some are constructed so as to leave the center on the instrument proper, others allow it to remain in the parallel plate. We believe the latter method the most defective of the two, because it throws the Y's out of adjustment every time the least dirt settles on either the socket or the cone, and because the bar and Y's have to be brought too high above the leveling screws. Both constructions have one common defect. The cone and the socket have to be stuck together tight to make the instrument steady, and in order to take it off again, it generally requires a sudden shock, which, of course, is liable to throw out the adjustment.

The foregoing description has shown the defects which all instruments are possessed of. We shall now describe our new arrangement, which remedies them.

On the tripod head, instead of the ordinary screw, we have three claws, (as shown in the accompanying cut) the base plate of the instrument is swallow-tail shaped on the inside (as shown by F) and is provided with the spring case C. The connection of the two is done by letting one of the cuts on the base plate meet either one of the claws on the tripod head, when a third of a revolution to the right will make the connection, the same time the spring C will fall into a hole on the tripod head, and thus prevent a disconnection, the latter can be done by lifting the spring C and turning to the left. If the tripod head should have been worn or bent by accident, the movable claw D, which is worked by the side screw E (with the large adjusting pin) will still enable to give the coupling friction enough to hold the instrument perfectly firm on the tripod.

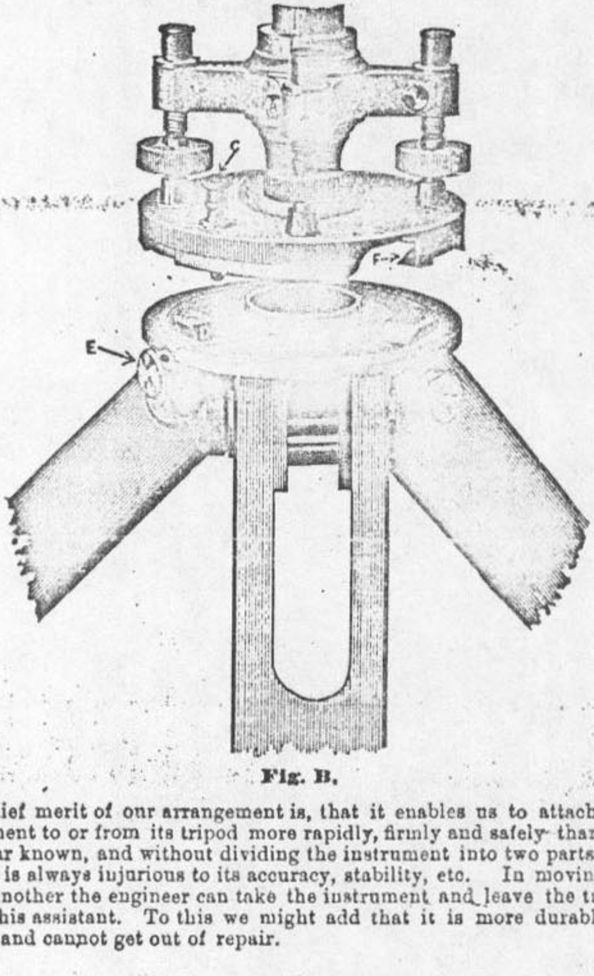


Fig. B.

The chief merit of our arrangement is, that it enables us to attach or detach the instrument to or from its tripod more rapidly, firmly and safely than any other device so far known, and without dividing the instrument into two parts, which latter method is always injurious to its accuracy, stability, etc. In moving from one station to another the engineer can take the instrument and leave the tripod to be carried by his assistant. To this we might add that it is more durable, easier to keep clean and cannot get out of repair.

TRANSITS.

The unreliability of the flat center or Surveyors' Transit has, during recent years, caused its being discarded by almost all Engineers and by a great many Surveyors. This is proved by the fact, that the very firm which introduced this style about 50 years ago, has, according to their own statement, almost abandoned it, and adopted for most of their instruments the long compound center construction. The greater friction of the plates upon each other in a flat center instrument, is liable to move the limb slightly, when the upper plate is turned in order to take an angle, and therefore will not give the correct one. Different readings taken for one angle, will often give different results, as probably all those who have used this style will have observed. One of the results of this great friction, is its wearing out the centers rapidly. Another defect of the flat center Transit, is its unsteadiness, which in a windy day is often so great as to render useless the attachments of a level to the telescope. One error which can be found frequently in these instruments, is the eccentricity of the limb, caused by an inaccurate centering on the graduating engine.

As the lower plate or limb is at the same time the center, it is evident that such an error can not be remedied, unless the graduation is taken off, and a new one put on.

The only advantage which is claimed by the few advocates of the flat center, is its ability to withstand rough usage. This is, however, of little importance, considering that a fall or blow which is capable of injuring long compound centers will in nine cases out of ten also bend the plates, standards, axis, &c., and necessitate its being repaired by a competent instrument maker.

From the above it will easily be seen, that a flat center instrument is imperfect, and can not give satisfaction; we will therefore state here, that we do not and will not manufacture this style. The superior qualities of the long compound center instrument will more than make up for the small additional cost, and we advise purchasers, wishing to save money, to rather buy a second-hand long compound center than a new flat center Transit.

We shall now describe those parts of our Transits, which are common to several or all of our different styles.

THE CENTERS.

The length of our centres is from 2¼ to 4 inches, according to size and style of instrument. To the best of our belief this is more than is possessed by the instruments of any of the many different makers, which are constantly passing through our hands for repairing. Yet, by examining our cuts, it will be noticed that the limb and vernier plates are nearer to the tripod head than theirs, owing to the judicious placing of the centers, which reach almost down to the base, thus insuring the utmost stability. Altogether regarding steadiness of construction the reader will consult his best interests by comparing our cuts with those of other makers, which will guide him in forming a correct idea better than the arguments of either ourselves or others based on mere assertion.

SHIFTING PLATES.

All our Transits are furnished with shifting plates for the precise centering of the instrument over a point after it is set approximately by the legs. This is of great convenience to the engineer, and, indeed we have made the observation, that whoever had occasion to use it once, will be unwilling to dispense with it afterwards. In order to centre the instrument, two of the leveling screws have to be loosened, then shift the instrument until the plumb bob is over the point and level up, which will clamp it again. We have placed a thin metal plate under the leveling screws, preventing the accumulation of dirt between the two shifting plates.

LEVELING SCREWS.

As the leveling screws are used more than any other part of the instrument, it is evident that they should be very durable. Ours have a very deep thread rounded a little on the edge, which insures a nice smooth motion and a greater durability than sharp-edged threads. The screws are made of composition metal. We do not use the common round nut for the leveling screws to work in, but have the lower part of all our instruments so constructed as to allow the leveling screws to pass through a slotted star, A, Fig. B. on Page 4. any lost motion of the screw can be taken up by the clamp screw B. This is of great importance on Leveling Instruments or Transits used for leveling. By placing caps above the screws, these are well protected against dirt.

TRIPOD LEGS.

We have adopted the new style of fitting legs to the tripod head, as the engraving will show. Instead of fitting the leg between two brass cheeks, we fit one cheek in the leg. In the old construction, the cheeks, when drawn closer by the bolts in order to tighten the leg when this gets loose, will often spring the plate or loosen the screws which hold the latter. In the new arrangement the tightening of the legs will not effect the plate in the least. While by the old method the legs would only fit at the lower part of cheeks when drawn in by the bolts, they will in the new one always fit the whole surface of the cheek, and will, after ten years' use, be just as steady as when new. The shoes are made tapering gradually to a sharp point and securely fastened to the leg.

If ordered, we furnish the round legs instead of the split ones.

SPIRIT LEVELS.

All Spirit Levels are ground to a proper curve and tested by us in person. Our advice is, not to meddle too frequently with the adjustment of a spirit level. Though it may appear to be out one day, it may be in perfect adjustment other days. It is the function of a Spirit Level to indicate the changes taking place in an instrument, so that the engineer may make proper allowance and apply his corrections, as the character of his work may require. The finer the instrument, the more sensitive the spirit levels must be, in order to admit of corrections to arrive at closer results. As a rule, a spirit level that does not indicate changes taking place in an instrument, is too insensitive for the character of the instrument, and in many cases entirely unfit or reasonable good work.

GRADUATION.

This very important part of a good instrument we guarantee *exact* and *accurately centered*, opposite verniers reading the same. The lines are straight, thoroughly black and uniform in width. There are two double verniers in every transit to read angles with great rapidity as well as to make four separate readings at every sight, when extreme accuracy in the repetition of angles is required. The horizontal circle is graduated from 0° to 360° with *two* sets of figures, running in opposite directions (unless ordered differently). The figures are large and distinct, and, to avoid mistakes in reading, the figures of these two sets of graduations, and those on the verniers, are *inclined* in opposite directions, thus indicating the directions in which the verniers should be read.

The remark is hardly necessary, that an instrument should always have two verniers, for the reason that the manufacturer himself cannot, without losing a great deal of time, be sure whether the graduation is correct or not, even if it is done on the most perfect engine. We believe that the facility of proving graduation and centers, which can be done only by having two opposite verniers, will be fully worth the slight additional cost. We will here venture the assertion, that those instruments with one vernier and flat center, generally known as surveyors' transits, are made in a manner not admitting of accuracy. To distinguish the verniers one from another we engrave the letter A on one, and B on the other, which is very convenient for those who always read only one vernier, as well as for those who read both.

It is well understood that the graduation is the most important point in a Transit, and any error renders the instrument almost useless, even if all the other parts are perfect. The most accurate graduation will, however, be of no value without a well fitting center. To prove both, several methods are employed. The surest test is to clamp the vernier plate to any point of the circle, and if by adding the two vernier readings together the sum is =180, and this same proceeding is repeated a number of times all around the circle with the same result, then they are correct. The graduation of an instrument having but one vernier can only be tested with the telescope, which test would take several days' time. All instruments, unless ordered differently, have the verniers so placed that they may be read without changing the position of the engineer after sighting through the telescope.

Glass covers protect the arc and verniers from exposure. For ease in reading the verniers, we have added to all of our instruments two plates of white glass, which cast a very clear light on the verniers in any position.

To graduate on solid silver adds $10 to the first outlay for the instrument, but its many advantages, great permanency and smoothness of surface renders it the only satisfactory surface for fine graduations.

THE COMPASS.

Our needles differ somewhat from others in shape, being a little lighter in the centre than towards the ends, for the reason that the magnetism is always in the ends only, decreasing towards the centre, so that all the metal there may be called dead weight. Compared with those of other makers, our needles are also a little lighter, which conditions the increased durability of the point.

Hard steel has the capacity of retaining magnetism longer and better than when tempered, and we therefore now leave one-half inch on both ends perfectly hard. The closest attention is given to the pin and centre cap, on which the accuracy or sensitiveness of the needle principally depends.

The lifter arrangement is made in such a manner as to raise and lower the needle gently, and to prevent the sudden jerking and falling, which so often is the cause for the rapid wearing out of the point and centre cap.

GRADIENTER SCREW.

This attachment was first introduced by Prof. Stampfer, of the Vienna Polytechnic School. It does not add to the weight of the instrument, and once used we have found it to be universally approved by our customers. By means of it *grades* can be established, and *horizontal distances, vertical angles* and *differences of level* can be measured with great rapidity. Indeed this attachment to an engineer's transit is one of the most useful introductions in practical engineering. It is so universal in its application to railroad and general work, that when once used it *will afterwards form an indispensable part of an engineer's outfit.*

CLAMP AND TANGENT SCREWS.

The lower clamp screw of our transits are of the best devised plan, they are strong and rigid and answer the slightest touch.

The upper clamp is so constructed that it leaves the limb circle untouched, just grasping the sleeve of outside center against this clamp works a fine micrometer screw with opposing spring. This clamp answers the slightest touch and is very rigid and the micrometer screw can never have any lost motion, as the opposing spring takes up all possible wear.

In closing these remarks, we shall call the attention of the reader to the loss of time and annoyance arising from a Tangent Screw having "lost motion" while adjusting the line of collimation in the telescope. While revolving this, the plate is liable to turn slightly, and the operator is never sure whether the cross hairs are in adjustment or not.

FIXED STADIA WIRES FOR DISTANCE MEASUREMENT.

We have specially devised an optical and mechanical apparatus for the purpose of placing fixed, or non-adjustable stadia wires so accurately upon the diaphragms of our telescopes that their distance apart will read 1': 100' + on any leveling rod, as with the gradienter screw, thus dispensing with a special rod.

It is well known that adjustable stadia wires are so apt to change their distance apart with every change of temperature, that no reliance can be placed upon them unless previously adjusted. With fixed stadia wires, annoyances of this kind are obviated—*they are reliable at all times.*

As regards the degree of accuracy attainable by the use of fixed stadia wires, experiments with our powerful telescopes, made optically as perfect as the most advanced optical and mechanical skill enable us, warrant us in saying that with some experience and proper care the results obtained will approximate and even equal those obtained by chain measurements. The price for this accessory in any new instrument is only $3.00, but if inserted into a telescope sent to us for that purpose, we must charge $10.00. We advise to order both the gradienter screw and the fixed stadia wires, as each in itself, separately or jointly, will prove of great value.

GENERAL MATTERS.

The general demand in these days is for light instruments. We have succeeded in producing such, without reducing their strength, but rather adding to it. This is accomplished by the method of bracing and ribbing all the heavy parts. By removing metal in such places which did not impart strength, and applying a part of it to points where the most strength is required, we have obtained stronger and somewhat lighter instruments.

Yellow brass has been entirely discarded by us, composition and bell metal being employed exclusively. The greater strength these metals have, compared with the former, is an important item, especially in case of accidents. When such take place with a yellow brass Transit instrument, the limb in most instances will have to be redivided, while when made of hard metal, it must be a very severe blow or fall which is capable of bending it, so as to require a new graduation. Many an accident which will damage a yellow brass instrument sufficiently to necessitate its being repaired, will not effect one made of hard metal. We ought to say here, that the employment of the harder metals increases the cost of manufacture, and this is the sole reason why it is not adopted by every maker.

Another defect yellow brass is possessed of is, that it easily frets. To prevent this as much as possible, we use for every movement two different metals, for one part composition, and for the other bell metal. Thus the axis to telescope is made of composition metal, the centre to the vernier plate of bell metal, that to the limb of composition, and the leveling screw, again of bell metal. The collars of the Level telescopes are made of extra hard bell metal, cast especially for us, to prevent wear.

LEGS.

These are made of well-seasoned ash. Experience has shown us that ash is preferable to mahogany. In fact for legs, the latter is even inferior to black walnut, for the reason, that if exposed to the weather and dampness of the ground, this soon becomes rotten, an observation which almost every engineer has made. Many instances as known to us where legs, after an ordinary use of two or three years, broke right above the shoe. For legs, we believe ash the best, being very durable and standing firmer than mahogany does.

The thickness of the wood of the boxes is ⅝ of an inch; they are nicely finished and provided with lock, key, brass hooks and leather strap for carrying conveniently.

PACKING OF INSTRUMENTS.

Every possible precaution is taken by us to secure safety. Each box is provided with adjusting pins and sun shade, a plumb bob, and magnifier for reading the graduation, is also furnished with Transits.

CARE OF INSTRUMENTS.

The usefulness of an instrument can be preserved for many years if proper care is taken of the same. We shall therefore mention a few of the principal points which the engineer will do well to observe.

To preserve the sensitiveness of the needle, the dulling of the centre pin must be avoided. The instrument should never be lifted without being sure the needle is up, and, if by letting it down again the swing is too large, it should be gently stopped when within a few degrees of its natural bearing. Should the point become dull, it is best to have it fixed by an instrument-maker; if such, however, is not accessible, or no time can be spared, a watchmaker perhaps can do it. It must be remembered, however, that after being sharpened the point must be centered, that is, must be brought in the center of the graduation. This work, however, can only be relied upon if done by the instrument-maker.

If a needle is made of good steel, well hardened and properly charged, it will not often lose its magnetism, and if, when placed away, it is always brought to lie in the meridian, it will retain, or even increase its polarity. It should not be left resting on the point, but after it has assumed its position it should be raised against the glass. If a needle has lost its magnetism it can be charged again with an ordinary horse shoe magnet; one of three inches in length will be suitable for this purpose. The operation is this: hold the magnet with the poles upward, then, with a gentle pressure, pass each pole of the needle from center to extremity over the opposite pole of the magnet, describing, before each pass, a circle with a diameter of about double the length of the needle, taking care not to return it in a path near the pole. If the magnet is strong enough, the needle need not be taken out at all, but by raising it against the glass and then passing the magnet over this, it will be charged sufficiently. After charging, the needle has lost its balance, which can easily be restored by shifting the brass wire on the South end.

The general tendency in the use of screws is to overstrain them. This should never be done, especially with the cross-wire screws, which, when too much tightened, are liable to constant change and loss of adjustment. Leveling and clamp screws also should not be overstrained, as it wears them out sooner and sometimes causes fretting. If this takes place they should be taken out and brushed with either soap and water or benzine. The nuts can best be cleaned by screwing a flat piece of soft wood through their apertures. In putting together, grease them slightly.

Fretting of the centers and of the telescope-slide will interfere more with a correct working of the instrument than any other part out of order. They should be watched therefore, very closely, and as soon as any rough motion manifests itself, it should be remedied at once, if possible, by an instrument-maker. If this cannot be had, and the fretting is in the slide, first scrape and then burnish down the place where it frets. It may also be ground slightly with oil and very fine pumice stone dust, which is best obtained by rubbing two pieces on each other. After grinding them a little, the tubes should be cleaned and placed together again with oil only, then move them in and out a number of times, wipe the oil off and finally put them together when dry. If the fretting takes place in the centers (when properly made and constructed, so that they do not come apart in detaching the instrument from the tripod, this will never happen), employ the same means, and if this is not effective, place a washer, made of paper or a thin card, between the shoulders. This will cause a shake, making accuracy impossible, and produce errors of parallax in reading off, which, however, is better than destroying the centers wholly. The best grease for centers is very fine watch oil. In regard to our centers, we can say that no fretting will ever happen, as they are always covered and carefully made. The object slide should not be greased. Never use emery paper or emery in repairing any movement, as it can not be removed again and will grind continually. For greasing, leveling and clamp screws, pinions, etc., good rendered marrow should be used.

In cleaning object and eye piece glasses, use a soft rag or chamois leather. If the glasses should become greasy or very dirty, wash them with alcohol. The inside of the glasses will very seldom require cleaning, and it is advisable not to take the telescope apart often, as it destroys adjustment, especially in those instruments in which the object glasses are loose in the cell. If dust should settle on the cross hairs, it is best not to touch them. The only means which may be tried is by taking out the object glass and eye piece and blowing gently through the tube. For dusting off an instrument a camel's hair brush is best suited. It will brush dust better out of the corners than can be done with a rag, and preserves the lacquer. Its use is especially recommended for cleaning limb, vernier and compass ring.

It is advisable to look sometimes after the fitting of legs and shoes. If there is any shake in the legs, or any shoe loose, the instrument can not be steady.

There should be no delay in repairing defects.

If an instrument is upset, bending centers and plates, do not turn it unnecessarily, as it will spoil the graduation, but send it to a competent instrument-maker immediately.

ADJUSTMENTS.

All the various adjustments which the engineer is required to look over occasionally consist in placing certain points, either at right angles or parallel with others. To adjust the verniers and compass, consists in placing certain points in a straight line, but as these adjustments are always made by the instrument-maker, they should hardly be termed such. We have inserted that of the needle and point, as these sometimes get out of order and are easy to correct. The adjustment of verniers and limb, if properly done, will not get out of order from ordinary use.

The general method used in performing the various adjustments is that of reversions. As these always double any existing error, it is evident that the mean between the difference indicates the true point. We shall commence by giving the adjustments to transits, which, in practice, should be made in the same order as given here.

OF TRANSITS.

I. LEVELS.

The object of this adjustment is to bring the levels at right angles to the centers of the instrument, so that when the bubbles are brought in the center of the tube, the vertical axis of the instrument stands in a true vertical position.

To perform it, bring the bubble in the center of the tube by means of the leveling screws, then turn the instrument 180 degrees. Should the bubbles not stand in the centers of the tubes again, correct one-half the difference by means of the capstan head screws of the levels, the other half with the leveling screws. If the proper corrections have been applied, the bubbles will remain in the center in any position of the instrument; if not, the same operation must be repeated. If the levels should be out much, it is best to adjust one, approximately, and then the other.

II. THE STANDARD BEARINGS.

The adjustment of these is necessary in order to make the telescope revolve in a true vertical plane when the centers of the instrument stand in a vertical position. To perform it, set up the instrument about fifty feet distant from a house. Take a well-defined point as high as possible, then turn the telescope and take another as low as can be obtained. After this, reverse the instrument on its center and direct the telescope again to one of the observed points. If, by turning, it does not strike the other point, correct one-half the difference, and the adjustment is done. It is not necessary to level the instrument, but preferable to bring it in such a position which permits to take two well-defined points. Care should, however, be taken that the observation is made at the intersection of the cross-wires, and that the instrument is securely clamped.

This adjustment should always be made before that of the cross-wires, for the reason that, unless points of equal height are taken for the latter, the adjustment will not be correct, if the axis does not revolve in a vertical plane. We make this remark because some catalogues are evidently in error on this point.

III. THE CROSS-WIRES.

The object of this adjustment is to make the line of collimation perpendicular to the axis, upon which the telescope revolves.

We assume that the telescope stands in the center of the instrument, that the tubes are perfectly straight, and are set at right angles with the axis upon which the telescope revolves, points which must be accurately performed by the instrument maker, and which are necessary, if the adjustment on a long distance shall also be correct on a short one.

There are two methods employed. The first one, which is most generally used, consists in taking back and fore-sights. Before making the adjustment, the vertical wire must be set truly vertical, so that the upper and lower end will remain upon the object if the telescope is depressed or raised. In order to do this, the instrument must be first leveled up.

Having performed this, proceed in the following manner: clamp the instrument, and by means of the tangent screw, set the intersection of the wires on some well defined point from one to five hundred feet distant, then revolve the telescope and take or place an object in the opposite directions at about the same distance. Now unclamp the instrument, turn it half way round, clamp it again, and set the wires again on the first point. If then, by revolving the telescope, the intersection bisects the second object, the vertical wire is in adjustment. If such is not the case, correct with the two capstan head screws, on the sides of the telescope, by moving the vertical wire back one quarter of the space between the point now obtained and the second object. If the correction has been exactly one quarter, the wire will be adjusted, if not, the same proceeding must be repeated. The reason why the correction is only one fourth is evident from the fact, that in first revolving the telescope, the error is doubled; then in revolving it again after the instrument has been reversed, the error is again doubled, but on the opposite side.

It is not necessary to level the instrument while making this adjustment, but in case leveling is dispensed with, the observation must always be made at the intersection of the wires. It must be remembered that the image at the cross-wires is inverted, that, consequently, the screws must be moved in apparently wrong directions. Old instruments which have back lash in the tangent screw, should be turned very carefully so as not to change their position.

The second method consists in locating with the telescope three points in one direction, which are necessarily in a straight line, no matter how much the wires are out of adjustment. The instrument is then moved to the center point and the wire set on either of the two other points. Then revolve the telescope and see whether the wire bisects the other point. If it does, the wire is in adjustment; if not, correct by moving it midway between the point obtained and the true point. This method requires leveling of the instrument.

We have been speaking so far only of the vertical wire, as this is the most important in a Transit Telescope. In a plain Transit—that is, one without level to telescope, and without vertical circle—the horizontal wire simply serves to define the center of the vertical wire, so that no error may arise in case the latter does not stand in a vertical direction.

If a level is attached to the telescope, the horizontal hair should be brought in the optical axis also before the level is set parallel with the line of collimation; otherwise, if adjusted for long distances, it will not be correct for short ones.

To perform adjustments, set up the instrument alongside a house or fence and level up carefully. Then clamp the telescope and by means of the tangent screw take a point several hundred feet distant; then turn the instrument on its center, and mark a point on the house or fence about 10 feet distant. Now unclamp the telescope, reverse it, clamp it again and set the wire again on the nearest point. Then turn the instrument on the center and see whether the wire bisects the other point. If not, correct by moving the wire half way between the two.

No directions are given for this adjustment in the catalogue of any other maker, which omission has for its cause their assumption that no accurate leveling can be done with a Transit; a supposition which we do not share with them.

IV. THE LEVEL TO TELESCOPE.

The object of this adjustment is to make the level parallel with the line of collimation. The method by which this is accomplished is based on the principle that points taken with the same angle of elevation or depression, and equally distant from the instrument, are of equal height.

To perform adjustment, the instrument must be carefully leveled, and on opposite sides, at equal distances, stakes must be driven, giving an equal reading. These two points are necessarily on a level with each other. Now move the instrument to a point in a line with both and about 10 feet distant from one. Level again; take a reading on the nearest, and then another on the further stake. If both agree, the level is in adjustment; if not, move the wire with the tangent screw over nearly the whole error, and sight again at the nearest stake. Repeat this until the readings are the same on both, when the telescope is truly horizontal. Now bring the bubble in the center of the tube, and the adjustment is completed.

THE ZERO LINE OF THE VERTICAL CIRCLE.

This adjustment, when once made by the instrument maker, will seldom get out of order. The object is to make the zero lines of the vernier circle agree when the level of the telescope is truly horizontal and the centers of the instrument stand in a true vertical position.

To perform adjustment, the instrument must be carefully leveled; first, with the small levels on the plates, and then with the level to telescope. When this has been done, shift the vernier until the zero lines cut each other.

OF THE Y LEVEL.

This requires three adjustments, viz.: 1. Making the level parallel with the bottoms of the collars. 2. Adjusting the Y's so that the bubble will be at a right angle to the vertical axis of the instrument. 3. Adjusting the line of collimation.

THE LEVEL.

The object of this adjustment is to make the level parallel with the line of collimation. At the same time the axis of the level must be brought in a plane with that of the telescope.

It is best first to bring the level and telescope into a vertical plane: *i. e.*, to correct the side motion of the level, which is done in the following manner: Clamp the instrument and bring the level in the centre of the tube; then turn the telescope in the Y's so as to bring the level on either side of the bar. If the bubble changes its position, it shows that its axis is not in a plane with that of the telescope. Correct by moving the two side screws until the bubble is half way back. If the level is funnel-shaped, which is often the case in poorly made instruments, the adjustment cannot be properly done, and the operator must always take care to have the level stand over the center of the bar.

The level must now be made parallel with the bottom of the collars, which is done in this manner: bring the bubble in the centre of the tube, then carefully reverse the telescope in the Y's, end for end. The motion of the bubble is the double error, which is removed by bringing this half way back by means of the adjusting nuts, the other half is corrected with the leveling screws. Repeat the same operation until the bubble remains in the centre.

Remarks.—To make the level parallel with the line of collimation it is only possible if the collars are of equal diameter. If such is not the case, the instrument will not be any better than a Dumpy Level, and must be adjusted as such. The level can be made exactly parallel to the bottom of the collars; the Y's adjusted so that the bubble remains in the center of the tube; the line of collimation brought in the centre of the revolution of the telescope, this reversed end for end in the Y's, leaving the bubble in the centre, no matter how much difference there may be in the diameter of the collars. It is the general opinion among engineers that after level, Y's and cross-wires are adjusted, the instrument must be correct, while this is by no means certain, as the least difference in the size of the collars, which difference is sometimes found in new instruments, more often produced by unequal wear, denting etc., will throw out the line of collimation considerably. It is therefore advisable that the equality of the collars should be tested from time to time, which can only be done by taking a test level. If found incorrect, it can only be remedied by the instrument-maker. More information regarding this point can be found under "Telescopes," where the subject has been treated more in detail.

THE Y'S

The object of this adjustment is to place the level and the line of collimation at right angles to the centre.

To perform it bring the bubble in the centre of the tube and over two opposite leveling screws, then turn the instrument half way around on its centre. The difference in the position of the bubble is the double error, one half of which is corrected with the nuts, and the other half with the leveling screws.

THE CROSS WIRES.

The object is to place the cross web or line of collimation in the optical axis of the telescope, so that their intersection will remain on an object in revolving the telescope.

To perform adjustment, set the intersection of the wires on some point about two hundred feet distant, then revolve the telescope half way around. If the wires have moved away from the point, bring them half way back.

Remarks.—In this, as well as in any other telescope, we assume that the tubes are straight, the object glass well centered, and the slide well fitted. If such is not the case, the telescope can only be adjusted for certain distances. It is urged by some makers that it is almost impossible to produce straight tubes, and that, therefore, the object slide must be adjustable. This is, however, not so. Perfectly straight tubes can be made if only the necessary time and money is expended. The fact is, that in most of these instruments the object glass is not centered, the slide poorly fitted, etc., which is by far more injurious than ever if the tubes are not quite straight; besides, the constant working of the slide in the adjustable ring will loosen the screws and cause a great deal of annoyance.

OF THE SURVEYORS' COMPASS.

The adjustments consist of:

1. The Levels.
2. The Needle and Centre Pin.
3. The Sights.

Properly speaking, only the first can be called an adjustment, and as this has been described already in that of the Transit, it is not necessary to repeat it here. The second and third are points which belong to the instrument-maker, but as Compasses are often subject to rough usage and liable to get out of order, we have inserted them to enable the surveyor to correct such defects temporarily.

THE NEEDLE AND CENTER PIN.

The former will very seldom require adjustment unless handled very carelessly. As the pin has to be taken out sometimes, in order to sharpen it, and in replacing the point will generally not return to its true position, it has to be brought again in the centre of graduation. As each depends on the other, they must be corrected together.

To perform adjustment, bring the N end of the needle on the N zero of the compass and note the position of the S end of the needle. Then turn half way around and bring the N end of the needle on the S zero of the compass, and note again the position of the S end of the needle. If this should have changed, *i. e.*, should have moved either to the right or left, it is evident that the pin is out of centre and must be bent. If the reading is the same, the pin is in the line with N and S zeros, and any existing error must be corrected by bending the needle. If the readings are not the same in amount, both the needle and pin must be bent—the needle most if the reading remains on one side, and the pin most if the reading is on both sides.

THE SIGHTS.

The object of this adjustment is to bring the slits in a vertical position when the instrument is leveled.

To perform, suspend a plumb line at a convenient distance and note whether it passes through the centre of the slits when the instrument is leveled. If not, correct by filing down the base on that side, which is the highest. It can also be temporarily remedied by placing paper under the lower.

REPAIR OF INSTRUMENTS.

This branch of our business has grown rapidly of late years, principally on account of the advantage Western Engineers derive from sending their instruments to us instead of to the East.

As our location requires us to repair all the various makes of the country, while Eastern establishments, as a rule, only repair their own, we were obliged to procure all the material, patterns, tools, etc., necessary for these. Having the patterns for all those parts which often want to be replaced when injured by falls, such as the axis to the telescope, centres, etc.; facilities for cutting any threads from 5 to 100 to an inch; object glasses and eye piece lenses of any desired focus; level vials of every diameter and length, including even the sometimes odd sizes of English instruments, we are prepared to do the work as economically and promptly as the maker himself can do it. By sending their instruments to us the Western Engineers and Surveyors will save time and expressage.

Instruments sent to us are always thoroughly overhauled and put in as good a condition as possible, unless directions are given specifying the repairs desired. We believe that the best policy, insuring satisfaction and a saving of money, is to leave it to our judgment, as there are often points appearing trivial to the engineer, but which must be corrected if the instruments are to be relied on.

A good deal of correspondence arises to us from inquiries about the cost of repairs, and, although it is impossible to state the exact figures, we will give a general idea of such here.

The most costly instrument to repair is the Transit, being the most complicated. If injured by a fall, new centers and new axis to telescope are generally required, the cost extending from $10 to $30, or sometimes even $50. If slightly injured, the cost will vary from $5 to $10.

Injuries that leveling instruments sustain from falling are generally less serious, ranging in cost from $5 to $15. A new level vial costs from $2 to $7.50, according to size and sensitiveness. In instruments which are defective in construction or workmanship, sensitive levels will be a source of constant trouble and annoyance to the engineer, and such bubbles are preferable which are in accordance with these qualities. As a rule, we place to the better instruments levels giving for each inch motion of the bubble an angle of two minutes: to inferior ones such giving three or four minutes.

Compasses sent to us are principally injured by the dulling of the center pin. Sometimes the plates and sights are bent and glass broken. Very often the center cap is worn out and a new one is required. The cost of repairing ranges from $2 to $8, and sometimes even $10. A new needle, having the largest breadth in a vertical direction, which is far superior to the flat style, costs $5. A new center point costs 75 cents. A new center cap, with jewel, $1.50.

Transits and levels should always be accompanied by the leveling plates; the legs and the head to them need not be sent. With compasses, the ball spindle should be sent along. We advise our customers to carefully pack instruments sent to us for repairs, as they might be sometimes injured by neglecting this precaution. When an instrument is sent to us, a letter or postal card should always be mailed the same day, giving us the directions and stating when the return is required.

TELESCOPES.

It is well understood that the Telescope forms a very essential part of a good instrument; hence, it will be of interest to follow up those rules of optics which govern the construction of such. We shall limit ourselves to the small field required for the special class of instruments we have been describing, and shall treat the subject in accordance with some of the best authorities on optics.

THE FORMATION OF IMAGES BY LENSES AND THEIR MAGNIFYING POWER.

When parallel rays, such as those from a star, (which by reason of their great length may be considered parallel) fall upon a lens in a direction parallel to its axis, the ray which coincides with the axis will pass through without suffering any refraction; but the other rays will be refracted and found to meet at a common point in the line of the axis. This point is called the focus of the lens. When the surfaces are equally convex, the focal distance is equal to the radius of the surfaces.

When the rays fall in a direction oblique to the axis, those which pass through the center of the lens will suffer refraction at each surface; but as the two refractions are equal and in opposite directions, the refracted rays will finally emerge in the same direction as the corresponding entering rays; consequently any ray passing through the center of the lens may be considered free from refraction, as the thickness of the lens is insignificant.

When the diverging rays, radiating from a point not very distant, fall upon a lens, the refracted rays will meet at some point more remote than the one for parallel rays of light—or in other words, its *principal focus.*

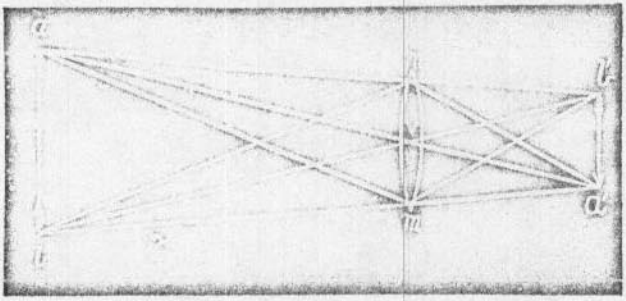
The nearer the radiant point approaches to the lens, the more the focus will recede from it; so that when it has approached as near as twice the *principal focal* distance, the focus will be at the same distance behind the lens as the radiant point is before it, and when it has approached to the principal focal distance, the rays will emerge parallel with infinitely distant focus.

When the principal focus of a lens is known, the formula for finding the focus for diverging rays is, $p =$ principal focal distance; $a =$ distance of the radiant point from the lens.

$$\frac{a\,p}{a-p}$$

As all the rays of one point will be again refracted to one certain point by a convex lens, so will the rays of a *great number* of points, of any object, be refracted and formed to an *image* on the above described principle; and it is a universal rule that

when an image is formed by a convex lens, it is inverted in position relatively to the position of the object, and its magnitude is to that of the object as its distance from the lens is to the distance of the object from the lens.



If $a\,b$ is an object placed before the convex lens $m\,m$, every point of it will send forth rays in every direction. Those rays which fall upon the lens $m\,m$ will be refracted to a foci behind the lens, and at such a distance from it as may be determined by the above formula.

The point a will send rays to every point of the lens, one of which will pass through the center v of it, hence will not suffer any refraction; consequently the point a' of the image representing the point a of the object must lie somewhere in the continued line $a\,v$—that is, where the refracted rays $a\,m$ meet this line. In the same way the rays of the point b or any point of the object will be refracted, so that a' represents a and b', b of the object, whose image is consequently inverted.

As the angle $a\,v\,b$ is equal to the angle $a'\,v'\,b'$, the length of the object $a\,b$ must be to the length of the image $a'\,b'$ as the distance of the object $a\,b$ from the lens $m\,m$ is to the distance of the image $a'\,b'$ from the lens $m\,m$.

The brightness of the image will always depend on the brightness of the object; when the brightness of the object increases, the brightness of the image will increase proportionately. It is also evident that we may increase the brightness of the image by increasing the size of the lens, or the area of its surface. If a lens has an area of 12 square inches, it will obviously intercept twice as many rays proceeding from every point of the object as if its area were only 6 square inches.

If we place the eye about 6 inches (the distance at which a normal eye will see small objects most distinctly) behind the image $a'\,b'$ we will see the same very clearly and distinctly, apparently suspended in the air. The cause of this will be readily understood if we consider that all the rays which form by their convergence the points $a'\,b'$ of the image, cross one another at $a'\,b'$, and diverge from these points exactly in the same manner as they would do from a real object of the same size and brightness placed in $a'\,b'$.

The image $a'\,b'$, therefore, may be regarded as a new object; and by placing another lens behind it, another image of the image $a'\,b'$ would be formed, exactly of the same size and in the same place as it would have been had $a'\,b'$ been a real object. Since the new image $a'\,b'$ must be inverted, this new image will now be an erect one of the object $a\,b$, obtained by the aid of two lenses; so that by using one or more lenses we can obtain erect or inverted images of an object at pleasure.

In order to explain the power of lenses in magnifying objects, or rather in giving magnified images of objects and bringing the image near us, we must examine the different circumstances under which the same object appears when placed at different distances from the eye.

If the eye looks at a man placed at a distance, his general outline only will be seen, and neither his features nor his dress will be distinguishable. When he is brought gradually nearer, we discover the different parts of his dress; till at a distance of a few feet we perceive his features distinctly.

The nearer an object is to the observing eye, the greater the angle will be under which it is seen; and the apparent magnitude of an object can, therefore, always be measured by the angle at which it is seen.

Suppose an object be placed at a distance of 100 feet from the eye, and a lens of 25 feet focal length be placed half way between the object and the eye—that is, 50 feet from each—this lens, as previously shown, will form an image of the object 50 feet behind it of the same size as the object. If this image is looked at by the eye placed six or eight inches behind it, it will be seen exceedingly distant, and nearly as well as if the object had been brought from a distance of 100 feet to a distance of six inches, at which we can examine minutely the details of the object.

Now in this case the object, though not actually magnified, has been apparently magnified, because its apparent magnitude is increased in the proportion of 100 feet to six inches, or 200 to 1.

When the focal length of the lens is quite inconsiderable, compared with the distance of the object, as it is in most cases, the proportion of magnifying power will be considerably changed, compared with the preceding illustration, on account of different foci at different distances.

Suppose a lens of one foot focal length forms an image of an object 1000 feet distant, this image would be formed at very nearly the distance of the principal focal length from the lens. If we could now place the eye in the center of the lens, we would necessarily see from this point the image at the same angle as the object would appear on the other side; hence, the apparent magnitude of the image would, when viewed from a place one foot distant from it, be the same as that of the object when viewed from the center of the lens, although actually diminished 1000 times. But as a normal eye can have a distinct view of an object at a distance of six inches, we can also approach to this distance from the image formed by a lens, and still see it distinctly. The apparent magnitude of the image then observed will be twice as large as the object appears when viewed from the center of the lens, and consequently the object will appear twice magnified.

In the case of a very short-sighted person, who sees objects distinctly at a distance of three inches, the magnifying power would be four.

From this, the rule for finding the magnifying power of the lens, when the eye views the image which it forms, is: Divide the focal length of the lens by the distance at which the eye obtains a distinct view of the image.

Here, then, we have the principle of the simplest telescope, which consists of a lens whose focal length exceeds six inches, placed at one end of a tube whose length must always be equal to the focal length of the lens, plus the distance for distinct vision.

But there is still another way of increasing the apparent magnitude of objects, particularly of those which are within our reach.

It is proved in optics that a good eye can see distinctly when rays of light parallel, or nearly so, fall upon it, as it has the power to accommodate itself to objects at different distances.

If we bring an object, or the image of an object, very near to the eye, so as to give great apparent magnitude, it becomes indistinct, as the rays of light which proceed from it diverge to such a degree as to render the eye unable to accommodate itself to them; but if we can, by any contrivance, make the rays enter the eye nearly parallel, we shall necessarily see the image distinctly.

But we have already shown that when rays diverge from an object placed in the focus of a lens, they will emerge parallel. If we, therefore, place an object or an image of one in the focus of a lens, held close to the eye, the rays will enter the eye parallel, and we shall see the object distinctly. The present short distance of the image to the eye is equal to the focal length of the lens, so that the magnifying power produced by it will be equal to six inches, divided by the focal length of the lens, consequently the shorter the focal length, the greater the magnifying power.

When a lense is used to magnify the image produced in a single lens telescope from a distant object, the two lenses together constitute what is called the astronomical telescope.

MAGNIFYING POWER OF TELESCOPES.

Every telescope consists of two distinct parts; the object glass forming the image and the eye piece by which this image is viewed and magnified.

Although the different kinds of telescopes differ in the construction of their eye pieces, they are yet subject to the same rules in regard to magnifying power, field and light; we will therefore illustrate these rules in the most simple manner, to avoid the extra trouble of tracing the light through two, three or more lenses, and describe the eye piece separately.

We have previously shown that, when viewing an image from a place as far distant as the focal length of the lens by which it is formed, it will have the same apparent magnitude as the object, and by placing a lens between the image and the eye in such a manner that the focus of the lens will be in the same plane with the image, we can see it distinctly by placing the eye close to the lens.

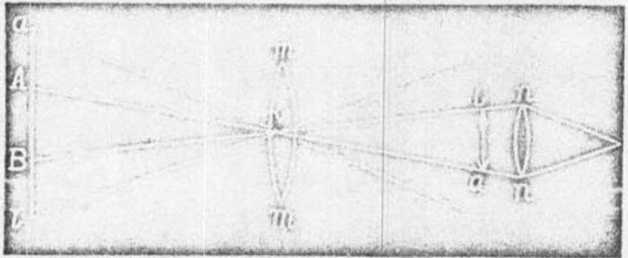
As the rays of light diverging from the focus of the lens emerge parallel, we see an object placed in the focus of a lens at the same angle as it would be seen from the center of this lens; and as the apparent magnitude of an object increases in proportion to the decreasing of the distance at which it is viewed, the rule for finding the magnifying power of an astronomical telescope with single lens eye piece, is:

Divide focal length of object glass by focal length of eye piece.

By this rule it is evident that a telescope with a long focal length object glass, and an eye piece of very short focal length, will magnify very much, but experience has shown that unless certain limits should be maintained, such a telescope would, by the loss in size of field and light, be rendered useless.

FIELD OF TELESCOPES.

The field of view of a telescope is always measured by the angle which the object visible through it subtends to the eye. Should the moon, for instance, just fill the field of a telescope, the field would be half a degree, as the moon subtends that angle when viewed with the naked eye.



Two lines drawn from the outer edge of the lens *n n* (in above figure, *m m* representing the object glass, *n n* the eye lens) to the center *v* of the lens *m m*, and continued would just cover the object *A B*. Suppose these lines *A v* and *B v* to represent the rays of light sent from the points *A* and *B* of the object through the center *v* of the lens *m m*, they will be incident at the very margin of the lens *n n*, thus the points *A* and *B* can just be seen through the telescope, while the points *a* and *b* can not, as the dotted lines *a v* and *b v* indicate. Therefore, the angles *A v B* or *n v n* are the greatest that can be seen through a telescope, and consequently constitute its field.

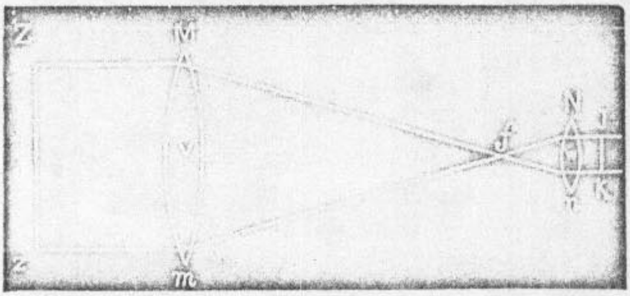
It is evident now that the size of the object glass does in no way contribute to the size of the field of view, but that the same may be increased by enlarging the eye lens or shortening the focal length of the object glass.

We have previously seen that in order to increase the magnifying power of a telescope by means of the eye lens, we must shorten its focal length; at the same time experience has shown that the diameter of the aperture of this lens must not exceed half its focal length, as otherwise the spherical aberration of such a lens would distort the image to a very annoying degree, which error necessarily must be avoided.

By this rule the field of view is always fixed for a single lens eye piece. For this reason and others, which will be explained under the heading of "Eye Pieces," a combination of two lenses is used with the improved astronomical telescope. Two lenses of equal focal length, combined, will act like one lens of half the focal length of each; the aperture of each lens being half its focal length, the two combined will, therefore, afford twice as large a field as a single lens of the same power.

LIGHT TRANSMITTED BY A TELESCOPE.

It is at once perceived that the quantity of light entering a telescope is dependent upon the size of the object glass or its aperture; the larger its area of surface, the more rays of light proceeding from every point of the object will be intercepted and transmitted.



$Z M$ and $z m$ are the outward rays of all those radiating from a distant point, and intercepted by the lens $M m$; they are refracted to a focus at f, forming the cone $M f m$, which receives all the light contained in the cylinder $Z M z m$; from point f they will diverge again, forming the cone $N f n$, of which a part of lens $N n$ forms the base; as the point f is the common focus of both lenses, the rays will emerge parallel from $N n$ forming the cylinder $N i n k$.

Evidently the light contained in the cylinder $N i n k$ is more dense than in $Z m z m$; the degree of density is reversedly proportional to the square of their vertical section. The diameter $N n$ is to the diameter $M m$, as the focal distance $w f$ to the focal distance $v f$, or as we have previously seen, as one to the number of times the telescope magnifies; hence the diameter $M m$ divided by the diameter $N n$ will give us the magnifying power.

This rule remains the same with all telescopes, the eye piece may consist of one, two, or four lenses.

By placing the eye a few inches from the eye piece of any telescope, the pencil or cylinder of light $N i n k$ will appear as a bright speck, diameter of which may be very closely measured by means of a finely graduated rule; divide by this diameter the diameter of aperture of the object glass, and the quotient is the magnifying power of the telescope.

In order that the whole pencil of light, $N i n k$, may be received by the eye, its diameter $i k$ must not exceed the diameter of the pupil of the eye, because being larger, a part of it could not enter the eye, and consequently part of the light intercepted by the object glass would be lost.

The diameter of the pupil is, as found by experiments on an average 1-10 of an inch, hence the construction of a telescope should aways be so, that $i k$ does not exceed 1-10 of an inch in diameter. Taking r to be the magnifying power of a telescope, the vertical section $i k$ is r times smaller than $Z z$; the square of $i k$, consequently, is $r r$ times smaller than the square of $Z z$; hence the brightness of light $r r$ time greater at $i k$ than at $Z z$.

According to this it would seem as though objects were seen $r r$ times brighter through a telescope than with the naked eye; but, considering the telescope as magnifying the diameter r times, and the square surface $r r$ times, the $r r$ times increased light will again be $r r$ times decreased.

Therefore no combination of lenses is possible, by which the brightness of an object would appear greater than when viewed with the naked eye under the same angle of sight.

We mentioned above, that the diameter $i k$ should not exceed 1-10 of an inch, in order not to lose any light; therefore a telescope constructed thus, to make the pencil $i k$ 1-10 of an inch in diameter, would, in regard to brightness of image, give the best result, as the diameter $i k$ would be equal to the diameter of the pencil of light, intercepted by the pupil when viewing with the naked eye.

When *i k* becomes smaller than 1-10 of an inch, the brightness of the object will be less than when viewed with the naked eye, as in the latter case the eye would receive a larger cylinder of light; the brightness will obviously decrease in the same proportion as the square surface of *i k* is smaller than the square surface of the pupil.

As the brightness of view is an indispensable requisite of a good telescope, the magnifying power should never be raised to an excessive degree, especially with terrestrial telescopes, which are very often used for viewing objects only faintly illuminated; nevertheless, experiments have shown, and it is universally admitted in optics, that the magnifying power may be increased to such a degree as to give the pencil *i k* only 1-20 to 1-24 of an inch diameter, before the eye will perceive a sensible diminution of light; this limit however, should never be exceeded.

A good telescope, magnifying thirty times, will show an object *only nearly* as bright at a distance at 900 feet, as when viewed from a distance of thirty feet with the naked eye; the reason for this is, the power of absorbing light possessed by all bodies; even the air, the most transparent body in nature, is capable of absorbing a great quantity of light. On the summit of the highest mountains, where their light has to pass through a much less extent of air, a much greater number of stars is visible to the eye than in the plains below. Glass is a medium of still greater absorbing power than air. Each refraction of light is also connected with more or less of light, through the existence of very small imperfections in the surfaces of even the most perfect of lenses, and which cause reflections and dispersion of light.

In the above instance the rays of light intercepted and transmitted by the telescope have to pass through 870 feet more of our atmosphere, through three (astronomical telescope), or five (terrestrial telescope) thicknesses of glass, and suffer six or ten refractions before entering the eye, whereas the light intercepted by the naked eye only passes through thirty feet of our atmosphere.

When the naked eye is viewing an object, for instance, large and well-defined black print on a white ground, faintly illuminated, it must approach to within a certain distance, in order to read the print, and see every line distinctly; if twice as much light is now turned upon the object, the eye may recede to nearly twice the distance as before, and still see the print as distinctly as in the first place; if the object is very brilliantly illuminated, the eye may recede to a considerable distance further from the object, and still read with the same distinctness.

In nearly in the same proportion may the eye, viewing through a telescope, recede from the object, as the brightness of the object increases.

If, in the above instance, the distance at which the eye may obtain a distinct view of the object is 6 feet at first, a good telescope magnifying 30 times, would, at nearly 180 feet show the object equally distinct and bright, to equal the distinctness of view from the second position of the naked eye, the distance being about 12 feet, the telescope could recede to a distance of about 360 feet, while, in the last instance, when the object is brilliantly illuminated, and the naked eye may see distinctly from a place 60 feet distance, the telescope would afford the same view, from a place about 1,800 feet distant, or, after making a liberal deduction for loss of light, at about 1,500 feet distant.

It is therefore evident that it would be absurd to use the distance at which any certain object can be seen distinctly through a telescope, as a measure for the quality of the same, without defining the brightness of the object, and also the state of our atmosphere at the time of observation; but, as this with naturally illuminated objects is very uncertain and difficult, it leaves large margin for exaggeration.

All the above comparisions with the naked eye presuppose a normal eye, which can see distinctly very small objects at a distance from 6 to 8 inches.

SPHERICAL ABERRATION OF LENSES.

We have heretofore assumed that the rays refracted at spherical surfaces will meet exactly in a common focus; but this is by no means strictly true.

The rays incident near the axis of a spherical surface, or of a lens, are refracted to a focus more remote from the lens, than those which are incident at a distance from the axis; therefore an image formed by an ordinary lens, is clear and distinct in the centre, but grows faint and indistinct at the edge.

In using a lens of different radical curvatures, or a plano convex lens, for forming an image, it is by no means immaterial which side is turned to the object. A plane convex lens, with its plane side turned to a distant object, will produce nearly four times as much spherical aberration as if its convex surface is turned to the object. For magnifying a near object, its plane surface must be turned to the object.

In using a plano convex lens, therefore, it should always be placed so that parallel rays either enter the convex surface or emerge from it.

The lens which has the least spherical aberration is a double convex one, whose radii are as 1 to 6. When the face whose radius is 1 is turned towards parallel rays, the aberration is only 1.07 of its thickness—that is, when the two surfaces meet in a sharp wedge, and the whole area of surface is used.

By reducing the diameter of the same lens by covering up the outer parts of it with a ring of black paper, the aberration will be greatly diminished; therefore the aberration will obviously increase with the diameter of the lens when its curvature remains the same.

The diameter of lenses used for forming an image should not exceed one-seventh of their focal length, or the angles which the lens subtends to its focus should not exceed 8 or 9 degrees.

But, though the spherical aberration of single lenses cannot be removed or diminished beyond a certain limit, yet, by combining two or more lenses and making opposite aberrations correct each other, this defect can be remedied to a very considerable extent in some cases, and in others altogether. Correct calculations for the spherical aberration are, in the construction of any optical instrument, of great importance.

CHROMATIC ABERRATION OF LENSES.

White light, as emitted from the sun, or from any luminous body is composed of seven different kinds of light, viz: red, orange, yellow, green, blue, indigo and violet; called the primary colors of the prismatic spectrum. This compound light may be decomposed or analyzed by refraction. A ray of white light incident upon the surface of a lens will not only be refracted, but also split into its prismatic colors. As these colored rays have different degrees of refrangibility, or different indices of refraction, it is evident that all the rays which compose the incident ray of white light cannot possibly be refracted in the same direction, so as to meet at one point; the formation of an image is therefore imperfect.

The focus of the extreme red ray with the index of least refraction will be more remote from the lens than that of the extreme violet ray, which has the greatest index of refraction, the intermediate rays having their foci at intermediate points between the two.

Therefore, the image of any luminous point consists of as many colored images as there are colored rays contained in white light; so that if we place the eye behind it, we will see a confused image, possessing none of that sharpness and distinctness which it would have had if formed only by rays of one color.

The combination of both spherical and chromatic aberration will, therefore, render an ordinary lens useless for forming an image, unless possessed of a very long focal length with a comparatively small aperture.

ACHROMATIC OBJECT GLASSES.

One of the greatest inventions of the last century was that of achromatic lenses, which destroy the chromatic aberration.

They are formed by combining two lenses, a double convex crown-glass lens and a *nearly* plano concave flint-glass lens; the inside surfaces are ground to the same radial curvature; as the concave lens has a longer focal length than the convex one, the combination still acts like one convex lens.

The proportion of their focal lengths is so calculated that the dispersion of light caused by the crown-glass lens is corrected by the flint-glass one.

The counteraction of the dispersion of light of one lens by means of another is a result of the difference of disperaive power, at the same mean refraction, of the two different kinds of glass.

o2

Suppose a ray of light incident upon a double *convex* lens; this ray, as we have seen, will be split into seven different colored rays having different degrees of refrangibility, and will, therefore, focus at different points from the lens. If we now place behind this lens a double *concave* lens of the same material, having its surfaces ground to the same radial curvature, it is obvious that the refracted colored rays, converging to their respective foci, will again be refracted, to emerge parallel from the concave lens. As the two refractions were equal, but opposite to one another, the dispersion of light caused by the first refraction is certainly corrected by the second one, and white light will finally emerge. But it is also evident that the combination forms a piece of glass whose faces are parallel, the outer surface of the convex lens being parallel to the outer surface of the concave one.

Though we have thus corrected the colors produced by the convex lens by means of the concave one, we have done this by a useless combination, since the two combined act only like a piece of plain glass, and are incapable of forming an image.

If we make the concave lens, however, of a longer focus than the convex one, the combination will act as a convex lens and will form images behind it, as the rays will converge to a focus behind the concave lens; and if we make it of another material having a greater dispersive power at the same mean refraction, we are able to correct the colors also.

The dispersive power of crown glass is to the dispersive power of flint glass as 1 to 1.8703. (This proportion varies somewhat with different glasses.) If we, therefore, combine a convex crown-glass lens of one inch focus with a concave flint-glass lens of 1.8703 inch focus, this combination, having a focal length of $\frac{1.8703 \times 1}{1.8703 - 1} =$ 2.149 inches, will refract white light to a single focus free of colors.

Such a lens is called an *achromatic* lens, or when used for forming the image in a telescope *achromatic object glass.*

The dispersion of light can, however, by a double lens never be *completely* corrected, as the equal spectra formed by the crown and flint glass are not in every respect similar; the colored spaces in the one are not equal to the colored spaces in the other; therefore, only those outer rays of the prismatic spectrum are completely corrected, upon which the calculation is based for finding the focal distance of the two lenses, while it leaves a slight degree of dispersion for the intermediate colored rays, thus forming the secondary colors of the prismatic spectrum. These are insignificant if the lens is otherwise perfect and of good workmanship.

In mounting the two lenses of an object glass in the cell, it is of great importance to get the axis of the two lenses to *coincide.* Gross neglect of this important rule is *very often* the cause of indistinctness of image. Another important requisite is to keep the inner surfaces slightly apart by means of three equally thick pieces of silver or tinfoil placed at the very margin, at equal distances between the two lenses. By neglect of this rule *colored rings* will be produced upon the surfaces.

The first of the above mentioned results is *only* attainable by the instrument maker. After the two lenses are carefully cleaned and properly placed in the cell, with little pieces of silver foil between them, which must be fastened with the least moisture of gum arabic.

By taking the lenses apart the centering of the same is disturbed, and the engineer is unable to replace them properly, especially when they fit loosely in their cell, which is very often the case. The staining of flint-glass lenses is caused by the corrosion of the oxide of lead contained in the glass. Generally, however, it will only occur when the lens is kept in a damp place for some length of time.

In cleaning an object glass, care should be taken *not* to rub it any more than is necessary. Brush off the dust first with a camel's hair brush or a soft piece of worn-out linen, and then wipe it carefully with a clean piece of chamois leather. When very dirty wash it with alcohol or water and soft chalk, being careful to have the chalk free from grit.

EYE PIECES OF TELESCOPES.

When an inverting or astronomical eye piece is used in surveying instruments, it is generally the so-called Ramsden Eye Piece. It consists of two crown-glass lenses, placed at such a distance as to correct the chromatic aberration of one lens by the other.

A ray of white light proceeding from the achromatic object glass will be refracted by the first eye piece lens and split into different colored rays; but these rays, being intercepted by the second lens at different distant points from the axis, will suffer different degrees of refraction.

The extreme red ray, with the index of least refraction, will be intercepted by the second lens at a point more distant from its axis than the extreme violet ray; therefore it will suffer a greater refraction than the violet one, notwithstanding its inferior refrangibility; so that the two rays will emerge parallel from the second lens, and therefore be colorless.

The erecting eye piece in general use consists of four crown-glass lenses, placed also at such distances as to correct the chromatic aberration. In this eye piece the inverted image of the object glass is again inverted, and an erect image is formed between the third and fourth lens, which is viewed and magnified by the fourth lens.

This form of eye piece, however, is inferior to the astronomical or inverting eye piece, owing to the loss of light it must suffer through obliging the light to pass through two more lenses.

At the same time the inverting eye piece allows a longer focal length object glass, which is very important in correcting spherical aberration.

For these reasons this eye piece is universally adopted in Europe for all surveying instruments, and we are perfectly convinced that it would also be preferred by our own engineers if they would accustom themselves to its use. It may seem inconvenient at first to work with an inverting telescope, but in a remarkable short time this difficulty is entirely overcome, and the work may be done with the same rapidity and certainty as with the erect one.

As the erecting eye piece is in general demand, we do not intend to introduce the inverting one, but, we think, however, that the professors of civil engineering in our colleges should draw more attention to the above facts, as gratifying results may be often obtained by the use of this eye piece with no material inconvenience.

We have previously seen, that by increasing the diameter of the eye piece lenses, we may enlarge the field of a telescope. In the erecting eye piece (Kellner Eye Piece) which we use in our telescopes, by inserting one achromatic lens, in place of a plain one, the formula is so changed as to permit the use of lenses of larger diameter, and thus increase the field considerably, compared with the ordinary eye piece of the same power.

In constructing a combination of crown glass lenses to be used for magnifying objects, the spherical aberration can easily be reduced to its minimum, by giving each lens its proper curvatures and position, while the chromatic aberration is far more difficult to overcome without the use of achromatic lenses; therefore, before achromatic lenses were invented, refracting telescopes had to be made of enormous length, with comparatively very small aperture of object glass, in order to reduce the chromatic aberration.

On the same principle the Kellner Eye Piece is improved by the use of achromatic lenses; it is, however, nothing new, and the only reason for its not being universally adopted in first class telescopes is, undoubtedly, its extra expense to the instrument maker.

TRANSIT TELESCOPES.

After having viewed the optical rules, which govern the proper construction of a telescope, the mechanical part will be easily understood.

The slide to which the object glass is attached fits directly in the outside or body tube. Particular attention is paid to this part, to prevent even the *slightest shake*, and still procure an equal and smooth motion, which is absolutely necessary, as otherwise no *true* adjustment for line of collimation is possible.

The slide is movable by a rack and pinion, to permit a precise focusing of the object. A slide protector is furnished with each Telescope.

The cross-wire frame is suspended in the tube by four capstan head-screws, by which it is also adjustable. The frame is so constructed that the cross-wires cannot be torn, in case the adjusting screws are tightened too much.

The spider's web, used for the cross-wires of our instruments, is always properly treated to avoid all *twist*, and prevent lengthening and becoming crooked in damp weather, and is well secured to prevent its coming loose. (See page 23—Glass Diaphragm.)

The eye-piece (always erect unless specially ordered) is so arranged as to permit its easy removal, if necessary, by simply unscrewing it. In replacing, it should always be well tightened up. It is movable in and out by a revolving motion, turning the cap about one-sixth of a revolution back or forward, a manner which affords a finer and more precise focusing of the cross-wires than a rack and pinion is capable of doing.

With our high power eye-pieces, a motion of only about three-sixteenths of an inch is necessary to allow for difference of eyes.

As the sliding motion of the eye-piece is *only* to allow for the difference of eyes, it is not at all necessary to disturb it after it is once properly set, as long as *the same* person is using the instrument; and even in packing it away in the box it may be left so, as we always allow for this extra motion in packing the instruments. The eye-piece cap is provided with a slide to protect the eye-lens from dust while the instrument is not in use; the engineer should never neglect to close up the eye-piece and also cover the object glass with its cap, as soon as the instrument is set at rest.

Considering that, in cleaning, each rub will destroy more or less of the fine finish of the lenses, upon which depends the brightness and brilliancy of the image, the engineer will be well repaid for his care in this particular.

LINE OF COLLIMATION.

The line of collimation in transit telescopes is a *perpendicular* line drawn from the center of the object glass upon the axis, or center of motion of the telescope; to the other end of this line the vertical cross-wire must be adjusted, thus marking this line in the field of view of the telescope.

As the line of collimation is a perpendicular line upon the axis, the slide by which the object-glass is moved in and out must also be perpendicular upon the axis, as otherwise the adjustment for *long* distances would not be true for *short ones.*

To obtain a *correct* adjustment for long and short distances, it is also necessary that the *line of collimation* shall lie in the same plane as the *vertical center* of the instrument.

If the line of collimation is adjusted for *long* distances and the slide *not* perpendicular to the axis, the center of the object-glass will be *shifted obliquely* to this line, when moving it out in order to focus a *near* object, and thus a new line of collimation parallel to the first one is formed for short distances, sometimes causing very serious errors.

In some telescopes the slide is adjustable in the same manner as the eye piece guide-ring by four screws. The principle of this adjustment is very good, but practically it is very objectionable, as the constant friction upon the ring will work it loose, after which nothing but a loose ring guides the slide; an attempt to correct it will be found most difficult, as there is no way of defining the value of the error, in reference to the adjustment, and, also, the inverted position of the image will confuse the engineer so that it will be abandoned before a true adjustment is obtained. The *only effective* manner in which to produce a *true slide* for the object glass is by good workmanship, without any adjustment whatever.

The above error may also be caused by crooked tubes; but a more frequent occurrence is *shake* in the slide. If this is the case, there is no true adjustment for line of collimation possible, as the slightest turn of the milled pinion head will throw the object-glass to one side or the other.

This defect can only be remedied by a competent instrument maker.

LEVEL TELESCOPES.

Our Level Telescopes are in every respect, except size, similar in construction to our Transit Telescopes.

In Y levels the telescope rests on two very hard bell metal rings, or collars, which are soldered fast to the tube, and it is reversible, end for end, in the Y's.

The *very first requisite* of a Y Level Telescope is to have these two rings of *exactly equal diameter*, and perfect cylinders. If they are of unequal diameter, the line of collimation, when the bubble indicates a horizontal position, will not be parallel with a tangent to the curve of the bubble at its highest point, and, therefore, no true level can be taken with such an instrument.

It is very often believed that, in the course of adjusting the Y level, by reversals of telescope and revolving on center, (see Level Adjustments), the bubble will show up any inequality of the collars. This is by no means true.

If the Y's are *both* filed out to *the same* angle (which is generally the case, or at least very near so, as they are by most all instrument makers filed out by gauges), the *inequality* of the collars may be *ever so much* and the instrument will *still be adjustable* in all its parts; that is, the instrument may be so adjusted that the bubble on *all* reversals, end for end, of the telescope, and revolving on center, will *always* give the same reading on both ends—that is, indicate a true horizontal position.

A *final test* is, therefore, necessary after the instrument is properly adjusted, to ascertain the equality of the collars.

Make two bench marks, place the instrument exactly midway between, and find the true difference of level between the two by reading leveling rods set upon them. Now place the instrument near one of the bench marks and read both rods. If the difference of the readings obtained now is equal to the true difference of level, then the collars are of equal diameter, and the line of collimination is at a right angle to the vertical center of the instrument.

If the distance at which this test is made be so long as to make corrections for curvature and refraction necessary, the difference of the readings with a true instrument would be equal, (when placed near the higher bench mark) to the true difference of level plus correction for curvature and refraction for the distance at which the rod on the lower bench mark is viewed.

When the instrument is placed near the lower bench mark, the difference of the readings must be equal to the true difference of level, minus corrections for curvature and refraction.

If the *line of collimation* is thus found to be *at right angles* to the verticle centre of the instrument, then this test, once made, is good forever, as it shows that the collars are of *equal* diameter; and, consequently, *a true adjustment* may be made in the manner described with level adjustments.

It need hardly be mentioned that denting, the settling of dirt on the collars and unequal wear will also affect the adjustment in the same manner.

If the test shows that the *line of collimation* is *not perpendicular* to the vertical centre, then the collars are of *unequal diameter*, and the instrument is virtually nothing more nor less than a *dumpy level*, as this defect deprives it of all the advantages for an easy and convenient adjustment, which characterize the Y Level in comparison with the dumpy.

The effectual remedy lies only with competent instrument maker.

But the defect may also be temporarily remedied or adjusted in the same manner as the line of collimation in the dumpy level is adjusted.

Establish a true level line as described in above test; place the instruments beyond one bench mark, and, by means of the parallel plate screws, bring the line of collimation in a true horizontal position; then raise or lower the adjustable end of the spirit level whatever may be necessary, until the bubble gives the same reading at each end. Now, the line of collimation is parallel with the bubble; that is, with the tangent to the curve of the bubble at its highest point. To place the line of collimation at right angles to the verticle center, place the telescope over a pair of parallel plate screws, and, by turning them, bring the bubble to the center; reverse the instrument about its vertical center as near 180° as possible; correct half the deviation of the bubble by raising or lowering one of the Y's, and the other half by means of parallel plate screws; repeat the operation until the bubble will give the same reading at each end in any position of the telescope during and entire revolution on the vertical center.

The telescope must now remain permanently in the Y's, as it would, if reversed end for end, double the error which existed previous to this adjustment.

The adjustment may also be made by placing the instrument beyond one bench mark, leveling it up and then simply changing the position of the horizontal crosswire by means of the capstan head screws to the place which will make the line of collimation truly horizontal, and at the same time be parallel with the spirit level, which was placed at right angles to the vertical center previous to this test. The instrument will then be in true adjustment.

The disadvantages of this adjustment, compared with the preceeding one, is that the line of collimation will not be parallel with the optical axis of the telescope; and, furthermore, the object glass slide, being made to slide parallel with the optical axis, will not move parallel with the line of collimation, and, for the same reasons as given with line of collimation of Transit Telescopes, the adjustment will not agree on short distances. Another advantage of the first adjustment is in its preserving the facility of overhauling the cross wire adjustment by turning the telescope round its longitudinal axis. The other adjustments, being stable and strong, remain perfect for a long time, while the cross wire adjustment is more easily deranged than any other, and, therefore, needs frequent inspection.

We have carefully explained this defect, owing to the conviction on our part that it is a much more common one than is generally suspected. Numbers of cases have come under our observation where the defect existed in a remarkable degree.

We are aware that correct leveling may be done with a level entirely out of adjustment by taking the utmost precaution for equi-distant sights. But looking at it from this point of view, why not use the dumpy level then, instead of the more costly Y level?

Upon perusing the numerous works on engineering and surveying, we notice but very few which mention the above defect, and still fewer which give a correct test for it.

TEST OF TELESCOPES.

If a telescope is to be tested for its qualities, make sure first that all the lenses are perfectly clean.

To test a telescope for its *definition*, small *clear print* should be used, and viewed from a distance of about 30 to 50 feet. If the print appears clear and well defined, and fully as legible at this distance as if viewed with the naked eye at the distance for distinct vision, the surfaces of the object glass are perfect and well finished. If, on the contrary, the print appears dull and indistinct, and the fine details illegible or even invisible, the surfaces are imperfect and not truly spherical, as the rays proceeding from each point of the object are not refracted to their corresponding points in the image.

Indistinctness may also be caused by *spherical aberration*.

To test this, cover the object glass with a ring of black paper, reducing the aperture to one half; focus small print to distinct vision; remove the ring of black paper and cover the center of the object glass (previously left open), then mark how much the object glass has to be moved in or out for distinct vision.

When the spherical aberration is reduced to its minimum, very little if any slide motion is necessary to obtain a distinct view under both tests. The amount of shift is, however, a measure for the spherical aberration of the object glass.

Another test, but not as good as the one above, is to focus the object to distinct vision, and then moving the object glass in or out by means of the milled pinion head, at the same time observing how much motion is necessary to render the object indistinct. If the spherical aberration is completely corrected, the object should, theoretically, be rendered indistinct by the slightest motion in or out; but, practically, it is not, as the eye will accommodate itself to a certain degree to the difference of divergence of the rays, which is caused by the motion, in or out, of the object glass, in the same manner as it will accommodate itself for near and distant objects when viewing without the aid of lenses.

So, if the image formed by a perfect object glass is viewed by another perfect lens of long focal length, say 6 inches, the object glass might be moved in or out one-fourth of an inch from the point of distinct vision, and the object will still appear comparatively distinct, as the one-fourth-inch motion, with an eye lens of such long focal length, cannot cause enough difference in the divergence of the rays to prevent the accommodation of most eyes to it. The shorter the focal length of the eye lens, the more rapid will be the change of divergence or convergence of the rays with a certain amount of motion; therefore the second test is only applicable with eye pieces of very high power, which at the slighest motion in or out, will cause a sufficient amount of divergence or convergence of the rays to prevent the accommodation of the eye to its change.

To test the *chromatic aberration*, either a celestial body or a white disc should be selected for an object.

Focus the object to distinct vision, and then move the object glass slowly in and out alternately. If, in the first instance, a light yellow ring is seen at the edge of the object, and in the second one a ring of purple light, the object glass may be considered perfect, as it proves that the most intense colors of the prismatic spectrum (orange and blue) are corrected.

To test the *flatness of field*, take a *square flat* object, not a round disc, whose sides are about 4 inches long and perfectly straight — the best object is a heavily lined square, drawn on white paper with India ink. Sight this object from such a distance that it will nearly fill the field of view of the telescope, and see if it still appears flat and its sides perfectly straight; if so, the telescope is a good one. If, on the contrary, the object appears distorted; i. e., if the sides, instead of being straight, form curves and the surfaces appear concave, instead of flat, the telescope is not good, as it shows that the proportions of foci, aperture and distances between the different lenses are not according to the laws of optics, owing, generally, to the attempt to force the magnifying power beyond its limits.

As all the refractions of light in the telescope are caused by flat and spherical surfaces, it is evident that the edge of a round flat object, when used for above test, cannot be distorted, but that *only* the surface will appear concave to a keen observing eye.

A Telescope which distorts the image to a perceptible degree, will, however, not cause any errors in common use, but is decidedly objectionable for stadia measurements where two points in the field of view are used at the same time.

STADIA MEASUREMENTS.

Having given an account of the different methods for measuring distances in another part of this book, we will treat the method termed stadia measurements more at length, as it is the most superior, in our belief, and one which will, in time, supersede all others, except chaining, of which it will always be a useful companion.

After having read the article on the "Formation of Images," the principle will be readily understood.

The length of image of a certain object, whose length and distance are known, is marked in the field of view by two extra cross-wires, equally distant from center cross-wire. The distance between the two wires may thus be used as a measure for finding the distance of any objects whose length is known.

The laws of dioptrics teach us that the length n of an image formed by a convex lens may be ascertained by the following rule: $n = \frac{p\,h}{a-p}$

p—focal length of object glass.
h—length of object.
a—distance of object from the center of object glass.

This formula shows at once that the greater the distance a the smaller will be the image n.

We learn, furthermore, that the distance b from the image to the center of object glass, using the above sign, is $\frac{a\,p}{a-p}$

This formula readily shows that a change in the distance a changes the distance b considerably, especially when distance a grows very small and becomes nearly equal to distance p.

Therefore, as a change in the distance a also changes the distance b, the image n of the object h (in the cut below) cannot grow smaller in proportion to the increase of distance a. We must, consequently, find a correction for the error which would be caused by making the center of the object glass the starting point for the measurements.

In the cut below, p—focal length of object glass.
h—length of object.
a—distance of object from center of object glass.
b—distance of image " " " " "
n—length of image.

As $n = \frac{p\,h}{a\text{-}p},$ therefore $a\text{-}p = \frac{p\,h}{n},$ or $\frac{h}{n}\,p = a\text{-}p$ or $\frac{h}{n} = \frac{a\text{-}p}{p}.$

Therefore the image is as many times smaller than the object as the focal length of the object glass (by which this image is formed), is contained in the distance from the object to a point one focal length in front of the object glass; consequently, this is the true starting point for all stadia measurements.

The Telescope must also be first-class in regard to power, definition and light, to enable the taking of long sights correctly without the use of two targets to rod; the latter style, however, insures a greater accuracy than the self reading ones, as by means of the vernier the rod may be read to 1-1000 of a foot.

To measure the distance between two certain points, the rod is placed at one of them, and the instrument over the other one; focus the rod precisely without parallax, and then take the reading, that is, see how many feet, and fractions of a foot, are covered by the two stadia wires in the field of view; add to the value of this reading the focal length, plus the distance of object glass to the center of the axis, and the sum is the desired distance between the two points.

The focal length of the object glass may be measured near enough for practical purposes with any ordinary foot-rule, by focusing a distant object, and then measuring the distance from the object glass to the center of the capstan head screws, by which the wires are adjusted, also, the distance from the object glass to the center of the axis.

The sum of these measurements is a *constant* to be added to *every single* stadia reading, no matter how short or how long the distance may be. To enable the rod to be held right angular to the line of sight on rising ground, a rod level should be used. To a transit instrument intended to be used with the stadia, a vertical circle or arc should be attached for measuring the angle of elevation or depression of the line of sight on inclined ground, in order to reduce the stadia distance to the desired horizontal distance.

The following will illustrate the necessity of employing first-class telescopes for stadia measurements.

Innumerable experiments, made by various philosophers, have shown that the human eye cannot perceive an object distinctly, when the angle which it subtends to the eye is less than forty seconds, or when the eye views them from a distance equal to 5,156 times their width.

This rule will change considerably with some individuals; while some are able to see objects distinctly when the above angle is only thirty seconds, there are also some with whom the above angle must not be less than sixty seconds. This peculiarity of the human eye, limiting the angle of sight for distinct vision is independent from long or short-sightedness.

This rule will also change with different degrees of illumination; it is, however, based on the illumination afforded by fair daylight.

It is understood that it is immaterial whether a real object, or the image of an object (as produced in a telescope), subtends the angle to the eye; both circumstances are subject to the same rules.

When a rod, divided to 1-100 of a foot, and having these divisions painted, alternately, black and white, is viewed with a good telescope magnifying the diameter twenty-eight times, the angle which is subtended to the eye by one such division of the image, is equal to forty seconds, when the rod is 1,444 feet distant.

Under very favorable circumstances, when the rod is well illuminated, and the atmosphere clear and pure, each character on the face of the rod may be seen clearly and distinctly enough to permit direct stadia readings without the use of targets; but under most circumstances this distance from distinct view will be found, by reason of the absorption of light, to be reduced to about 1,200 to 1,300 feet.

For greater distances, this rod will be found insufficient for correct stadia readings, and either another rod with fewer divisions must be used, or the ordinary leveling rod provided with two targets.

With the aid of the above rule, knowing the magnifying power of the telescope, and the longest probable sight which may be taken, a self-reading rod can always be made to suit, if, for very long distances, allowance is always made for the loss of light.

It will thus be found, that the better the telescope, the finer may be the single divisions on the self-reading rod, and, consequently, the stadia readings obtained will be so much the closer.

One of the chances for errors in taking long stadia readings, is in the thickness of the wires covering a portion of the greatly diminished image, and thus causing an uncertainty in the readings, from center to center, of the wires. Considering that the image of an object 1,500 feet distant, formed by a nine inch focal length object glass, is diminished 2,000 times, 1-100 part of a foot in the object will only measure $\frac{1}{200,000}$ part of a foot, or $\frac{1}{1668}$ part of an inch in the image, which is far less than the very finest thread of a spider's web will cover. It will be found that closer stadia readings may be obtained from upper to upper edge, or from lower to lower edge, of the stadia wires. In the one case the intersected parts of the image are covered, while, in the other one, the intersecting edges of the wires may be considered mathematical lines, not covering any space at all.

Both wires must, necessarily, be of the same thickness.

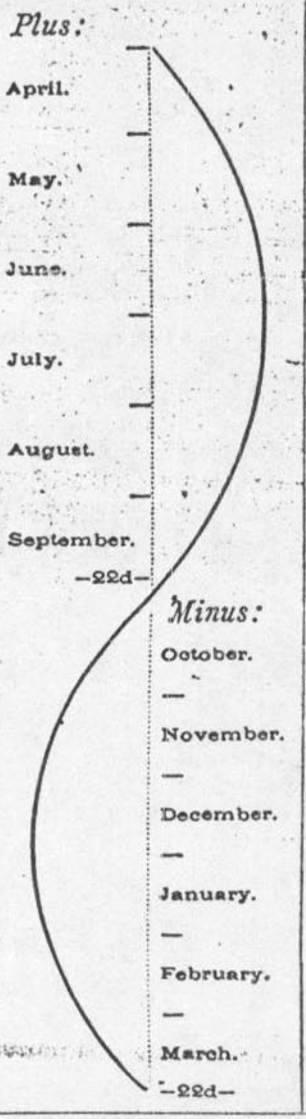
GLASS DIAPHRAGMS.

Quite a number of these have been cut by us for the U. S. Coast and Geodetic Survey. A small disc of very thin glass is fastened to the diaphragm instead of the spider webs, and fine lines are drawn with a diamond on same; it is easily seen that these cannot get out of shape; for stadia measurements we think them to be of great advantage. The only disadvantage there may be found, is that small particles of dust will settle on the plate glass sometimes, and as these are in the focus of the eye piece they will always be visible to the observer.

We make no extra charge for putting these diaphragms into our new instruments if ordered in time.

TABLE OF REFRACTIONS IN DECLINATION FOR SOLAR COMPASSES AND SOLAR TRANSITS.

(From the Surveyor's Companion, published by Wm. Schmolz, 1882.)



BY SUN'S DECLINATIONS NORTH,
From March 22d to September 22d, ADD:

For Latitude.	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 September 22d to March 22d, SUBTRACT:

For Latitude.	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
"	2.	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 CURVATURE OF THE EARTH.

Dist. in miles.	Height.	Dist. in miles.	Height.	Dist. in miles.	Height.	Dist. in miles.	Height.
	inches.		ft. in.		feet.		feet.
¼	½	7	32.5	15	149	40	1064
½	2	8	42.5	16	170	45	1346
1	8	8	53.8	17	192	50	1662
	ft. in.	10	66.4	18	215	60	2394
2	2.6	11	80.2	19	240	70	3258
3	6	12	95.4	20	266	80	4255
4	10.6	13	112	25	415	90	5386
5	16.6	14	130	30	599	100	6649
6	23.9			35	814		

PART II.

Catalogue and Price List

OF

IMPROVED

ENGINEERS' AND SURVEYORS' INSTRUMENTS

WARRANTED FIRST-CLASS.

MADE BY

A. LIETZ & CO.

(Successors to Karl Rahsskopff,)

No. 422 SACRAMENTO STREET,

SAN FRANCISCO.

Engineers' and Surveyors' Transits.

Transits No. I to No. I C.

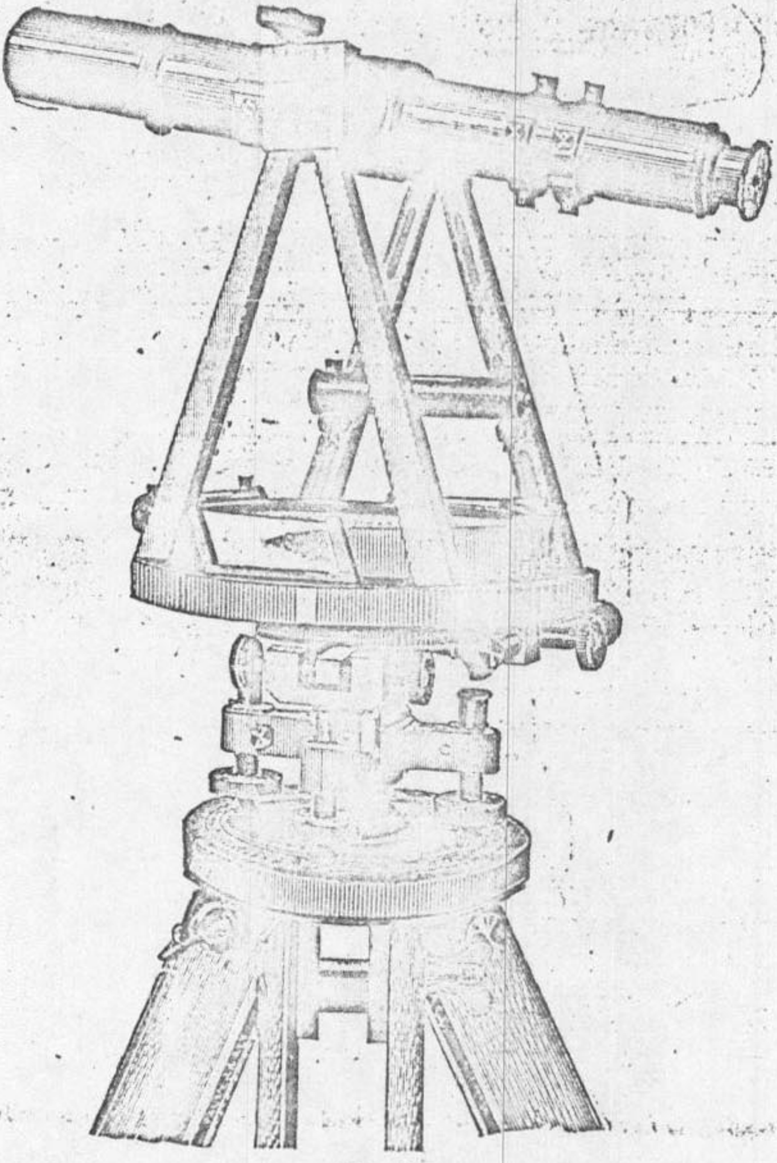
DIMENSIONS.

Horizontal Circle	6½ inches	Diameter.
Vertical Arc	5 "	"
Compass	4½ "	"
Object Glass	1 3-16	"
Weight of Instrument	15½ pounds.	
" Box	8 "	
" Tripod	8 "	

The instrument is designed for engineering work of a high class, such as is required on bridge building, water works, and for city and land surveying. The size of the circle is such that it may be graduated to read to 30″ or 20″ without fatigue to the eye. The Telescope is of the best definition, and has a large aperture with perfectly flat field. The eye-piece is achromatic, and gives a large field with plenty of light. The horizontal circle has two double verniers, reading to single minutes, which are placed so as to allow a reading without stepping aside when sighting through the Telescope. Long compound centers; improved Telescope object erect. Telescope balanced and reversing both at eye and object ends, and with one end of its axis adjustable; protection to object slide; shifting tripod head, and our new improved tripod coupling. The case has a leather strap, hooks, etc. It contains a sunshade, a plumb-bob, a magnifying glass, and several adjusting pins.

Extras to Transit No. I to I C, Inclusive.

Striding-Level to Axis of Telescope	$20 00
Graduations on Horizontal Circle, on solid silver	10 00
" " " reading to 30″	10 00
" " " " " 20″	20 00
" on Vertical Arc or Vertical Circle, on solid silver	5 00
Gradientor Attachment	5 00
Stadia Wires, fixed	3 00
" " adjustable	10 00
Three Leveling Screws, instead of four	10 00
Shifting Center for Instrument with three leveling screws	5 00
Arrangement for Offsetting at Right Angles	5 00
Variation Plate	10 00
Bottle of Watch Oil to lubricate the Centers	25



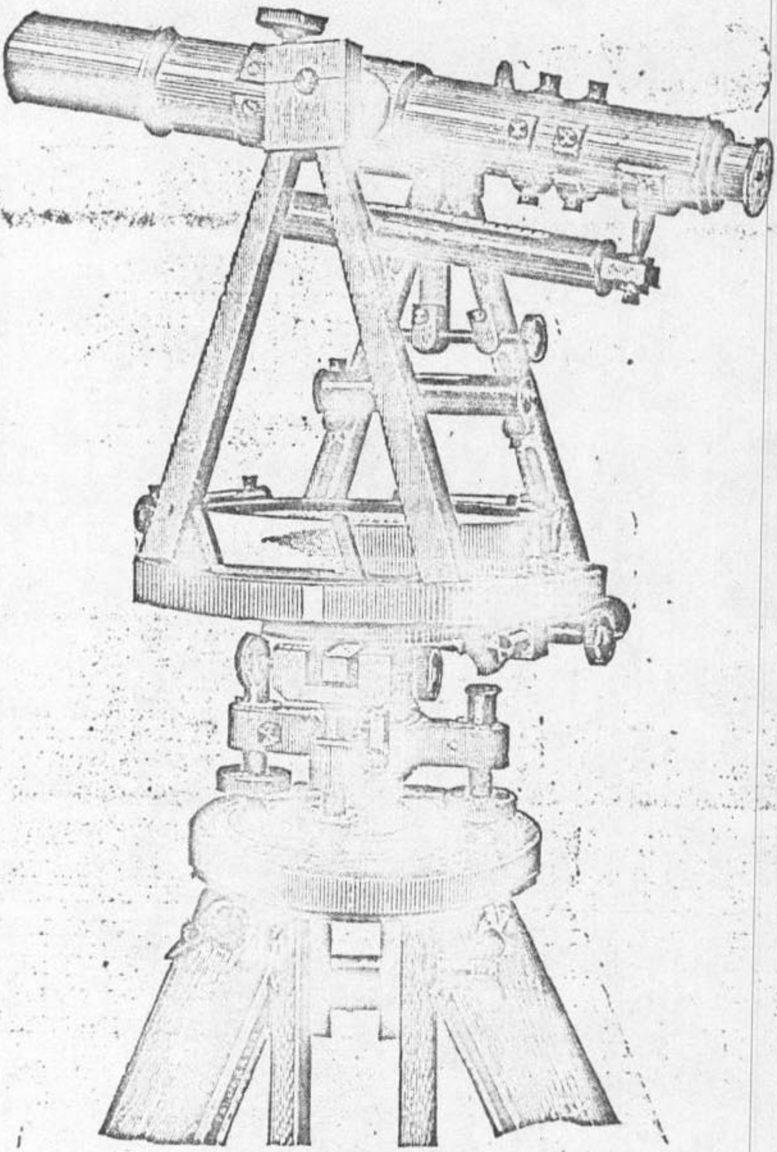
No. 1.

As made by A. LIETZ & CO.

PLAIN TRANSIT.

Price as above..$185 00

For size and description of this Instrument, as well as for extras, see preceding page.



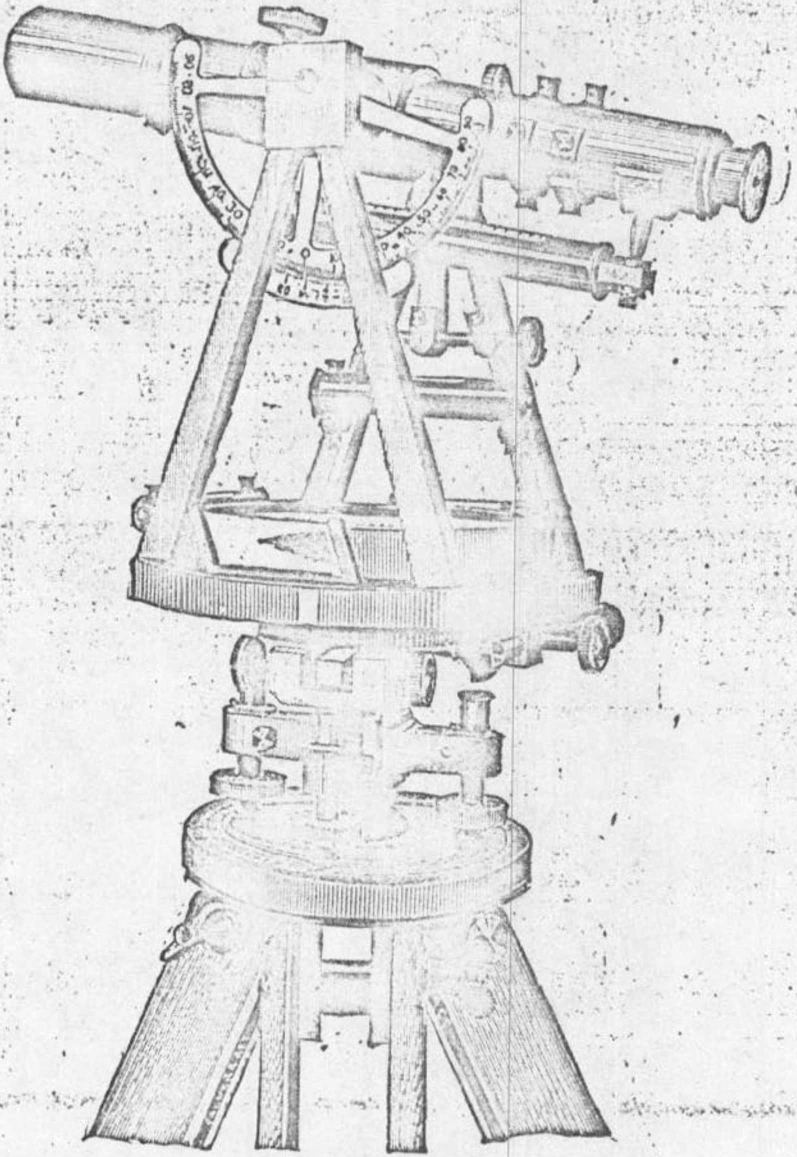
No. 1a

As made by A. LIETZ & CO.

TRANSIT, with Level Attachment to Telescope.

Price, as above, $215 00.

For size and particulars of this Instrument, as well as for extras, see page 32.



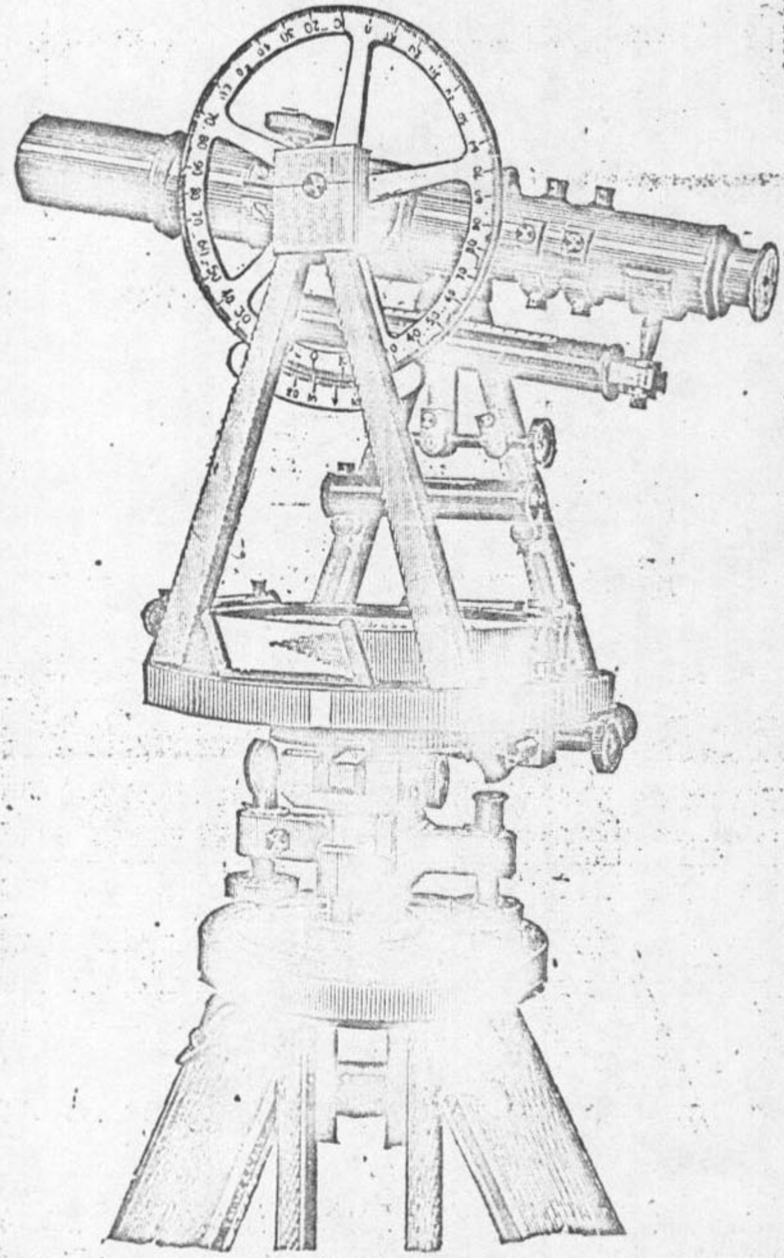
No. 1b.

As made by A. LIETZ & CO.

Complete Engineers' and Surveyors' Transit.

Price, as above, $230 00.

For size and particulars of this Instrument, as well as for Extras, see page 32.



No. 1c.

As made by A. LIETZ & CO.

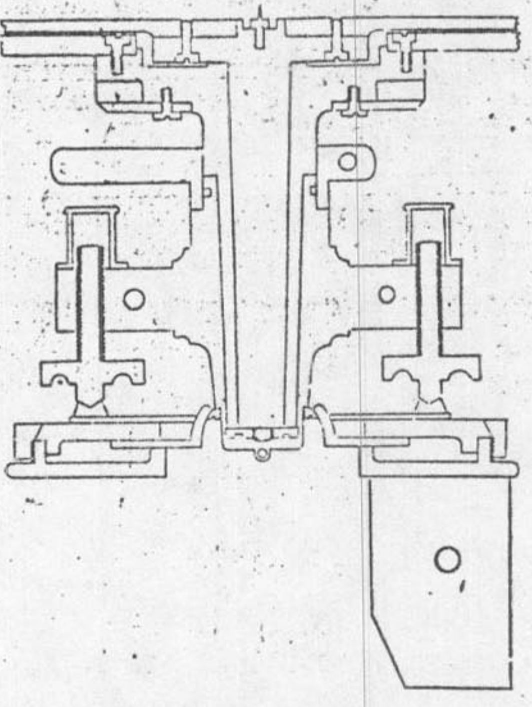
Complete Engineers' and Surveyors' Transit.

The 5-inch vertical circle is provided with double verniers, reading to minutes. Price, as annexed $235 00

For sizes and particulars, as well as for Extras, see page 32.

The sectional cut, Fig. C, shows the construction, and the attention of the engineers is called to this point, on which steadiness and strength of the instrument principally depends. As will be observed, the centers extend down to the base of the instrument, which construction permits giving them their full length, and at the same time brings the plates or center of gravity as near as possible to the tripod head.

Fig. C.

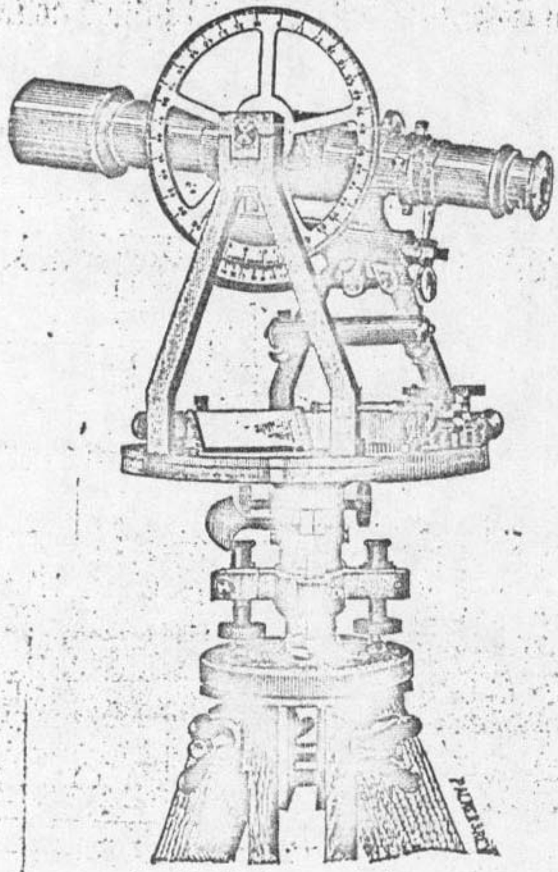


SECTIONAL CUT

—OF—

ENGINEERS' AND SURVEYORS' TRANSIT.

One improvement which we have added to all our instruments, is this: We place an extra piece on the shoulder of the center (not shown in the cut) on which the clamp fits. This extra piece enables us to continue the outer center through the clamp up to the plates in the Transits. It also serves to lessen the damage in case of a fall.



No. 2.

As made by A. LIETZ & CO.

COMPLETE MOUNTAIN AND MINING TRANSIT.

SMALL MOUNTAIN AND MINING TRANSIT.

No. 2. PLAIN TRANSIT.

This Instrument is made exactly as those enumerated under No. I, with the exception of size and weight. We can recommend it as being a very reliable and superior instrument for general land surveying and mining purposes.

DIMENSIONS.

Horizontal Circle	5-inch diameter.
Vertical Arc	4 " "
Compass	3½ " "
Object Glass	1 " "
Weight of Instrument	8½ pounds.
" Tripod	6½–7 "
Price as above	$180 00

Extras to Plain Transit.

Vertical Circle (reading to minutes of Arc)	$ 25 00
Or Vertical Arc	15 00
Clamp and Tangent Movement to Axis of Telescope	15 00
Long Level on Telescope, ground Graduated Bubble	15 00
Graduation of Horizontal Circle, on solid silver	10 00
" Vertical Circle, or Vertical Arc, on solid silver	5 00
Variation Plate	10 00
Arrangement for Offsetting at Right Angles	5 00
Three Leveling Screws, instead of four	10 00
Shifting Center for Instrument with three leveling screws	5 00
Stadia Wires, fixed	3 00
" " adjustable	10 00
Striding Level	20 00
Lamp for mining engineering, of brass, with ground lens	7 00
Reflector, for illuminating the cross-wires	4 00
Prism, attachable to eye-piece	8 00
Detachable side Telescope	35 00
Half-length Tripod	13 00
Extra Extension Tripod	15 00
Plummet Lamp	10 00
Gradienter Attachment	5 00
Large Plumb-bob, weight 4 pounds, for use in shafts	5 00
Bottle of fine watch oil	25

No. 3. MINING TRANSIT.—Dimensions as in No. 1. Graduations on solid silver; verniers, reading to minutes, are provided with glass shades; 5-inch full vertical circle; spirit-level, clamp and tangent screw to telescope; extension tripod, etc. Price, $253.

No. 4. MINING TRANSIT.—Dimensions as in No. 2. Graduations on solid silver; verniers, reading to minutes, are provided with glass shades; 4-inch full vertical circle; spirit-level, clamp and tangent screw to telescope; extension tripod, etc. Price, $253.

Mining Transits Constructed with Eccentric Telescopes to Order.

TRANSIT-THEODOLITE.

For Use in Cities, in Tunnels, and for Triangulation.

No. 5. Of late years it has been found desirable to design a transit for use where instruments of ordinary construction would fail to give satisfaction, or do not permit of rapid work where the highest degree of accuracy is required. The instrument, as shown in the accompanying illustration has no compass, and therefore the upper frame mounting the telescope is in one piece, which is provided with ribs, and which rests directly on the top flange of the inner center. The result of this is that great lateral strength is obtained, which permits of mounting the telescope axis by means of cylinders at each end in wyes. On top of each bearing of the telescope axis is mounted a cap provided with an adjusting screw, with which the necessary friction for the revolving telescope is obtained, and these caps are also provided with two milled-headed screws, which can be removed readily when the telescope is to be reversed for straight line measurements over the bearings. These caps are so arranged as to completely exclude dust from the axis. In this new arrangement the telescope can be reversed as in ordinary instruments through the standards, as well as over the bearings, as is usual in triangulation and for aligning straight lines; and last, but not least, the movement of the telescope in the vertical plane is the most accurate known. Ordinary transits cannot fulfill these functions owing to the peculiar form of the bearings wherein the telescope axis revolves, which bearings are so made to give lateral stiffness to the telescope, on account of the slenderness of the standards resting on the upper plate. The instrument is provided with three or four leveling screws. The verniers can be placed at right angles to the line of sight, or as shown in the cut. The dimensions, etc, are: Horizontal plate 6¼ inches, *graduation on solid silver* protected as in our regular engineers' instrument; two double opposite verniers, reading to 30″; two rows of figures in opposite directions; long compound centers; 11-inch telescope (inverting or erect); 1⅛ inches clear aperture; power, 24 diameter; *protection to object slide*; single spring tangent screws for the upper and lower plates; 4 leveling screws; shifting center; split-leg tripod; case; etc.

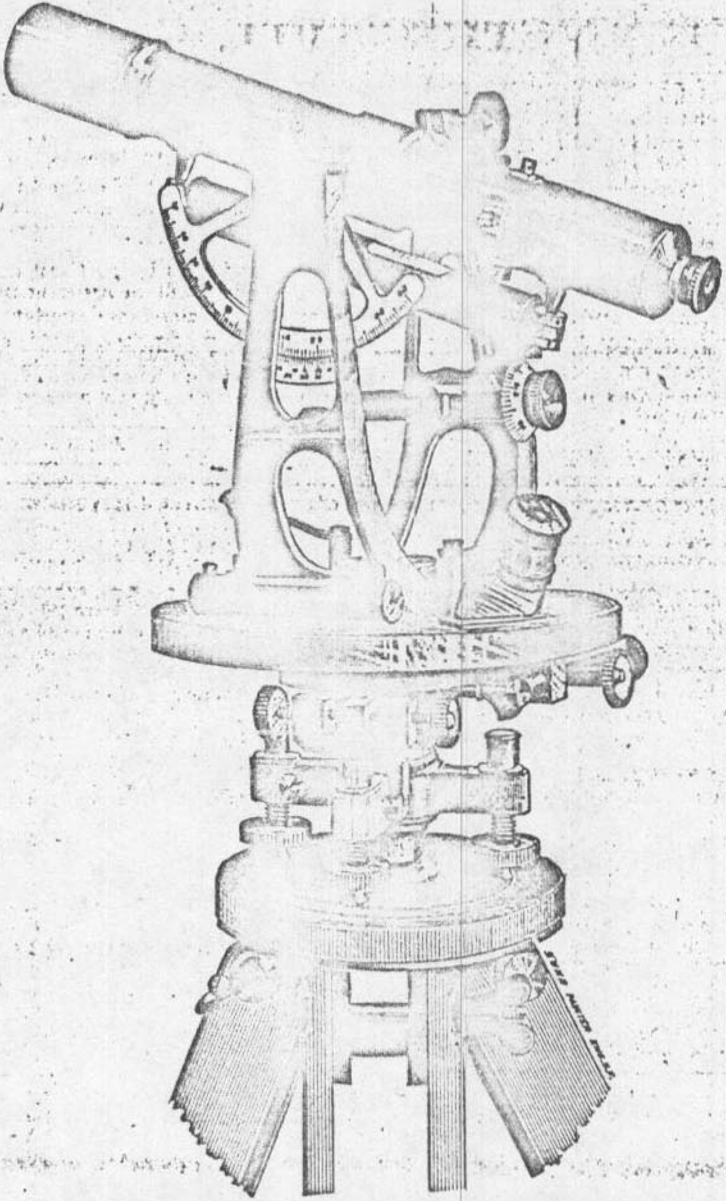
Price for plain Transit-Theodolite .... $240.

Extras to Plain Transit-Theodolite.

FOR EXTRAS TO TUNNEL TRANSITS, SEE EXTRAS TO MINING TRANSITS, Page 39.

Horizontal Limb 6¼ inches in diameter, verniers reading to 20″	$ 10 00
" " 7 " " " " 10″	35 00
Vertical Arc 5 " " " " minutes	20 00
Full 5-inch Vertical Circle, " " "	25 00
Two Reading Glasses, with ground glass shades to verniers	15 00
Instrument provided with 3 Leveling Screws	10 00
Shifting Center for Instrument with three leveling screws	5 00
Stadia Wires, fixed	3 00
" " adjustable	10 00
Striding Level	20 00
Six-inch Spirit Level with reversible clamp, tangent & gradienter to telescope	40 00
Oblong Compass, with motion for setting off the variation. (Three-inch needle reads only a few degrees each way from zero.)	20 00

NOTE.—A Plain Transit-Theodolite is without a level, clamp and arc to telescope.



COMPLETE TRANSIT-THEODOLITE.

—FOR USE—

IN CITIES, IN TUNNELS, AND FOR TRIANGULATION.

As made by A. LIETZ & CO.

THE LEVEL.

The three main qualities to be secured in a Level are: stability, powerful Telescope and a sensitive Bubble.

In regard to the first point, an examination of the cut will be sufficient to show that this has been accomplished in a perfect manner. Our Patent Coupling, which principally rendered this possible, as the instrument need not be taken apart in order to attach it conveniently and safely to the Tripod, and the continuation of the center through the clamp up to the bar, enabled us to bring the center of gravity as near as possible to the Tripod Head.

The Center or Spindle is almost three and one-half inches long. Great care is taken in fitting it to the socket, and, being made of steel, it will be apparent that it is an utter impossibility to wear out these parts even by fifty years' constant use. The liability of bending the Spindle, so common an accident with instruments having brass centers, and the fretting of the same which will also sometimes happen, is altogether avoided by a steel center. The fact is, that every level ought to have one, and the reason for its omission by other makers is simply because it is more expensive to manufacture.

It is always desirable to have a sensitive Bubble in Level, as the engineer will sometimes be called upon to do accurate work, which a dull one is not capable of performing. Our Level Tube is curved so as to give for every two minutes of angle one inch motion of the Bubble. One inch of the scale is divided into twelve parts, which gives for each division an angle of ten seconds, and as a moving of the Bubble of one division will cause a difference of two in the reading of the two ends, it will be seen that a difference of one division in the reading of the two ends indicate an angle of five seconds.[*]

The remark is hardly necessary that a Level Telescope should have power and definition. To obtain this result, and the same time to keep the dimensions of the Telescope and the other parts of the instrument within the proper limits for steadiness and portability, has been our earnest endeavor.

A length of 18 inches we have found the most advantageous in result. Experience has shown us that, though an increased length adds to the magnifying power, it will only be of *some* value if the other parts of the instrument are enlarged in proportion, which however, will make it too heavy for carrying conveniently. While for some exceptional cases such an instrument might be preferable, we believe that in our 18-inch Level we can meet even the most extensive requirements called for in engineering.

Our new improved Eye Piece, and the application of a large diameter of object glass and tubes than is usually found, enables us to obtain a magnifying power of 33. The increase in size of diameter of object glass and tube adds but very little to the weight of the Telescope, and does not require a longer bar and larger plates, as an increase of length necessarily will, to retain steadiness. An aperture of one and three-eighth inches used to its full value, as the tubes are large enough to let all the rays proceeding from the object glass pass through to the field of view (which important point is disregarded in the majority of instruments of other makers), affords a high illumination, with the above mentioned power. This power is in proportion with the laws of optics given in our account of telescopes.[†]

It has been there shown that the size of the aperture of the object glass divided by the power gives the diameter of the pencil of light entering the eye, and as this in our Telescope is one and three-eighths, divided by thirty-three, giving one-twenty-fourth of an inch, it will be seen that power and brightness are in accordance with these laws. To force the power beyond these limits we cannot conscientiously do, as it would be preferable only under certain circumstances, such as in a perfectly clear atmosphere with a strong illumination of object.

The collars are made of the hardest bell metal, and of exactly equal diameter. How important this equality is, will be seen in our account of Level Telescopes.

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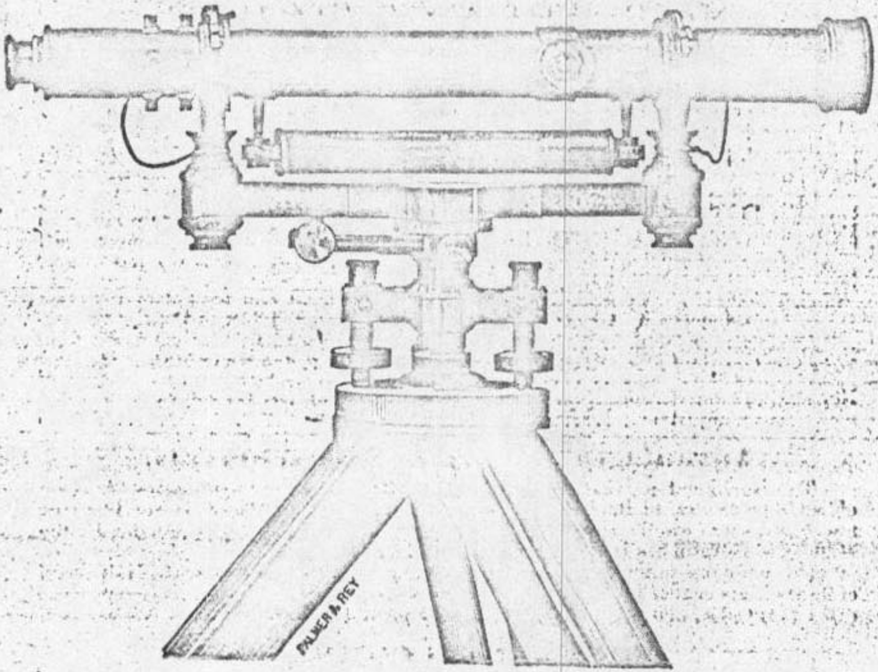
[*] Such a Bubble, however, will only do good service with an instrument perfectly steady and provided with a powerful and sharply-defining Telescope. If placed in an instrument which in construction is top heavy, or where the settling of the dust on the socket and cone will throw out the Y's every time they are detached from the leveling screws, it will only be a source of annoyance in working. These defects are probably the cause why a great many engineers are prejudiced against sensitive levels, and prefer a sluggish or dull one. We assure the reader that a sensitive bubble, even if a little out of center by reversing the instrument, will still afford better results than a dull one, which gives the instrument the appearance of steadiness. The engineer only deceives



No. 6.

As made by A. LIETZ & CO.

18-INCH ENGINEERS' Y LEVEL.

Price, as shown, packed complete in box, with usual accessories............$145 00

For Agate Fitted Wye's, we make an additional charge of $10.00.

No. 7. ENGINEER'S DUMPY LEVEL.

This instrument—in Europe employed almost exclusively—has been used but very little in American Engineering, caused partly by the greater inconvenience in adjusting as compared with the Y Level, and partly on account of the defective construction, inferior Telescope, etc., to be found in most of this style Instruments, we believe that a Dumpy Level possessing a good Telescope, sensitive bubble and stability, will do just as good work as the more costly Y Level. While the adjustment of the latter is easier made, the former will retain it longer.

Our Dumpy Level has a steel centre, 15 inch Telescope, the Level is placed between the Telescope and the bar, and the vial is curved so as to give for each inch motion of the bubble an angle of 3 minutes. The instrument is attached to the tripod with our new tripod coupling.

The price is complete... ....$100 00

The same with three leveling screws, $10 extra.

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himself by using a poor Bubble giving apparent satisfaction by concealing the errors which a sensitive one will show. A good instrument will not suffer from having its qualities indicated by a sensitive Bubble.

[†] To better understand the principles and laws of optics, by which the construction, power, illumination, etc., of telescopes is governed, the reader would do well to study the short treatise on telescopes we have inserted in this book. It will also serve to correct impressions formed by some through several publications issued of late years, claiming what can only be called "sensational qualities" for telescopes.

No. 8. PLANE TABLE.

The principal novelty in our Plane Table is the reduction of weight effected by the ribbing and bracing of all the heavy parts.

The table is usually 24 inches square, and consists of eight different pieces of hard and dry pine wood, which are so joined as to make warping impossible. The Alidade is 21 inches, and the Telescope 15 inches long. The latter is either inverting or erect, has a magnifying power of 32 diameters, and is always supplied with stadia hairs.

The radius of the vertical arc, if such is attached, is 3½ inches. In case a level is required to the telescope, we recommend the "Striding Level." For the compass a 4-inch needle will answer. The instrument is always provided with a plumbing bar.

The price of this instrument, with table 24 inches square, vertical circle or arc, level to telescope, stadia hairs, compass box, clamp, etc., is $300.

SOLAR ATTACHMENTS.

No. 9.—G. N. Saegmuller's Patent Solar Attachment with sun shade and prism for eye piece	$60 00
No. 10.—Schmolz Patent Solar Attachment with improved level for polar axis adjustment	$60 00

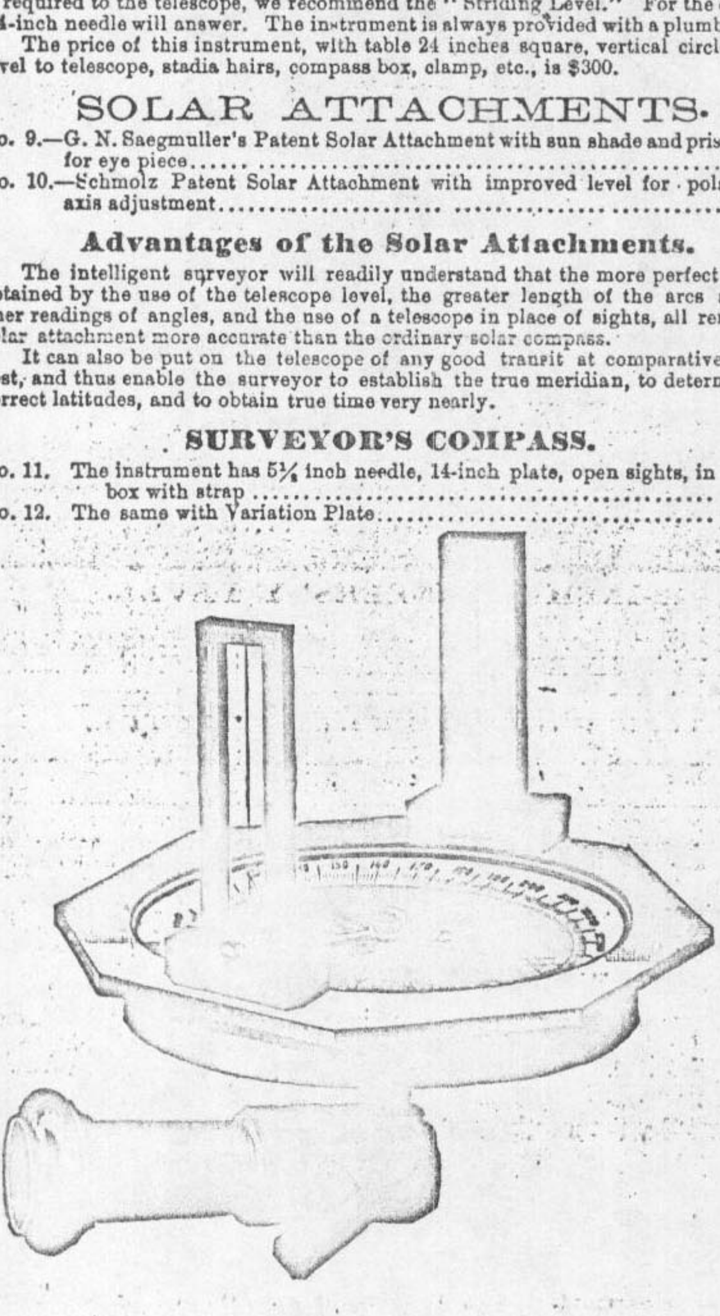
Advantages of the Solar Attachments.

The intelligent surveyor will readily understand that the more perfect horizon obtained by the use of the telescope level, the greater length of the arcs allowing finer readings of angles, and the use of a telescope in place of sights, all render the solar attachment more accurate than the ordinary solar compass.

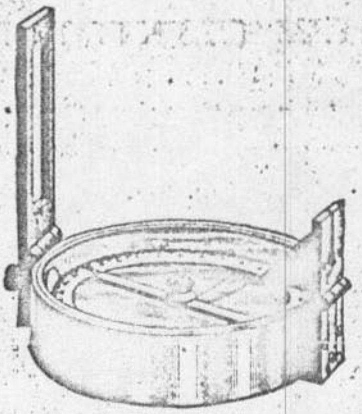
It can also be put on the telescope of any good transit at comparatively small cost, and thus enable the surveyor to establish the true meridian, to determine the correct latitudes, and to obtain true time very nearly.

SURVEYOR'S COMPASS.

No. 11.	The instrument has 5½ inch needle, 14-inch plate, open sights, in box with strap	$45 00
No. 12.	The same with Variation Plate	50 00

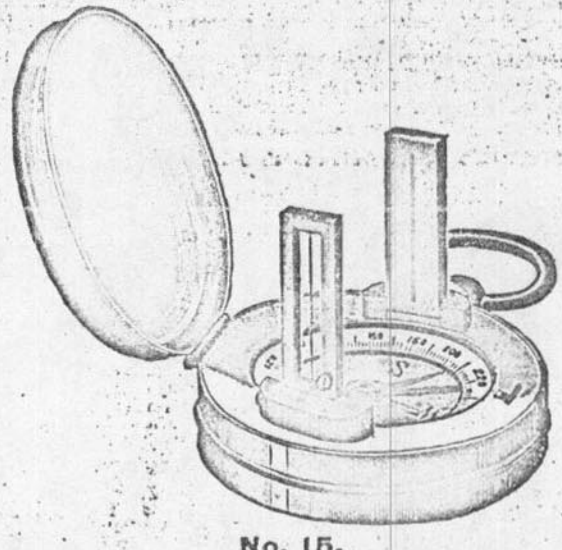


No. 13. Pocket Compass with folding sights. Price..........$6 to $25 00



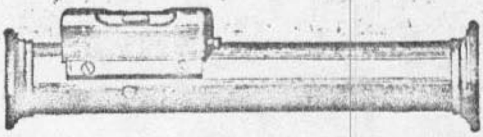
No. 14.

Prismatic Compass, 3 inches diameter, with divided ring on needle and folding sights; packed in neat case, very convenient for reconnoissance.... $15 00



No. 15.

No. 15. Small Pocket Compasses without and with sights, from........$1 to $8 00



No. 16.

No. 16.	Lock's Hand Level	$8 75
No. 17.	Lock's Hand Level, round	5 75

No. 18.

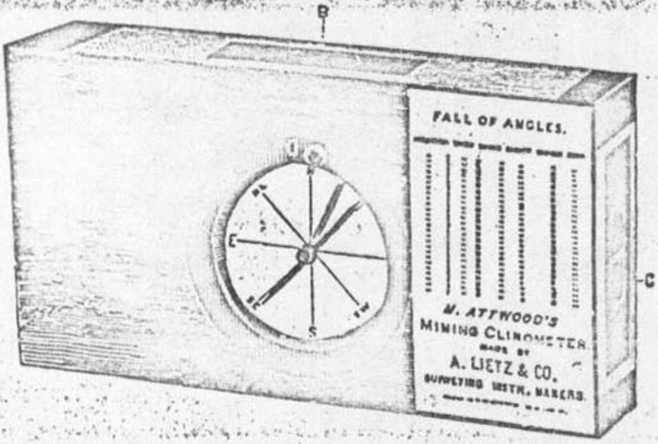
No. 18.	Abney's Reflecting Level or Pocket Altimeter, improved, with divided arc to show gradients, in morocco case, each	$15 00
No. 19.	Abney's Reflecting Level or Pocket Altimeter, with Bar Needle, Compass and socket for Jacob Staff	18 00

A NEW CLINOMETER.

Price $10 00.

"The accompanying cut is about half size and represents a new clinometer, designed by Melville Attwood for the use of the miner and prospector. It can easily be carried in the pocket, and is made as small as possible consistent with accuracy.

No. 20.

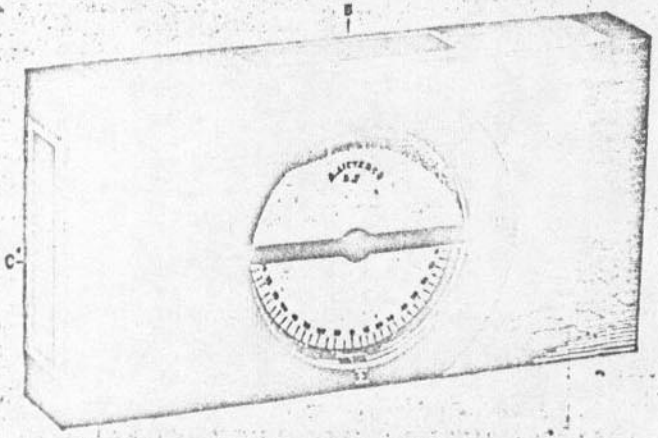


Attwood's Clinometer, showing Compass.

E, is the graduated circle which is kept in place by a small spring at *A*, a slight pressure on the knob of which sets the circle free, and on the removal of the fingers the instrument can be taken up and the angle of inclination easily read.

D represents a compass for taking approximate bearings.

B and *C* are small levels, one on the top and the other at the end of instrument.



Circle of Attwood's Clinometer.

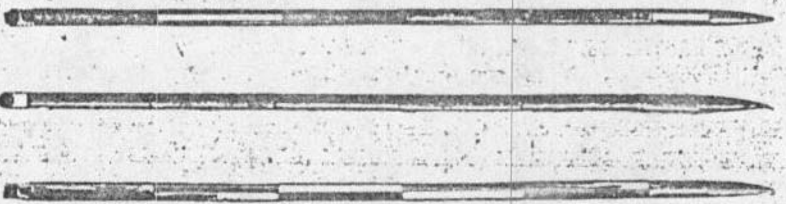
With this Clinometer and a small straight-edge the under lay of any metaliferous vein may be accurately taken, and in positions where a larger instrument could not be used; also the dip of any bed, or stratum of rock or seam of coal.

The timbering of any level, shaft or incline may be set by it. It can be used in quartz mills to give the proper angle to the silvered plates, blanket, trays, and sluice boxes. The instrument is a very practical one.

No. 21. Attwood's Improved Clinometer in metal frame.................... $25 00

Lamp for Illuminating Graduations.

No. 22.	Lamp for illuminating graduations, cross wires, etc., for use in underground work, of brass with ground lens..................	$7 00
No. 23.	Small **Plummet Lamp** of brass, steel point................	8 00
No. 24.	Large " " " "	10 00
No. 25.	**Plumb Bobs** of the most improved shape, from.........$1 to	5 00



LEVELING RODS.

No. 26.	Philadelphia self-reading rod with vernier clamp and target, reading to 1000ths from 6 to 8 feet long..............................	$19 00

MINING ROD.

No. 27.	3 feet long, sliding out to five feet with vernier clamps and target, reading to 1000ths..	$14 00

RANGING POLES.

No. 28.	6 and 8 feet long, with steel pointed shoe and divided red and white alternately, each..	$2 75
No. 29.	7 feet long of steel, each	3 00

SURVEYOR'S CHAINS.

No. 30.	Iron Chain, Brass Handles, No. 8 wire, 33 feet....................	$ 2 60
" 31.	" " " " 50 "	3 25
" 32.	" " " " 66 "	4 00
" 33.	" " " " 100 "	5 25
" 34.	Steel Chains, " No. 10 " 33 "	3 50
" 35.	" " " " 50 "	4 25
" 36.	" " " " 66 "	6 50
" 37.	" " " " 100 "	8 00
" 38.	Steel Chains brazed links and ring No. 12 wire, 33 feet..........	5 50
" 39.	" " " " " 50 "	6 00
" 40.	" " " " " 66 "	10 00
" 41.	" " " " " 100 "	11 50

CHESTERMAN'S STEEL TAPES.

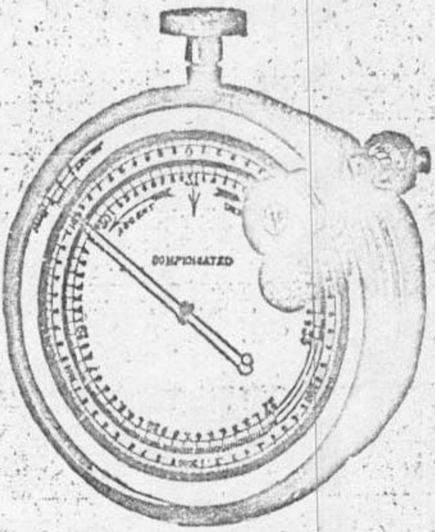
No. 42.	25 feet..	$ 4 50
" 43.	33 "	5 50
" 44.	50 "	7 50
" 45.	66 "	10 00
" 46.	75 "	11 50
" 47.	100 "	12 00

CHESTERMAN'S METALLIC TAPES.

No. 48.	33 feet..	$2 25
" 49.	50 "	2 75
" 50.	66 "	3 00
" 51.	75 "	3 75
" 52.	100 "	4 50

No. 53. Rod Level for Plumbing, a Rod or Flagstaff....$5 00

ANEROID AND ALTITUDE BAROMETERS.



Prices from $12 to $60 according to size and altitude scale.

Aneroid barometers made expressly for us by the best makers, in German silver or nickel plated cases, truly compensated for temperature, with or without thermometers, ranging from 5,000 feet to 20,000 feet, size 1¾, 2½ and 5 inches. Guaranteed correct, every one being subjected to a severe test before being sold.

MERCURIAL STANDARD MOUNTAIN AND SEA BAROMETERS.

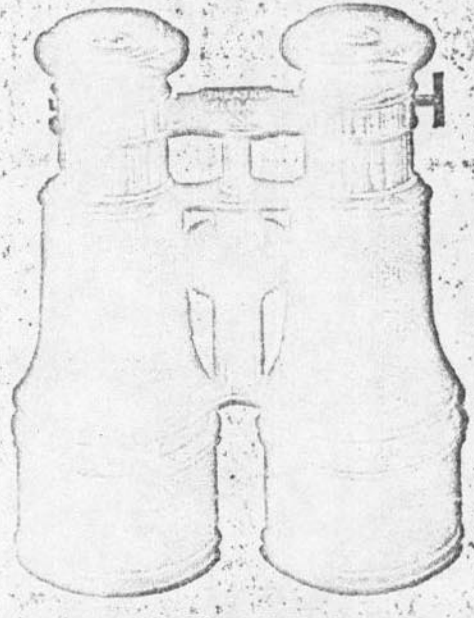
Prices from $20.00 to $100.00.

Supplies for these Barometers, as tubes, mercury packings, etc., we have constantly on hand.

HELIOTROPES.

No. 58.	Gauss Heliotrope	$150 00
No. 59.	The Telescope body is an iron tube, in the middle is a wood screw with joint for attaching the Instrument to a tree, or post. Price in box.	30 00
No. 60.	Heliotrope as made by us for the United States Coast and Geodetic Survey with wooden base, mirrors 4x4	$35 00
No. 61.	Same as before, but with mirror 6x6	41 50
No. 62.	Same with mirror, 8x8	48 50
	Prices for larger sizes on application.	
No. 63.	Pocket Heliotrope, Steinheil's, a beautiful instrument that requires no adjustment. In case	25 00
	Extras to Heliotrope No. 60 to 62 inclusive.	
	Tangent Screws for vertical and horizontal movement	7 50
	Outlifting arrangement for Tangent Screws	5 00

ACHROMATIC FIELD & MARINE GLASSES AND TELESCOPES.



Prices from $8.50 to $25, according to size and quality.

ODOMETERS.

No. 64.	For measuring distances by wagon. It is enclosed in a brass box. 4½ inches diameter, furnished with leather case and double straps to fasten to the center of the wheel. It is the most correct Odometer for practical use. Price	$17 00
No. 65.	McDonnell Adometers	5 00

PEDOMETERS.

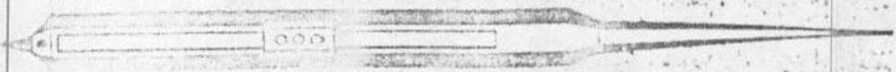
Pedometers are pocket instruments for measuring the distance traversed in walking, the number of miles being registered by a mechanism inclosed in a nickel-plated watchcasing, and operated by the motion of the body.

66.	Watch size, registering 20 miles and divided in ¼ of mile.......Price,	$ 5 00
67.	The same with three faces and hands, registering single steps...Price,	„ 9 00

M. Attwood's Micrometers for Measuring Quartz Screens.

It is a very small vest-pocket instrument by which the diameters of the apertures in different punched slot and wire screens can be measured with tolerable accuracy. Those mill superintendents who are particular in their work will find this little instrument a very handy one for the purposes indicated.

No. 68.	In Brass,	reading to	100 ths	$1 50
No. 69.	" Nickel,	"	"	1 75
No. 70.	" Brass,	"	200 ths	2 50
No. 71.	" "	"	"	2 75



Proportional Dividers, Steel Spring Dividers, Bow Pens, Pencils, Marking Pens, Lithographers' Dividers, Curved Pens, Railroad Pens, Etc, Prices according to quality of goods.

LEVEL CONSTRUCTED FOR THE USE OF MILLWRIGHTS, MACHINISTS AND CARPENTERS. The Iron Frame is twenty-eight inches long; has two adjustable levels six and three inches long.

No. 72.	With Common levels	$13 00
No. 73.	Same with grand Levels	20 00

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