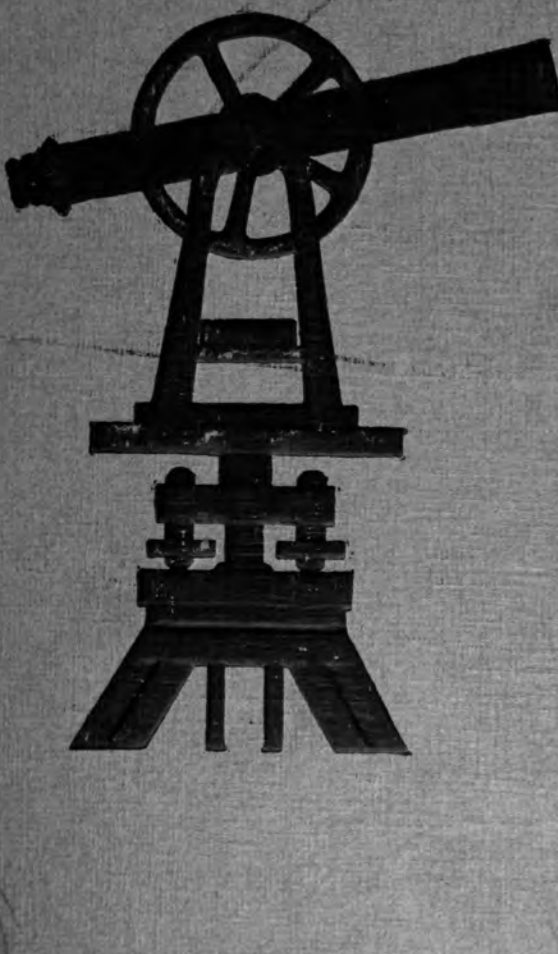
THE A. LIETZ CO

SAN FRANCISCO, CAL.



Lietz

MANUAL A

OF

Modern Surveying Instruments

AND THEIR USES

TOGETHER WITH A

CATALOGUE AND PRICE LIST

OF

SCIENTIFIC INSTRUMENTS

ELEVENTH EDITION

MADE BY

The A. Lietz Company

Established 1882

632-634 Commercial Street

SAN FRANCISCO, CALIFORNIA

1911-12

NOTICE

THIS Manual supersedes the former edition of our catalogue, and is carefully revised and corrected to date.

The articles manufactured by this Company are quoted at prices consistent with the quality of workmanship and material. We endeavor to place before the public an equivalent of the very best that can be obtained, without imitating in shape or design any make whatever. All our articles are of the most recent standard, with every known improvement.

The Lietz Instruments are well known to the profession, having been made under the personal supervision of our Mr. Lietz since 1882; and with our new building and the latest improved machinery, designed to meet our peculiar methods of obtaining the highest results, we are producing the nearest to perfection at moderate prices.

Distant purchasers will please remit by check, money order, or registered letter, or order C. O. D.

According to the rules of Wells, Fargo's Express Company, a surveying instrument, carefully placed in its case and in a packing box, is shipped as merchandise and charged at "single rate." "Three rates" will be charged if this precaution be not taken. The customer should not omit, therefore, to pay strict attention to this rule of the express company and avoid unnecessary overcharges.

Packing boxes are furnished by us at a nominal rate.

TELEGRAPHIC CODE

To Accompany the Eleventh Edition of the Manual of Modern Surveying Instruments and Their Uses, Together with Catalogue and Price List.

BY THE

A. LIETZ CO.

SAN FRANCISCO, CAL.

CABLE ADDRESS: CYCLOTOMIC, SAN FRANCISCO

We have A. B. C., Fourth Edition, and the Following Code.

Transits and transit theodolites, except No. 22, are supplied with solid silver graduations (unless ordered to the contrary), and all complete transits and transit-theodolites are furnished with stadia lines, fixed 1:100 (unless ordered to the contrary).

CATALOGUE NO.	TRANSITS.	CODE WORD.
No. 1		Bugbear
" 2		Buggy
" 3		Buglehorn
" 4		Bugler
" 6		Building
" 7		Bulbous
" 8		Bulged
" 9		Bulimy
" 10		Bulkiness
" 11		Bullace
" 12		Bullcalf
" 16		Bulldog
" 17		Bulletin

PRELIMINARY TRANSITS.

No. 22	Bullock

TRANSIT THEODOLITES.

No. 5	Bulltrout
" 13	Bulrush

Y LEVELS.

No. 19	Bumboat

DUMPY LEVELS.

No. 20	Bumper
" 20A	Bumkin
" 21	Bumptious

EXTRAS FOR TRANSITS AND LEVELS.

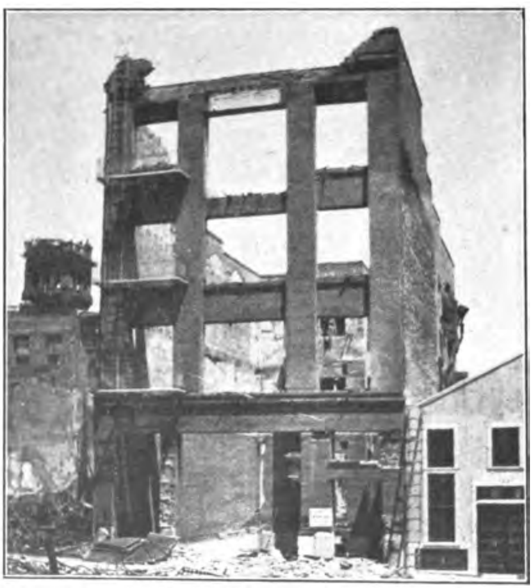
Made of Hard Aluminum Alloy	Culotte
Verniers Reading to 30 sec. on Horizontal Circle	Cullyism
" " 20 sec. " " "	Culminate
Gradienter Attachment	Culpable
Variation Plate	Culprit
Arrangements for Offsetting Right Angles	Cultivate
Striding Level to Axis of Telescope	Cultrated
Reversion Level to Telescope	Culture
Constructed with 3 Leveling Screws instead of 4	Culverin
3 Leveling Screw Shifting Center	Cumber
Prism to Eye-piece	Cumbersome
Extension Tripod in Lieu of Ordinary	Cumbrance
Saegmüller Solar Attachment	Cumbrous
Guard for Vertical Circle	Cumshaw
Half Length Tripod	Cumulus
Detachable Side Telescope	Cuneated
Reflector for Illuminating Cross-Hairs	Cuneiform
Quick Leveling Tripod Attachment	Cunning
Vertical Circle Graduated on the Periphery	Cupbearer
Telescope Inverted	Cupboard
Mirror to Control Bubble at Eye End	Cupid
Agate Fitted Y's	Cupidity
Stadia Hairs Fixed	Cupola
" " Adjustable	Cupping
Split Tripod Legs in Lieu of Ordinary	Curdiness

EXTRAS FOR TRANSIT THEODOLITES.

Verniers Reading to 20 sec. on a 6¼ in. Horizontal Circle	Cupreous
Verniers Reading to 10 sec. on a 7 in. Horizontal Circle	Curable
A 5 in. Vertical Arc Reading to Minutes	Curacy
A 5 in. Full Vertical Circle Reading to Minutes	Curateship
A 5 in. Full Vertical Circle with Opposite Double Verniers Reading to Minutes	Curative
Two Vernier Microscopes	Curbing
Long Ground Level to Telescope with Compound Clamp and Tangent Screw Telescope Reversible, Supplied with Gradienter	Curbstone
Box Needle on Plate	Curbles

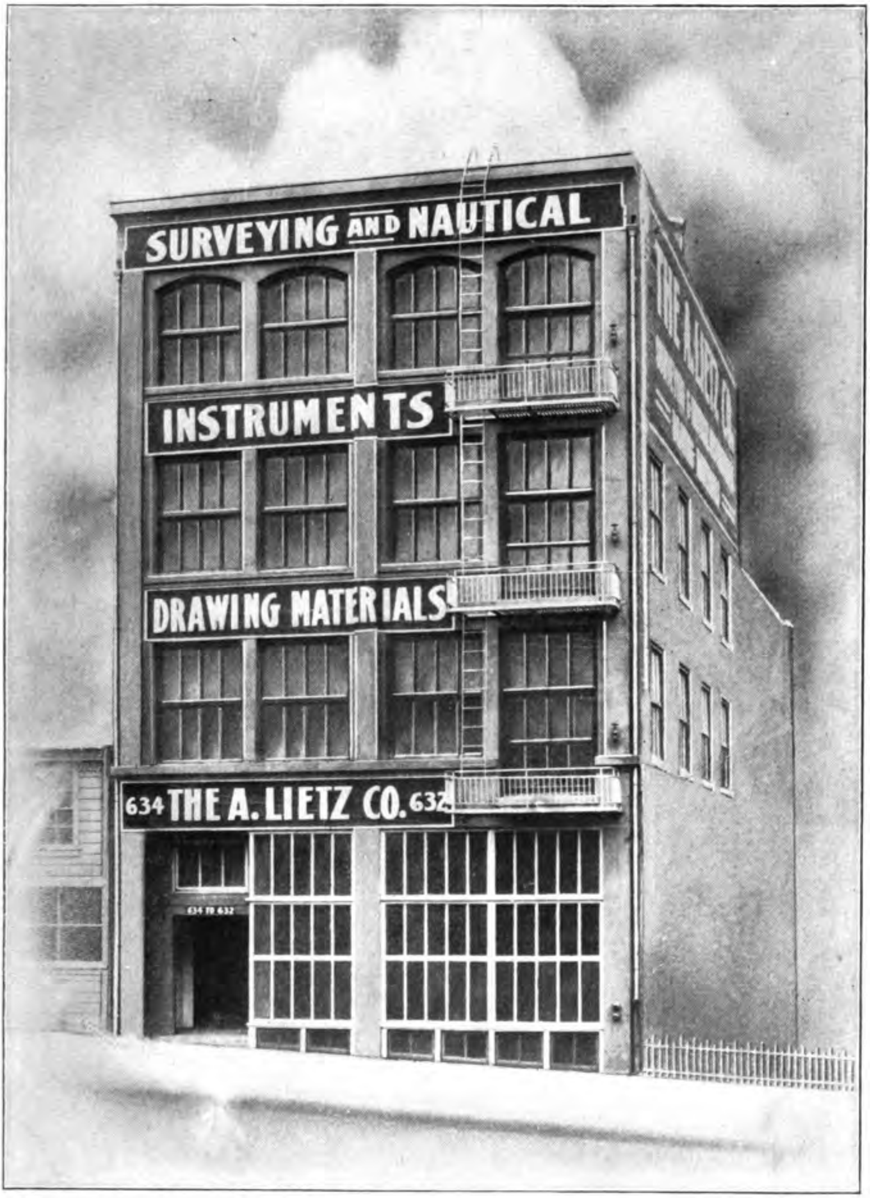
THE A. LIETZ CO. BUILDING

Before the San Francisco Catastrophe of April 18, 1906.



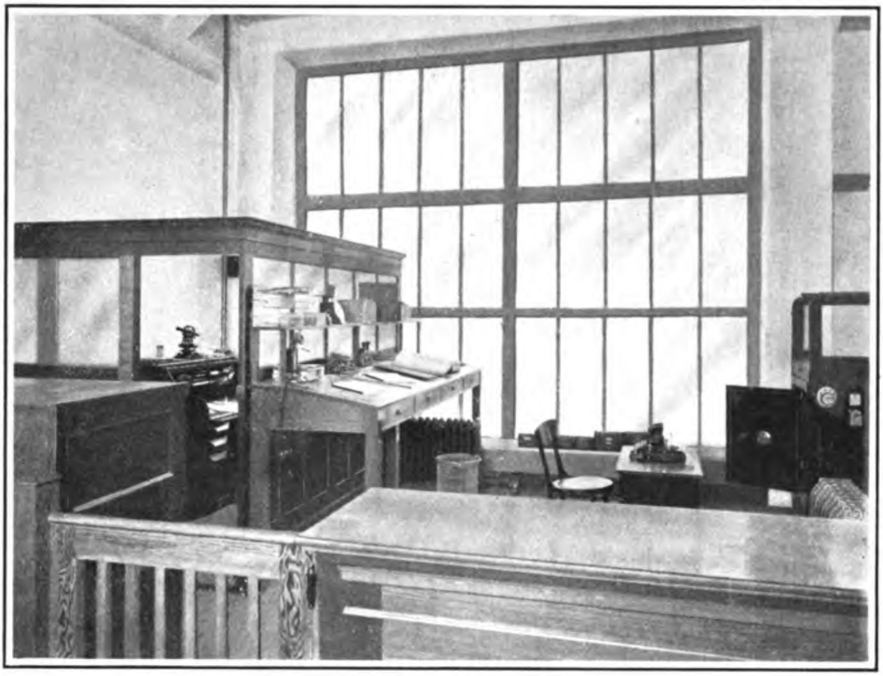
THE A. LIETZ CO. BUILDING

After the San Francisco Catastrophe of April 18, 1906.

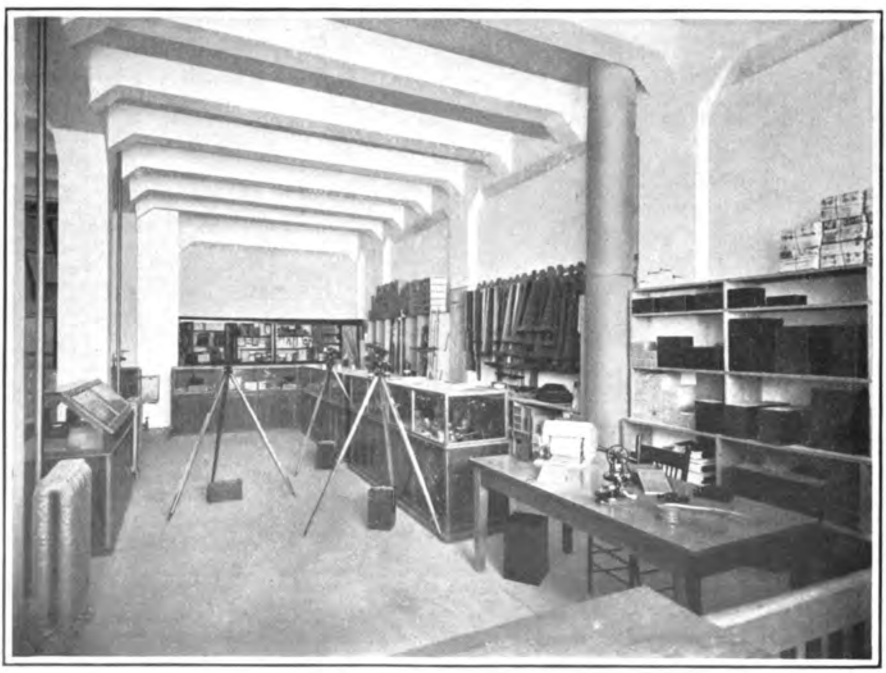


THE NEW A. LIETZ CO. BUILDING

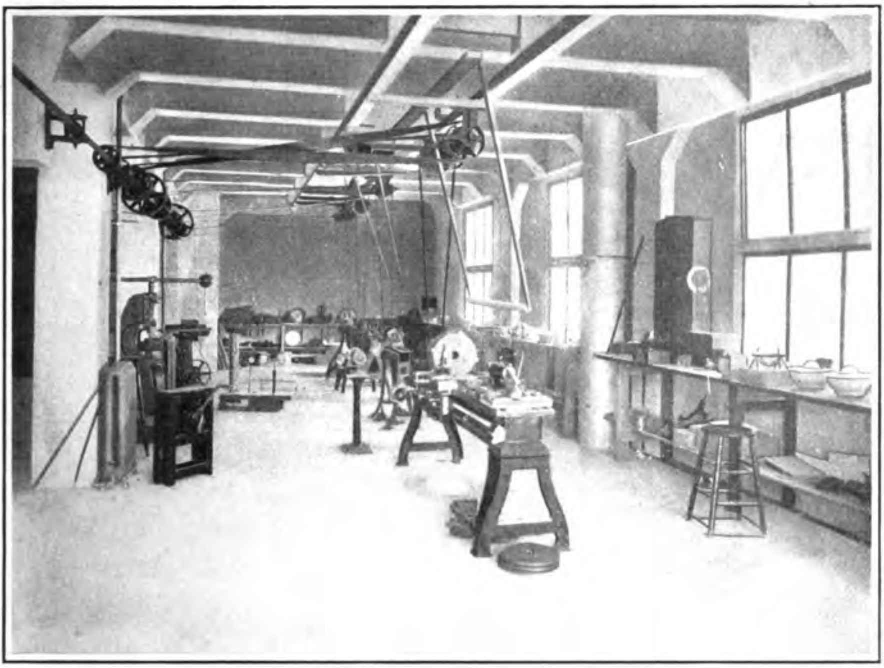
Fifteen months after the San Francisco Catastrophe of April 18, 1906. Entirely reinforced concrete, wired-glass windows, metal window frames, self-closing. Secures greatest stability for precision work.



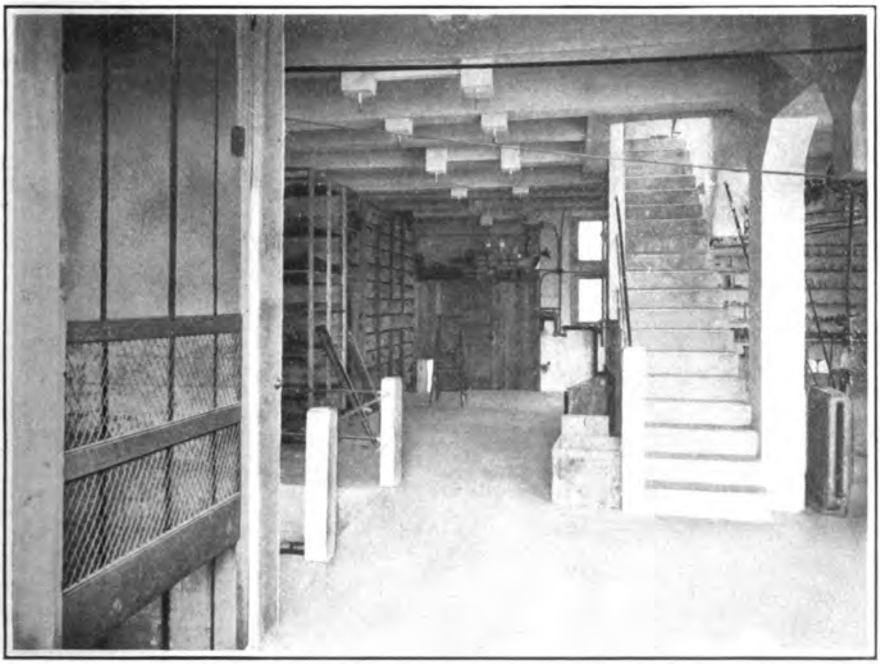
GENERAL OFFICE.



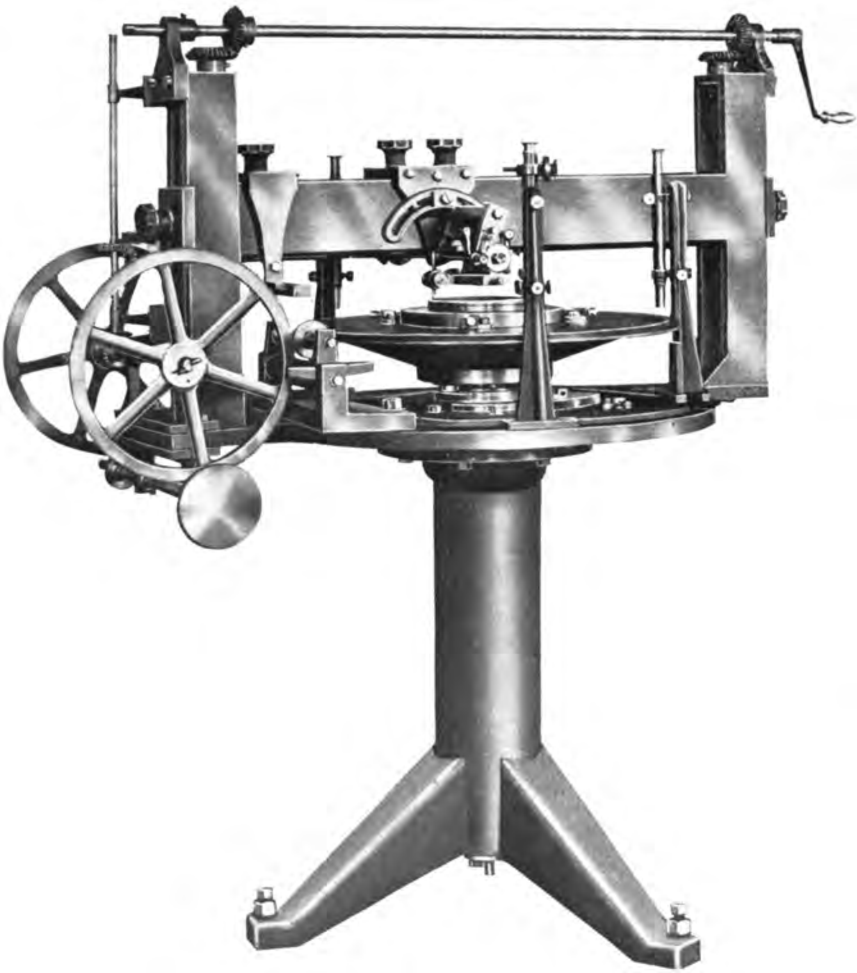
EAST SIDE OF SALES DEPARTMENT.



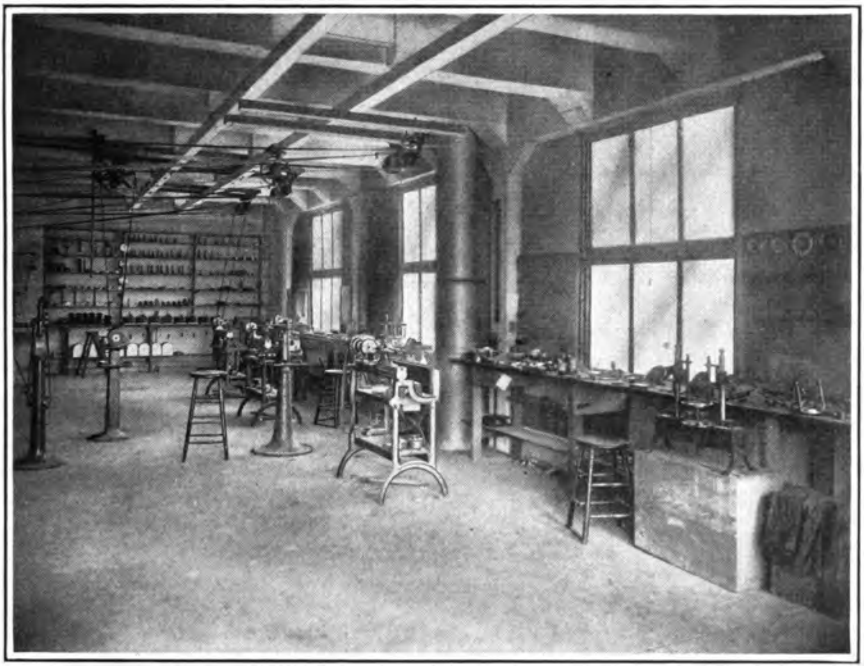
MACHINE AND TOOL MAKING.
Second Floor.



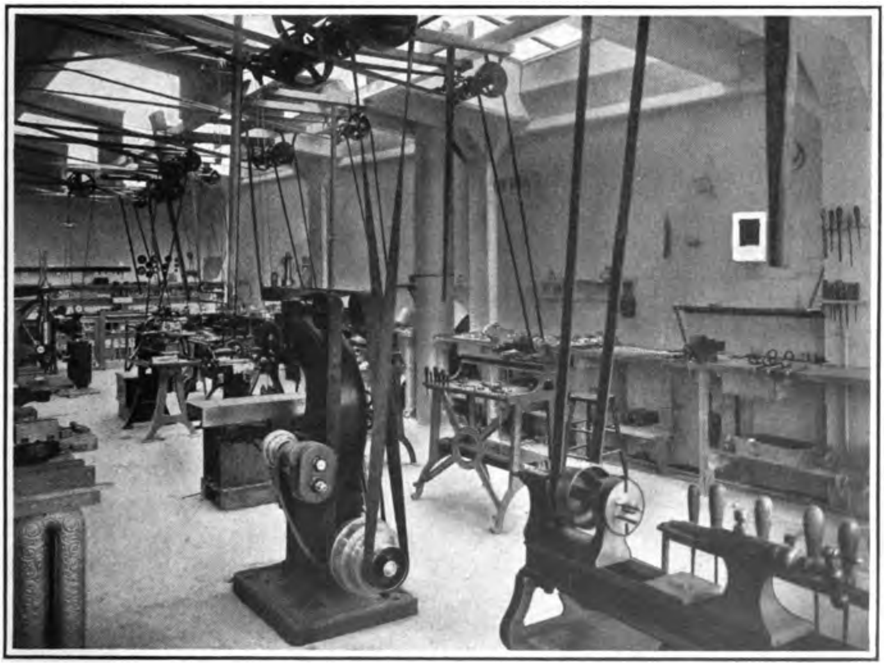
STORE-ROOM.



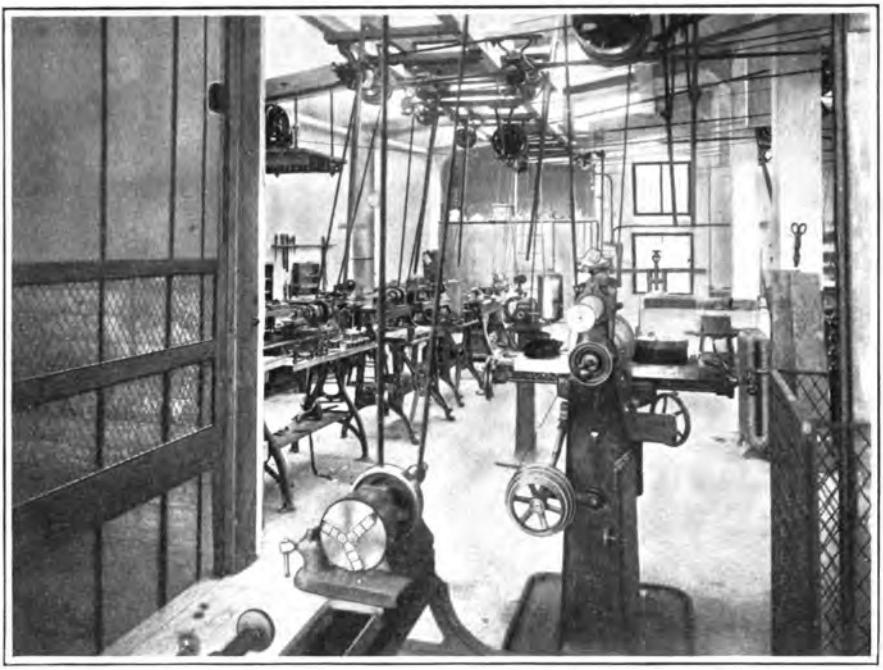
CIRCULAR DIVIDING ENGINE.
Built by A. Lietz Co. for the Graduating Department.



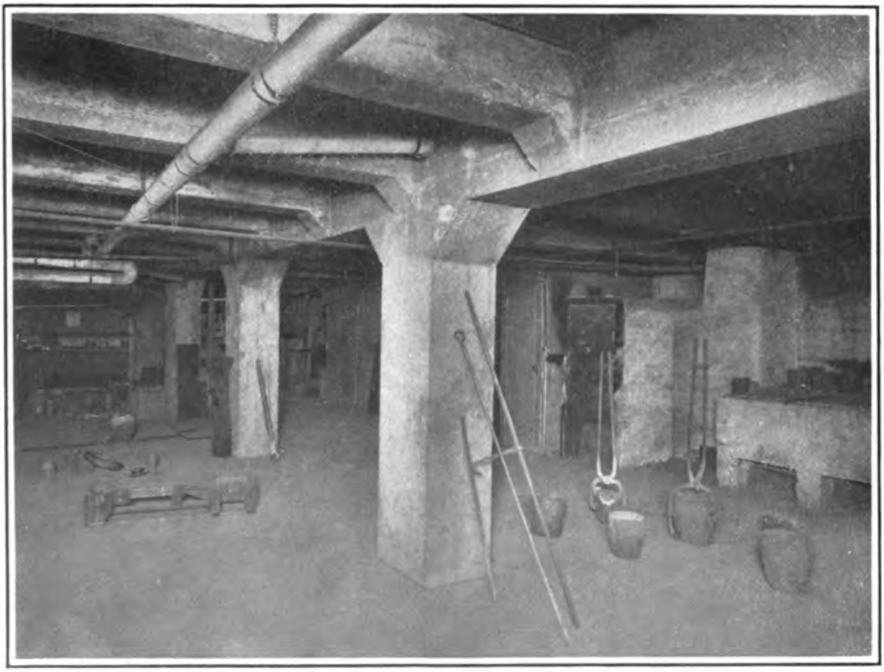
ASSEMBLING AND ADJUSTING DEPARTMENTS,
Third Floor.



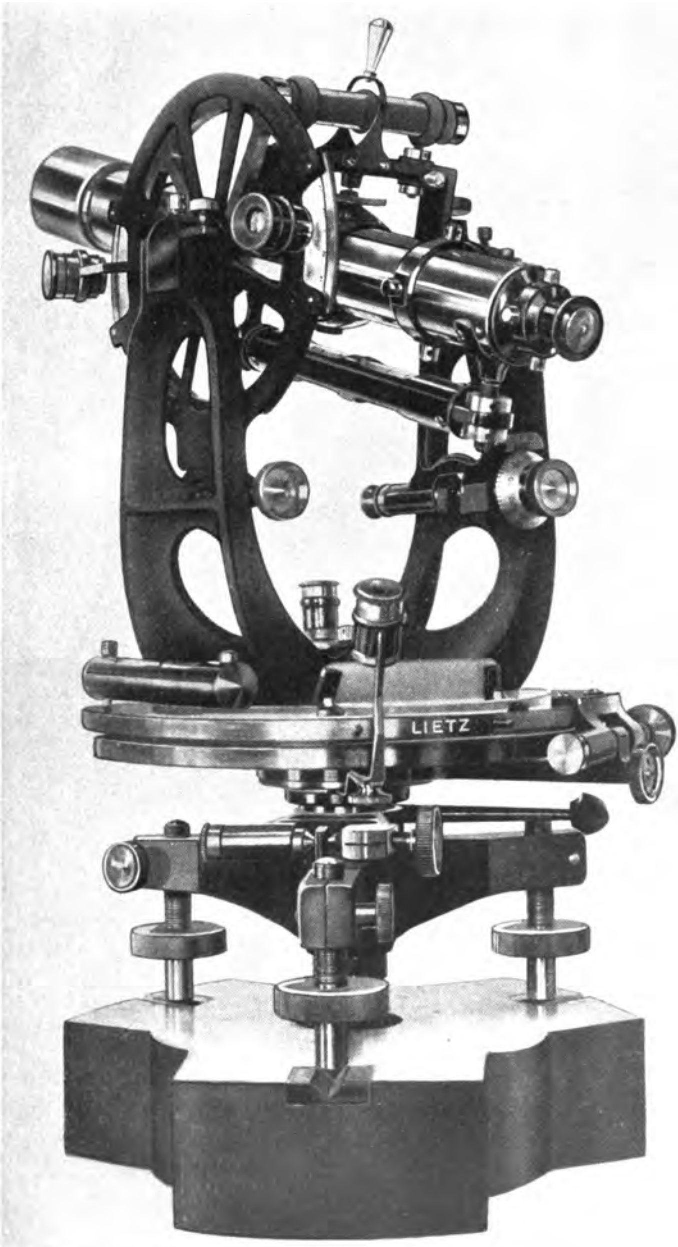
MANUFACTURING DEPARTMENT,
Fourth Floor, East Side.



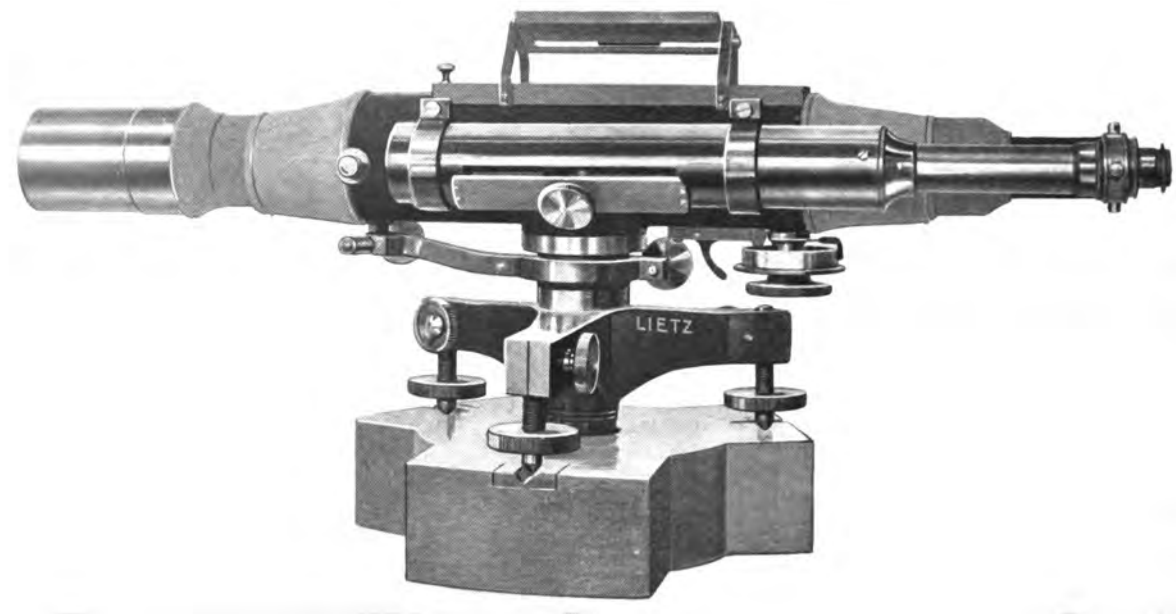
MANUFACTURING DEPARTMENT,
Fourth Floor, West Side.



FOUNDRY.
We make our own Castings.



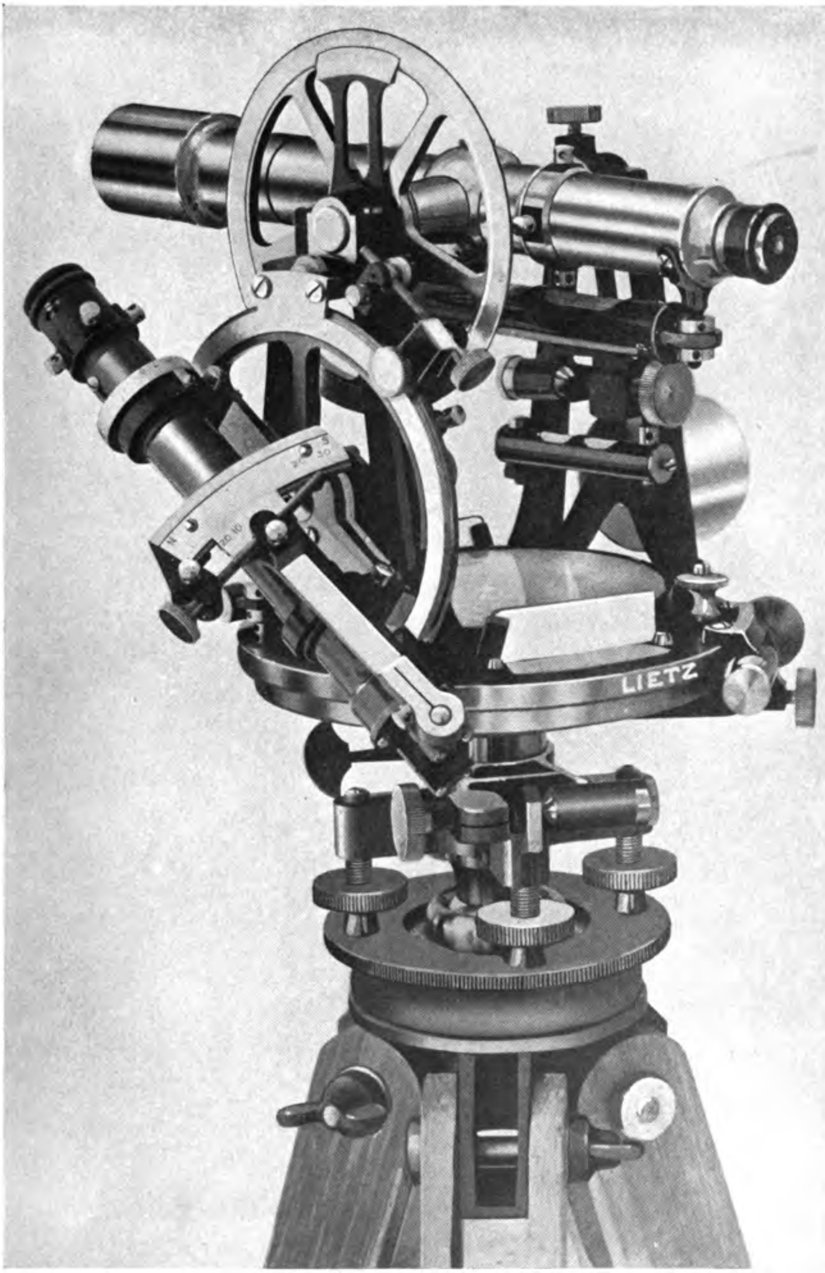
Type of Instrument approved by and made for the Bureau of Engineering of the City of San Francisco.



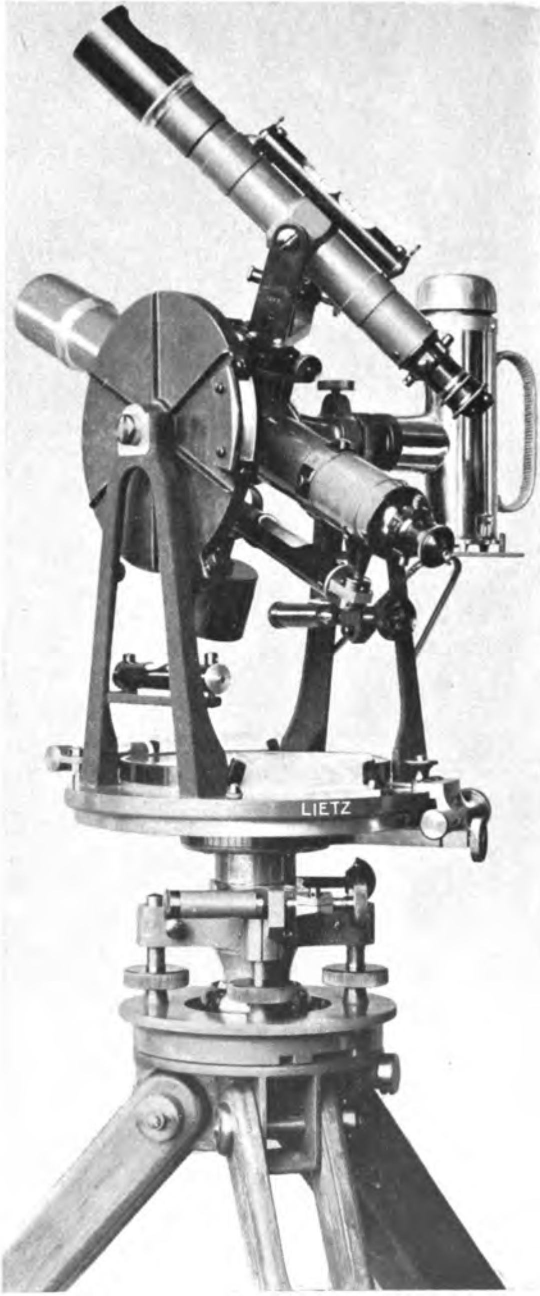
PRECISE LEVEL.

Design of the U. S. Coast and Geodetic Survey..

Made for the Bureau of Engineering of the City of San Francisco.



LIETZ TRANSIT WITH SMITH SOLAR ATTACHMENT.



MINING TRANSIT.

Special Features: Vertical Circle, enclosed dust proof, and graduated on the Periphery so that it can be read from the front; Detachable Illuminating Apparatus with Central Reflector inside of Telescope.

TESTIMONIALS

U. S. Coast and Geodetic Survey,
Sub-Office, June 2, 1888.

A. Lietz Co., San Francisco, Cal.:

Gentlemen—I have your note of 1st June, asking me to express an opinion of your character as Mathematical Instrument makers.

For the six years since you succeeded to the business of Carl Rahsskopff, I have been so well satisfied with the character of your workmanship upon the various kinds of instruments which I have intrusted to your care that I have seen no reason whatever to make any change.

In the matter of new instruments and novel devices, you have fully comprehended the wants of the observer and have intelligently supplied them.

Very respectfully,

George Davidson.

San Francisco, May 14, 1888.

A. Lietz Co., San Francisco:

Gentlemen—My acquaintance with your establishment for the manufacture of Nautical and Field Instruments, and the knowledge I have of your excellent appliances for such work, prompts me to a statement thereof, especially as you have furnished me with a substantial proof of your workmanship in the Transit purchased of you some months ago. This instrument has since been constantly used in important surveys in an extremely rough mountainous country, and I am informed by my son, who has been operating with it, that it is in every respect exceedingly accurate in all operations for which a Transit is designed. I am glad to express my satisfaction of its results and consider it a high recommendation of your ability to make superior instruments.

Respectfully yours,

Calvin Brown, C. E.

Berkeley, Cal., May 24, 1888.

A. Lietz Co., San Francisco, Cal.:

Gentlemen—Having your Transit in use, I take pleasure in expressing my satisfaction. I am pleased particularly with the Tripod Coupling, it saving much time.

Respectfully,

R. E. Bush,
Civil Engineeer.

San Jose, Cal., June 4, 1888.

A. Lietz Co., San Francisco:

Gentlemen—It is with great pleasure that we add our testimony to the excellency of your instruments. The two Transits and one large Y-Level bought of you are in every respect as good and serviceable as the instruments made by the most reputed of Eastern firms, and as a purely California or home production deserve the greatest credit.

The graduations made on your own graduating machine are clear, sharp and exact, the glasses of the very best make and power, and the needles much superior to the general run of needles.

Your Tripod Coupling is at once simple, effective and safe, and we consider it better than any other coupling used by other makers.

We can but congratulate you upon your success in the production of A No. 1 California-made instrument, and heartily recommend you to the profession.

Very truly yours,

Hermann Bros.,
Surveyors and Civil Engineers.

LA PORTE, CAL., June 5, 1888.

A. LIETZ Co., San Francisco:

Gentlemen—I take pleasure in stating that the Mountain Transit with which you have provided me in April, 1887, has proved excellent. In regard to accuracy of the graduation, stability of tripod, reliability of instrument in its adjustments and strength combined with lightness, it gives entire satisfaction.

Very respectfully, WM. SCHULD,
U. S. Deputy Mineral Land Surveyor.

OAHU RAILWAY AND LAND COMPANY,
HONOLULU, H. I., December 1, 1892.

A. LIETZ Co., San Francisco, Cal.:

Gentlemen—In 1890 this Company bought one of your Transits (No. 204). It has been in use in a variety of work and gives excellent satisfaction. It has several improvements on former instruments. All the parts are conveniently arranged. The verniers are in the right place.

Yours truly, C. H. KLUEGEL, Chief Engineer.

MAXWELL, CAL., July 15, 1891.

A. LIETZ Co., San Francisco:

Dear Sirs—The Transit made for me by you is all that an instrument should be. It is almost perfect. Have used it as a level and it is as good as most 18-inch levels.

I am now making a survey which tests its qualities very closely, and the results obtained are excellent. Stadia measurements of distances up to seven hundred feet frequently check within two feet. It is faster and cheaper than chaining.

Very respectfully,
A. J. BUTLER, Civil Engineer.

SAN FRANCISCO, Dec. 23, 1891.

A. LIETZ Co., San Francisco:

Gentlemen—It gives me great pleasure to certify to the merits of Transit, No. 202, which I purchased from you in August, 1890. I used it on town and water works surveys, and found it in every respect a first-class instrument.

Very truly yours,
H. S. DAVIDSON, Civil Engineer.

VIRGINIA, NEV., October 28, 1892.

A. LIETZ Co., San Francisco:

Gentlemen—We take pleasure in stating that the instruments, Transits and Levels, which you have furnished us, have given the utmost possible satisfaction.

The two transits have been in constant use for three years, and have proven themselves well adapted to mountain and underground work. They are light witbout weakness, and possess an extraordinary degree of accuracy; and, furthermore, we must acknowledge the promptness you have displayed in filling our sometimes imperious orders. We are, gentlemen,

Yours very respectfully,
HELLMANN & HAIST, Civil and Mining Engineers.

SAN FRANCISCO, October 29, 1892.

A. LIETZ Co., San Francisco:

Sirs—I have used the Y-Level, No. 231, made by you, and I take great pleasure in stating that it has given entire satisfaction. It is absolutely accurate and in every way reliable.

The same merit can be claimed by your Transits. I have used one of them for five months, and it is fair to state that I have never handled a better instrument.

Yours respectfully,
FRANCIS BRIDGES, Civil Engineer.

ASPEN, COLORADO, October 31, 1892.

A. LIETZ Co., San Francisco:

Sirs—It is with great pleasure that I avail myself of the opportunity presented me to say a kind word for you and your work. The Transit made by you and used by me for the last three years, I am certain is not excelled by any other in this State or elsewhere.

In convenience, accuracy of centering, and graduation, it leaves nothing to be desired. That it is today in as good a condition as when it left your shop, speaks well of its construction in other directions than accuracy alone.

Yours truly,

C. S. BATTERMAN.

WOODLAND, YOLO CO., CAL., November 3, 1892.

A. LIETZ Co., San Francisco:

Sirs—Regarding Level, No. 224, which I purchased of you, I have to say that the year I have owned the same has not made it a bad name. I like it even better than I did when I purchased it. For very accurate work in either still or windy weather I have never used its equal.

Very respectfully yours,

P. N. ASHLEY, City Engineer.

AGENCY SIERRA BUTTES GOLD MINING COMPANY, LIMITED,
SAN FRANCISCO, CAL., November 5, 1892.

A. LIETZ Co., San Francisco:

Dear Sirs—I take pleasure in stating that the Level I bought of you is a first-class instrument, and gives perfect satisfaction.

Yours respectfully, WM. JOHNS.

WARDNER, IDAHO, December 8, 1892.

A. LIETZ Co., San Francisco:

Gentlemen— * * * * * * * I prefer your instruments to any I have seen yet.

Respectfully yours,

JOSEPH P. KEANE.

MODESTO IRRIGATION DISTRICT,
LA GRANGE DAM, January 11, 1893.

A. LIETZ Co., San Francisco:

Gentlemen—I take pleasure in certifying that the Transit and Level bought of you three years ago have given perfect satisfaction, the adjustments remaining longer than in any instrument I have used in twenty-five years' practice. The inverting telescopes that I ordered I consider superior to the erecting form, and for hard usage and accurate work I know of no make of instrument superior to your Company's.

Very truly yours,

C. D. RHODES, Civil Engineer.

CLIPPER MILLS, BUTTE CO., CAL.,
February 3, 1895.

A. LIETZ Co.:

Gentlemen—You would hardly believe it, but I have used your Transit (No. 235) for over a year without having to adjust it, as it has retained perfect adjustment. I am very careful with it.

Yours respectfully,

H. W. CADWELL, C. E., E. M.,
Sec. Con. Gentle Anna Mining Co.

EUREKA, Feb. 1, 1894.

A. LIETZ Co., San Francisco:

Gentlemen—I have had the pleasure of standing behind one of your improved levels, and am free to say, "She's a bird."

Very respectfully,

A. T. SMITH,
U. S. Deputy Surveyor.

CANDELARIA, NEVADA, March 20, 1893.

A. LIETZ Co., San Francisco:

Dear Sirs—I am highly pleased with my Transit, No. 254, made by you, which I have been using constantly for over a year. It is thoroughly reliable, and I consider it one of the best in use. I have had occasion to use it a great deal in long leveling practice, and my limit of error per mile has never exceeded one-tenth of a foot. It is a combination of accuracy, strength and lightness, and I can safely recommend the same in every particular to the engineering profession.

Yours truly,

JOHN G. BOOKER,
U. S. Deputy Mineral Surveyor for Nevada.

LAKE GREENO, CAL., March 27, 1893.

A. LIETZ Co., San Francisco:

Gentlemen—Over two years ago I purchased one of your 18-inch Y-Levels. It has been in constant use ever since, sometimes subjected to very severe handling, and I desire to say that in over fifteen years' practice in the field, using instruments from most of the standard makers, yours is the peer of any in design, workmanship, action and all of the attributes of a first-class instrument. The ease of manipulation and constancy of adjustment are qualities possessed by it in a marked degree, and the improvements are just what are needed.

In short, I would not exchange mine now for an instrument of the same grade from any other maker. I expect soon to lay aside all others and to use none but Lietz instruments in all branches of my field work covered by them.

It is a great pleasure to me to show the good points of my level to my professional brothers.

Yours respectfully,

P. M. NORBOE,
Civil Engineer.

JUNEAU, ALASKA, January 14, 1893.

A. LIETZ Co., San Francisco:

Gentlemen—I take pleasure in stating that the Mountain Transit purchased from you and used the past season has proven excellent. The graduations are clean and sharp. In regard to accuracy of the graduation, reliability of instrument in its adjustments—the tripod not only simple and safe, but always rigid—and strength combined with lightness, it proves entirely satisfactory.

Yours truly,

CHAS. W. GARSIDE,
U. S. Deputy Mineral Surveyor for Alaska, and Mining Engineer.

SAN FRANCISCO, March 10, 1895.

A. LIETZ Co., San Francisco:

Gentlemen—In the prosecution of my work in opening up the gravel mines of the Playa de Oro Mining Company, in Ecuador, South America, we had occasion to use one Lietz Transit, one Y-Level, and one Dumpy Level.

These instruments were covered with water-proof cloth, and despite constant rain and exposure incident to such work, and in such a wet climate, proved thoroughly satisfactory, and I can most strongly recommend them.

Very truly,

MARK B. KERR
Civil and Mining Engineer.

SILVER CITY, N. M., October 31, 1906.

THE A. LIETZ Co., San Francisco:

Gentlemen—* * * * * will try and place an order with you at an early date, as I prefer your transits for all kinds of work to those of any other make.

Yours very truly,

JOHN M. SULLY,
Consulting, Mining and Mechanical Engineer.

SILVER CITY, N. M., February 25, 1907.

THE A. LIETZ CO., San Francisco:

Dear Sirs—I received instruments today and am delighted with same. I used a ——— for eleven years and know something about Transits, and you are sure welcome to the price I paid.

Thanking you for promptness and good packing,

Yours truly,

N. C. TITUS,
Consulting Mining Engineer.

DOWNIEVILLE, CAL., February 21, 1907.

THE A. LIETZ CO., San Francisco:

Dear Sirs—I have used my new Lietz Transit two weeks now, and am much pleased with it. In all my twenty-two years' experience with Transits, I have never handled a more satisfactory instrument.

Yours truly,

GEO. F. TAYLOR,
Civil Engineer.

CLIO, PLUMAS COUNTY, CAL., May 4, 1907.

THE A. LIETZ CO., San Francisco:

Gentlemen—We have a number of your Transits and Levels in use on the construction of the Western Pacific Railway through the Sierra Nevada Mountains, both for tunnel work and outside work, and all the men prefer them, in consequence of which, in ordering I always specify your make.

Yours truly,

J. Q. JAMIESON,
Division Engineer.

ITHACA, N. Y., May 9, 1907.

THE A. LIETZ CO., San Francisco:

Gentlemen—* * * * * will say that the Transit purchased of you last year appears to be of first-class workmanship. It has given entire satisfaction and is placed among our best instruments.

Very respectfully,

C. L. CRANDALL,
College of Civil Engineering, Cornell University.

CALEXICO, CALIFORNIA, May 2, 1907.

THE A. LIETZ CO., San Francisco:

Dear Sirs—The small Transit you sent us recently has given entire satisfaction.

Yours truly,

F. C. HERMANN,
Chief Engineer, California Development Co.

FAIRBANKS, ALASKA, November 23, 1906.

THE A. LIETZ CO., San Francisco:

Dear Sir—The Mining Transit, No. 9, Aluminum, purchased of you last March, gives good satisfaction, and for precision and all-around work I have never seen its superior. With best wishes for your future success, I remain,

Yours very truly,

L. S. ROBE,
Civil and Mining Engineer.

ALUMINUM INSTRUMENT TESTIMONIALS

San Jose, Cal., April 14, 1895.

A. Lietz Co.:

Gentlemen—We have used one of your Aluminum Mountain Transits for nearly a year, for all kinds of engineering work, in places exposed to great heat and strong winds, and find that it gives us better results and more satisfaction than heavy transits of brass.

We find that its small weight allows an easier and quicker handling in rough, mountainous places, and also keeps the instrument in better adjustment and more free from accidents. In fact, we don't see how we got along so far without it, and why engineers and surveyors, who have a great deal of mountain work to do and carry their own instrument, insist upon breaking their backs with a 25-pound instrument, when they can get one which weighs 7 pounds, and does the work fully as well.

Respectfully yours,
Herrmann Brothers,
Surveyors and Civil Engineers.

The Mineral Farm Consolidated Mining Co.,
Aspen, Colorado, April 30, 1895.

A. Lietz Co.:

Dear Sirs—I have been using for several months a Transit of your make, having inclined standards.

The standards and telescope are of your aluminum alloy, and give perfect satisfaction, as does the entire instrument, which is of special make throughout. This makes two Transits of your manufacture that I have used.

Yours truly,
C. S. Batterman,
Manager.

San Francisco, May 7, 1895.

A. Lietz Co.:

Dear Sirs—Your small Aluminum Transit, No. 342, proves to be for my purposes the most convenient and satisfactory instrument I have yet had in use.

It is well constructed and large enough for all ordinary underground and surface surveys, and being very light is particularly handy for rapid work.

Yours truly,
Ross E. Browne,
Mining and Hydraulic Engineer.

University of California,
Department of Civil Engineering and Astronomy.
Berkeley, May 10, 1895.

A. Lietz Co., San Francisco:

Gentlemen—The Plane-Table Alidade made by you for the University several years ago has always given satisfaction.

We have instruments made by several of the first-class makers in this country, and your Alidade compares very favorably with these.

Very respectfully,
H. I. Randall,
Instructor in Civil Engineering, University of California.

FERNDALE, CAL., May 15, 1895.

A. LIETZ Co., 422 Sacramento St., San Francisco:

Dear Sirs—I desire to state that I am well pleased with your small Aluminum Transit, which I purchased from you about two years ago. It is small, light and accurate. Being light it is particularly adapted for mountain field work.

There is no question but that the Aluminum Transit is the one for the engineer, as it combines accuracy with lightness.

Yours respectfully,

J. A. SHAW,
Civil Engineer and State Licensed Surveyor.

BOARD OF STATE HARBOR COMMISSIONERS,
No. 10 California St.
SAN FRANCISCO, May 29, 1895.

A. LIETZ Co.:

Gentlemen—With regard to the Aluminum Y-Level, No. 304, made by your Company for the Board of State Harbor Commissioners, I take pleasure in informing you that it has given perfect satisfaction, and I will state that if it were not possible otherwise than by paying double the price of the old-style brass instrument, I would willingly do so in order to get one of aluminum manufacture.

One only has to use such an instrument for a day to appreciate the difference.

As to the workmanship of the above level, I have never seen better in my experience as an engineer.

Yours respectfully,

HOWARD C. HOLMES,
Chief Engineer.

COUNTY SURVEYOR'S OFFICE, SANTA CRUZ COUNTY.
SANTA CRUZ, CAL., June 1, 1895.

A. LIETZ Co., San Francisco:

Gentlemen—I take great pleasure in informing you that I have used the Aluminum Transit, No. 320, made for me by your firm about a year ago, on all kinds of city and county work, and find it in every way the equal of any old style (bronze) instrument I have ever used.

It holds its adjustments very well, and is as steady in the wind as any of the heavier instruments, while the saving of labor in carrying it is a gain that cannot be over-estimated. I think that when it has been once thoroughly tested by any engineer, he will abandon his old instrument in its favor in every instance.

The graduations and workmanship are in all respects excellent.

Yours truly,

CHAS. L. PIODA,
City Engineer.

SAN FRANCISCO, Sept. 6, 1894.

I have had occasion to use a small Aluminum Transit, weighing 4½ pounds, continuously for about six months, and during that time I made it a point to use it in very severe and stormy weather.

I recall a very strong breeze near a California mountain town, when the local engineer of the work, upon which I was then engaged, and I were operating together, he with a large Transit weighing 17½ pounds, without the tripod. Although my instrument trembled, its motion was not a violent one, and I could still read a stadia rod at 400 feet distant, when it was utterly impossible for him to manage his heavy instrument at all. The amplitude of its vibrations was longer, and its larger superficial area gave the wind more surface to act upon. Whenever there was a lull in the wind, my Transit would stop trembling at once, while the heavy instrument would continue shaking until the next gust would strike it again.

It was proven to our satisfaction that the small Aluminum Transit was by far steadier than the large instrument, although the latter exceeded it 13 pounds in weight; it was not as top-heavy and the wind had less effect upon it.

The local engineer referred to, who had had quite an objection to a 4½-pound Transit, became fully converted to aluminum instruments after our first mutual experience in the wind, and is today as firm a believer in this metal as I am myself.

OTTO VON GELDERN.

MOUNTAIN HOME, ELMORE CO., IDAHO, May 5, 1894.

THE A. LIETZ COMPANY, 422 Sacramento Street,
San Francisco, Cal.:

Gentlemen—The instruments ordered (Aluminum Transit and Level) came to hand in due course of time all O. K., and I have neglected writing you on account of press of business and wanting to have an opportunity to test the transit in different ways.

What can I say in praise of the same? Words are useless. Money could not buy them if I could not replace the same. I think that will give you an idea of my appreciation of your instruments.

The objection was raised by several engineers that the Transit would shake in heavy wind. I know better, and experience is the best of knowledge. Example: Having a placer claim to survey, situated upon a low flat island in Snake River, I crossed the island when the waves were rolling about three feet high, and each roller helped to make it uncomfortable by washing into the boat; commenced at lower end of island, stake No. 1, and ran around the island sixteen courses and angle corners, and closed within three feet on stake No. 1, by calculation Lat. & Dept. Area 93 acres. Now any instrument that will do such work as that in a windy day on Snake River (and just knows how it blows there), I think is beyond criticism.

Having many levels to run, I have used the Telescope for running the same on one of our canal lines. Preliminary survey. Ran south on Twp. line, and at 700 ft. set stake on lower side of ravine. Returned to starting point and ran south-easterly, crossed ravine in narrow place for flume, and ran down south bank of ravine to stake at 700 ft. and closed; looked at other paper on which I had taken levels on Twp. line and found that readings were same for that point. Elevation 9.40 ft. Such an instrument will answer for me; those who want a better one can hunt for it.

The level is a *Daisy* and meets all requirements.

An engineer or surveyor can carry it all day and not feel like leaving it where he stops at night. I would recommend the same to any one of my profession, and advise them to go and do as I did: Buy the same from A. Lietz Company.

Yours respectfully,
SAMUEL G. RHODES,
U. S. Dep't Surveyor for Idaho.

PORT CHESTER, N. Y., Feb. 10, 1904.

Gentlemen—The Aluminum Transit Theodolite made for me by your firm seven years ago has proven to be a most satisfactory instrument.

It has been in use almost continuously these years on all kinds of work met in the general practice of a civil engineer, has had rough usage, but escaped serious injury, and has not once been to the makers for repairs.

I have heard objections urged against the use of aluminum in mathematical instruments, the fear being expressed that the metal would not meet the requirements of surveying instruments particularly.

My experience has proven such objection groundless, for notwithstanding the seven years' usage given this instrument by myself and assistants, it shows no indication of wear or fatigue, and gives promise of a long life of usefulness.

I would add that I believe the staunchness of the instrument in question is due in a large measure to the design of which the essential features are the strong, single centre and "U"-shaped standards cast in one piece, these wrought by skillful workmanship and furnished with one of the best divided circles, complete an instrument that for accuracy, strength and lightness is rarely equaled.

Very respectfully yours,
F. S. ODELL.

SAN FRANCISCO, CALIFORNIA, July 19, 1904.

THE A. LIETZ COMPANY, 422 Sacramento Street, San Francisco, Cal.:

Sirs—It affords me great pleasure to testify to the merit of an Aluminum Transit, your small instrument, No. 9, which I have had for over eight years, which has accompanied me on long voyages, has been exposed to extremes of climate, to rough handling in all sorts of transportation, and yet has never failed to do excellent and absolutely reliable work.

The light metal was chosen because it was an object to me in my hazardous travels to reduce the weight of my outfit as much as possible, and a Transit weighing but little over five pounds with its box became an item of inestimable value to me.

This little instrument has had many adventurous mishaps, but it has never lost its usefulness, and is as trustworthy today as when first bought.

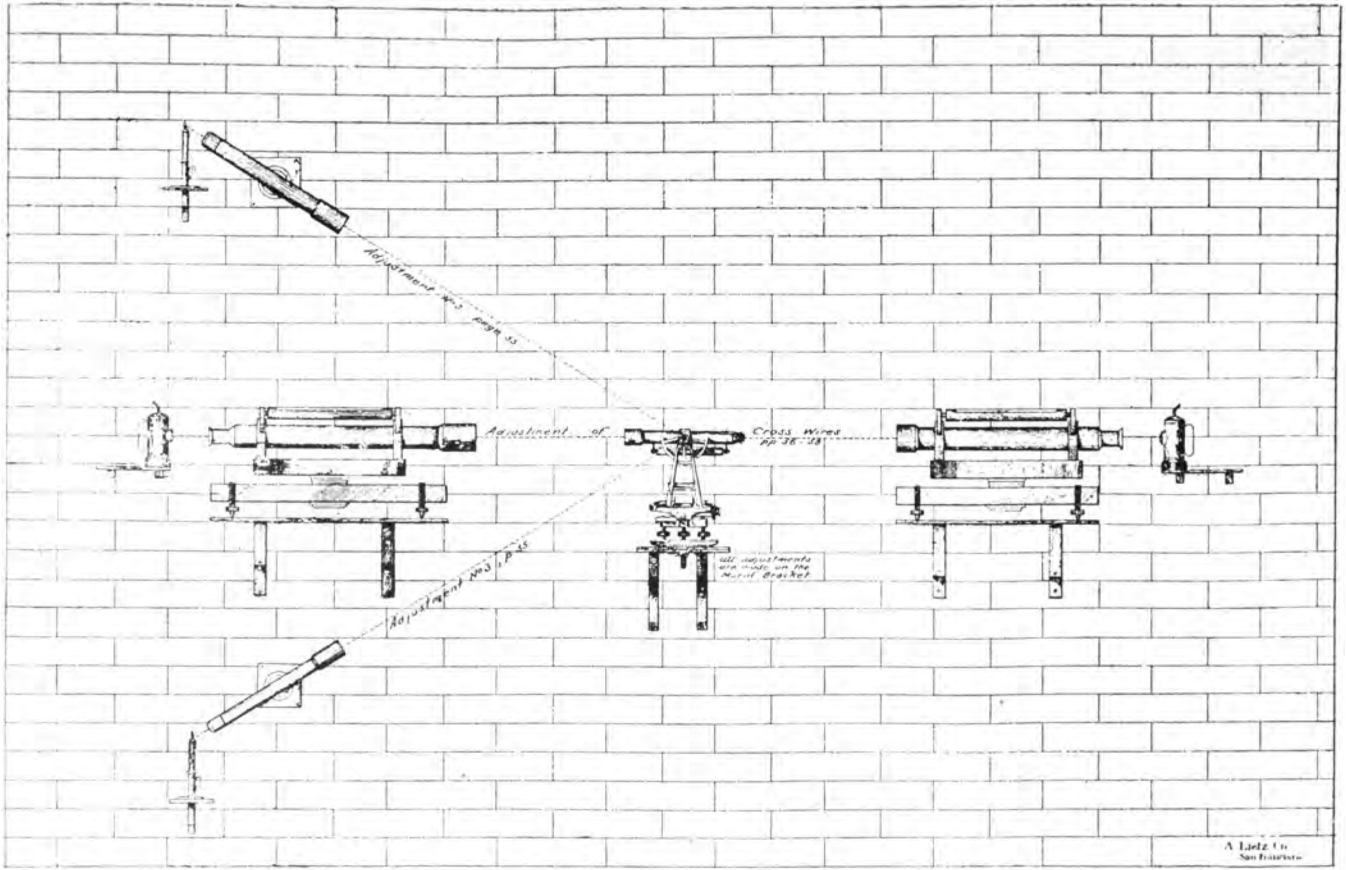
Some years ago, while in Siberia, an accident happened to our boat while journeying on a river, and the instrument fell into the water. It was recovered after a considerable effort, but it had suffered no injury. From the rigorous climate of Siberia it was taken to the Argentine Republic, under climatic conditions entirely different, yet it did its work as well there as in Siberia.

It underwent a similar change by taking it to the Klondyke, where it had the misfortune to fall from a second-story window, and yet it did not suffer sufficiently to prevent me from completing my work. It has become a Transit with a history, and I have learned to appreciate the very excellent qualities it possesses. It is light, rigid, firm, tough and extremely well constructed, compact, with proper dispositions for work that I have to do with it.

I realize that aluminum is the proper metal for the universal instrument, that is for an instrument called upon to do any engineering work in any climate, under very trying conditions, where it is impossible to devote that attention to its safety that under ordinary conditions, with every facility and assistance, is expected to be given to a delicate tool.

I take great pleasure in recommending such instruments to the profession. You have skillfully, intelligently and conscientiously made for me an article that I have every reason to appreciate very much.

Yours very truly,
CHAS. F. HOFFMANN,



MURAL COLLIMATOR APPARATUS.

CAUTION

In order to prevent changes in the magnetism of the Needle, do not bring your transit instrument into juxtaposition with objects generating or transmitting strong electric currents, such as *dynamos, electric car lines, etc.* If absolutely necessary to be within the influence of strong currents, allow the needle to swing freely. Avoid riding in electric cars with your transit, if possible.

Description of Instruments

MANUFACTURED BY

THE A. LIETZ COMPANY

SAN FRANCISCO, U. S. A.

With Remarks on their proper Use, Care, Preservation and Adjustments.

Description of the Lietz Instruments

INCLUDING REMARKS ON THEIR USE, HANDLING, CARE, PRESERVATION AND ADJUSTMENTS.

THE ENGINEERS' TRANSIT OR THEODOLITE.

In reviewing the different parts of the transit and theodolite, it will answer our purpose to include them, for the present, under one head, using both terms as synonymous — The word theodolite having been defined as an instrument of angular measure, possessing two graduated circles, normal to each other, which during manipulation are set in horizontal and vertical planes respectively. Bauernfeind says that it is generally believed that the word theodolite (theodolith) is a combination of θεα sight, οδος road, and λιθος stone. He says that in order to understand this derivation it must be known that formerly all supports upon which theodolites were placed were made of stone. This meaning, however, seems somewhat ambiguous, and other derivations have been sought. The etymology of the word is uncertain.

In classifying there appear two distinct groups of theodolites: the simple theodolite, in which the lower clamp and tangential movement is neglected; and the repeating theodolite, possessing the double horizontal movement on spindle and plate, which is the principal feature of all complete field instruments made for the engineer at the present time.

The various parts of the transit or theodolite may be grouped under the following heads, viz.:

Beginning from the base-plate we have:

1—The tripod connection with the leveling, plumbing and centering apparatus;
2—The centers;
3—The graduated plate and verniers;
4—The compass and variation plate;
5—The standards with the vertical arc and its movements;
6—The gradienter;
7—The spirit levels;
8—The telescope.

1. The Tripod Connection.

An important feature of the Lietz instruments is that they are attached to the tripod by a *friction coupling.*

It has been customary to accomplish this, heretofore, in two different ways. One is to attach the instrument to the tripod by means of a screw at the base-plate, whereby it remains complete in all its parts and is never separated above the leveling screws. This is the method employed by the best makers, but it is somewhat tedious and unsafe, as every engineer has had occasion to find out. It is often the case that the screw will not catch, and there is always a loss of time and patience in trying to enter the thread properly. Another point is that while turning it on, the entire weight of the instrument rests upon the screw thread, with a constant tendency to wear it away.

The second method of fastening the transit to the tripod is by means of the center, making it attachable or detachable above the leveling screws. In most cases the foot screws may also be turned from the tripod head, but it is not unusual to have them remain as a fixed part of it. This mode of coupling seems to us very defective. The exposed center is liable to injury in many ways. Dust particles accumulate, and it moves with difficulty in consequence, if it does not cause fretting. But its greatest fault is the incumbent necessity of providing for it what is called the *flat center,* for turning the upper plate. In such an instrument the plates stand too high above the leveling screws, which causes unsteadiness. We believe it to be very difficult, if not impossible, to do accurate work with such an instrument, to which point we shall refer again hereafter.

These substantial reasons have caused Mr. Lietz to invent a *new tripod coupling,* which is regarded as the most successful innovation by all who have had occasion to use it.

Figure 1 fully illustrates this simple but most effectual device.

On the tripod head, instead of the ordinary screw, there are three jaws. The base plate of the instrument is swallowtail-shaped on the inside (as shown at *F*), and is provided with the spring case *C**. The coupling of the two is done by letting one of the grooves on the base plate meet any one of the jaws on the tripod head, when one-third of a revolution to the right will make the connection; at the same instant the spring *C* will fall into a hole in the base-plate, which thus prevents any possible disconnection; the latter is effected by lift-

* The spring C in the latest construction is now placed on the tripod head, between the lugs.

ing the spring *C* and turning to the left. If the tripod head should have been worn or bent by accident, the movable jaw *D*, which is worked by the side-screw *E* (with a large adjusting pin), will again give the coupling friction enough to hold the instrument perfectly firm on the tripod.

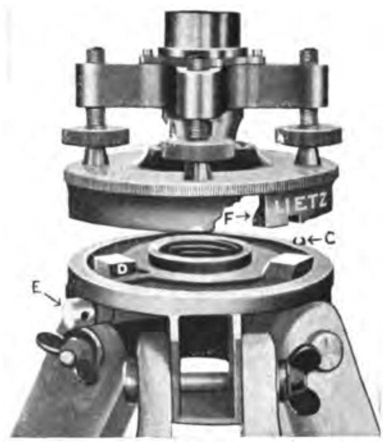


FIGURE I.

The chief merit of our arrangement is that it enables one to attach or detach the instrument to or from its tripod more rapidly, firmly and safely than by any other device so far known, and that, too, without dividing the instrument proper into two parts, which is always injurious to its accuracy and stability, as we have just pointed out. To this we may add that it is more durable, easier to keep clean and cannot get out of repair.

The movable jaw, once set for the instrument, need not again be interfered with. It is absolutely needless to adjust the friction every time the instrument is placed on the tripod.

We feel quite confident in saying that every engineer who has once used this new coupling will readily detect its great merits, and will never be without it. All the large-sized transits and levels of the Lietz make fit the same tripod head, and are instantly adjusted.

a. Leveling Screws.

As these are used more than any other part of the instrument, it is evident that they should be very durable. Those of the Lietz make possess a very deep thread, rounded a little on the edge, which insures a very smooth motion and greater durability than sharp-edged threads. The screws are made of composition metal.

The lower construction of the transit is made with the view of affording the greatest steadiness under all conditions. For that reason the leveling screws are not run through a thin metal disc, with a common nut attached for their operation, but an extra strong, star-shaped casting, made in one piece, is provided, through which the screws are passed and in which they operate.

The whole construction of this part is intended to insure the absolute steadiness of the instrument, and to give it rigidity even in a strong wind. Any other construction, with a light disc parallel to the base-plate, cannot afford that stability which a first-class transit or level should possess; and, since this is one of the prerequisites of an instrument of precision, we have laid particular stress upon our leveling arrangement, which is of the most approved modern design.

For instruments of the greatest precision, as those used in triangulation or geodetic work, it may be an advantage to arrange the base with three leveling screws instead of four. These changes will always be made upon application. While the ordinary complete transit is more compact and of greater utility with four screws, in a specially designed instrument for the finest work it will always be well to consider the advantages of the three-screw system, universally adopted in European instruments.

b. Shifting Center for Facilitating Plumbing and Centering.

All our complete instruments are furnished with shifting plates for the purpose of setting them precisely over a point, after having approximately done so by the tripod legs. This arrangement is of the greatest utility to the field man, and we are convinced that those who have adopted it will never again dispense with it.

While it does not make the instrument less rigid or portable, it is so easily manipulated, and becomes a great labor-saving factor. In order to center the instrument accurately, two of the leveling screws require a slight loosening, when the transit may be shifted upon the tripod until the center of the plumb-bob is directly over the point to be occupied. The screws are then turned down and the instrument leveled up in the usual manner, when it will stand as firm upon its base as required.

2. The Centers.

In manufacturing this all-important feature, the very backbone of the instrument, too much care and attention cannot be bestowed.

It is essential that both of these metal axes should have the same absolute center as the graduated plate and the horizontal telescope axis, whichever way the instrument may be turned. This is accomplished by the A. Lietz Company by making this detail a specialty. The carefully chosen material for the vertical axes, the exact method of turning and fitting them, and the precision reached in the manner of centering them, together with the subsequent scrutinizing test to determine the slightest eccentricity, have accomplished results as perfect as mechanical means and human ingenuity can achieve.

Eccentricity has been a source of annoyance and error to the engineer, to determine which a number of practical methods have been invented and put to use. One of the most ingenious has been inserted in this catalogue, which will be found in full elsewhere.

But with our modern transit, if used with ordinary care, this source of error has been eliminated, or at least reduced to the lowest possible minimum.

The length of our centers is from 2¾ to 4 inches, according to size and style of instrument. To our best belief, this is more than the instruments of any of the many different makers possess, having constantly handled a great many of them in repairing. Yet, by examining our illustrations, it will be noticed that with us the limb and vernier plates are nearer to the tripod head than in those of other make, owing to the judicious placing of the centers, which reach down into the base, thus insuring the utmost stability. By comparing our cuts with those in other catalogues, the reader will obtain a pretty fair idea of what we mean to impress upon him—such a comparison being better than any argument by either ourselves or others, based upon mere assertion.

Examine carefully our construction of the centers, and you will be soon convinced that our claim for rigidity and stability is fully warranted.

3. The Graduated Plate.

We have now come to the most essential part — the very soul of the instrument. It is needless to dwell upon the necessity of an accurate graduation; it is self-evident, and it becomes the instrument-maker's pride to make it so.

We guarantee our work in this particular as perfectly reliable, the graduation lines straight, thoroughly black and of uniform width.

The plate is accurately centered and free from eccentricity, as already explained.

The horizontal circle is graduated from 0 to 360 degrees, with two sets of figures running in opposite directions (unless ordered differently). They are large and distinct, and, to avoid errors in reading, the figures of these two sets, and those on their corresponding verniers, are inclined on opposing slants, thus indicating the direction in which the vernier should be read.

We recommend graduations on a solid *silver* ring, as that metal offers many advantages for the purpose—in fact, its great permanency and smoothness renders it the only satisfactory surface for fine graduations. However, they are made as the customer desires; but since the additional outlay for silver graduation is only $10, we seldom have any difficulty in impressing the purchaser with its advantages.

It is customary with us to graduate circles so that they may be read to single minutes or thirty seconds of arc. We make any degree of refinement called for, but our manufactured goods are always on hand in the two vernier divisions named.

a. The Vernier.

This consists of a small sliding scale, movable upon a larger one, so graduated that n parts thereof shall include either $n + 1$, or $n - 1$ parts of the larger scale. The scale may be applied to either straight lines or arcs, and aids to determine the smaller divisions of measure between the lines on the larger scale.

A tedious method for measuring small values of arc by means of concentric circles was given in the early part of the sixteenth century by a Portuguese, Pero Nuñez (Nonius), and after him the name of *nonius* is still applied in Germany and other countries to what we exclusively call a *vernier* here. This term was justly given it in honor of the Dutch captain, Peter Werner, who gave to the scale the sliding shape in which we now apply and use it practically. Signing himself "Pierre Vernier" in a discussion of the "Nonius," written by the inventor in the French language and published in Brussels in 1631, gave rise to the term we now almost universally employ.

The graduations on a vernier are usually so made that n divisions thereof shall equal $n - 1$ divisions on the circle.

It becomes a simple problem to determine the value of n from the following equation:

Let l = length of one division on circle,

l_1 = length of a vernier division, it is evident that

$l\ (n - 1) = l_1\ n$, or

$$n = \frac{l}{l - l_1}.$$

The value of any quantity in the equation may then be readily expressed in terms of the other; $l - l_1$, or the smallest readable division, being equal to $\frac{l}{n}$.

It is customary to graduate the circles of the Lietz transits in 20-minute divisions, reading to either 20 or 30 seconds on the vernier. The value of n in these cases is $\frac{20 \times 60}{20}$, or 60 in the former, and $\frac{20 \times 60}{30}$, or 40 in the latter; or, in other words, 59 and 39 divisions on the circle will correspond to 60 and 40 on the vernier respectively. Instruments reading to one minute of arc are divided to 30 minutes on the plate; in that case 29 circle spaces are equal to 30 vernier spaces.

The verniers should be covered with glass to protect them from exposure, and for ease in reading they should be provided with ground glass shades.

Our verniers are in such position that the observer need not step aside in order to read them, for we place them about 30 degrees from the line of collimation. The method of thus placing them has been pronounced objectionable, because the size of the plate level, which is at right angles to the line of collimation, and the more important of the two, has to be reduced. By examining our instruments, however, any one will see that we have attained the object without reducing its length, without placing it over the vernier, and without allowing it to extend materially beyond the circumference of the plate — all of which would be objectionable features.

The space between the circle and the vernier must appear, through a magnifying glass, like a fine black line. No accurate reading can be taken if the space appears wider than a mere line of *uniform* thickness under the revolution of the plate.

b. Clamp and Tangent Screws.

The lower clamp screw of our transit is of the best devised shape and arrangement. It is strong and rigid, and answers the slightest touch.

The upper clamp does not come in contact with the limb, but grasps the sleeve of the outside center. This is far preferable to the old method of pressing together the two plates by means of a screw placed at some point on the circumference.

The tangent screws are *single* only, and operate in metal cases against opposing springs. Great care has been bestowed in eliminating all lost motion of these screws. We consider double tangent screws, working against a tongue, as entirely obsolete. Any instrument sold today with double opposing tangent screws may be set down as antiquated and behind the times. It is absolutely necessary that everything tending to create lost motion must be carefully avoided. While adjusting the line of collimation, this source of error becomes very annoying, for, in revolving the telescope, the plate is liable to turn slightly and the operator is never sure whether the cross-hairs are in adjustment or not.

The arrangement of our tangent screws combine simplicity with absolute reliability. Being single, they require but one hand in manipulation, and their judicious location and spring case arrangement make them active and operative at any instant.

4. The Compass.

Our needle differs somewhat in shape from others, being a little smaller in the center than towards the ends, for the reason that the magnetic influence is manifested at the ends only, so that all the central metal may be called dead weight. Compared with those of other makers, the Lietz needle is, therefore, a little lighter, which conditions the increased durability of the point upon which it poises.

Hard steel has the capacity of retaining magnetism longer and better than when tempered, and for that reason we have adopted the plan of leaving one-half inch on both ends perfectly hard.

The closest attention is given to the center cap — which contains an agate setting—and to the pin upon which the needle rests, for the accuracy or sensitiveness depends principally upon these two details. These needles possess that degree of sensitiveness required in a high-grade instrument. A sluggish needle—one that will hang like a dead load—is not fit for the observation of a reliable azimuth.

The center pin must occupy the true center of the graduated circle, and must stand normal to its plane. We utilize precise instruments with high magnifying power to obtain the absolute true position of the pin, in order to avoid all errors due to eccentricity.

The *lifting arrangement* is applied with the view of raising and lowering the needle gently and gradually, as any sudden drop to the pin, or any quick action of arresting its motion, is sure to cause a rapid wearing of the point and the cap.

The *Compass* is divided into 30-minute divisions, and numbered from 0 to 90 degrees in each quadrant from the north and south points. This is done to conform with the usual practice of surveyors in this country to record bearings in the four quadrants. But any desired method of numbering the compass, either from 0 to 180 degrees, or from 0 to 360 degrees, may be had upon application.

In order to record at once the true bearings in the field, instead of the magnetic, the instrument can be provided with a *variation plate*, *i. e.*, an arrangement for laying off the local deviation of the needle by a movement of the graduated compass ring, so that the indicated course of a line shall show at once its relation to the true meridian. It is so made that the variation may be laid off with precision to the minute, by the aid of the instrument's vernier.

This is done in the following manner:

Having set the plate vernier to zero, adjust the instrument and, with the aid of a good reading glass, place it in such a direction that the north end of the needle shall point to the zero of the compass ring, which latter must coincide with the little pointer provided for that purpose. Having carefully set the instrument thusly by means of the lower clamp and its tangent screw, which can certainly be done to the nearest minute of arc, we release the clamp of the plate and proceed to lay off the amount of the local deviation of the needle in degrees and minutes by means of the plate-vernier—to the left if the variation be east. The instrument is now again in a fixed position, the telescope pointing to the true north, or as much to the left of the needle as the magnetic variation is east. We now insert the small phosphor-bronze pin supplied for that purpose on the side of the compass ring, and proceed to turn the ring until its zero shall coincide exactly with the north end of the needle, when every subsequent reading of the compass, in any position, will indicate the bearing of the vertical telescope axis from the true meridian.

This simple little device is fully up to the standard of accuracy required, for with care in setting the needle we can always obtain results correct within the nearest minute. We find that by this method the additional vernier, usually placed inside of the compass ring, becomes superfluous, as the plate and vernier of the transit are perfectly capable of taking care of the duties of this unnecessary accessory.

The variation plate has proven a great labor-saving device, as the observed courses require no reduction to the true meridian subsequently. It is now almost universally called for; and for those practitioners with whom land surveying is a specialty we should, by all means, recommend it as an indispensable feature.

5. The Standards and Vertical Arc.

The standards are so constructed as to give the maximum support to the telescope, commensurate with the size of the plate. They are light, but rigid and strong.

To avoid unequal expansion of the metal in the standards by exposure in the hot sun, which has a tendency to elevate one end of the telescope axis and to depress the other, vitiating the adjustment, they are now what is called cloth-finished. This finish, being a non-conductor of heat, reduces to a minimum this source of possible error, which, in very sensitive instruments, is of sufficient moment to be guarded against. Other parts of our instruments are also finished in the same manner, particularly Level telescopes, which we shall have reason to mention again hereafter.

The bearings for the telescope axis are made with extra care and attention.

The axes of the Lietz transit telescopes are cut to conical bearings, which is a feature altogether preferable to the corrugated shape frequently found in surveying instruments. The advantage of the former is very evident, in that there is less friction than by any other contact; and, in addition to that, it affords a much finer fitting by reason of its conical shape. But it is *very essential* that the *hardest metal* should be used for this purpose, as a material of insufficient hardness would soon wear, and the axes would become elliptical.

One of the standards is supplied with an adjusting device to regulate any inaccuracy in the motion of the telescope in the true vertical plane, when the centers of the instrument stand vertically.

One standard carries the arc for observing vertical angles, which may be either a full or a half-circle, as the customer desires. It is usually made to read to minutes, but may be graduated finer if so ordered. A clamp and tangent screw are provided on the right-hand standard, which are made like those already described for the horizontal movement. Every part of the vertical measuring apparatus is strongly and accurately made and fitted, to insure the best results in its practical application.

6. The Gradienter.

The head of the tangent screw of the vertical arc movement is made somewhat larger, properly silvered and graduated into a number of equal parts on its circumference, the thread of the screw being cut with great precision, so that its revolution may be accurately recorded by the divisions of the micrometer head.

One complete revolution of the screw corresponds to $^5/_{10}$ of a foot of difference in level in 100 feet. Since the head is divided into fifty parts, it follows that one division equals a difference of $^1/_{100}$ of a foot in 100 feet.

With this attachment grades may be established very quickly. It is only necessary to set the screw head to zero, level and clamp the telescope, and turn the screw up or down as many spaces as there are hundredths of a foot of rise or fall in one hundred feet of the grade to be laid out. With the small scale over the screw thrown back, the gradienter is used as an ordinary tangent screw. It is one of the most useful accessories, is easily applied, and adds nothing to the weight of the instrument.

This attachment is also useful in the determination of horizontal distances, it being obvious that the difference in rod reading between two complete revolutions of the screw will indicate at once the distance of the rod from the observer. Where the ground is level, or nearly so, the simple difference in rod reading will suffice; but when this is not the case, the necessary corrections will have to be applied to obtain the true horizontal distance.

7. The Spirit Levels.

We have already noted that for our purposes we import the very best article obtainable in Europe.

An instrument of precision, capable of measuring delicate differences, requires delicate and sensitive levels. This is so obvious that we ought not to call attention to it here, were it not for the fact that we are frequently approached by surveyors who wish to impress upon us the idea that this or that make of instrument met with their approval because its bubbles would stay in place when once adjusted. For this reason we want to repeat that it is no claim for superiority of a spirit level because it works sluggishly. An engineer in the field must know when his instrument is absolutely level, and its bubbles should indicate to him at once when this is not the case. If they do not do so, then the instrument does not come up to the required standard of a precise tool. It would hardly do to place a carpenter's level on a transit, yet we have no doubt that its excellent qualities of remaining stationary would find admirers.

Remember, also, that sluggish levels are cheaper, and that it is not to the instrument-maker's financial benefit to put in a delicate and, therefore, much more costly article.

There is, of course, a limit to the degree of sensitiveness, and that we never exceed, adapting it in all cases to the work demanded of the particular instrument in hand.

Our levels are ground to the proper curvature, and each is carefully tested upon our *level tester* before it is attached anywhere.*

8. The Telescope.

We have now reached another most essential feature of the instrument—that which may be compared to the head of the body, containing the delicate organ of sight—the lens.

a. The Lenses.

We have already called attention to the fact that our optical accessories are imported from Europe, and that we take great pains to obtain the best article for the purpose.

Without going into the detail of optical mathematics and formulæ, that can be readily found in any text-book on physics, we all know that it has been the constant aim to produce lenses as free from spherical and chromatic aberration as it is possible to make them. The lenses of the Lietz telescopes are of the celebrated Jena glass—an achievement in theoretical and practical science of which it would be interesting to make some explanation here.

The Jena Glass Works.

The far-famed glass melting works for optical and scientific purposes of Schott and Associates, in Jena, was founded in 1884 by men who were of eminent scientific attainments, and who based the magnificent industry upon long continued research in this particular field. Our information comes from a short description furnished by the leading men of the enterprise, which was published some time ago in connection with a list of the glass varieties manufactured.

The industry originated from a series of scientific investigations made for the purpose of determining, from their chemical combinations, the resulting optical properties of fusible compositions having an amorphous congelation. These experiments were undertaken by

* The telescope may be furnished with a reversible level.

Professor Abbé and Dr. Schott, to obtain information regarding the chemical and physical principles underlying the manufacture of optical glass. This work began in January, 1881, and was prosecuted in accordance with a prearranged plan in such wise: that Dr. Schott made the necessary melting tests at his home in Witten, while the optical investigations of the samples obtained were carried on in Jena by Professor Abbé, or his assistant, Dr. Riedel, by means of spectroscopic analysis.

The melting tests were made at that time on a very small scale (not over 300 to 900 grains in bulk), and were solely directed to the one object of studying carefully the influences of all chemical elements that may possibly obtain in any form in amorphous fusible compositions, upon the power of refraction and dispersion in their manifold combinations.

By carefully continuing the investigations in this manner to the end of the year 1881, a number of facts and data had been collected regarding the specific optical effect of certain masses, which gave promise of new glass combinations that, for certain purposes, would possess more advantageous characteristics than those offered by the ordinary crown and flint.

In order to utilize these results in practical optics as much as possible, it was decided to continue the work on a new plan, and that was: to combine systematically glass fusions on the optic-chemical principles established by the preceding experiments that should possess, as far as possible, all the desirable optical properties, together with other physical qualities fitting them specially for practical use, such as hardness, unchangeableness, freedom for color, etc.

With this end in view, Dr. Schott removed his residence to Jena in the spring of 1882, where a special laboratory, with every facility for melting, was fitted up in a building rented for the purpose.

With the aid of gas furnaces and modern blowing apparatus, it became possible to make melting tests on an amply large scale, up to quantities of about 25 pounds.

With the assistance of another chemist for the analytical investigations, which had to be carried on simultaneously with the synthetical work, and one workman, the tests were continued in this laboratory until the end of the year 1883, whereby two special lines of investigation were closely followed, which practical optics had laid out as the principal directions of research.

The first problem considered the making of crown and flint glass couples, possessing as near as possible a proportional dispersion in the various sections of the spectrum, for the purpose of obtaining a higher degree of achromatism than had heretofore been possible by employing the usual optical glass; that is, it was sought to obviate, or to reduce the very considerable secondary aberration, which the silicate glasses still permit in all their achromatic combinations, and which is due to the disproportionate dispersive powers in crown and flint.

The second problem—considered of no less importance, although the subject involved had, generally speaking, not been deemed a necessary feature in optics up to that time—consisted in obtaining a greater variety of gradations or modifications of the two principal constants in optical glasses, viz.: the exponent of refraction and the mean dispersion.

The silicate glasses in use at that time, true to the simplicity and uniformity of their chemical constituents, show images of a simple series in which, ascending from the lightest crown to the heaviest flint, the dispersion increases in the same measure as the exponent of refraction increases, up to very small and practically immaterial deviations.

But the theoretical consideration of dioptric questions establishes without doubt, that it would simplify greatly this problem, in which numerous conditions are to be fulfilled at the same time, if the optician had his choice of *such* glasses, in which the dispersion with the same index of refraction, or the index of refraction with a constant dispersion, could be made to undergo a very considerable gradation. In this direction it must be looked upon as a progressive step, that the systematic use of a greater number of chemical elements in glass fusions makes it possible to create the varying grades referred to—that is, it enables one to extend the variety of glasses at disposal, in some places at least, in two dimensions, which heretofore had been essentially linear in character; but the realization of this advance in practice may only be expected gradually, because of the necessity of supplying further theoretical and mathematical bases for these productions.

The experiments led to the most satisfactory results, which, for the purpose of our catalogue, it would be unimportant to elaborate in further detail; suffice it to say that the faithful endeavors of these men were universally appreciated, and that their conclusions gained the fullest confidence of those who were best able to judge of the value of their labors.

The results were reached in the autumn of 1883, and the entire research would have been completed then, had it not been for the instigation on the part of several prominent scientists, that the investigators take hold of the practical application of their theoretical achievements themselves, and to begin the industrial production of this article immediately in connection with the preceding laboratory research.

This finally led to the erection of glass melting works at Jena, with all the facilities for successful practical operation, established with the coöperation of Doctors Carl and Rod. Zeiss, who had previously given valuable assistance in the preliminary investigations. In the autumn of 1884 the factory was in condition to prepare for the production of optic glass on a large scale—both of the kind previously in use, as well as that of the newly created combinations.

To carry out the necessary and very expensive experiments on a factory scale, it was fortunate that means were furnished by a number of liberal appropriations granted from the Prussian State Treasury, which received the hearty endorsement of all scientific circles.

After surmounting great and numerous difficulties, naturally retarding the progress in a new technical field, in which the enterprise is thrown entirely upon its own resources, without any assistance from previous experience, the Jena factory has now become a successful industry that has made its way to remain as a valuable permanent feature. Its capabilities have been sufficiently tested during the last eight years, in the intercourse with most of the optical works in Europe, so that it is now fully able to compete with them on a commercial basis.

These remarks on the Jena glass factory will convince the reader that the article deserves that general preference which is universally given it—its evolution is one based upon a true scientific foundation—for, in this case, the practical application depended entirely upon a previous theoretical research, and theory and practice must work hand in hand to achieve lasting results. A new era in optics began when the Jena glass became a merchantable article. And this new optical advance was not without effect upon those fields of science in which optical apparatus is used, for the achievements in one particular line alone—in microscopy—received a fresh impulse from that time, which was again felt in other departments, as in physiology, biology, bacteriology, hygiene—those most important to the welfare of man.

This short diversion leads us again to the subject of the telescope for engineering purposes, with which we are more particularly concerned.

b. The Object Glass.

Arrangements have been made by which our lenses are specially ground for us in Europe, and not one is accepted that will not stand the most critical test. We receive objectives and eye-pieces in sets at stated periods, so that we are always in position to supply our demand. Neither time, trouble nor expense has been spared to produce a telescope up to the standard of the most approved pattern, that shall possess all the refinement required of an instrument designed for scientific work.

The objective is formed by a combination of two lenses, a crown and a flint glass, one of which is biconvex, the other plano-concave. The inner faces have the same curvature. As the concave lens has the longer focal length, this combination maintains the characteristics of one convex lens. The focal lengths are so proportioned that the dispersion caused by the crown-glass lens is corrected by the flint—the well-known principle of counteracting the dispersion of light of one lens by interposing another of a different glass is made use of.

Our objectives possess these achromatic lenses, made of the Jena glass, with special care, by the most skillful opticians. The focal lengths of these objectives vary from 17½ inches, in the case of the large Y-level, to 10 inches, in the large transit, and to 7½ inches in the smaller instrument.

In mounting the two lenses in the cell, great care is taken that their axes are made to coincide. Should this important point be neglected, an indistinctness of image would be likely to result.

c. The Eye-Piece.

The simplest form is the so-called Ramsden eye-piece, in which two plano-convex lenses are mounted so as to turn the convex surfaces toward each other. The distance between them is such that the chromatic aberration of one lense is corrected by the other—which, however, is not fully accomplished.

Another form of eye-piece was invented by the optician Karl Kellner, of Wetzlar, and fully described in a paper published in 1849. It was called the orthoscopic ocular (from ορθος straight, and σκοπεω observe), by reason of its principal advantageous feature of furnishing of every object a straight, perspectively correct, and, in every extent, sharp and well-defined image. The Kellner eye-piece also consists of two lenses: a biconvex collective, of which the flatter curvature is turned toward the objective, and an achromatic eye-glass, whose construction is similar to the Fraunhofer achromatic lens. According to the inventor's description, the three lenses used in this eye-piece possess only four reflecting surfaces, and the two lenses composing the eye-glass must therefore come in absolute contact with each other. There may be two forms of the eye-lens: a plano-convex, with the curved face towards the collective; and the double-convex.

An ocular of this order, wherein both the collective and the eye-lens are compound, is the Steinheil eye-piece, which is doubly achromatic, but which gives a very flat field.

These forms of positive eye-pieces, wherein the focus of the objective lies in front of the combination, together with several of the negative form (the Huyghens and the Airy), wherein the objective's focus lies between the two lenses, give an inverted image, which is considered by many as an undesirable feature in surveying instruments. Nevertheless, they possess many valuable points in their favor, and for that reason they are universally adopted in Europe. In the first place this form admits of a greater amount of light than the erecting eye-piece. It also allows a longer focal length to the object glass, which is very important in correcting spherical aberration, besides increasing the magnifying power, which is a value dependent upon the ratio of the focal lengths of the object glass and eye-piece.

We have always considered this inverting form the more advantageous of the two; and we are convinced that if our engineers would accustom themselves to its use, it would finally be preferred. There is absolutely no difficulty in the inverted position of objects, and it is remarkable with how little effort the mind adjusts itself to it, so that the work may be done just as expeditiously as though the observer saw the objects erect.

But, as the erecting eye-piece is in general demand, we do not intend to introduce the inverting one; all that we wish to point out is that the latter possesses many advantages not generally sufficiently considered, and that seeing objects upside down is not an obstacle at all, for upside down and right side up are only relative impressions, which impose no task upon the brain. If the professors of civil engineering in our colleges would draw more attention to these facts, the results would soon be quite gratifying.

The erecting or terrestrial eye-pieces require four lenses, placed so as to correct the chromatic aberration. In this form the inverted image of the object glass is again inverted, and an erect one is created between the third and fourth lens, which is viewed and magnified by the fourth. This is the form used for our transits and levels, and we can again insure our patrons that in this line nothing better is produced. The optical powers of the telescope are in perfect keeping with the accuracy of the centers, graduation and spirit levels, insuring a complete reliability and harmony in every part of the instrument for the most refined surveying work.

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 backward or forward—a manner which affords a finer and more precise focusing of the cross-wires than by means of a rack and pinion.

Having reviewed generally the optical details of the telescope, we shall describe in a few words the mechanical construction of its other parts.

d. Other Parts of Telescope.

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

The sliding tube is protected from dust and dirt by an exterior metal cylinder, called the *slide protector.*

A *sun shade* is provided for the objective, which should always be attached, as the telescope, when focused to mean distance, is balanced with it; and a cap is provided for the protection of the objective when not in use.

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

The *spider web* used for our instruments is properly treated to avoid all twist, and to prevent its lengthening and becoming crooked in damp weather; it cannot become loose, as it is well secured.

For mining and tunnel transits we can provide proper means for *illuminating* the cross-wires—an arrangement that is readily supplied upon application.

Quite a number of *glass diaphragms* have been cut by us for the United States Coast and Geodetic Survey. Instead of the spider webs, a small disc of very thin glass is fastened to the diaphragm, on which fine lines have been drawn with a diamond. It is readily seen that these cannot get out of shape, and for stadia measurements we think them of great advantage. The only drawback is that small particles of dust may settle on the glass disc, and, as they are in the focus of the eye-piece, they will be constantly visible to the observer.

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

Stadia hairs are placed in our transits (and levels), when ordered. We have superior facilities for setting them with great precision to any desired ratio between distance and rod reading. It is customary to place them so that they shall read 1 foot on the rod for a distance of 100 feet, and to this measure we always have them in our stock on hand.

The stadia hairs may be *fixed* or *adjustable*. We advise the fixed, as they are less liable to change their distance. In an adjustable set the observer is never certain that the position of the wires has remained unchanged. We have constructed a delicate optical and mechanical apparatus for fixing stadia hairs accurately to any proportion; and by means of our powerful telescope, which has superior optical qualities, we can safely say that, with proper care and a little experience in that method of measuring, very satisfactory results may be obtained. The facilities for measuring across inaccessible places, and the speed with which it enables one to get distances, has brought this method into deserved prominence with our engineers. For topographical surveys it is indispensable.

For the benefit of our patrons we have added a short treatise on stadia measurements, together with a table for correcting the observed reading to the horizontal distance and difference in level, which see under professional papers.

When purchasing a new instrument, it is advisable to get one that has fixed stadia wires, which increases the cost only $3, while we charge $10 to put them into a transit or level sent to us subsequently.

In sighting with the telescope it is of considerable advantage to have it *reversible,* and our transits are made so as to allow this free revolution in a vertical plane. The telescope balances accurately when in focus to mean distance, the friction in the bearings being shaded to such a degree of nicety that it shall neither work too hard nor too loose—a feature which ought to have very close attention.

e.—General Remarks about Telescopes.

When selecting or examining an instrument, the engineer should be particularly careful to test the qualities of the telescope.

It should have sufficient magnifying power to correspond with the finer qualities of the graduation, axis, centers, spirit levels, etc., of the instrument. There can be no doubt that the excellencies of each detail must compare with that of any other.

Now, by using a low-power telescope, the *defects* of an *inferior instrument may be hidden, or left undiscoverable,* and for this reason they will always be found in articles of lower grade. Had such an instrument lenses of sufficient magnifying power, the defects would become apparent to the engineer at once. We lay the greatest importance upon these facts, and for this reason call particular attention to them. *Scrutinize the optical abilities of the telescope, and you will obtain the character of the whole instrument.*

For obvious reasons, some makers—but more especially dealers—give the magnifying power of the telescopes of their instruments much higher than it really is. An engineer should, therefore, be careful to convince *himself* of the real magnifying power before making a purchase. He will find it much to his interest to do so.

We have found that the power of first-class instruments should be about twice as many diameters as the length of telescope expressed in inches. In inverting telescopes it may be materially increased, which shows again that they are of considerable importance in very high grade instruments.

In another place we have added a practical method for finding the magnifying power of a telescope, to which we would advise our engineers to give some attention, and to make use of when about to choose an instrument.

We have already pointed out the importance of perfectly centering the lenses, especially the objective. If this is not properly attended to, the adjustment can never be perfected for long and short distances.

We have heard many complaints of various makes about the change in adjustment, and after careful examination we have found that the adjustments remained intact, but that the fault lay in the objective, which had not been correctly centered. We take great pains to center our object glasses perfectly, and to insert the lenses in such a manner that if taken out they may be replaced in the old position, which is secured by a notch and a pin. It is not advisable for engineers, however, to take these lenses from the cell, as their cleaning may be effected without removing them.

Reverting again to the magnifying power of telescopes, it may be asserted that an increase thereof reduces the field. This is no defect, if the size of the latter is retained large enough to admit of stadia lines so placed as to read 1:100. We often leave the field much larger, however, in which case there appears just a slight dimness at the extreme border; this is unimportant, for it does not retract any of the virtues of the glass, and possesses, if anything, an advantage of finding an object more readily.

The quality of some of the telescopes of our best makers has often been questioned by competent engineers on account of a peculiar haze ascribed to the glass. This was found to be caused by a small film of moisture, which settles between the crown and the flint, and is not visible to the naked eye. We have been convinced, by advising with our optician, that the crown and flint glasses should always be connected with balsam. This does not decrease the amount of light, as formerly thought, but, on the contrary, it has advantages of clearness, in that it prevents foreign matter from settling between the lenses, which always destroys the image; the refrangibility, too, is under more favorable conditions in the balsam.

Extra Accessories for the Transit.

There are a number of additions made for transits used for special purposes, and these we keep on hand, and supply them when called for.

For *laying off right-angles,* for instance, we can make any provision, if the customer will order it in time. In fact, any of the accessories, not usual in the ordinary complete field instrument, will be made as an extra if our patrons will notify us.

For the *solar attachment* we provide a block with a thread on the telescope axis to receive these beautiful little apparatuses of which complete descriptions will be found later.

The Finish.

This is made to give the instrument an elegant, tasteful appearance, without adopting a color glaring to the eye. Our instruments are finished in a number of hues, and may be bronzed to the special taste of the purchaser, if he chooses to order it.

Size of Transit.

The dimensions and proportions of the several parts of the transit are given in Part II of this catalogue, where the different sizes and varieties of instruments made are described more in detail.

Packing.

This is not at all an unimportant feature. Our transit is easily taken from the tripod by means of the Lietz friction coupling already described, and set upon a wooden slide, to which it is fastened by means of two thumb screws and wooden clutches—a manipulation requiring but a moment's time. Nothing is taken from the instrument except the shade—it remains a complete whole from the base-plate to the top of the telescope. The board slides into the box with the transit in an upright position, with the clamps secured to keep it from turning. An extra place is provided for the solar attachment, if there be one. The door may then be locked, and the instrument is absolutely safe, with the least effort of packing and adjusting in the box.

Rubber cushions are provided at the bottom of the case, to take up any sudden jar or jolt to which it may be exposed during transportation.

A rubber bag, or a silken one, may be had as an extra to each instrument, as well as a bottle of fine watch oil for lubrication of centers, etc., and camel-hair brushes for dusting. Likewise are a number of adjusting pins supplied.

The Tripod.

We have adopted the new form of *split leg*—a construction which combines the greatest stiffness and strength with the least weight. The old form of the heavy solid leg has long since been abandoned, and we no longer make such a tripod, unless specially ordered by some conservative customer, or for very small instruments. We aim to reduce the weight of everything, without sacrificing steadiness or strength in any particular, and that the split leg meets these conditions better than the solid one must stand to reason.

The very best white ash is chosen and carefully worked. Instead of fitting the leg between two brass cheeks, we fit one cheek in the leg. In the older construction it frequently happened, in drawing the bolts closer to tighten a loose leg, that the cheeks would spring the plate, or weaken the screws that hold it. This is entirely obviated by the new arrangement of these parts, for the tightening can no longer affect the plate in the least. While in the former the leg would only fit at the lower part of the cheeks when drawn in by the bolt, it will always fit the whole surface of the cheek in the plan we follow, and after ten years' use it will be just as steady as when new.

The *shoes* are made on a gradual taper to a sharp point, and securely fastened to the leg. They are provided with a projection for pressing upon with the foot when setting up.

The large transit and the level fit the same tripod—in fact, any Lietz instrument may be readily fitted upon the tripod we manufacture, for the adjustment of the friction coupling allows a perfect accommodation to any slight variation in the parts of the base-plate.

LEVELING INTRUMENTS.

Lietz levels are manufactured in two different varieties, which we aim to keep constantly in stock, the *Y-level* and the *dumpy level.*

In the manner of making these instruments, much that has been said of the transit will hold good here, and need not be repeated.

The three main qualities to be secured in a level are: *stability*, a *sensitive bubble* and a *powerful telescope.*

To secure the first, we need only refer to the solid construction of the star-shaped casting through which the leveling screws operate, already described in speaking of that feature in the transit. The Lietz coupling, too, plays an important part here, for we can make the tripod connection absolutely rigid.

The *center,* or spindle, is almost three and one-half inches long, and is continued through the clamp up to the bar, which enables us to bring the center of gravity as near as possible to the tripod head. Great care is exercised in fitting the center to the socket, and, being made of the hardest composition, it must 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 soft centers, and the fretting of the same, also likely to happen at times, is altogether avoided.

The reasons for having a *sensitive bubble* have also been carefully set forth heretofore. Accurate work cannot be done with a sluggish bubble. No matter how much the virtues of the staying qualities may be extolled by some men, they are not fit for refined work if they do not answer the slightest touch of the leveling screw. If you can give a screw a twist or two before the bubble loses its peaceful equanimity, the work in hand would not be likely to inspire any great confidence.

Our level tube* is curved, so as to give for every two minutes of arc a one-inch motion of the bubble. A refined level of this character, however, will only do good service in an instrument having perfect steadiness and a powerful and sharply defining telescope. If placed in a level so constructed as to be topheavy, or in one whose center is frequently exposed by being a part of the tripod head—and therefore liable to collect dust both on the cone and in the socket, introducing sources of error after every detachment—then it will indeed prove very annoying, should an active bubble accompany such an instrument. These structural defects are probably the cause why many of our engineers are prejudiced against sensitive levels, and prefer a sluggish or dull one. We can only assure the reader again that a lively bubble,

* Also furnished reversible for extreme accuracy.

even if a little out of center by reversing the instrument, will still accomplish better results than an inactive one—one that gives the instrument an appearance of steadiness, which in reality it is far from possessing. An engineer only deceives himself if he trusts to a slowly acting level, which gives apparent satisfaction by concealing the errors that a sensitive one would soon indicate. A well-made instrument never suffers by having its qualities exposed by a high-grade bubble.

The level *telescope* should have power and definition. It is hardly necessary to make that statement, after all that has been said on this subject in a previous chapter. It has been our earnest endeavor to obtain these results, without increasing the dimensions of the telescope and the other parts of the instrument, beyond the proper limits for steadiness and portability. A length of eighteen inches we have found to give the most advantageous results. Experience has shown us, that although an increased length adds to the magnifying power, it would only be of value if the other parts of the instrument were enlarged in proportion, which, on the other hand, would make it too heavy for convenience in carrying and offer more surface to the wind, thereby reducing steadiness, we believe that with our 18-inch level even the most extensive requirements in engineering are fully met.

Our new and improved eye-piece, and the use of an objective of larger diameter than ordinarily found, enable us to obtain a magnifying power of 33. An increase of diameter adds very little to the weight of the telescope, and does not require a longer bar and larger plates, as an increase in length necessarily would, to retain steadiness. An aperture of 1⅜ inches, used to its full value, affords a high illumination with the above-mentioned power, as the tube is large enough to let all the rays proceeding from the object glass pass through to the field of view—an important point disregarded by a number of manufacturers.

The diameter of the aperture of the object glass divided by the power, gives the diameter of the pencil of light entering the eye. In our telescope we obtain, therefore, $1\frac{3}{8} \div 33 = {}^1/_{24}$ of an inch, which shows that power and brightness are in accordance with optical law. To force the power beyond these limits we cannot conscientiously do, as that would be allowable only under certain circumstances—such as a perfectly clear atmosphere with a strong illumination of the object.

The *collars,* upon which the telescope rests in the Ys, are made of the hardest bell metal, and admit of a position in either direction, that is, the telescope is reversible. The very first requisite is that these collars must be of exactly *equal diameter* and *perfect cylinders.* If this be not the case, the line of collimation will not be parallel to a tangent of the bubble's curve at its highest point, when the latter indicates a horizontal position, and, for this reason, a true level cannot be obtained with such an instrument.

It is very often believed that in the course of adjusting the Y-level, by reversal of telescope and revolving on center, the bubble will indicate any inequality of the collars, but this is by no means true. If the Ys are both filed out to the same angle (this is generally the case, or at least very nearly so, as most makers file them out by means of gauges), the *inequality* of the collars may be quite appreciable, and yet the instrument will be adjustable in all its parts; in other words, it may be so adjusted that the bubble on all reversals in the Ys and revolutions on center, will always give the same reading at both ends, that is, indicate a true horizontal position. A final test is necessary, therefore, after the instrument is properly adjusted, to ascertain the equality of the collars. This will be mentioned further on under the head of adjustments.

Similar causes for error are introduced if a particle of sand lodges between the collar and Y, which illustrates the necessity of keeping these parts free from all dust and dirt.

It is readily demonstrated to what considerable difference any slight inequality in the diameters of the collars may give rise to, but the space here will not permit of a mathematical discussion of the subject.

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. Numerous cases have come under our observation, where this fault existed in a remarkable degree. And in the perusal of many works on engineering and surveying, we have noticed very few that call attention to this material defect, and still less that give a correct test for it.

We are aware that accurate leveling may be done with a level out of adjustment, if the utmost precaution is taken to have equi-distant fore- and backsight. But looking at it from this point of view, why not use the dumpy level then, instead of the more costly Y-level?

The Finish is made to give the instrument an elegant appearance, and yet obtain all the qualities alluded to in a previous discussion of the same subject. The telescope is usually *cloth finished* to avoid that unequal expansion of the metal heretofore mentioned. This finish is of a color pleasing to the eye, is applied so that it remains intact for a long time, and if somewhat worn after a long period of exposure, it can be readily reapplied without difficulty at a trifling expenditure. The cloth finish is a modern feature, and one that is so universally preferred, that we have no hesitation in recommending it to our patrons as worthy of their consideration. However, we keep in stock the bronzed and lacquered, as well as the cloth-finished level telescopes, so that the customer may have his choice in the matter.

The level telescope is supplied with a *slide protector* and with a *sunshade;* the latter should always be put on to balance it evenly. A cap is also provided for the objective and a shutter for the eye-lens.

In all other matters the transit details obtain here also.

Fixed stadia wires are supplied, set to read 1:100, for which an extra charge is made if ordered.

The center movement is checked and regulated by a *clamp* and *tangent screw,* exactly similar to those of the transit.

Other useful accessories are attached, but any feature not usually found in the Y-level, must be ordered beforehand. If desired, we place *agate fittings* in the Ys for the collar contact, but for this we also make an extra charge.

We are likewise in a position to make, but upon order only, *levels of precision* for the most exact work that the geodetic surveyor is called upon to perform. These are provided with all the delicate details that such an instrument must possess. We invite correspondence upon the subject of geodetic instruments, and will cheerfully furnish prices after consulting with our patron upon the nature and character of the instrument required.

The *packing* in the case has been made so as to assure safety in transportation, with the least trouble and inconvenience to the operator. The level is taken from the tripod by a third of a revolution of the base plate, which undoes the Lietz Coupling. It is let down to stand upright in the box, when the closing of the lid holds everything firmly in place. In all minor details the level box is similar to the transit case, every means being employed to insure absolute safety.

The Dumpy Level.

In this instrument the aim has been to construct it in such a manner that it shall be as compact as possible by dispensing with certain features of the Y-level, not absolutely necessary in order to do good and reliable work.

The principles governing its construction are the same as those that obtain in the more elaborate Y-instrument.

The telescope is permanently held by two vertical arms attached to the level bar, and cannot be taken therefrom. The level tube rests upon these arms, over the telescope, and is also fixed. The telescope tube is thereby brought as close as possible to the tripod head, which is a desirable characteristic. All the other features remain the same as in the Y-level construction.

This instrument, which is almost exclusively used in Europe, has not yet met with that favor by American engineers, which its simplicity and accuracy so justly deserves. This is due partly to its greater inconvenience in adjusting as compared with the Y-level, and partly on account of defective construction, inferior telescope and other neglected details, which usually obtain in instruments of this kind.

We are confident 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 made more readily, the former will *retain* it longer.

Our dumpy level has a bronze center, a 15-inch telescope, and a vial of such curvature, as to give for each inch of motion of the bubble an angle of three minutes.

There is no clamp or tangent screw to this form unless ordered by the customer.

The bar, telescope and vial case are cloth finished, and the latter may be provided with a folding mirror, which acts as an important protection to the more exposed spirit level when shut down, or as an indicator to the observer at the eye-piece, of the exact position of the bubble, when elevated.

The stadia hairs may also be supplied to the dumpy level.

Other Levels on Sale.

In addition to the high grade instruments described, we also keep on hand a supply of smaller and less costly goods for leveling. With these instruments work may be done by the ditcher, irrigator, contractor, grader, farmer, dike-builder, gardener, plumber, architect, forester and military man, sufficiently precise for many ordinary purposes, wherein great accuracy is not required.

For a more detailed description of these instruments, see Part II of this catalogue, containing a price list of articles on sale.

Remarks.

In the foregoing we have endeavored to give the reader a fair idea of the principal engineering instruments made by this firm. We desire to convince our future customers—our old patrons we have long since convinced—that we are building conscientiously upon scientific principles, that every part and detail has been carefully studied to meet the requirements of our engineering fraternity, of the climate, and of all those conditions that influence the shape and character of every feature of the surveying instrument. It must permit of all operations at the least expenditure of time, it must be compact, it must be light, it must be absolutely accurate, it must be rigid, it must be stable and it must possess strength. And wherever a possible improvement is suggested in any detail, it must be applied at once and tested as to its probable merits, and if it prove of value, no time must be lost in introducing it. These are the principles that have governed the manufacture of the articles which we have brought to your notice.

New improvements have always had our attention, without any regard of the expenses incurred in experimenting. We need only refer to the introduction of aluminum in the manufacture of surveying instruments, which, we are fully convinced, has been crowned with success, to prove to our patrons that we never allow any conservative notion to rule the establishment. The particulars of this new field of manufacture will be found in another chapter of this part of the Manual.

With the object constantly in view to make only the very best article that can be procured anywhere, and ever ready to introduce improvements and to experiment with suggestions that may lead to them, our instruments are held at a price that is commensurate with their qualities. Their values are rated by those current among first-class instrument makers; they are *no more,* but they are *no less.* We do not handle cheap goods, and the trade that we are most anxious to please is that *willing to pay a fair price for a number-one article.*

It was our purpose to describe in this catalogue only the instruments for which there exists the greatest demand, and for this reason we do not intend, at this time, to enter into any detail of the manufacture of other scientific apparatus that we are in position to furnish upon due notice.

Theodolites of the highest grade for the most exact purpose, reading with micrometers to the most refined division, will be made upon order to any desired shape and design, and with every required accessory.

We also manufacture the topographer's *plane-table,* either in its simplest form, as recently perfected by the highest authorities, or in its most delicate arrangement of parts, as devised for work of the greatest precision capable of being put on paper. A number of plane-tables made for our institutions of learning, and for surveying departments of the U. S. Government, have given absolute satisfaction, as shown by testimonials in our possession.

The modern improved plane-table alidade is a particular specialty, to which we have given considerable time and attention. This instrument has been constructed by us of aluminum, which has been a perfect success, proven by the fact that one of them has been almost daily in use for many years, under very trying conditions, without giving rise to the first complaint. Under the head of *Aluminum for Surveying Instruments,* this will be again referred to. By a combination of aluminum and aluminum bronze, the center of gravity of the alidade may be brought close to the foot of the standard, which is a very essential point in its construction.

ALUMINUM FOR SURVEYING INSTRUMENTS.

A great deal has been said and written about this comparatively new metal of late, so that its characteristics have become generally known.

Its color is a dull white, similar to silver, and rather pleasing to the eye. It embodies many qualities that make it a very valuable material in the mechanic arts. It is quite soft, but possesses malleability, tenacity and ductility, so that it may be made into very thin sheets, or drawn out into fine wire. It is a conductor of heat and electricity. One of its principal features is that it does not oxydize in the atmosphere, and that it does not lose its brightness under conditions that would tarnish silver and blacken it, for sulphuretted hydrogen or sulphide of ammonium do not influence its color. But the greatest advantage is its remarkable light weight, the specific gravity being only 2.6, or one-fourth of that of silver, and for this particular quality its use has been sought in the manufacture of articles requiring small weight, ever since the cost of its production has justified it.

One of the many alloys is the so-called aluminum bronze, which unites hardness with malleability, and is therefore extensively used for many purposes. This alloy, however, gains little in lightness as compared with the ordinary metals.

Since it has been the constant aim to produce field instruments that shall combine strength with the least practical weight, there could not have been found a better application for aluminum than in the instrument-maker's art.

It was necessary to experiment with it in different directions, particularly as to the proper alloy—it being much too soft in its pure state—that shall give the required tensile strength and stiffness, make it workable without fretting, and yet add little to its weigh. An alloy with silver is now made that fully satisfies these conditions.

One of the principal objections urged against it in the manufacture of surveying instruments is, that on account of extreme lightness they would not be steady enough in the wind. This firm has built over 1000 transits and levels of aluminum, and, in our opinion, they are quite as rigid as any other, if properly constructed, care being taken to adhere to the old material in such details where it cannot be dispensed with.* We have found that the stability of an instrument depends more particularly upon the construction of its lower parts. If the combination of base-plate and leveling apparatus be made so that the instrument can be rigidly held, the center of gravity may be brought down lower, and that in itself would tend to increase its stability.

Aluminum transits are made by the A. Lietz Company in three sizes, being complete field instruments with every accessory. The large transit weighs 7½ pounds, and the smaller one 3 pounds, which reduces the weight about one-half. The construction is precisely the same as in the instruments already described.

The base-plate is of composition metal, the inner center of the hardest bell metal, and the outer center of bronze. The leveling screws are also of composition, as well as the telescope axis.

These transits may either be left in the beautiful natural color of the metal, or other shades may be applied. The standards are cloth-finished.

The *Lietz Telescopic Solar Attachment is now made of aluminum,* which can only be an improvement in any direction, whether its weight be added to the top of a transit made of the red metal, or to one of the new metal. Lightness in the solar attachment is a very desirable feature, and that may be easily obtained now.

In the *Y-level* the base-plate and leveling screws and center are of composition metal; the collars, the hardest bell metal; and the rest, aluminum. It has an 18-inch telescope, its weight being 5½ pounds.

We also manufacture a *plane-table alidade* of aluminum, with a ruler of aluminum bronze. This instrument, although of the same weight as one of the ordinary metal of the same size, possesses the particular advantage of having its center of gravity as low as it can possibly be brought to the table, and that when placed upon the board

* See Testimonials for instruments made of our aluminum alloy, on fly-leaves.

it will be absolutely stable, and will not be influenced by the wind, which causes the ordinary alidade to tremble and travel on the paper.

And this is the reason why we should object very strongly to an aluminum rule in a plane-table alidade. This part of the alidade should be of heavy material, as well as the lower part of the standard, while the rest may be constructed as lightly as possible. In this case little or nothing may be gained in the weight, but very much is gained in stability, when compared with an instrument made of one metal throughout. Under no condition should the RULE, which is the BASE of the structure, be made of a light material.

After twenty years of experience in the construction of aluminum surveying instruments, we are ready to advocate the *judicious* use of this material. We have applied it in transits and levels, and have accomplished a saving in weight of about 50 per cent. Great care is exercised in the proper distribution of the metal. We have already stated that in a transit aluminum is never used in the construction of the base-plate, centers, leveling screws, telescope axes and all minor parts having threads. The principal horizontal members, the plates, are of aluminum, strongly ribbed.

Much has been written about its high coefficient of expansion, and particular stress has been laid upon the effect of unequal expansion necessarily induced by the use of different metals. If this matter be considered for one moment, however, it will soon be seen that practically there can be no serious result from this source. In the first place, the difference between the coefficients of brass and aluminum is altogether too small* that the effect of any possible distortion in material judiciously placed need necessarily be feared. Glass plays a very important part in the make-up of a transit. The coefficient of expansion in glass is very low (0.8 mm. per meter, raised 100° C) and a metal best adapted for our purpose would be one having the same coefficient. Now, as far as brass and aluminum are concerned, it is readily seen that there is practically no difference in them when compared with glass. As long as glass is used, one may as well employ aluminum as brass for the constructive parts, for while the expansion of the latter exceeds that of glass 0.000072 inches per linear foot for 1° Fahrenheit, that of the former does so only by 0.000103. Unequal expansion, therefore, is not a source of error that need reasonably be feared.

The more vital objection to a light instrument—its greater un-

* (The Physical Laboratory of the German Empire has established the following: For brass 1.88 mm. per meter of length, raised in temperature 100° C; for aluminum 2.34. Our reductions are made from these data.)

steadiness in the wind when compared with a heavier make—is something we have already referred to. We have made and sold over 1000 aluminum transits and levels, and every one has been a proof of our statement made twenty years ago: that the stability depends more upon the construction of its base and connection with the tripod than it does upon the weight of what may be called its superstructure—the part above the leveling head.

It may also be mentioned incidentally that a fall will injure an aluminum instrument less than if made of red metal. Not only is this theoretically correct, but our actual experience in this line has proven to us the fact that from ordinary accidents the lighter instruments are always less seriously injured than the heavier ones.

The testimonials from our customers will show the public that the aluminum instruments made by our firm have given the fullest satisfaction, and have not disappointed our expectations.

We are firmly convinced of the adaptability of aluminum for surveying instruments, and for that reason our firm has gone extensively into that branch of manufacture, for which every facility has been added recently to the capacities of the shop. The aluminum instrument is fifty per cent. lighter than the other, is just as strong, is just as precise in its workings, possesses every requisite detail of a complete field instrument, and, *we claim,* is just as stable. Those of the engineering fraternity who have to carry the transit all day, the mining and railway men, who climb the mountain sides during the long summer days from early until dark, will not be long in finding out these advantages and in putting them to a severe test in every direction. After manufacturing aluminum instruments for fifteen years we have had no occasion to regret it, and find constant encouragement from the best professional men.

CARE OF INSTRUMENTS.

The greatest source of danger to a delicate instrument is *careless handling.* It is often subjected to violent usages for which there is absolutely no need. The rude way of manipulating its delicate parts; the unnecessary display of digital strength in operating a clamp; the useless strain applied to the leveling screws; the careless manner of carrying it; the rough method of taking it out of its case, or replacing it; and the incautious closing of a lid or door of a box by force, before the instrument is somewhat adjusted to its position; all these are sources of danger that vitiate its adjustments and cause no end of trouble and expense. Although a well-made instrument is so designed as to stand many a shock without direct injury, any daily repeated abuse is sure to have its ill effect, from which your work must suffer.

As the usefulness of a transit or level may be preserved for many years by a little attention to details, we shall enumerate a few of the principal points which the engineer will do well to observe.

Always protect your instrument from rain by throwing over it a waterproof bag; and if it gets wet at all, clean it thoroughly after getting under shelter. It is not well to enter a hot room from the cold air, without giving it some protection. The condensing vapor settling on the metal and glasses is certain to give rise to injuries. It is always safe to place the instrument in its case before going into a warm room in winter. It is not wise to leave your transit or level exposed for hours to the hot sun. Shade must be given either by a hood thrown over the instrument, or by holding an umbrella.

But accidents are liable to happen, and for that reason we have noted down a few remedies in case of an emergency.

The general tendency in the use of the screws is to overstrain them. This should never be done, especially with the cross-wire screws, which, when brought up too tight, are liable to constant change and loss of adjustment. The leveling and clamp screws, if overstrained, wear out sooner and may show fretting. If this takes place, they should be taken out and brushed with a little coal oil or benzine. The nuts are best cleaned by screwing a flat piece of soft wood through their apertures. In putting them together oil 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 then 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. Should the fretting occur in the centers (if 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 be not effective, place a washer, made of paper or a thin card, between the shoulders. This will cause a shake, making accuracy impossible, and will introduce errors of parallax in reading off, which is better, however, than to destroy the centers wholly. The best unguent for them is very fine watch oil. Regarding *our centers,* we are fully prepared to *assure* our customers that *no fretting will ever happen,* as they are never exposed, and made with the utmost care.

The object-slide should not be oiled. Never, under any condition, use emery in trying to repair an instrument, as it cannot be removed again and will grind continually.

An efficient lubricant for leveling screws, clamps, pinions, etc., is well-rendered marrow.

If an instrument is upset, thereby bending centers and plates, do not turn it unnecessarily, as this will disfigure the graduation, but send it to a competent instrument maker immediately. There should be no delay in repairing defects.

In the matter of the tripod, it is wise to look to the screws that hold the legs frequently, and to keep them well tightened up; and to inspect the shoes, to see that they do not come loose. An instrument cannot be steady if there is any shake in the tripod, which is its support and must be firm in every particular.

The graduation is a very delicate detail to handle, and should be approached only with the utmost care. It is safe to leave this part to the instrument maker, and not to attempt to remove the plates, as they cannot be properly recentered without the aid of a testing apparatus. An exposed graduation may be cleaned with a little watch oil and a chamois skin, taking care not to touch the edges while this is done.

To preserve the sensitiveness of the *needle,* the center pin must be prevented from becoming dull. The instrument should never be lifted without raising and arresting the needle, and if, upon letting it down again, the swing is too large, gently stop it when within a few degrees of its natural bearing. Every check and start must be made gently, never abruptly. Should the point become dull, it is best to send it to an instrument maker; if this be not practicable, a watchmaker may perhaps attend to it. It should be remembered, however, that the point of poise must be centered—that is, occupy the center of the graduated circle. This cannot be done by a watchmaker, and is only to be relied upon if made in an instrument maker's shop.

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 line in the meridian, it will retain, or even increase is polarity. If a needle has lost its magnetism it may be charged again with an ordinary horseshoe 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 may be easily restored by shifting the balance wire on the south end.

The observer should always satisfy himself that there be nothing about his clothing, especially in the make of the buttons, that would have any influence upon the needle.

In the matter of the telescope, intelligent handling will do much towards preserving its accuracy and reliability for a long time. In cleaning any of the lenses, use a soft rag or chamois leather. If the glasses should become greasy, or very dirty, wash them with alcohol. The inner faces will seldom require cleaning, and it is not advisable to take the telescope apart too often, as it is likely to destroy its adjustment. If dust should settle on the cross-hairs, it is safest not to touch them. The only remedy that may be tried is to take out both the object-glass and the eye-piece, and to blow gently through the tube. This may remove the dust without injuring the threads, but it is quite a delicate operation.

Cross-hairs may be replaced in the field by the engineer. The spider web is cleansed from dirt by placing it in water for a few minutes. A little manipulation readily removes any particle that may adhere to the thread. After drying for a moment, adjust it to the diaphragm, previously cleaned from dust, and attach it by means of a little shellac. It requires considerable practice to do this nicely, for a spider's web, although quite strong, cannot be handled by clumsy fingers without parting; but in the case of an emergency the engineer must try to do the best under all circumstances.

Referring again to the lenses, it is well to remember that in taking them apart, the centering is disturbed, and the engineer is not able to replace them properly, especially if they fit loosely in the 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. This will generally occur when the lens is kept in a damp place for some time.

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

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

Similar attention must be bestowed upon the *eye-piece.* With our high power eye-pieces, a motion of only three-sixteenths of an inch is necessary to allow for difference in eyes. As the sliding motion is for this purpose alone, it is not at all necessary to disturb it after it has once been properly adjusted, as long as *the same* person is using the instrument; even in packing it away in the case the eye-piece may be left so, as this extra extension is allowed for in the box. The cap is provided wih a slide to protect the eye-lens from dust while the instrument is not in use; the engineer should never neglect to close this, and to cover the object-glass with its cap as well, as soon as the instrument is set at rest.

Repairs.*

We are fully prepared to make careful repairs to all instruments, from the graduation of an arc or circle, and the straightening of a center or plate, to the setting of a simple screw. In this particular branch we have operated here for the last twenty-six years, and have gained the fullest confidence of our people. We need only state here that we guarantee satisfaction to our customers in every way.

As we are located in California, separated by the breadth of the continent from our Eastern colleagues, we are necessarily required to repair instruments of almost every known make, and this has compelled us to procure the various requisites in the workshop for all emergencies. Today we are in the position to renew any part of an instrument, no matter where it was originally manufactured. Time and money will be saved by sending directly to us, and we shall try to give our customers every satisfaction. Whatever is entrusted to us will be thoroughly overhauled and put in the best possible condition, unless specified orders are received to confine the repairs to certain details.

* Experience has taught us that it is not wise to allow an ordinary mechanic to attempt instrumental repairs, as frequently resorted to in inland towns. It is always the case that this proves ruinous to the instrument, and subsequent repairs will be more extensive and expensive than if it had been shipped to the instrument-maker at once. Express charges are of far less importance, and may be made very reasonable. See notice in front of this manual.

As a general thing it ought to be left to our judgment as to what the instrument requires; it may cost a little more if you follow our advice in this particular, but it will certainly be more satisfactory in the end. It will save time, trouble and additional expense. In the course of our examination of an instrument needing repairs, we discover defects that could not be apparent to any one before its parts were separated and individually tested. What may appear of no consequence, and is therefore neglected, is quite likely to lead to all sorts of subsequent inaccuracies in your work. Years of experience in this particular line have taught us the advisability of urging this point upon our patrons.

Considerable correspondence is had from inquiries about the cost of repairs. Although it is impossible to state the exact figures before an examination, there are certain rates for ordinary repairing that we may mention here.

The most expensive instrument in this regard is the transit, being the most complicated in parts. If injured by a fall, new centers and a new telescope axis are generally required, the cost varying from $10 to $30, reaching sometimes as high as $50. If slightly injured it will vary from $5 to $10.

Injuries sustained by leveling instruments are generally less serious. A new level vial costs from $2 to $7.50, according to size and sensitiveness. Instruments defective in construction or workmanship will not require a sensitive level, as that would be a source of constant annoyance to the engineer; the bubble should be chosen to harmonize with the general qualities. As a rule, we attach to the better class of instrument a level that shall give for each inch of motion of the bubble an angle of two minutes; to the inferior grade, one of three or four minutes.

Compasses sent to us are generally injured by the dulling of the center pin. Sometimes the plates and sights are bent and the glass broken. Often the center cap is worn out, and a new one is required. The cost of repairing ranges from $2 to $8, and even as high as $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 pin, 75 cents. New center cap with jewel, $1.50.

Careful readjustments made under the collimators are charged for at the rate of $2.50 for each instrument.

Transits and levels should always be accompanied by the leveling plates; the tripod and head need not be sent. With compasses the ball spindle should be sent.

We advise our customers to pack their instruments carefully, when sending them to us for repairs, as they are liable to material injury if this precaution be neglected. The space in the box between the different parts—of the transit particularly—may be filled with soft paper wads to protect it from jars and blows. It is well to put the case in an additional box, a little larger in dimensions, in such a manner that the top of the case is plainly visible and its leather strap handy for carrying. The space between the case and the box may be padded with shavings, or some soft material to take up the shocks. Mark upon the top of the box in large legible letters:

☞ THIS SIDE UP ! !
SCIENTIFIC INSTRUMENT,
Handle With Care ! !

And ship through a responsible express company, plainly addressed to:

THE A. LIETZ CO.,
632-34 COMMERCIAL STREET,
San Francisco, Cal.

The name of the *sender* and *his address,* together with the *value of the instrument,* should also appear on the box.

This will insure comparative safety in transportation, which is a point that should be well observed by the engineer. And this precaution would also increase the responsibiliy of the carrier, in case the instrument had suffered during transportation.

When an instrument is sent to us for repairs, a letter or postal card should be mailed at the same time, to inform us of the fact, giving the necessary directions, and stating when the return is required. The receipt of the instrument will be acknowledged by us at once.

ADJUSTMENTS.

Adjusting an instrument consists in delicately moving to the right or left, and up or down, certain parts that must be either parallel or at right-angles to each other. This is done by slightly turning a number of capstan-headed screws or nuts by means of a small steel rod, called an adjusting pin. Adjusting the vernier and compass consists in placing certain points in a straight line; but as these corrections are always made by the instrument maker, they do not properly apply to the subject before us. Verniers, limb and needle, if properly placed at the outstart, will not need any correction in the ordinary use.

Of the Transit.

1. ADJUSTMENT FOR PARALLAX —This is a very essential one, and must be looked to carefully in every surveying instrument, whether transit, level or theodolite. It consists in so focusing the eye-piece that the cross-hairs shall stand out distinctly and well-defined, when the telescope is directed upon an object in focus. If this is not properly done the hairs will be dim; they will appear to travel and to seem unsteady when set on a mark. We know that this has given considerable vexation to the observer, and instruments have been disparagingly condemned for their apparent parallax, when nothing more was necessary than a slight movement of the eye-tube to focus the hairs properly. This fact should be well borne in mind. Our eye-pieces are quite easily moved in or out by a revolving motion, which affords a very fine and precise adjustment to focus.

Operation.—Direct the telescope so as to have a clear view of the sky, and then turn the eye-tube by the cap as just described, until the cross-hairs stand out like two sharp and distinctly drawn black lines. After a few trials this is accomplished without difficulty. Then try the telescope upon some object brought into focus and test the clearness of the wires. A point now bisected must stay so while the eye is moved laterally in front of the eye-hole. If it remains stationary, there is no parallax and the adjustment is made. Once properly set, the eye-piece may remain for the same observer for all time, and need not be adjusted from day to day. Attention has already been called to this point in a previous chapter, where it was noted that the instrument box was made large enough to allow the eye-piece to extend beyond the tube. (The sun-shade should be put on the telescope first, and then focused to mean distance to balance it properly.)

2. PLATE LEVELS.—The object is to set the levels at right-angles to the vertical axis of the instrument, so that when the bubbles are centered the axis is truly vertical.

Operation.—Bring the bubbles to the middle of the tube by means of the leveling screws, then turn the instrument on its center 180 degrees. If they remain central for any position, they are in adjustment; if not, they must be elevated or depressed at one end to correct them. One-half of the required correction is made with the capstan-headed screws on the vial case, the rest by the leveling screws of the instrument. Several repetitions of the operation may be required before attaining accuracy. It is well to have the plate in such a position, that the levels shall be parallel to a pair of opposing foot screws. If they are out considerably, it is better to adjust one first, approximately, and then the other.

3. THE STANDARD BEARINGS.—The telescope should revolve in a vertical plane when the instrument is level. One end of the telescope axis must be either raised or lowered until accuracy is reached. A capstan-headed screw is attached for that purpose.

Operation.—Set the instrument up within about fifty feet of the wall of a house. Take a well-defined point as high up as possible on he wall; clamp and bisect; then turn down the telescope and put a point in line as low on the wall as may be conveniently reached. Reverse the telescope and direct again to the upper mark, if you please; clamp and bisect; turn down to the lower mark, and if it is bisected, the telescope revolves in a vertical plane and requires no adjustment. If it does not strike the point absolutely, one-half of the difference is taken up by the capstan-headed screw, and the adjustment is done. Several repetitions of the operation may be required. It is not necessary to level the instrument, but it should be brought in such a position as to admit the bisecting of two well-defined points. Care should be taken, however, 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 this reason: that unless points of equal height are taken in the subsequent adjustment of the vertical hair, it will only then prove correct, if the telescope revolves in a truly vertical plane. It is, therefore, always better to look to this before the cross-hairs are adjusted.

This adjustment may also be made by means of an accurate striding level, such as manufactured by this Company for use in high-grade instruments. The transit must be precisely leveled up by the foot-screws and plate bubbles, after which the striding level is placed across the telescope, resting upon its axis. It is evident that the bubble will indicate any deficiency in the horizontal parallelism of this axis, and, therefore, any error in the true vertical motion of the telescope, which may be corrected until the bubble of the striding level remains centered.

4. THE CROSS-WIRES.—The line of collimation should be at right-angles to the axis upon which the telescope revolves.

Assuming that all the required conditions have been fulfilled by the instrument maker—having placed the telescope in the center of the instrument, and having the tubes perfectly straight and normal to the telescope axis, which are necessary instrumental requirements, there are two methods that may be employed. One is by means of back and fore-sights, which is that generally used; the other consists of a test by means of three points in a range, where the middle one is occupied. Preceding either method the hair should be made truly vertical, so that either the upper or lower end will bisect a point when the telescope is moved up and down. This is easily done by loosening the diaphragm and turning it slightly in the required direction. To accomplish this the instrument must be leveled up.

Operation, First Method.—Occupying a point, direct the telescope to some well-defined mark, about four hundred or five hundred feet distant; clamp and bisect it; then revolve the telescope and place a point in the opposite direction at about the same distance. Now unclamp and turn the instrument half-way around; set the hair again on the first point, revolve the telescope and sight to the second point. If the intersection bisects the latter, the vertical hair is in adjustment. If not, the error can be corrected by the capstan-headed screws, which afford a lateral motion of the diaphragm. With them the vertical thread should be moved one-fourth of the space intercepted between the direction of the telescope and the direction of the second point. Several repetitions may be necessary to obtain accuracy.

The reason why only one-fourth of the space should be corrected for, becomes evident from the fact that in the first revolution of the telescope the error of the hair is doubled; and after reversing the instrument and revolving the second time, it is again doubled, but on the opposite side, so that the true direction lies exactly half way between the two, and to correct for it we must move the hair one-half the space between the true line and one of the points.

It is not necessary to level the instrument in order to make this adjustment; but in case it is not leveled up, the observations must be made exactly at the intersection of the cross-wires.

It must be remembered that the image at the cross-hairs is inverted, and that in consequence the screws must be moved in apparently wrong directions.

If there is any lost motion in the tangent screw, great care should be exercised in handling the telescope, so as not to influence its alignment.

Operation, Second Method.—Locate with the telescope three points in one direction, which are necessarily in a straight line, as long as the vertical movement of the telescope is in adjustment. Occupy the middle point with precision, and bisect one of the end points; revolve the telescope and sight at the other end point. If this is bisected, the instrument is in adjustment; if not, correct for it by taking up one-half the error. This method requires leveling of the instrument.

Thus far we have been speaking of the vertical hair only, as it is the more important in a transit telescope. In a plain transit—that is, one without a telescope level and without a vertical arc—the horizontal thread simply serves to define the middle of the vertical one, so that the observation may always be confined to a particular *point* in the latter. But if a level is attached to the telescope, then the horizontal hair should be brought into the optical axis, before the level is set parallel to the line of collimation; otherwise, though adjusted for long distances, it will fail to be correct for short sights.

Operation.—Set up the instrument near a house or fence and level up carefully. Clamp the telescope, and by means of its tangent screw bisect a point several hundred feet distant; then turn on center and mark a point on the house or fence, about ten feet distant. Now unclamp telescope, reverse it, revolve on center, and again bisect the nearest point. Turn instrument on center and see whether the hair intersects the further point. If it does not, the correction must be made, by lifting or lowering the diaphragm by means of the upper and lower capstan-headed screws, until the bisections, after repeated trials, will coincide.

5. THE TELESCOPE LEVEL.—The object of this adjustment is to make the level parallel with the line of collimation. The principle underlying the method is: that points taken with the same angle of elevation or depression, and equally distant from the instrument, are of equal height.

Operation.—Set up on a nearly flat surface and level carefully. On opposite sides, at *equal* distances, drive two stakes giving the *same* level-rod reading, with the telescope bubble centered in each instance. These points are necessarily on a level with each other. Now move the instrument to a point in line with both, and about ten feet distant from one. Level up again. Take a rod reading on the nearer and then on the further stake. If they agree, the level is in adjustment; if not, move the telescope with its tangent screw over nearly the whole error, and sight again at the nearer stake and then at the further, repeating 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 by the correcting screws of the level, and the adjustment is completed.

This adjustment may also be made in a room with the aid of a surveyor's level, with absolute accuracy.

Operation.—A few feet (one or more) from each other set up the transit and level, each directed to the other. The cross-hairs of the level must be illuminated by a light, so that they shall become plainly and clearly visible through the transit. For this purpose cover the eye-end of the level with a bit of white paper and place a lamp behind it. Focusing both instruments properly will make the hairs appear very distinctly. Now, if both instruments are properly collimated, the level carefully leveled up, and the transit telescope of such height that we may view the interior of the level's tube, we are ready to adjust the transit telescope to a level plane, which is done by simply placing the intersection of its cross-hairs delicately over the intersection of the level's cross-hairs. All that is required after that, is to center the transit's level bubble by means of the proper adjusting screws.

This method recommends itself on account of its extreme simplicity.

6. Zero of Vertical Arc.—This adjustment, once made by the instrument maker, is seldom vitiated. The object is to have the zero line of the circle agree with the zero mark of its vernier, when the level of the telescope indicates a horizontal position, and when the centers of the instrument are truly vertical.

Operation.—The instrument must be carefully leveled by the small plate bubbles, and then the telescope by means of its level. This accurately accomplished, the vernier is shifted until the zero lines coincide. This must be carefully done, so that the instrument is not disturbed, and, when the vernier is fastened, care must be taken to allow a space that shall neither be too small nor too great between it and the vertical circle. In the first case it would bind under certain conditions of temperature, and in the latter the observer would not be able to obtain an accurate reading. The coincidence of the zero-lines must be made with a magnifying glass, and all parallax avoided.

7. Centering the Field of View.—On some transit telescopes there will be found another set of four capstan-headed screws, exactly

alike to that which regulates the cross-hair diaphragm, and placed in a position quite close to it. These screws are for the purpose of directing the tube of the eye-piece in such a manner that the field of view may be divided by the cross-wires into four uniform quadrants; that is, they enable the operator to so adjust his field that it may be bisected horizontally and vertically by the threads. In the Lietz transits this adjustment has been omitted, for the reason that the tubes are made of such length and with such care—being absolutely straight—that there is no need of displacing the field, after the line of collimation has been made to agree with the optical center, and the hairs are properly adjusted. The lines can never appear noticeably out of the field in our transits, and any additional movement in the parts of the telescope would neither be useful nor desirable. A first-class transit instrument can dispense with this arrangement altogether, and for this reason it is not usually found there. With an extra long telescope, however, there would be a slight advantage in being able to direct the field of view, for a possible fall of the instrument may so injure the tube that it could not be made absolutely straight again afterwards, and in consideration of this, we have adopted this correction only in the case of the 18-inch Y-level, which is the most liable to be damaged in that way. It alone possesses two sets of capstan-headed screws near the eye-end of the telescope—one for the adjustment of the cross-hairs, and the other for shifting the field of view so that it shall appear equally divided by them.

Of the Y-Level.

There are three principal adjustments. The spirit level must be parallel to the axis of collimation; it must be at right-angles to the vertical axis of the instrument; the axis of collimation must agree with the optical axis.

There are other instrumental requirements which belong to the instrument maker, however, and it is with the above three adjustments only that the surveyor has to deal, as they are likely to become disturbed in time.

Before examining the adjustments, the sun-shade should be placed on the telescope, as it is only accurately in balance with this.

1ST ADJUSTMENT.—To set the spirit level parallel to the line of collimation, and, at the same time, place its axis in a plane with that of the telescope. It is best to attend to the latter first.

Operation.—Turn the telescope so as to stand over two opposing foot-screws, clamp the instrument and bring the bubble to the center of the tube; then rotate the telescope in its Ys, so as to put the level considerably out of a vertical—say about 15 or 20 degrees. If the bubble changes its position, it shows that the axis is not in a plane with that of the telescope. Correct it by moving the two side screws of the level case, until one-half of the deviation has been taken up. A few repetitions will insure accuracy, and destroy the side motion of the level.

The level must now be made parallel with the line of the bottom of the collars.

Operation.—Bring the bubble to the center of the tube; then reverse the telescope in the Ys end for end; do this carefully. The displacement of the bubble, if there be any, is the double error, which is corrected by taking up one-half of it by means of the adjusting nuts on the level case, and the other half with the leveling screws of the instrument. This operation is repeated until the bubble remains in the center.

To accomplish a proper adjustment of the level to the line of collimation, it becomes absolutely necessary that the collars be of equal diameter. We have already referred to the importance of even collar dimensions, and have laid great weight upon this requisite; and here again we shall point out the errors to which a neglect therein may lead. A Y-level in such an event is not any better than a dumpy, and will have to be adjusted as such.

Providing the Ys are filed out to the same absolute angle, the instrument may still be adjustable in all its parts:—the spirit level may be made parallel to the line of the bottom of the collars; the Ys may be so adjusted that the bubble will remain in the center of the tube; the line of collimation may be brought to the center of revolution of the telescope; and this reversed end for end in the Ys, leaving the bubble in the middle, even if there be some difference in the diameter of the collars. It is the general opinion that after level, Ys and cross-wires are adjusted, the instrument must be correct. This is by no means certain, as the least difference in the size of the collars will throw out the line of collimation considerably. This difference is sometimes found in new instruments, and is also produced by unequal wear, denting, etc. It is therefore advisable that the equality of the collars should be tested from time to time, which is done by a method given further on.

2D ADJUSTMENT.—To place the level at right-angles to the vertical axis of the instrument.

Operation.—Turn the instrument so that the telescope shall stand over the line of two opposing leveling screws, and bring the bubble to the center of the tube; then turn the instrument 180 degrees on its center. If the bubble shows any displacement, correct one-half of it by means of the nuts under the bar at the Y supports, and one-half by the foot-screws. Several trials will make the correction perfect.

3D ADJUSTMENT.—To place the cross-web in the optical axis of the telescope, so that the intersection will remain on an object in revolving it.

Operation.—Set the intersection of the hairs on a point about two hundred or three hundred feet distant, then revolve the telescope in its Ys half-way, so as to have the level case on top. If the wires have moved from the point, bring them back one-half of the amount of the displacement. Try again, and repeat the operation if necessary.

The eye-piece may then be properly aligned and directed by the four black capstan-headed screws (nearest the eye-end of the telescope), so that the field of view shall appear evenly divided by the cross-hairs, as already explained.

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 be 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, however, is entirely erroneous. Perfectly straight tubes *can* be made, if the necessary time and money be expended, which is the only requisite. In a great many instruments sold today, you will find that the object-glass is not centered, that the slide is poorly fitted, and that all these inaccuracies, which are not apparent at a glance, prove more injurious than ever if the tubes are not quite straight. It must also seem clear to any one that the constant working of the slide in an adjustable ring would loosen the screws and cause considerable annoyance.

PARALLAX is adjusted by moving the eye-piece in or out until a clear and distinct view of the cross-hairs is obtained, as in the case of the transit already described.

THE COLLAR TEST.—After the instrument is properly adjusted, the equality of the collars may be ascertained in the following manner:

Operation.—Make two bench-marks, place the instrument exactly midway between them, and find their true difference of level by reading leveling rods set upon them. Now place the instrument near one of the bench-marks and read the rods again. If the difference of the reading is equal to the true difference of level, the collars are of equal diameter, and the line of collimation is at right-angles to the vertical axis of the instrument. This test, once made, holds good ever after, as it shows that the collars are true, and consequently that a correct adjustment is assured of all its other parts, as already described. But it need hardly be mentioned that denting, the settling of sand particles 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 line of the vertical center, then the collars are of unequal diameter, and the instrument is really nothing more or less than a dumpy level, as this defect deprives it of all the advantages for an easy and convenient adjustment, which characterizes the Y-level in comparison with the dumpy.

This defect may, however, be temporarily remedied or adjusted in the same manner as the line of collimation in the dumpy level is adjusted, but it must ever thereafter remain permanently in its Ys, as it would, if reversed end for end, double the error which existed previous to this adjustment.

The correction may also be made by displacing the horizontal cross-hair to the extent that the line of collimation shall be truly horizontal and, at the same time, parallel with the axis of the spirit level; but, in that event, there will be no longer any agreement with the optical axis, which again gives rise to a number of inaccuracies that cannot be obviated.

A Y-level, in order to deserve that name at all, must have equal diameters of its collars; and if that is not found after a crucial test, the instrument maker should be called upon to remedy this discrepancy.

No doubt can possibly exist in the mind of any engineer of the absolute necessity of the collar test. Considering the required parallelism of the axis of collimation and the axis of the spirit level, he must know that a contact can only be made between telescope and Ys by means of the collars, whose exteriors may either be parts of the surface of a cylinder, or that of a cone, and that the required parallelism is only possible in the former case. If one collar exceed the other in diameter, the centered level bubble, if reversed in the Ys, will indicate a displacement corresponding to four times the angle intercepted between the collar axis and that of the spirit level. No further demonstration of this fact is necessary.

Of the Dumpy Level.

In principle, the same laws govern the requirements of the dumpy that hold good in the Y-level. Although its construction differs, the condition of its line of collimation, optical center and level vial must be such as to bear that universal relation to each other which we have fully explained in the other instruments. It is not difficult to make all the necessary adjustments properly, although it may not appear quite so handy to correct its errors as in the case of the Y-level. Once adjusted, however, the instrument will remain so for a long time, and it will give the operator considerable satisfaction, if used with the ordinary care.

The adjustments of the level, and the telescope for collimation, will now be briefly mentioned.

Put on the sun-shade, and focus the eye-piece until the hairs are distinctly visible and the parallax destroyed; then proceed as follows:

Operation.—Turn the instrument so that the telescope shall stand directly over the line of two opposing leveling screws, and draw the bubble to the middle of the tube by means of the foot-screws. Then turn the instrument on its center 180 degrees, and if the bubble remain centered the adjustment is perfect. Any displacement, however, will have to be corrected by taking up one-half of it with the capstan-headed screws attached to the level case, and the other half by the foot-screws. This operation must be repeated several times, in directions normal to each other—that is, over one set of opposing foot-screws as well as over the other, until the telescope may be swung in any position and the bubble will remain in the middle. See that the adjusting screws of the level vial are firm, yet avoid all unnecessary force in tightening them; all cramming is injurious, and tends to destroy the proper degree of refinement required.

After having set the diaphragm so that the cross-hairs shall be absolutely horizontal and vertical, which is easily done by loosening the capstan-headed screws and turning the diaphragm slightly, being guided by some point bisected by the horizontal hair, we now proceed to adjust the cross-hair, which must be brought into the collimation line. Several methods are known; the one which is always available, however, is that by means of stakes and level-readings upon them, and it is to this that we shall confine ourselves here.

Operation.—Choose a piece of ground nearly level, set up the instrument and center the bubble. Drive a stake (point 1) firmly, say two hundred or three hundred feet from the instrument, in any convenient direction therefrom. Hold the level rod upon it and take a reading. Now point the telescope in the opposite direction, the bubble being centered, and plant another stake (point 2) at the same distance from the dumpy, driving it until the rod shall read the same as upon the first point. These two stakes are on the same level. Now set up the instrument abount ten or fifteen feet from the first stake, and bring the bubble to the center; take a rod-reading on point 1, and then on point 2. If the two readings are alike, with a truly centered bubble, the hair is collimated. If there is any difference, take up nearly all of it by moving the diaphragm with the cross-hairs either up or down, as already explained. Repeat this operation until the readings on points 1 and 2 are identical, when the instrument is in adjustment.

The vertical hair is of no particular importance.

With these precautions, a dumpy level may be made absolutely accurate, and there is no reason why, for any of the land surveyors, and for nearly all of the engineer's work, this compact and steady instrument should not meet every requirement. We frequently discuss its merits with our customers, and have never hesitated to recommend it.

Test of Telescopes in General.

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

To test for *definition,* use small, clear print, and view it from a distance of from thirty to fifty 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 of 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 finer details illegible, or even invisible, the surfaces are imperfect and faulty, for the rays proceeding from the various points of the object are not refracted to their corresponding points in the image.

Indistinctness may be caused by *spherical aberration.*

To test this, cover the object-glass with a ring of black paper, reducing the aperture to one-half; again 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. If the spherical aberration has been reduced to a minimum, very little, if any, slide motion is necessary to obtain a distinct view under both tests. The amount of movement, however, constitutes a measure for the spherical aberration of the object-glass.

Another test, but not as good as the one just mentioned, is to focus an object to distinct vision; then slide the object-glass in or out, observing at the same time the quantity of motion necessary to render the object indistinct. If the spherical aberration is completely corrected, the object should, theoretically, be rendered indistinct by the slightest motion of the lens; but, practically, this is not the case, as the eye will accommodate itself in a measure to the difference of divergence of the rays, caused by the motion, in or out, of the object-glass, in the same manner as it will accommodate itself to 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 six 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 clear, 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 slightest motion in or out, will cause a sufficient amount of divergence of the rays to prevent the accommodation of the eye to the 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, thereupon 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, the sides of which are about four 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, for 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 the above test, cannot be distorted, but that the surface only will appear concave to a keen observing eye. A telescope which distorts the image to a perceptible degree will not, however, cause any errors in common use, if only one point in the lens is taken in all observations, but it is decidedly objectionable in stadia measurements, where two points in the field of view are used at the same time.

To Find the Magnifying Power of a Telescope.

A practical method for finding the magnifying power, available to anyone, which does not require any apparatus, taking up only a few moments' time, is the following:

Set up the instrument, and about twenty or thirty feet therefrom hold up a graduated rod. Observe the rod with one eye by direct vision, and with the other through the telescope. Assume a certain space on the rod, say the height of a numeral, or two sharply drawn lines, and count the number of divisions on the rod in that space; then observe the number of divisions that are seen by the naked eye in the same space enlarged. The ratio between the two is the power sought. It is the reading of a magnified space of known length on the graduated face of the rod. With a little practice both eyes will be able to distinguish the rod divisions at the same time. If what is known to be 0.1 of a foot, is enlarged by viewing it through a telescope so as to cover the space of 2.4 feet as seen by the unaided eye, the magnifying power is 24 for the distance in focus. The real power is somewhat less, for as the tube of the telescope is drawn out for near objects, the power necessarily increases. The magnifying power obtained by this method holds good for the distance that the rod can be read by the unaided eye, and it is always somewhat greater than the actual power.

For a very accurate determination of the magnifying power, it is necessary to ascertain the focal length of the objective and that of the eye-piece, in order to compare them and to find their proportion. While the former is easily obtained by a direct measurement from the objective lens to the cross-hairs, the latter, usually containing an entire system of lenses, presents numerous difficulties. For this purpose we possess an apparatus, designed and built by a prominent optician in Germany, and which is perfectly adjusted to do its work.

Dividing the focal length of the objective (when the telescope is focused to mean distance) in millimeters, by the equivalent gives the magnifying power of the telescope under consideration.

If any our customers want the focal length of an eye-piece determined, we shall cheerfully do so, without charge, upon receipt of it, which should be sent carefully packed by express.

Adjustments of the Plane-Table Alidade.

Without going again into all the details of instrumental adjustments, it behooves us to enumerate the points required of this instrument when in proper condition. These are:

1st—That the *fiducial edge* of the rule be absolutely straight;

2d—That all *parallax* be destroyed, by placing the cross-hairs in proper focus;

3d —That the line of collimation move in a vertical plane;

4th—That this plane be normal to the plane of the ruler;

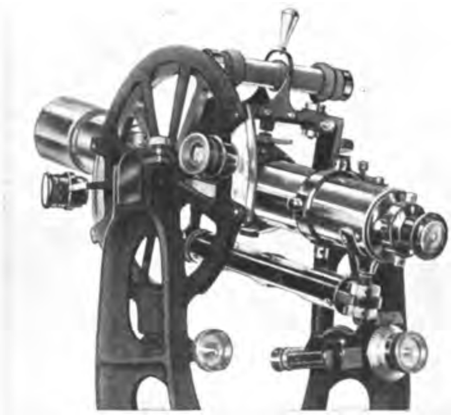
5th—That the same plane also intersect the fiducial edge of the ruler, or at least be parallel thereto;

6th—That during parallelism of the optical axis and the fiducial edge, the zeros of the vertical arc and its vernier correspond.

This instrument is used in the topographical departments of the U. S. Coast and Geodetic Survey, and the U. S. Geological Survey, and is exclusively applied in mapping the topographical features of the country in Europe, usually by officers of the army, who control these surveys, after the triangulation points have been established.

This method of surveying has been constantly improved in practice, particularly by the experts of the Geological Survey, and it may be safely said that, with the required accuracy, nothing surpasses it for small-scaled work in speed and application. All the bulky parts of the table have been reduced to a minimum, so that it may be handled with comparative ease in the roughest mountain country.

We refer our readers to appendix No. 22 of the Coast Survey Report of 1865, which may be had separately in bound book form, called *The Plane-Table and its Uses,* as an excellent theoretical and practical treatise of this interesting subject.



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Professional Papers

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No. 1.

A SHORT AND PRACTICAL TREATISE ON STADIA SURVEYING, OR TACHYMETRY,

With Tables for the Determination of Horizontal Distance and Elevation.

WRITTEN FOR THIS MANUAL BY OTTO VON GELDERN.

The value of this method of obtaining distances is now so generally appreciated, that every engineer will use it in his work, wherever the accuracy obtainable is sufficient for his purpose. While it cannot replace the usual means of precise linear measurements employed in cadastral surveys, it offers many other advantages that cannot be too highly estimated. Under difficult topographical conditions the results, if carefully obtained, may be even better than those of the ordinary chain. At all events, the rapidity with which distances may be measured at all times, and its adaptability to inaccessible places, have given it that prominence in topographical work which it justly deserves.

To make quick and reliable observations of this character, the instrument used should be a good one, and its telescope, above everything else, must possess power, definition and light in a high degree, in order to enable the observer to read the so-called telemeter rod with precision on long sights.

The Principle of the Stadia Method.

The fundamental basis underlying this method of measuring is well known, and is simply the geometrical proposition that parallel lines subtending the same angle from a given point, are proportional in length to their distances from that point. This explains generally the applied principle governing the stadia; all the modifications of it are due to the structure of the instrument used, and to certain optical and geometrical principles that involve corrections to be introduced under certain conditions of sight.

By placing two additional horizontal threads in the telescope, at equal distances from the middle hair, we obtain a gauge that may be applied to a graduated rod, the intercepted space upon the rod increasing, as the distance between it and the telescope increases. If the graduation to some adopted unit of measure be so marked, that it may be read clearly and distinctly without error on longer distances, it is evident that a mere inspection of the rod by means of the telescope, will be sufficient to indicate its distance from the instrument.

The threads may be inserted at random, and the rod marked to correspond to known distances; or they may be placed so as to intercept one unit of measure on the rod to a given number of units in distance. The latter is that generally employed, and the usual ratio is 1 in 100.

When the distance measured between two points is at an angle with the horizon, it becomes possible to determine the co-ordinates of horizontal distance and difference in elevation of the triangle, provided the angle of the slope is known. This may be read on the vertical arc of the instrument. If, in such cases, the telemeter rod be held at right angles to the line of sight, the horizontal distance will equal the cosine of the observed vertical angle, multiplied by the distance indicated by the rod. This must be corrected by certain small values, to which reference will be made further on. And similarly does the sine of the angle indicate the difference in elevation.

The usual custom here is to hold the rod vertical under all conditions, which is more readily accomplished, and, in certain localities, perhaps the only possible way of holding it.

Optical Features and the Constants c and k.

Certain optical principles do not admit of a stadia measurement from the point occupied by the center of the instrument, but from a point outside of the objective lens, equal in distance to its focal length. This gives rise to a certain value by which the stadia distance must be increased, and which may be practically a constant for any length. It may be determined with sufficient accuracy by adding two measurements, taken with an ordinary scale or tape, from the object glass of the telescope, when the latter is focused to a distant object: one to the capstan-headed screws, holding the diaphragm with the cross-hairs, and the other to the center of the axis. The sum of these two ($f + h$, figure 1) is the constant c, which must be added to every horizontal distance, irrespective whether long or short.

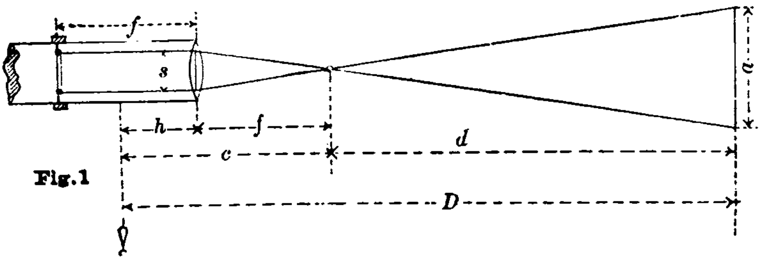

Fig. 1

In figure 1, let a = any rod reading, K = a constant expressed by the relation of the distance between the stadia threads and the focal distance of the object glass, then $K\,a = d$ = distance from the focal point to the rod, for

$$s : f :: a : d, \text{ or}$$

(1) $\quad d = \dfrac{a\,f}{s}$, wherein $\dfrac{f}{s}$ represents the constant K.

It must be mentioned, however, that this is not *strictly* correct, because the focus is changed with the distance of the object, and the value f therefore variable. Nevertheless, the results, unless obtained on very short ranges, are as close as required for the purpose of the stadia, by assuming $\dfrac{f}{s}$ as a constant of any value that we may choose to assign it when we place the hairs, the ratio 1 : 100 being usually adopted.

To express the distance D of the rod from the point occupied by the instrument, on a level surface, we have, therefore,

(2) $\quad D = K\,a + c$,

remembering c as the constant expressing the distance from the center of the instrument to the outer focus of the objective, which must be added in every case.

If K, as customary, equal 100 and $c = 1.15'$ (as in the ordinary large transit), then $D = 100\,a + 1.15'$, so that the following rod readings would correspond to the distances as shown:

1 foot = $100^{\text{ft.}} + 1.15^{\text{ft.}}$ = 101.15 feet.
1.69 feet = $169^{\text{ft.}} + 1.15^{\text{ft.}}$ = 170.15 "
2.33 " = $233^{\text{ft.}} + 1.15^{\text{ft.}}$ = 234.15 "
1 meter = $100^{\text{m.}} + 1.15^{\text{ft.}}$ = 100.35 meters,

and so on.

Reduction of Elevated or Depressed Sights.

If, now, the observation be made on a slope with rod held vertically, the angle of elevation or depression may be expressed by n, and the angle intercepted between the stadia hairs by 2 m.

Any rod reading a may then be reduced to the reading a_1, or normal rod.

reading, by the following formula, which is obtained from the elements given in the diagram, figure 2:

$$(3) \qquad a_1 = \frac{a}{\cos n + \tfrac{1}{2} \sin n \,[\, \tan (n + m) + \tan (n - m) \,]}$$

Now, since the angle m in an instrument rated 1 : 100 only amounts to 17 minutes, it is evident that the expression

$$\tfrac{1}{2} \sin n \,[\, \tan (n + m) + \tan (n - m) \,]$$

is almost the same as sin n tan n, the difference being so small that it will not be noticeable at all in any of the stadia requirements, and writing sin n tan n in terms of the cosine, we have $1 - \cos^2 n$, and substituting in formula (3), it will reduce to the simple expression

$$(4) \qquad a_1 = a \cos n.$$

This, then, is the normal rod reading, which, by applying the constant K, gives the distance $K\,a \cos n$, representing the hypothenuse h of a right-angled triangle, of which the horizontal distance d and the difference in elevation e are the co-ordinates. Their values in turn are proportional to the cosine and sine of the angle n, so that the distance

$$(5) \qquad d = K a \cos^2 n,$$

and the elevation $e = K a \cos n \sin n$, which is

$$(6) \qquad e = K a \tfrac{1}{2} \sin 2n.$$

(It is understood, in the case of the difference in elevation between the two points (e), that the middle hair touches the rod at a mark corresponding to the height of the instrument, as shown in figure 2.)

Introducing, now, our constant c, which causes corrections also dependent upon the angle n, we must add to the horizontal distance d the value $c \cos n$; and to the elevation e the value $c \sin n$, so that the corrected horizontal distance is

$$(7) \qquad D = c \cos n + K a \cos^2 n,$$ and the corrected elevation

$$(8) \qquad E = c \sin n + K a \tfrac{1}{2} \sin 2n;$$

or, if the constant $K = 100$,
and the constant $c = 1.15$,
then $D = 1.15 \cos n + 100\, a \cos^2 n$,
and $E = 1.15 \sin n + 100\, a \tfrac{1}{2} \sin 2n$.

If, for example, the rod reading a be 2.22 feet, and the vertical angle $n = 20°$, then

$$D = (1.15 \times \cos 20° = 1.08) + (222 \times \cos^2 20° = 196.03) = 197.11 \text{ ft.}$$
$$E = (1.15 \times \sin 20° = 0.40) + 222 \times \left\{ \frac{\sin 40°}{2} = 71.35 \right\} = 71.75 \text{ ft.}$$

The second member of the equation is the important one, and that which characterizes the formula, the first being small and a constant for the same angle, independent of the distance. But as it cannot well be neglected altogether, it is customary—since it is not readily incorporated in tabular values—to supplement a table that shall furnish the values of d and e for different angles of inclination, by the terms $c \cos n$ and $c \sin n$ in a special place, usually at the bottom, where they may be readily found and applied. They vary so little from degree to degree that for the ordinary stadia measurements they may be entirely neglected.

The annexed tables were calculated by the formulæ

$$d = K a \cos^2 n$$
$$e = K a \tfrac{1}{2} \sin 2n,$$

and so arranged as to give the distance d and the elevation e for every 2 minutes

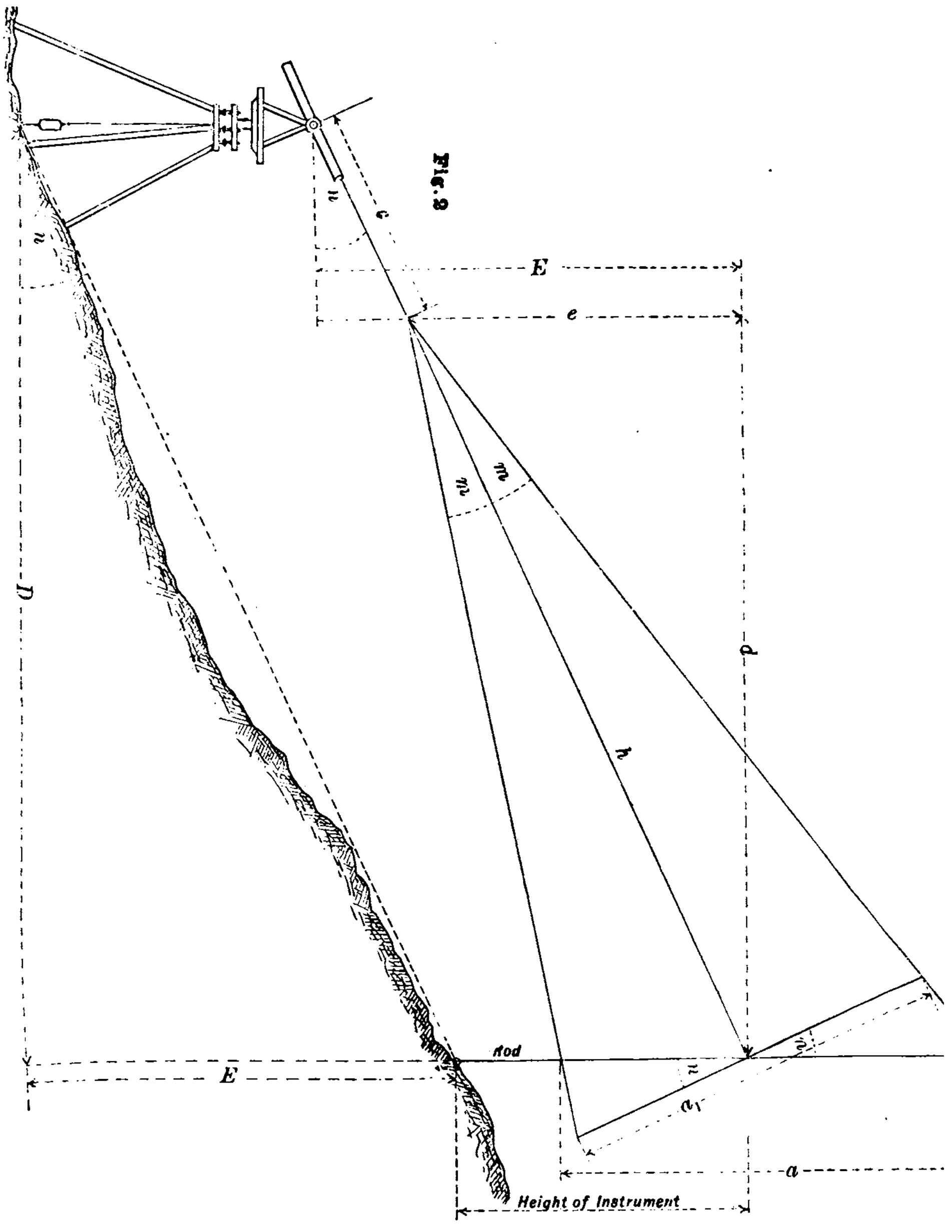

Fig. 2

of arc for a value of $K a = 100$, the rod held vertically. They admit of a simple application.

By what has preceded, let it be required to find the horizontal distance and the difference in elevation, when the rod indicated 285 feet and the vertical arc 10° 12′. Look for the column headed 10°; run down this column with your finger to the figure on the same line with number 12 in the left-hand or minute column, where, for 100 feet, d is found as 96.86, and e 17.43. Multiply both of these by 2.85. This reduces the distance 285 feet to $d = 276.05'$, and $e = 49.67'$. At the bottom of the page will be found values of the corrections due to c for different focal lengths. Three values obtain: 1.90 (the large Y-level), 1.15 (the large transit), and 0.75 (the small transit). If a large transit has been used we look for the corrections corresponding to $c = 1.15$, and in the case before us we would obtain 1.13 and 0.21. These are added to the values already obtained, and we have:

$$\text{corrected horizontal distance } D = 277.18 \text{ feet,}$$
$$\text{and corrected difference in level } E = 49.88 \text{ feet.}$$

The Stadia Board or Telemeter Rod.

For stadia work an ordinary leveling rod may be used, and, with the aid of a pocket level (a so-called rod level with a circular bubble, that may be fitted and held to the edge of the rod), its vertical position may be assured. By employing two targets and reading them with care, the results will be as precise as the telescopic power admits. It is usual, however, in order to save time, to prepare a self-reading rod, so marked that it shall facilitate rapid observation and reduce all chances of error from a wrong reading. Many patterns are employed by a combination of geometrical figures and by different colors (red, black, white), that are intended to indicate at a glance the space between the upper and lower hair in terms of the rod measure. These patterns are either painted directly on a board from 10 to 12 feet long, that may be folded for convenience in transportation by a hinge in the middle, or on stiff canvas, in which case it may be rolled up for carrying in the pocket, and tacked to a suitable board whenever required. These so-called flexible stadia boards answer very well, but the former are to be preferred in accurate work, as they cannot be materially distorted by conditions of weather.

In case the stadia hairs were set arbitrarily, it becomes a simple matter to ascertain the constant K. A distance of eight hundred feet or more is laid off on a level surface with a steel chain, and marked at each hundred feet. The instrument is placed the distance of its constant c away from one of the end points, and readings are taken on a leveling rod at every hundred-foot mark. From these the ratio between distance and rod reading is readily determined.

Or, a stadia board may be so divided that a unit of its measure shall agree with a hundred-foot space. If a blank board be held at every hundred-foot mark on the ground, we may draw upon it the intersection of the upper and lower hair for each station. If the rod units so obtained vary slightly from each other, the mean of them may be adopted without appreciable error, which is subsequently divided into smaller spaces, to read as close as desirable. In this wise we obtain a rod corresponding with the instrument of which it then becomes a part.

Some instruments possess adjustable stadia wires. In that event the hairs may be set to suit the rod.

In all these cases it is evident that the constant c must be previously determined and properly applied.

General Remarks.

In making a stadia observation, after having set up and adjusted the transit over a point, direct the telescope to the rod and clamp the instrument in position. Move the telescope in a vertical plane, until the middle hair of the three intersects a line on the rod as high above the ground as the telescope axis is over the point occupied, and read the space intercepted between the upper and lower hair. An even foot-mark, or unit-mark, can always be found, upon which either the upper or lower hair may be placed, that will satisfy the conditions nearly under which *a* should be taken, and from it the rod may be read quickly up or down. To obtain the vertical angle, the telescope should then be moved either up or down with its tangent screw, to the exact intersection on the rod corresponding to the height of the instrument—which is 4.5′ ordinarily—and the vertical arc read.

There are occasions when the middle hair cannot be placed on the rod as explained—in the woods, for instance, when parts of the rod may be covered by leaves—and in that event we may read it wherever its exposed space permits, and make the necessary corrections afterwards. It is one of the particular advantages of the stadia that it may be used under very unfavorable conditions of the field, in forests, swamps, along declivities, etc., and yet obtain very reliable results. As long as the rodman is able to get to a place and to hold up his rod, and the observer can see a clear space on the face of it, the reading may be obtained that shall lead to the determination of the horizontal distance and to the difference in elevation.

In cases where both stadia wires are not visible on the rod, the space between the middle hair and the visible one may be read off and multiplied by 2, it being presumed that the upper and lower are equidistant from the middle hair. But where very large vertical angles accompany the sight, however, it is not well to rely absolutely upon the result, for it is quite readily demonstrated that the horizontal distance will be either too large or too small by a quantity, that, in a rod-reading of 5, doubled to 10 feet, for instance, with a constant $K = 100$, an angle $n = 40°$, will come within about 4/10% of the correct value. With a vertical angle of 20° under the same conditions, the error in distance is about [illegible] %. In the former case the correction would be plus or minus 2.43, and in the latter plus or minus 1.59 feet. But it shows that even under the most unfavorable con ditions of sight we are able to approach the true distance within all the requirements of topographical surveying.

A survey may be made with the stadia altogether, or it may be preceded by a triangulation, in order to locate a number of fixed points—the relative elevations of which are established with a leveling instrument—between which the topography is filled in with the stadia. The latter method is necessarily more trustworthy, and should always be adopted where large areas are to be surveyed; but if the engineer is pushed for time, he may omit the triangulation and yet obtain very good results. In such an event great care should be exercised in locating the turning points. Occupying point 1 and observing upon point 2, read carefully the azimuth on the plate, and check it by recording the bearing of the needle also. Read your distance from the rod and record that. Having placed the middle horizontal hair on the rod as high above its foot as the telescope axis is over point 1, observe the vertical angle, which is either plus or minus, and note it down. Leaving point 1 and proceeding to point 2, set the instrument over the latter and level up. It may be clamped upon any desired known azimuth, but the reading of the plate should not be omitted in a direction toward point 1. Record this with the bearing of the needle, which will give the reverse course of the sight 1 to 2. Observe again the distance between the points as shown by the rod, and note it down, as well as the vertical angle from 2 to 1, as explained, which should give the same result as before with reversed sign. These precautions of observing twice between turning points form a very valuable check, and should never be omitted where every other datum is lacking and the stadia method alone is relied upon. After having taken his back-sights, the surveyor proceeds with the observation of all intermediate points required for his topographical details, before locating point 3 for a further advance.

Work may be done still more rapidly by occupying every other point only; but in that case the bearings of the lines are solely obtained by the needle, and there is no check.

By employing two or even three rodmen, distributed about the field as advantageously as possible, the engineer is able to observe rapidly without loss of time. It is always well to have a recorder accompany the party, whose sole duty it becomes to note down the observations of points, and the description as to what these points represent. If necessary and desirable, a small drawing-board may be taken into the field, and, instead of a recorder, a plotter may be employed. who lays down the reduced observations as the work progresses. This is considerably slower, but it offers the advantage of a completed field map when the survey is finished.

Instead of employing the tables here give, the reductions may be quite expeditiously and accurately made in the field by means of the *logarithmic slide scale,* which the author employs in his surveys altogether, a description of which is readily obtained.

With a little practice the engineer will work himself into the use of the stadia, and become an expert. Tachymetry, as it is called, is an indispensable method of measuring, and one that the surveyor of today must acquire.

Considerable might be said regarding useful hints and instructions for the field, but we prefer to let every engineer find his own method in the practical application, knowing well that after he has mastered the principle, he will adopt a system of work best suited to his requirements.

The essential requisites for a successful operation are a good clear telescope, affording a distinct view of the rod on long ranges (the author prefers the inverting eye-piece, as one affording better light and a more distinct image, there being no particular advantage in seeing objects erect, as the mind soon accustoms itself readily to an inverted vision), a steady instrument, and, for the method under discussion, a true *vertical* rod.

TABLE OF STADIA REDUCTIONS

For a Constant of 100.

ROD VERTICAL.

Min.	0° Hor. Dist.	0° Diff. Elev.	1° Hor. Dist.	1° Diff. Elev.	2° Hor. Dist.	2° Diff. Elev.	3° Hor. Dist.	3° Diff. Elev.
0'	100.00	.00	99.97	1.74	99.88	3.49	99.73	5.23
2	100.00	.06	99.97	1.80	99.87	3.55	99.72	5.28
4	100.00	.12	99.97	1.86	99.87	3.60	99.71	5.34
6	100.00	.17	99.96	1.92	99.87	3.66	99.71	5.40
8	100.00	.23	99.96	1.98	99.86	3.72	99.70	5.46
10	100.00	.29	99.96	2.04	99.86	3.78	99.69	5.52
12	100.00	.35	99.96	2.09	99.85	3.84	99.69	5.57
14	100.00	.41	99.95	2.15	99.85	3.90	99.68	5.63
16	100.00	.47	99.95	2.21	99.84	3.95	99.68	5.69
18	100.00	.52	99.95	2.27	99.84	4.01	99.67	5.75
20	100.00	.58	99.95	2.33	99.83	4.07	99.66	5.80
22	100.00	.64	99.94	2.38	99.83	4.13	99.66	5.86
24	100.00	.70	99.94	2.44	99.82	4.18	99.65	5.92
26	99.99	.76	99.94	2.50	99.82	4.24	99.64	5.98
28	99.99	.81	99.93	2.56	99.81	4.30	99.63	6.04
30	99.99	.87	99.93	2.62	99.81	4.36	99.63	6.09
32	99.99	.93	99.93	2.67	99.80	4.42	99.62	6.15
34	99.99	.99	99.93	2.73	99.80	4.48	99.62	6.21
36	99.99	1.05	99.92	2.79	99.79	4.53	99.61	6.27
38	99.99	1.11	99.92	2.85	99.79	4.59	99.60	6.33
40	99.99	1.16	99.92	2.91	99.78	4.65	99.59	6.38
42	99.99	1.22	99.91	2.97	99.78	4.71	99.59	6.44
44	99.98	1.28	99.91	3.02	99.77	4.76	99.58	6.50
46	99.98	1.34	99.90	3.08	99.77	4.82	99.57	6.56
48	99.98	1.40	99.90	3.14	99.76	4.88	99.56	6.61
50	99.98	1.45	99.90	3.20	99.76	4.94	99.56	6.67
52	99.98	1.51	99.89	3.26	99.75	4.99	99.55	6.73
54	99.98	1.57	99.89	3.31	99.74	5.05	99.54	6.78
56	99.97	1.63	99.89	3.37	99.74	5.11	99.53	6.84
58	99.97	1.69	99.88	3.43	99.73	5.17	99.52	6.90
60	99.97	1.74	99.88	3.49	99.73	5.23	99.51	6.96
c= .75	.75	.01	.75	.02	.75	.03	.75	.05
c=1.15	1.15	.01	1.15	.03	1.15	.05	1.15	.07
c=1.90	1.90	.02	1.90	.05	1.90	.08	1.90	.12

Min.	4° Hor. Dist.	4° Diff. Elev.	5° Hor. Dist.	5° Diff. Elev.	6° Hor. Dist.	6° Diff. Elev.	7° Hor. Dist.	7° Diff. Elev.
0'	99.51	6.96	99.24	8.68	98.91	10.40	98.51	12.10
2	99.51	7.02	99.23	8.74	98.90	10.45	98.50	12.15
4	99.50	7.07	99.22	8.80	98.88	10.51	98.48	12.21
6	99.49	7.13	99.21	8.85	98.87	10.57	98.47	12.26
8	99.48	7.19	99.20	8.91	98.86	10.62	98.46	12.32
10	99.47	7.25	99.19	8.97	98.85	10.68	98.44	12.38
12	99.46	7.30	99.18	9.03	98.83	10.74	98.43	12.43
14	99.46	7.36	99.17	9.08	98.82	10.79	98.41	12.49
16	99.45	7.42	99.16	9.14	98.81	10.85	98.40	12.55
18	99.44	7.48	99.15	9.20	98.80	10.91	98.39	12.60
20	99.43	7.53	99.14	9.25	98.78	10.96	98.37	12.66
22	99.42	7.59	99.13	9.31	98.77	11.02	98.36	12.72
24	99.41	7.65	99.11	9.37	98.76	11.08	98.34	12.77
26	99.40	7.71	99.10	9.43	98.74	11.13	98.33	12.83
28	99.39	7.76	99.09	9.48	98.73	11.19	98.31	12.88
30	99.38	7.82	99.08	9.54	98.72	11.25	98.29	12.94
32	99.38	7.88	99.07	9.60	98.71	11.30	98.28	13.00
34	99.37	7.94	99.06	9.65	98.69	11.36	98.27	13.05
36	99.36	7.99	99.05	9.71	98.68	11.42	98.25	13.11
38	99.35	8.05	99.04	9.77	98.67	11.47	98.24	13.17
40	99.34	8.11	99.03	9.83	98.65	11.53	98.22	13.22
42	99.33	8.17	99.01	9.88	98.64	11.59	98.20	13.28
44	99.32	8.22	99.00	9.94	98.63	11.64	98.19	13.33
46	99.31	8.28	98.99	10.00	98.61	11.70	98.17	13.39
48	99.30	8.34	98.98	10.05	98.60	11.76	98.16	13.45
50	99.29	8.40	98.97	10.11	98.58	11.81	98.14	13.50
52	99.28	8.45	98.96	10.17	98.57	11.87	98.13	13.56
54	99.27	8.51	98.94	10.22	98.56	11.93	98.11	13.61
56	99.26	8.57	98.93	10.28	98.54	11.98	98.10	13.67
58	99.25	8.63	98.92	10.31	98.53	12.04	98.08	13.73
60	99.24	8.68	98.91	10.40	98.51	12.10	98.06	13.78
c= .75	.75	.06	.75	.07	.75	.08	.74	.10
c=1.15	1.15	.09	1.14	.11	1.14	.13	1.14	.15
c=1.90	1.89	.15	1.89	.18	1.89	.21	1.88	.25

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TABLE OF STADIA REDUCTIONS.—Continued.

Min	8° Hor Dist	8° Diff. Elev	9° Hor Dist	9° Diff. Elev	10° Hor. Dist.	10° Diff Elev	11° Hor Dist	11° Diff Elev.
0′	98.06	13.78	97.55	15.45	96.98	17.10	96.36	18.73
2	98.05	13.84	97.53	15.51	96.96	17.16	96.34	18.78
4	98.03	13.89	97.52	15.56	96.94	17.21	96.32	18.84
6	98.01	13.95	97.50	15.62	96.92	17.26	96.29	18.89
8	98.00	14.01	97.48	15.67	96.90	17.32	96.27	18.95
10	97.98	14.06	97.46	15.73	96.88	17.37	96.25	19.00
12	97.97	14.12	97.44	15.78	96.86	17.43	96.23	19.05
14	97.95	14.17	97.43	15.84	96.84	17.48	96.21	19.11
16	97.93	14.23	97.41	15.89	96.82	17.54	96.18	19.16
18	97.92	14.28	97.39	15.95	96.80	17.59	96.16	19.21
20	97.90	14.34	97.37	16.00	96.78	17.65	96.14	19.27
22	97.88	14.40	97.35	16.06	96.76	17.70	96.12	19.32
24	97.87	14.45	97.33	16.11	96.74	17.76	96.09	19.38
26	97.85	14.51	97.31	16.17	96.72	17.81	96.07	19.43
28	97.83	14.56	97.29	16.22	96.70	17.86	96.05	19.48
30	97.82	14.62	97.28	16.28	96.68	17.92	96.03	19.54
32	97.80	14.67	97.26	16.33	96.66	17.97	96.00	19.59
34	97.78	14.73	97.24	16.39	96.64	18.03	95.98	19.84
36	97.76	14.79	97.22	16.44	96.62	18.08	95.96	19.70
38	97.75	14.84	97.20	16.50	96.60	18.14	95.93	19.75
40	97.73	14.90	97.19	16.55	96.57	18.19	95.91	19.80
42	97.71	14.59	97.16	16.61	96.55	18.24	95.89	19.86
44	97.69	15.01	97.14	16.66	96.53	18.30	95.86	19.91
46	97.68	15.06	97.12	16.72	96.51	18.35	95.84	19.96
48	97.66	15.12	97.10	16.77	96.49	18.41	95.82	20.02
50	97.64	15.17	97.08	16.83	96.47	18.46	95.79	20.07
52	97.62	15.23	97.06	16.88	96.45	18.51	95.77	20.12
54	97.61	15.28	97.04	16.94	96.42	18.57	95.75	20.18
56	97.59	15.34	97.02	16.99	96.40	18.62	95.72	20.23
58	97.57	15.40	97.00	17.05	96.38	18.68	95.70	20.28
60	97.55	15.45	96.98	17.10	96.36	18.73	95.68	20.34
c= .75	.74	.11	.74	12	.74	14	.73	15
c=1.15	1.14	.17	1.13	.19	1.13	21	1.13	.23
c=1.30	1.88	.28	1.87	.31	1.87	35	1.86	.38

Min.	12° Hor. Dist	12° Diff. Elev	13° Hor Dist	13° Diff. Elev	14° Hor Dist	14° Diff Elev	15° Hor Dist	15° Diff. Elev.
0′	95.68	20.34	94.94	21.92	94.15	23.47	93.30	25.00
2	95.65	20.39	94.91	21.97	94.12	23.52	93.27	25.05
4	95.63	20.44	94.89	22.02	94.09	23.58	93.24	25.10
6	95.61	20.50	94.86	22.08	94.07	23.63	93.21	25.15
8	95.58	20.55	94.84	22.13	94.04	23.68	93.18	25.20
10	95.56	20.60	94.81	22.18	94.01	23.73	93.16	25.25
12	95.53	20.66	94.79	22.23	93.98	23.78	93.13	25.30
14	95.51	20.71	94.76	22.28	93.95	23.83	93.10	25.35
16	95.49	20.76	94.73	22.34	93.93	23.88	93.07	25.40
18	95.46	20.81	94.71	22.39	93.90	23.93	93.04	25.45
20	95.44	20.87	94.68	22.44	93.87	23.99	93.01	25.50
22	95.41	20.92	94.66	22.49	93.84	24.04	92.98	25.55
24	95.39	20.97	94.63	22.54	93.81	24.09	92.95	25.60
26	95.36	21.03	94.60	22.60	93.79	24.14	92.92	25.65
28	95.34	21.08	94.58	22.65	93.76	24.19	92.89	25.70
30	95.32	21.13	94.55	22.70	93.73	24.24	92.86	25.75
32	95.29	21.18	94.52	22.75	93.70	24.29	92.83	25.80
34	95.27	21.24	94.50	22.80	93.67	24.34	92.80	25.85
36	95.24	21.29	94.47	22.85	93.65	24.39	92.77	25.90
38	95.22	21.34	94.44	22.91	93.62	24.44	92.74	25.95
40	95.19	21.39	94.42	22.96	93.59	24.49	92.71	26.00
42	95.17	21.45	94.39	23.01	93.56	24.55	92.68	26.05
44	95.14	21.50	94.36	23.06	93.53	24.60	92.65	26.10
46	95.12	21.55	94.34	23.11	93.50	24.65	92.62	26.15
48	95.09	21.60	94.31	23.16	93.47	24.70	92.59	26.20
50	95.07	21.66	94.28	23.22	93.45	24.75	92.56	26.25
52	95.04	21.71	94.26	23.27	93.42	24.80	92.53	26.30
54	95.02	21.76	94.23	23.32	93.39	24.85	92.49	26.35
56	94.99	21.81	94.20	23.37	93.36	24.90	92.46	26.40
58	94.97	21.87	94.17	23.42	93.33	24.95	92.43	26.45
60	94.94	21.92	94.15	23.47	93.30	25.00	92.40	26.50
c= .75	.73	16	.73	17	.73	19	.72	20
c=1.15	1.12	.25	1.12	.27	1.11	.29	1.11	.31
c=1.30	1.86	.41	1.85	.44	1.84	.48	1.83	.51

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TABLE OF STADIA REDUCTIONS.—Continued.

Min	16° Hor. Dist.	16° Diff Elev	17° Hor. Dist.	17° Diff. Elev.	18° Hor. Dist.	18° Diff. Elev.	19° Hor. Dist.	19° Diff. Elev.
0'	92.40	26.50	91.45	27.96	90.45	29.39	89.40	30.78
2	92.37	26.55	91.42	28.01	90.42	29.44	89.36	30.83
4	92.34	26.59	91.39	28.06	90.38	29.48	89.33	30.87
6	92.31	26.64	91.35	28.10	90.35	29.53	89.29	30.92
8	92.28	26.69	91.32	28.15	90.31	29.58	89.26	30.97
10	92.25	26.74	91.29	28.20	90.28	29.62	89.22	31.01
12	92.22	26.79	91.26	28.25	90.24	29.67	89.18	31.06
14	92.19	26.84	91.22	28.30	90.21	29.72	89.15	31.10
16	92.15	26.89	91.19	28.34	90.18	29.76	89.11	31.15
18	92.12	26.94	91.16	28.39	90.14	29.81	89.08	31.19
20	92.09	26.99	91.13	28.44	90.11	29.86	89.04	31.24
22	92.06	27.04	91.09	28.49	90.07	29.90	89.00	31.28
24	92.03	27.09	91.06	28.54	90.04	29.95	88.96	31.33
26	92.00	27.13	91.02	28.58	90.00	30.00	88.93	31.38
28	91.97	27.18	90.99	28.63	89.97	30.04	88.89	31.42
30	91.93	27.23	90.96	28.68	89.93	30.09	88.86	31.47
32	91.90	27.28	90.92	28.73	89.90	30.14	88.82	31.51
34	91.87	27.33	90.89	28.77	89.86	30.19	88.78	31.56
36	91.84	27.38	90.86	28.82	89.83	30.23	88.75	31.60
38	91.81	27.43	90.82	28.87	89.79	30.28	88.71	31.65
40	91.77	27.48	90.79	28.92	89.76	30.32	88.67	31.69
42	91.74	27.52	90.76	28.96	89.72	30.37	88.64	31.74
44	91.71	27.57	90.72	29.01	89.69	30.41	88.60	31.78
46	91.68	27.62	90.69	29.06	89.65	30.46	88.56	31.83
48	91.65	27.67	90.66	29.11	89.61	30.51	88.53	31.87
50	91.61	27.72	90.62	29.15	89.58	30.55	88.49	31.92
52	91.58	27.77	90.59	29.20	89.54	30.60	88.45	31.96
54	91.55	27.81	90.55	29.25	89.51	30.66	88.41	32.01
56	91.52	27.86	90.52	29.30	89.47	30.69	88.38	32.05
58	91.48	27.91	90.48	29.34	89.44	30.74	88.34	32.09
60	91.45	27.96	90.45	29.39	89.40	30.78	88.30	32.14
c=.75	.72	.21	.72	.23	.71	.24	.71	.25
c=1.15	1.10	.33	1.10	.35	1.09	.37	1.09	.38
c=1.30	1.82	.54	1.81	.57	1.80	.60	1.79	.63

Min.	20° Hor. Dist.	20° Diff. Elev.	21° Hor. Dist.	21° Diff. Elev.	22° Hor. Dis.	22° Diff. Elev.	23° Hor. Dist.	23° Diff. Elev.
0'	88.30	32.14	87.16	33.46	85.97	34.73	84.73	35.97
2	88.26	32.18	87.12	33.50	85.93	34.77	84.69	36.01
4	88.23	32.23	87.08	33.54	85.89	34.82	84.65	36.05
6	88.19	32.27	87.04	33.59	85.85	34.86	84.61	36.09
8	88.15	32.32	87.00	33.63	85.80	34.90	84.57	36.13
10	88.11	32.36	86.96	33.67	85.76	34.94	84.52	36.17
12	88.08	32.41	86.92	33.72	85.72	34.98	84.48	36.21
14	88.04	32.45	86.88	33.76	85.68	35.02	84.44	36.25
16	88.00	32.49	86.84	33.80	85.64	35.07	84.40	36.29
18	87.96	32.54	86.80	33.84	85.60	35.11	84.35	36.33
20	87.93	32.58	86.77	33.89	85.56	35.15	84.31	36.37
22	87.89	32.63	86.73	33.93	85.52	35.19	84.27	36.41
24	87.85	32.67	86.69	33.97	85.48	35.23	84.23	36.45
26	87.81	32.72	86.65	34.01	85.44	35.27	84.18	36.49
28	87.77	32.76	86.61	34.06	85.40	35.31	84.14	36.53
30	87.74	32.80	86.57	34.10	85.36	35.36	84.10	36.57
32	87.70	32.85	86.53	34.14	85.31	35.40	84.06	36.61
34	87.66	32.89	86.49	34.18	85.27	35.44	84.01	36.65
36	87.62	32.93	86.45	34.23	85.23	35.48	83.97	36.69
38	87.58	32.98	86.41	34.27	85.19	35.52	83.93	36.73
40	87.54	33.02	86.37	34.31	85.15	35.56	83.89	36.77
42	87.51	33.07	86.33	34.35	85.11	35.60	83.84	36.80
44	87.47	33.11	86.29	34.40	85.07	35.64	83.80	36.84
46	87.43	33.15	86.25	34.44	85.02	35.68	83.76	36.88
48	87.39	33.20	86.21	34.48	84.98	35.72	83.72	36.92
50	87.35	33.24	86.17	34.52	84.94	35.76	83.67	36.96
52	87.31	33.28	86.13	34.57	84.90	35.80	83.63	37.00
54	87.27	33.33	86.09	34.61	84.86	35.85	83.59	37.04
56	87.24	33.37	86.05	34.65	84.82	35.89	83.54	37.08
58	87.20	33.41	86.01	34.69	84.77	35.93	83.50	37.12
60	87.16	33.46	85.97	34.73	84.73	35.97	83.46	37.16
c=.75	.70	.26	.70	.27	.69	.29	.69	.30
c=1.15	1.08	.40	1.07	.42	1.06	.44	1.05	.46
c=1.30	1.78	.66	1.77	.70	1.76	.73	1.74	.76

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TABLE OF STADIA REDUCTIONS.—Continued.

Min.	24°		25°		26°		27°	
	Hor Dist.	Diff. Elev.	Hor. Dist.	Diff Elev.	Hor. Dirt.	Diff. Elev.	Hor. Dist.	Diff.. Elev.
0'........	83.46	37.16	82.14	38.30	80.78	39.40	79.39	40.45
2........	83.41	37.20	82.09	38.34	80.74	39.44	79.34	40.49
4........	83.37	37.23	82.05	38.38	80.69	39.47	79.30	40.52
6........	83.33	37.27	82.01	38.41	80.65	39.51	79.25	40.55
8........	83.28	37.31	81.96	38.45	80.60	39.54	79.20	40.59
10........	83.24	37.35	81.92	38.49	80.55	39.58	79.15	40.62
12........	83.20	37.39	81.87	38.53	80.51	39.61	79.11	40.66
14........	83.15	37.43	81.83	38.56	80.46	39.85	79.06	40.69
16........	83.11	37.47	81.78	38.60	80.41	39.69	79.01	40.72
18........	83.07	37.51	81.74	38.64	80.37	39.72	78.96	40.76
20........	83.02	37.54	81.69	38.67	80.32	39.76	78.92	40.79
22........	82.98	37.58	81.65	38.71	80.28	39.79	78.87	40.82
24........	82.93	37.62	81.60	38.75	80.23	39.83	78.82	40.86
26........	82.89	37.66	81.56	38.78	80.18	39.86	78.77	40.89
28........	82.85	37.70	81.51	38.82	80.14	39.90	78.73	40.92
30........	82.80	37.74	81.47	38.86	80.09	39.93	78.68	40.96
32........	82.76	37.77	81.42	38.89	80.04	39.97	78.63	40.99
34........	82.72	37.81	81.38	38.93	80.00	40.00	78.58	41.02
36........	82.67	37.85	81.33	38.97	79.95	40.04	78.54	41.06
38........	82.63	37.89	81.28	39.00	79.90	40.07	78.49	41.09
40........	82.58	37.93	81.24	39.04	79.86	40.11	78.44	41.12
42........	82.54	37.96	81.19	39.08	79.81	40.14	78.39	41.16
44........	82.49	38.00	81.15	39.11	79.76	40.18	78.34	41.19
46........	82.45	38.04	81.10	39.15	79.72	40.21	78.30	41.22
48........	82.41	38.08	81.06	39.18	79.67	40.24	78.25	41.26
50........	82.36	38.11	81.01	39.22	79.62	40.28	78.20	41.29
52........	82.32	38.15	80.97	39.26	79.58	40.31	78.15	41.32
54........	82.27	38.19	80.92	39.29	79.53	40.35	78.10	41.35
56........	82.23	38.23	80.87	39.33	79.48	40.38	78.06	41.39
58........	82.18	38.26	80.83	39.36	79.44	40.42	78.01	41.42
60........	82.14	38.30	80.78	39.40	79.39	40.45	77.96	41.45
c= .75....	.68	.31	.68	.32	.67	.33	.66	.35
c=1.15....	1.05	.48	1.04	.50	1.03	.51	1.02	.53
c=1.90....	1.73	.79	1.72	.82	1.70	.85	1.69	.88

Min.	28°		29°		30°	
	Hor. Dist	Diff Elev.	Hor. Dist	Diff Elev.	Hor. Dist.	Diff. Elev.
0'........	77.96	41.45	76.50	42.40	75.00	43.30
2........	77.91	41.48	76.45	42.43	74.95	43.33
4........	77.86	41.52	76.40	42.46	74.90	43.36
6........	77.81	41.55	76.35	42.49	74.85	43.39
8........	77.77	41.58	76.30	42.53	74.80	43.42
10........	77.72	41.61	76.25	42.56	74.75	43.45
12........	77.67	41.65	76.20	42.59	74.70	43.47
14........	77.62	41.68	76.15	42.62	74.65	43.50
16........	77.57	41.71	76.10	42.65	74.60	43.53
18........	77.52	41.74	76.05	42.68	74.55	43.56
20........	77.48	41.77	76.00	42.71	74.49	43.50
22........	77.42	41.81	75.95	42.74	74.44	43.62
24........	77.38	41.84	75.90	42.77	74.39	43.65
26........	77.33	41.87	75.85	42.80	74.34	43.67
28........	77.28	41.90	75.80	42.83	74.29	43.70
30........	77.23	41.93	75.75	42.86	74.24	43.73
32........	77.18	41.97	75.70	42.89	74.19	43.76
34........	77.13	42.00	75.65	42.92	74.14	43.79
36........	77.09	42.03	75.60	42.95	74.09	43.82
38........	77.04	42.06	75.55	42.98	74.04	43.84
40........	76.99	42.09	75.50	43.01	73.99	43.87
42........	76.94	42.12	75.45	43.04	73.93	43.90
44........	76.89	42.15	75.40	43.07	73.88	43.93
46........	76.84	42.19	75.35	43.10	73.83	43.95
48........	76.79	42.22	75.30	43.13	73.78	43.98
50........	76.74	42.25	75.25	43.16	73.73	44.01
52........	76.69	42.28	75.20	43.18	73.68	44.04
54........	76.64	42.31	75.15	43.21	73.33	44.07
56........	76.59	42.34	75.10	43.24	73.58	44.09
58........	76.55	42.37	75.06	43.27	73.52	44.12
60........	76.50	42.40	75.00	43.30	73.47	44.15
c= .75....	.66	.36	.65	.37	.65	.38
c=1.15....	1.01	.55	1.00	.57	0.99	.53
c=1.90..	1.67	.91	1.65	.94	1.64	.95

No. 5.

A SHORT AND PRACTICAL METHOD TO FIND THE LENGTH OF ONE MINUTE OF LONGITUDE IN ANY LATITUDE, BASED UPON CERTAIN DEVELOPMENTS OF THE TERRESTRIAL SPHEROID.

By OTTO VON GELDERN.

For the determination of arcs of the Parallel and Meridional arcs, certain elements of the terrestrial spheroid have been used.

Up to within the last ten or fifteen years, Bessel's determinations of the earth's magnitude were employed, which were:

Equatorial Radius, $a = 6{,}377{,}397$ meters,
Polar Radius, . $b = 6{,}356{,}079$ meters.

$$\text{Compression} = \frac{1}{299.153}$$

Upon these elements the usual tables for the polyconic projection of maps were based, until those of Col. A. R. Clarke, R. E., were adopted, which furnish results more in harmony with recent geodetic measurements. Colonel Clarke's researches were published in his *Comparison of the Standards of Length of England, France, Belgium, Prussia, Russia, India and Australia, made at the Ordnance Survey Office, Southampton, 1866.*

The U. S. Coast and Geodetic Survey has adopted the Clarke form, and published a long and carefully computed series of polyconic projection tables for it in 1884, which are still in use. (See Appendix No. 6, Report 1884.)

Limiting the figure to that of an ellipsoid of revolution, Clarke's values are:

$a = 6{,}378{,}206$ meters,
exceeding Bessel's 809 m.
$b = 6{,}356{,}584$ meters,
exceeding Bessel's 505 m.

$$\text{Compression} \ \frac{1}{294.98}$$

It shows that this spheroid is somewhat larger than Bessel's and that the eccentricity is also greater.

These elements have satisfied the conditions developed during scientific measurements of large areas, so that they may be safely adopted without fear of appreciable error.

It is not the present purpose to enter into the subject mathematically.

If the earth were a perfect sphere with a radius R, the expression for the value of one minute of longitude in any latitude would be

$$\cos \text{lat.} \cdot \frac{2\ R\ \pi}{360 \times 60}$$

Assuming R equal to the length of the equatorial radius, 6,378,206 meters, the constant 1855.3 is obtained for the second member. By this constant the cosine of the latitude would have to be multiplied, in order to determine the length of one minute of longitude in meters. Or logarithmically expressed it is:

log. cos lat. + 3.2684256.

As we are dealing with a compression of nearly $\frac{1}{300}$ however, it becomes necessary to take some recognition of this fact in the determination of distances on the parallel. For our present purpose it will answer if we find a method that shall furnish results approaching the truth within reasonably narrow limits, without considering exact mathematical formulæ for obtaining very great precision.

After a careful study of this subject, based upon comparisons with very exact tabular values, the following method is proposed by the author, who has had occasion to make frequent use of it.

Approximate Method.

If the length of one minute of arc on the parallel be required, that shall not vary greatly from the correct value, observe the following rule:

To the logarithmic constant 3.2684256 add the logarithmic cosine of any given latitude *less 5 minutes,* and the result will be the length in meters of one minute of longitude in the given latitude.

Example:—What is the length of one minute of longitude in latitude 37° 47′?

Log. constant	3.2684256
Log. cosine of latitude 37° 42′	9.8982992
(37° 47′ — 05′ = 37° 42′)	3.1667248

Answer, 1468.0 meters.
(Correct within 0.2 m.)

By this method results are obtained correct within 0. 3 m. from the equator up latitude 60°; from 60° to 70° within 0. 5 m.; beyond that limit the deviations from the true values grow more rapidly, yet even at 80° a minute of longitude thus obtained would have an excess of 1. 6 m. only. For all ordinary requirements, therefore, the above rule will apply.

A deduction of an even 5 minutes gives the best *average* results, and for that reason it has been adopted. If we want to be a little more precise about it, we may use 4 minutes from 0 to latitude 25°, and from 65° upwards; 5 minutes from 25° to 35°, and from 50° to 65°; and 6 minutes from 35° to 50°. With this precaution the results will not vary more than 0. 2m. for any case from the equator up to latitude 70°.

If the distance is desired in feet instead of meters, multiply the result by 3.28087, or use the logarithmic constant 3.7844146 instead of the one given above.

A More Accurate Method.

Where greater refinement is required, say that instead of one *minute* we should want the length of one *degree* of arc without appreciable error, the deductions from the latitude must be defined a little more closely still, if they shall furnish reliable results.

By using the deductions given in minutes and seconds in the table below, for every 5° of latitude, results may be obtained that will be without appreciable deviation from the truth, even in the case of the length of one degree on a parallel.

In latitude	0°	deduct	0′ 0″.	In latitude	45°	deduct	5′ 50′.
" "	5°	"	1′ 00″.	" "	50°	"	5′ 40′.
" "	10°	"	1′ 50″.	" "	55°	"	5′ 30′.
" "	15°	"	2′ 40″.	" "	60°	"	5′ 00′.
" "	20°	"	3′ 50″.	" "	65°	"	4′ 30′.
" "	25°	"	4′ 30″.	" "	70°	"	3′ 50′.
" "	30°	"	5′ 00″.	" "	75°	"	3′ 00″.
" "	35°	"	5′ 30″.	" "	80°	"	2′ 00′.
" "	40°	"	5′ 40′.				

Any intermediate value may be interpolated.

Referring again to the previous example, let us find the value of one minute of longitude in latitude 37° 47′ by this method.

By consulting our table we find that for 37° 47′ we must deduct 5′ 35″, leaving 37° 41′ 25″. Then write:

Log. constant, ...	3.2684256	
Log. cosine of latitude 37° 41′ 25″,	9.8983724	
	3.16677980	
Answer, ...		1468.2 meters.

(Which is correct to the nearest tenth.)

If the length of a degree is wanted, multiply the result by 60, or use the constant 5.0465769 instead of the one above given.

Example:—What is the length of one degree of longitude in latitude 17°?

Log. constant, . . .	5.0465769	
Log. cosine 16° 56′ 45″,	9.9807216	
(17° — 3′ 15″)	5.0272985	
Answer, ...		106,487 meters.

(Which is correct to the nearest meter.)

Again, for latitude 74°?

Log. constant, . . .	5.0465769	
Log. cosine 73° 56′ 50″,	9.4417308	
	4.4883077	
Answer, ...		30,782 meters.

(Correct within 1 meter.)

These results are readily reduced to either nautical or statute miles, by dividing by 1853.248 (log. 3.2679335) in the former, and by 1609.33 (log. 3.2066449) in the latter case. The logarithmic constant may be changed to suit these measures.

The Nautical Mile.

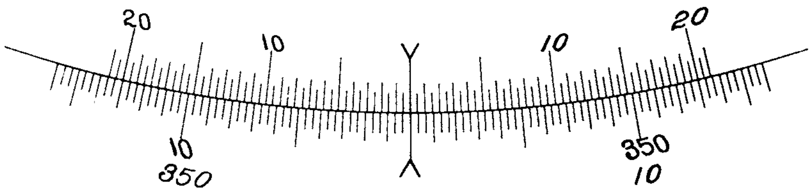
The length of a nautical mile has been adopted at 1853.248 meters, or 6080.27 feet. It will be noticed that this is 2.1 meters less than the length of one minute of longitude at the equator, which is ordinarily assumed as that which defines the nautical mile. The fact is that this unit of measure has been arbitrarily based, and that it varies as the data from which the deductions are made. In order to establish uniformity for all time, the nautical mile is now defined as the length of one minute of a great circle of a sphere that shall have the same superficial area as the terrestrial spheroid. This basis was adopted by the United States Coast and Geodetic Survey, and computed from Clarke's elements.

Length of One Minute of Latitude in Different Latitudes.

At the Equator, . . .	1842.8 meters	At 50°, ...	1853.8 meters
" 10°, ...	1843.4 "	" 60°, ...	1856.9 "
" 20°, ...	1845.0 "	" 70°, ...	1859.4 "
" 30°, ...	1847.5 "	" 80°, ...	1861.1 "
" 40°, ...	1850.5 "	" 90°, ...	1861.7 "

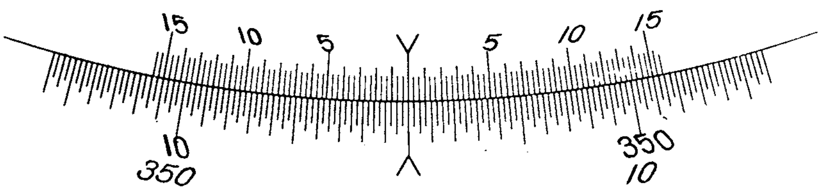
Figs. 1 to 6 show the customary styles of verniers used on The Lietz instruments.

No. 1 Double vernier reading to 30″. Circle graduated to 20′.



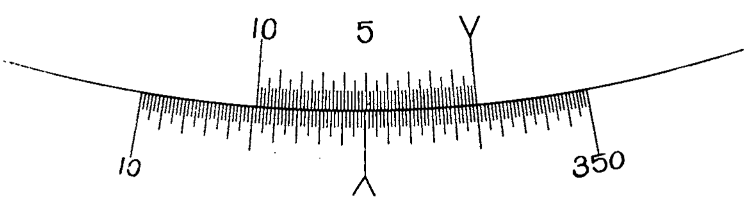
No. 1.

No. 2 Double vernier reading to 20″. Circle graduated to 15′.



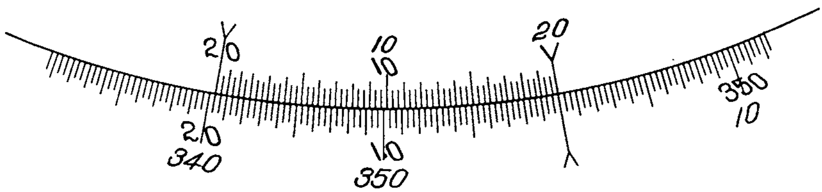
No. 2.

No. 3 Single vernier reading to 10″. Circle graduated to 10′ with one row of figures.



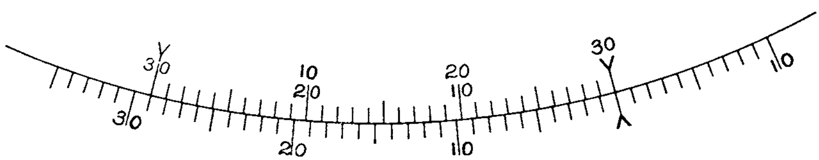
No. 3.

No. 4 Single vernier reading to 20″. Circle graduated to 20′ with two rows of figures.



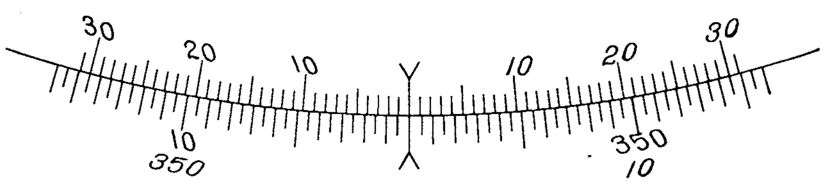
No. 4.

No. 5 Vernier reading to 2′. Circle graduated to single degree.



No. 5.

No. 6 Double vernier reading to single minutes. Circle graduated to 30′.



No. 6.

Design No. 180C Stadia Rod is prepared under specifications for the markings furnished by Mr. C. E. Grunsky, who states that he has found no other self-reading rod equally satisfactory for general use. The markings were originally devised in the office of the State Engineer of California (Wm. Ham. Hall, State Engineer) about 1880, and Mr. Grunsky assisted in devising the original rod. He says: "The reading is to the nearest-hundreth of a foot along the oblique lines of the black triangle. The figures which the cross-hair cuts are always read. They stand on the footmarks. The black rectangle of the odd tenths backed by a black triangle, together with the superimposed triangle of the next even tenth make a characteristic design, Fig. 180C, which helps the eye to mount from point to point with certainty by two-tenth intervals. The tops of the figures are always at three-tenth points. The five-tenth points are identified by the red diamond-shaped marks, and the full foot by similar elongated red spear-heads, or half spear-heads, extending across the face of the rod. The rod is serviceable for all ordinary leveling work, and can be read as quickly as though every tenth were marked with a figure.

☞For illustration and price see pages 161 and 162.

REVISED EDITION OF

PART II

ILLUSTRATED CATALOGUE AND PRICE LIST

OF

Modern Engineers' and Surveyors' Instruments

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Manufacturers of Scientific Instruments

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INTRODUCTION TO PART II.

The following illustrations show the principal articles manufactured by this Company, being in the case of this catalogue almost exclusively confined to instruments required by the civil, mining, irrigation, hydraulic and military engineer, for making accurate measurements and surveys for any purpose whatever.

Of the surveying instruments each illustration, or plate, is complete within itself. Every part is carefully noted upon the back, together with the price, and a general description in a condensed form. The additional accessories that may be had in each instance, are also enumerated and their prices given. It is well, however, that the engineer who is looking for an article, should consult the preceding part of this Manual, wherein every detail is carefully described and extensively discussed. If pains are taken to look this over, the reader will obtain all the information that could possibly be given him in the shop.

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is all that is required to designate to us exactly what is desired by our patron.

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See also Telegraph Code in front of book.

With the detailed information on its reverse side, every plate becomes a complete price list of the particular instrument illustrated. Every effort has been made to make this part of the book as intelligible as possible, without the necessity of searching over numerous pages to gather information.

Although we shall make any instrument of precision called for, we desire to state clearly that we have made a particular specialty of engineers' and surveyors' instruments, because there is for them alone a demand at the present time, and for this reason our shop facilities have been especially designed and improved for the manufacture of these articles.

If instruments for a more scientific purpose are wanted, for astronomical or geodetic work, for instance, we can either *make* them on a special order, or we can *import* them for our customer, having made arrangements in Europe, which enables us to sell such instruments as cheaply as any one in the United States. For institutions of learning we import without payment of duty.

In all our manufacture the prices have been marked commensurate with the quality of the work, and no deductions can be made from our price list, which agrees in all its quotations with those of our best Eastern firms.

We furnish a first-class article at a fair price, and all goods stand upon their individual merit. It has been our object to create the best that the instrument maker's art can make or devise, and with the records of the past decades before us we feel that we have been successful in every way.

A. LIETZ COMPANY.

ENGINEERS' AND SURVEYORS' TRANSITS.

(Double Spindle Repeating.)

Nos. 1 to 4.

These are elegant instruments, absolutely accurate in all working parts, designed for land surveying and engineering work of a high character.

The general dimensions are given on the back of each illustration, as well as the price, and the extras that may be had upon application. By carefully inspecting the plates, the price list and the enumerated extras, the purchaser is enabled to choose the article and any desired accessory, and make an estimate of its cost.

We make each style, if desired, in hard aluminum, which increases the price 15 per cent.

The horizontal circle is graduated to read to either 60, 30 or 20 seconds, two double verniers being provided, placed so as to afford a reading without stepping aside. The vertical arc or circle is graduated to read to 60 or 30 seconds. Every instrument has long compound centers, shifting plates on tripod head, with new improved coupling. The telescope possesses definition, light and power in a high degree. It has Jena glass lenses, achromatic objective and eye-piece. Erect vision. The telescope is reversible and evenly balanced, provided with slide protector, and screw motion for focusing cross-hairs. The standards are cloth-finished. The case has leathern straps, rubber cushions, and contains all the usual accessories. For a minute description of every detail, see first part of the Manual.

No. 1.

PLAIN TRANSIT.

Price, $185.00.

☞ For details and extras see the following page.

No. 1.

Dimensions and Weight.

Horizontal Circle (measured to the edge of graduation)	6¼	inches	diam.
Compass Needle	4½	"	long
Object Glass	1⅛	"	diam.
Telescope	11	"	long
Magnifying power	24		
Weight of instrument	15	lbs.	
" tripod	8½	"	
" box	8	"	
Weight of this instrument if made of hard aluminum	7½	"	

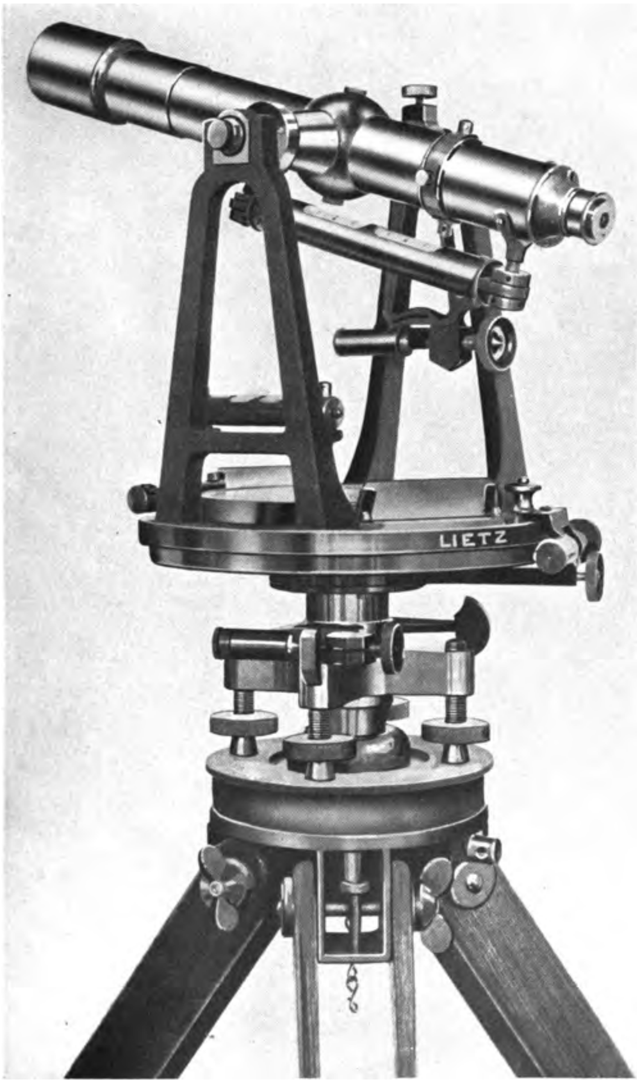
The price of this instrument as shown is..............................$185 00

And if made of hard aluminum, 15 per cent is added.

The Extras, for which additional charge is made, are as follows:

Solid Silver Graduations:	
On horizontal circle	$10 00
Verniers, reading to 30″	10 00
" " 20″	20 00
Stadia hairs, fixed	3 00
" " adjustable	10 00
Variation plate	10 00
Arrangement for offsetting right angles	5 00
Striding level to axis of telescope	20 00
Constructed with three leveling screws on base-plate, instead of four	10 00
Three-leveling-screw shifting center	5 00
Extra extension tripod in lieu of ordinary	5 00
Protection bag	1 00
Bottle of fine watch oil	25

NOTE.—On all Lietz Transits the variation of the needle may be laid off to the minute, see page 36.



No. 2.

TRANSIT, WITH LEVEL TO TELESCOPE.

Price, $215.00.

☞ For details and extras see the following page.

No. 2.

Dimensions and Weight.

Horizontal Circle (measured to the edge of graduation)	6¼	inches	diam.
Compass Needle	4½	"	long
Object Glass	1⅛	"	diam.
Telescope	11	"	long
Magnifying power	24		
Weight of instrument	15	lbs.	
" tripod	8½	"	
" box	8	"	
Weight of this instrument if made of hard aluminum	7½	"	

The price of this instrument as shown is $215 00

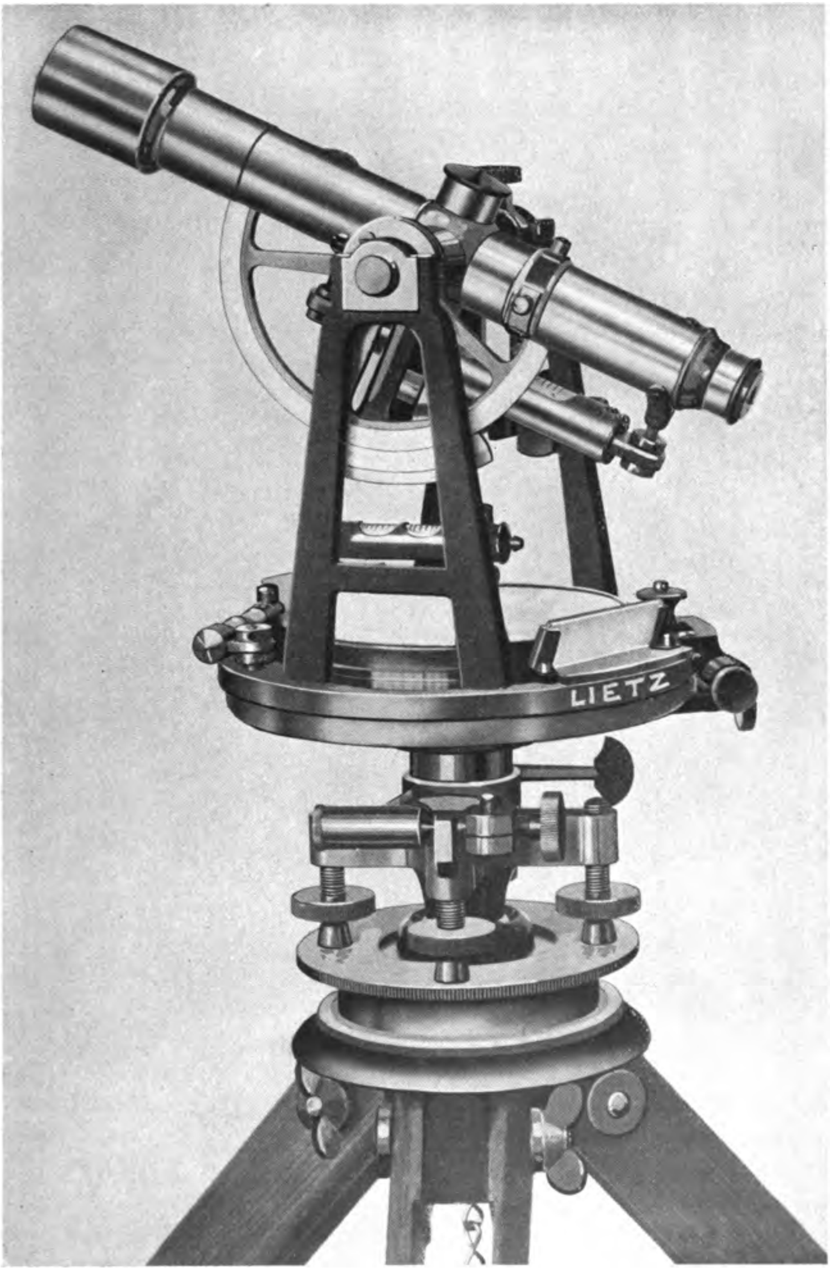
And if made of hard aluminum, 15 per cent is added.

The Extras, for which additional charge is made, are as follows:

Solid Silver Graduations:	
On horizontal circle	$10 00
Verniers, reading to 30″	10 00
" " 20″	20 00
Gradienter attachment	5 00
Stadia hairs, fixed	3 00
" " adjustable	10 00
Variation plate	10 00
Arrangement for offsetting right angles	5 00
Striding level to axis of telescope	20 00
*Reversion level for telescope	10 00
Constructed with three leveling screws on base-plate, instead of four	10 00
Three-leveling-screw shifting center	5 00
Extra extension tripod in lieu of ordinary	5 00
Protection bag	1 00
Bottle of fine watch oil	25

The Reversion Level.

* The REVERSION LEVEL is ground on both sides, and the case open on top and bottom, so that the bubble is always visible when the telescope is revolved in transit. Absolute levels may be obtained, and errors in adjustment may be corrected in reversion, by a method of vertical double centering.



No. 3.

COMPLETE ENGINEERS' TRANSIT.

WITH VERTICAL ARC.

Price, $230.00.

☞ For details and extras see the following page.

The 5-inch vertical arc is provided with a double vernier reading to minutes.

No. 4.

Dimensions and Weight.

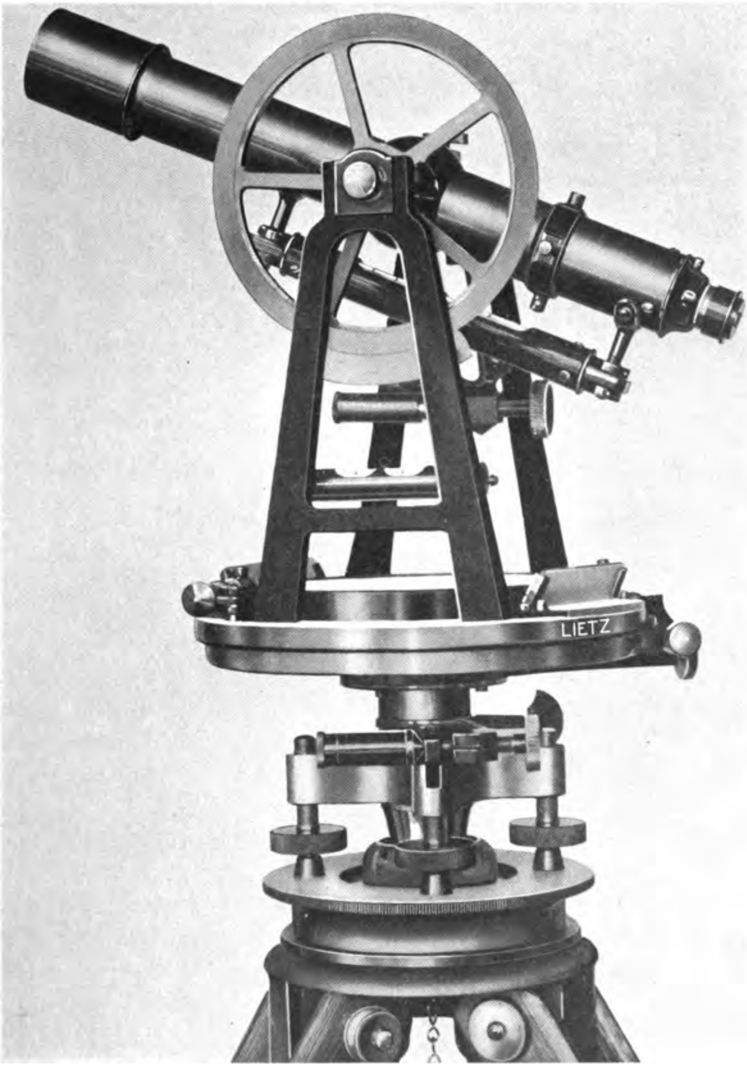
Horizontal Circle (measured to edge of graduation)	6¼	inches	diam.
Vertical Circle (measured to edge of graduation)	5	"	"
Compass Needle	4½	"	long
Object Glass	1⅛	"	diam.
Telescope	11	"	long
Magnifying power	24		
Weight of instrument	15	lbs.	
" tripod	8½	"	
" box	8	"	
Weight of this instrument if made of hard aluminum	7½	"	

The price of this instrument as shown is $235 00

And if made of hard aluminum, 15 per cent is added.

The Extras, for which additional charge is made, are as follows:

Solid Silver Graduations:	
On horizontal circle	$10 00
On vertical circle	5 00
Verniers, reading to 30″ on horizontal circle	10 00
" " 20″ " "	20 00
Gradienter attachment	5 00
Stadia hairs, fixed	3 00
" " adjustable	10 00
Variation plate	10 00
Arrangement for offsetting right angles	5 00
Striding level to axis of telescope	20 00
Reversion level to telescope (see footnote, page 130)	10 00
Constructed with three leveling screws on base-plate, instead of four	10 00
Three-leveling-screw shifting center	5 00
Prism, attachable to eyepiece	8 00
Extra extension tripod in lieu of ordinary	5 00
Protection bag	1 00
Bottle of fine watch oil	25
Saegmüller solar attachment of aluminum	50 00
Guard for vertical circle	5 00



No. 4.

COMPLETE ENGINEERS' TRANSIT.

WITH FULL VERTICAL CIRCLE.

Price, $235.00.

☞ For details and extras see the following page.

The 5-inch vertical circle is provided with a double vernier, reading to minutes.

No. 5. Transit-Theodolite.

This is an instrument of very superior construction.

The standards upon which the telescope rests are cast in one U-shaped piece, thus affording more strength than the ordinary form.

The telescope is reversible in position, as well as exchangeable in its bearings, which are provided with dust-caps and screws, to give them the proper friction. The telescope is either erect or inverting. For reasons already set forth, the inverting form should be given the preference. The telescope possesses the finest lenses and optical accessories. It has a slide-protector and is provided with a sunshade. The cross-hairs are focused by a screw motion of the eyepiece.

All the graduations are on solid silver. The horizontal circle reads to either 30, 20 or 10 seconds, by two opposite verniers, near the line of collimation, which are supplied with two attached reading-glasses, if desired. The vertical arc or circle is graduated to read to 30 seconds.

The instrument is furnished with either three or four leveling screws, that operate through a star-piece, as already described in the case of the other instruments.

The U-shaped casting, constituting the support for the telescope, may be either in cloth-finish, or in bright lacquer, like the rest of the instrument. The metal finish may be had of any desired color.

The new Lietz Tripod Coupling is furnished without extra charge.

The case contains all the usual accessories, such as plumb bob, screw-driver, adjusting pins, etc.

Dimensions and Weight.

Horizontal Circle (measured to edge of graduation)	6¼	inches	diam.
Vertical Arc or Circle (measured to edge of graduation)	5	"	"
Compass Needle (in box on plate)	3½	"	long
Telescope	11	"	"
Object Glass	1⅛	"	diam.

Magnifying power	24	
Weight of instrument	16	lbs.
" tripod	8½	"
" box	8	"

If made of aluminum, the weight of the instrument is reduced 50%.

The price of the plain transit-theodolite (without a level, clamp and arc to telescope) is $240.00, and if made of hard aluminum 15% is added.

The Extras, which make the instrument more complete, are as follows:

Verniers reading to 20″ on a 6¼-inch horizontal circle	$10 00
" " 10″ " 7 " " "	35 00
A 5-inch vertical arc, reading to minutes	20 00
A 5-inch full vertical circle, reading to minutes	25 00
" " " " with opposite double verniers, reading to minutes	50 00
Two vernier microscopes	15 00
Long ground level to telescope, with compound clamp and tangent screw, telescope reversible, and supplied with gradienter attachment	40 00
Reversion level for telescope (see footnote, page 130)	10 00
Striding level	20 00
Stadia hairs, fixed	3 00
" " adjustable	10 00
Box needle, on plate	20 00
Constructed with three leveling screws on base-plate, instead of four	10 00
Three-leveling-screw shifting center	5 00
Prism, attachable to eyepiece	8 00
Protection bag	1 00
Bottle of fine watch oil	25
Saegmüller solar attachment of aluminum	50 00
Guard for vertical circle	5 00

No. 9.

COMPLETE MOUNTAIN AND MINING TRANSIT.

Nos. 6 to 9.

No. 6 is the Plain Mountain and Mining Transit.
No. 7, the same as No. 6, with telescope level.
No. 8, the same as No. 7, with a vertical arc.

☞ For details, prices and extras, see the following page.

Nos. 6 to 9. Small Mountain and Mining Transit.

The Plain Transit.

This is a beautiful instrument, made to correspond in every way with No. 1, except in size and weight. It is a superior and reliable article for general land surveying, and particularly for mining purposes.

Dimensions, Nos. 6 to 9.

Horizontal circle (measured to edge of graduation)	5	inches	diam.
Vertical arc or circle (measured to edge of graduation)	4	"	"
Compass needle	3½	"	long
Object glass	1	"	diam.
Telescope	8	"	long
Magnifying power		18	
Weight of instrument	8½	lbs.	
" tripod	6	"	
" box	6	"	
Weight of this instrument if made of hard aluminum	4½	"	

The price of the plain transit, No. 6, is	$180 00
With level to telescope and tangential movement, No. 7	210 00
With vertical arc in addition, No. 8	225 00
With full vertical circle, No. 9	230 00

And if made of hard aluminum, 15 per cent is added.

The Extras, for which additional charge is made, are as follows:

Solid Silver Graduations:	
On horizontal circle	$10 00
On vertical arc or circle	5 00
Gradienter attachment	5 00
Stadia hairs, fixed	3 00
" " adjustable	10 00
Variation plate	10 00
Arrangement for offsetting right angles	5 00
Striding level to axis of telescope	20 00
Reversion level to telescope (see footnote, page 130)	10 00
Constructed with three leveling screws on base-plate, instead of four	10 00
Three-leveling-screw shifting center	5 00
Prism attachable to eyepiece	8 00
Half-length tripod	13 00
Extra extension tripod	15 00
Extension tripod in lieu of the ordinary	5 00
Detachable side telescope	35 00
Lamp for mining engineering, of brass, with ground lens	7 00
Reflector, for illuminating cross-hairs	4 00
Plummet lamp	10 00
Large plumb-bob, weight 4 lbs., for use in shafts	5 00
Protection bag	1 00
Bottle of fine watch oil	25
Saegmüller solar attachment of aluminum	50 00
Guard for vertical circle	5 00

No. 10. Mining Transit.

The same dimensions as in Nos. 1 to 4. Graduations on solid silver; verniers, reading to minutes, provided with glass shades; 5-inch full vertical circle; spirit level, clamp and tangent screw to telescope; extension tripod, etc. Price, $258.00. If made of hard aluminum, 15% added.

No. 11. Mining Transit.

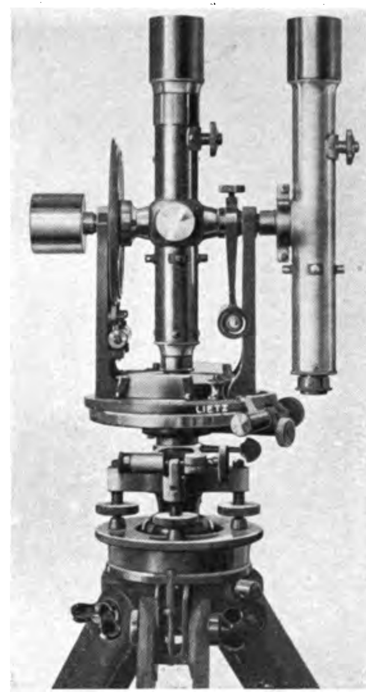
The same dimensions as in Nos. 6 to 9. Graduations on solid silver; verniers, reading to minutes, provided with glass shades; 4-inch full vertical circle; spirit level, clamp and tangent screw to telescope; extension tripod, etc. Price, $253.00. If made of hard aluminum, 15% added.

It must be apparent that there cannot be any great difference in price between a large and a small-sized instrument. The workmanship in each is alike, and, if anything, more complicated and costly in the smaller. The only difference is in the quantity of metal used, but as this cannot possibly amount to much in price, it is more than compensated by the additional care required in handling the smaller parts. This explanation would hardly seem necessary, were it not for the prevailing impression that all merchantable articles of the same kind should be rated by their respective sizes. That this cannot obtain in the case of instruments must stand to reason. The price of a transit can only be reduced by omitting certain features, or by changing it to a simpler construction.

No. 12. Mountain and Mining Transit.

The illustration on page 141 represents our Mountain and Mining Transit, No. 12. While with the introduction of our special aluminum alloy we have been the producers of the lightest instruments for years, yet some of our patrons have expressed a desire to possess an instrument of smaller size, admitting of easier transportation in mountainous country. Transit No. 12 is made with as much care as our larger instruments; the constructive details are similar, and full reliance may be placed upon this instrument as to the performance of its working parts in every respect. We would especially recommend our friends to order this instrument in our special aluminum alloy, which not only makes it lighter, but which adds considerably to the rigidity, lateral strength, and to its steadiness. This statement is made and based upon our experience gained in the last fifteen years, during which time we have manufactured almost one thousand instruments of our special aluminum alloy, and it is verified by authorities who constantly use them. At first thought the statement may seem paradoxical that an instrument made of lighter material should be steadier than one made of heavier metals, and we are constantly confronted with queries from engineers, when we recommend instruments of the lighter type, whether these will prove steady enough in the wind. It seems that the ordinary opinion is not based upon practical experience, but created by the reasonable assumption that heavier weight will offer more resistance to disturbing influences than light weight.

While it cannot be denied that the weight of an instrument adds to its steadiness, it must be borne in mind that instruments have not been made of the older metals in order to gain steadiness, but simply because this was the best material available for the purpose. Wear and resistance in case of accident were the principal features sought. A light material, provided it has these qualities, offers the best opportunity to produce the most rigid instrument, for the reason that it admits of lowering the center of gravity by a judicious distribution of the metals, and this is what we have aimed at, and believe we have fully accomplished in our aluminum alloy instruments. This instrument is rigid and firm; it offers more resistance in case of a fall than the heavier metals; its wearing qualities are such that no bushing is required; the coefficient of expansion and contraction is eliminated, so that their adjustments will remain constant under severe conditions. Their qualities during the last fifteen years have been so thoroughly tested that we conscientiously recommend them to the profession.



LIETZ MOUNTAIN AND MINING TRANSIT No. 12.

☞For details and price see pages 117, 118 and 120.

No. 12. Mountain and Mining Transit.

It possesses a double center, lower clamp and tangential movement, plate movement with the clamp and tangent screw, and sensitive plate levels; two double verniers reading to minutes, placed conveniently for reading without stepping from the eye-piece end. The telescope is reversible, has a clamp and tangent movement, long level and vertical circle with double vernier reading to single minutes. The telescope is either erect or inverting. It possesses the finest lenses and optical accessories. The cross-hairs are focused by a screw motion to the eyepiece.

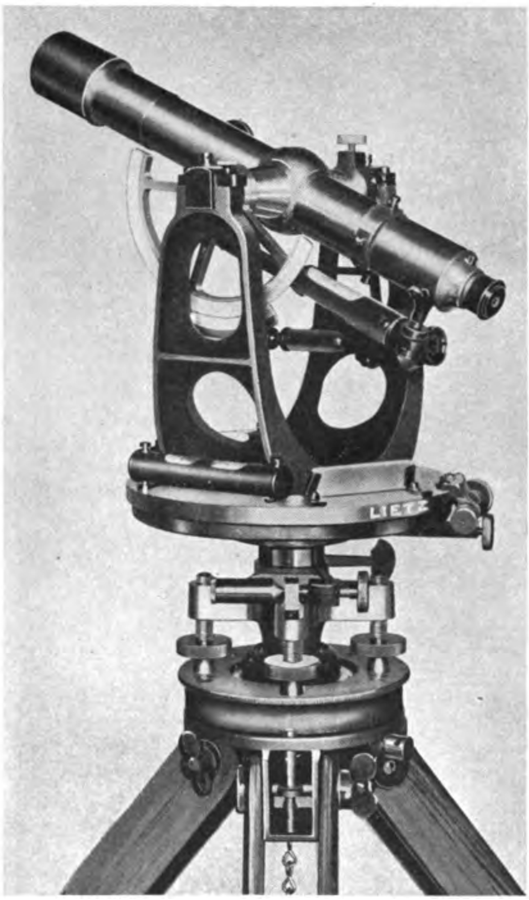
Horizontal and vertical graduations are on solid silver. The instrument has a Lietz Tripod Coupling and a shifting center. The case contains all the usual accessories, such as screw-driver, adjusting pin, reading glass, etc.

Dimensions and Weight.

Horizontal circle, measuring to the edge of graduation	4	inches	diam.
Vertical arc or circle " " " "	4	"	"
Compass needle	2½	"	long
Object glass	1	"	diam.
Telescope	8	"	long
Magnifying power	18		
Weight of instrument	5	lbs.	
" tripod	5	"	
" box	4	"	
Price of instrument	$228 00		
If made of hard aluminum	250 00		

Extras for which additional charge is made:

Gradienter attachment	$ 5 00
Stadia hairs, fixed	3 00
Variation plate	10 00
Reversion level to telescope (see footnote, page 130)	10 00
Prism to eyepiece	8 00
Half-length tripod	13 00
Extension tripod in lieu of ordinary	5 00
Detachable side telescope	35 00
Guard for vertical circle	5 00
Vertical circle graduated on the periphery admitting a reading of the vernier from the front of eyepiece end	25 00
V-shaped standard	10 00
Circular compass for V-shaped standard	20 00



No. 13.

COMPLETE TRANSIT-THEODOLITE.

☞ For details and price see the following page.

No. 13. Transit Theodolite.

This instrument is of the same type and embodies the same characteristics as our No. 5. It is only of a smaller and more portable size. It possesses a double center, lower clamp and tangential movement; plate movement with the clamp and tangent screw, and sensitive plate levels; double verniers reading to minutes, placed conveniently for reading without stepping from the eye-piece end. The telescope is reversible in position, as well as exchangeable in its bearings, which are provided with dust caps, and screws, to give them the proper friction. The telescope is either erect or inverting. For reasons already set forth, the inverting form should be given the preference. The telescope possesses the finest lenses and optical accessories. It has a slide-protector and is provided with a sunshade. The cross-hairs are focused by a screw motion to the eye-piece.

All the graduations are on solid silver, reading to single minutes, the horizontal circle by two opposite verniers, near the line of collimation, the vertical arc by one double vernier. The instrument has the Lietz tripod coupling and a shifting center. The case contains all the usual accessories, such as plumb-bob, screw-driver, adjusting pin, reading-glass, etc.

DIMENSIONS AND WEIGHT.

Horizontal circle measured to the edge of the graduation, 5 inches diameter; vertical circle measured to the edge of the graduation, 4 inches diameter; telescope, 8 inches long; object glass, 1 inch diameter; magnifying power, 18. Weight of the instrument, 8½ pounds; weight of tripod, 6 pounds; weight of box, 6 pounds; weight of instrument, if made of hard aluminum, 4½ pounds. Price of this instrument, complete as above, $257.00, and, if made of hard aluminum, 15% is added.

The extras, for which additional charges are made, are as follows:

Vernier, reading to 30″ on the horizontal circle	$10 00
Two vernier microscopes	15 00
Reversion level to telescope (see footnote, page 130)	10 00
Striding level	20 00
Stadia hairs, fixed	3 00
Box needle on plate	20 00
Constructed with three leveling screws on base-plate, instead of four	10 00
Three-leveling-screw shifting center	5 00
Extension tripod in lieu of ordinary	5 00
Saegmüller solar attachment	50 00
Guard for vertical circle	5 00

A. Lietz Company
Makers
San Francisco, Cal.

No. 16.

COMPOUND MINING AND SOLAR TRANSIT.

Price, Complete, $318.00.

☞ For details see the following page.

No. 16. Compound Mining and Solar Transit.

This instrument is like No. 4, with the Saegmüller Solar Attachment.

It possesses a double center, lower clamp and tangential movement; plate movement with clamp and tangent screw, and sensitive plate levels; double verniers reading to minutes, placed conveniently for reading, without stepping from the eye end. Compass needle and graduated compass ring, with variation plate. Cloth-finished standards, carrying an improved telescope. The telescope is reversible and evenly balanced; it affords ample definition, power and light; fixed stadia hairs are supplied; it has a long level and possesses a clamp and tangential movement; also gradienter attachment; a full or half vertical circle reading to minutes. All graduations are on solid silver. The instrument has the Lietz tripod coupling, and a shifting center.

The solar attachment is detachable, screws into the top of the telescope axis, and becomes a part of the instrument. It answers all the purposes of a side telescope, as shown in the marginal sketch.

The whole instrument is packed in a handsome case, with a special place for the solar attachment, containing a plumb bob, adjusting pins and all the usual accessories.

Dimensions and Weight.

Horizontal circle (measured to edge of graduation)	6¼	inches	diam.
Vertical arc or circle (measured to edge of graduation)	5	"	"
Compass needle	4½	"	long
Telescope	11	"	"
Object glass	1⅛	"	diam.
Magnifying power	24		
Weight of instrument	16	lbs.	
" tripod	8½	"	
" box	8	"	
Weight of this instrument if made of hard aluminum	8	"	
The price of this instrument, complete, is	$318 00		

And if made of hard aluminum, 15 per cent is added.

The extras, for which additional charge is made, are as follows:

Verniers, reading to 30″ on horizontal scale	$10 00
" " 20″ " "	20 00
Adjustable stadia hairs	10 00
Arrangement for offsetting right angles	5 00
Striding level to axis of telescope	20 00
Constructed with three leveling screws on base-plate, instead of four	10 00
Three-leveling-screw shifting center	5 00
Prism attachable to eyepiece	8 00
Extra extension tripod	15 00
Extension tripod in lieu of the ordinary	5 00
Reversion level on telescope (see footnote, page 130)	10 00
Half-length tripod	13 00
Detachable side telescope	35 00
Lamp for mining engineering, of brass, with ground lens	7 00
Reflector for illuminating cross-hairs	4 00
Plummet lamp	10 00
Large plumb-bob, weight 4 lbs., for use in shafts	5 00
Protection bag	1 00
Bottle of fine watch oil	25
Guard for vertical circle	5 00

A. Lietz Company
Makers
San Francisco, Cal.

No. 17.

COMPOUND MINING AND SOLAR TRANSIT.

Price, Complete, $313.00.

☞ For details see the following page.

No. 17. Compound Mining and Solar Transit.

This instrument is like No. 9, with the Saegmüller solar attachment.

It possesses a double center, lower clamp and tangential movement; plate movement with clamp and tangential screw, and sensitive plate levels; double verniers reading to minutes, placed conveniently for reading without stepping from the eye end. Compass needle and graduated compass ring, with variation plate. Cloth-finished standards, carrying an improved telescope. The telescope is reversible and evenly balanced; it affords ample definition, power and light; fixed stadia hairs are supplied; it has a long level and possesses a clamp and tangential movement; also gradienter attachment; a full or half vertical circle reading to minutes. All graduations are on solid silver. The instrument has the Lietz tripod coupling and a shifting center.

The solar attachment is detachable, screws into the top of the telescope axis, and becomes a part of the instrument. It answers all the purposes of a side telescope, as shown in the marginal sketch.

The whole instrument is packed in a handsome case, with a special place for the solar attachment, containing a plumb-bob, adjusting pins and all the usual accessories.

Dimensions and Weight.

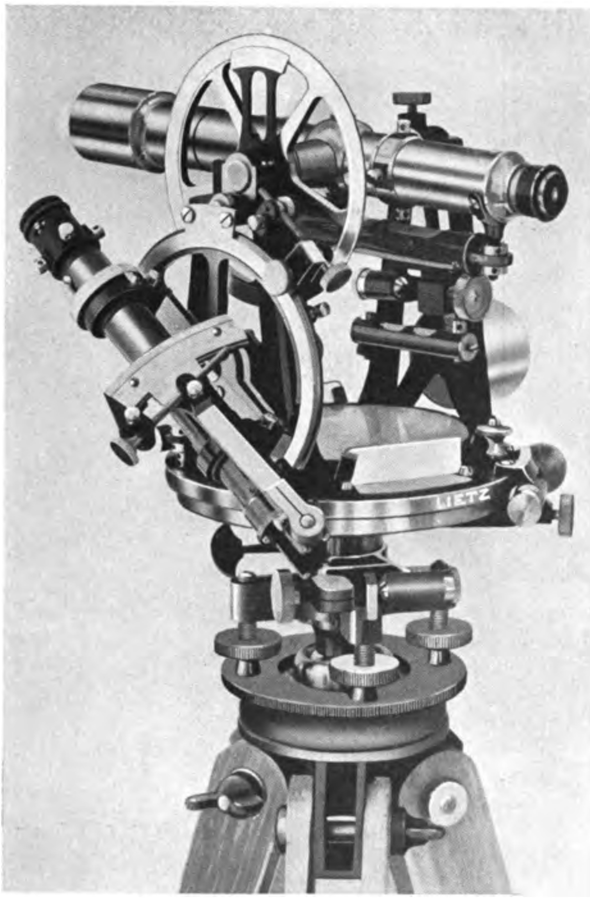
Horizontal circle (measured to edge of graduation)	5	inches	diam.
Vertical circle (measured to edge of graduation)	4	"	"
Compass needle	3½	"	long
Telescope	8	"	"
Object glass	1	"	diam.
Magnifying power	18		
Weight of instrument	9	lbs.	
" tripod	6	"	
Weight of this instrument if made of hard aluminum	5	"	

The price of this instrument, complete, is....$313 00

And if made of hard aluminum, 15 per cent is added.

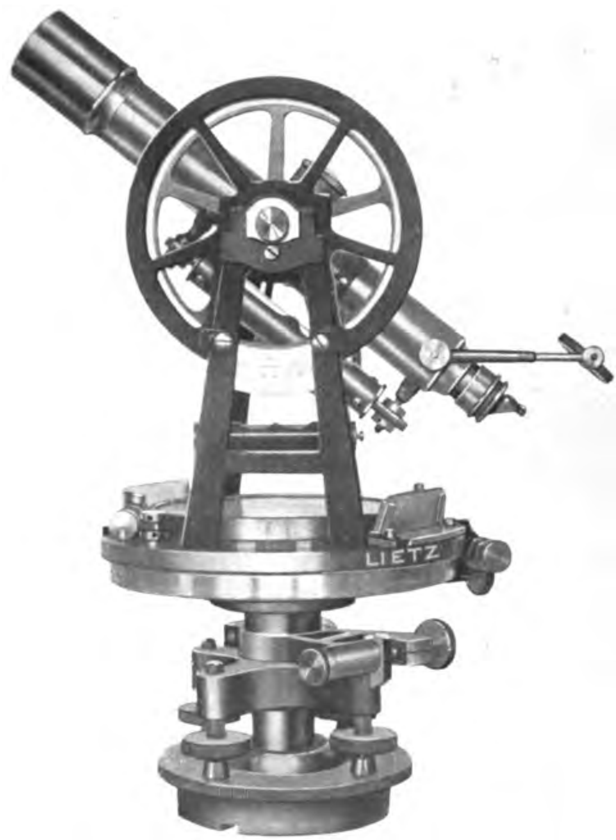
The Extras, for which additional charge is made, are as follows:

Adjustable stadia hairs	$10 00
Arrangement for offsetting right angles	5 00
Striding level to axis of telescope	20 00
Reversion level for telescope (see footnote, page 130)	10 00
Constructed with three leveling screws on base-plate, instead of four	10 00
Three-leveling-screw shifting center	5 00
Prism attachable to eyepiece	8 00
Extra extension tripod	15 00
Half-length tripod	13 00
Extension tripod in lieu of the ordinary	5 00
Detachable side telescope	35 00
Lamp for mining engineering, of brass, with ground lens	7 00
Reflector, for illuminating cross-hairs	4 00
Plummet lamp	10 00
Large plumb-bob, weight 4 lbs., for use in shafts	5 00
Protection bag	1 00
Bottle of fine watch oil	25
Guard for vertical circle	5 00



SMITH SOLAR ATTACHMENT.

Price, $85.00.

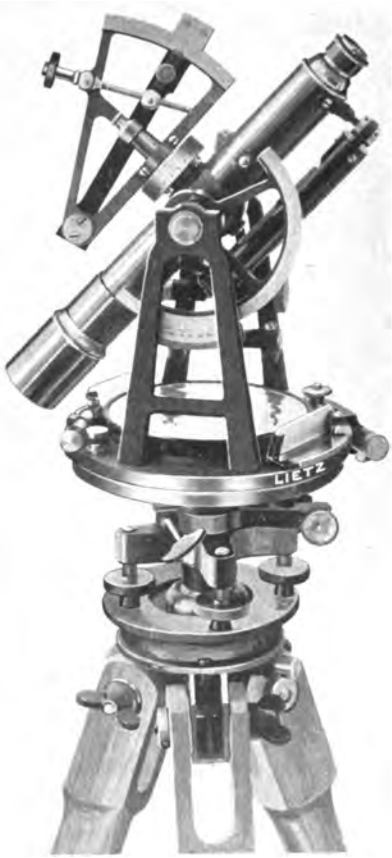


DAVIS SOLAR SCREEN.

Price, complete with prism, $14.00.

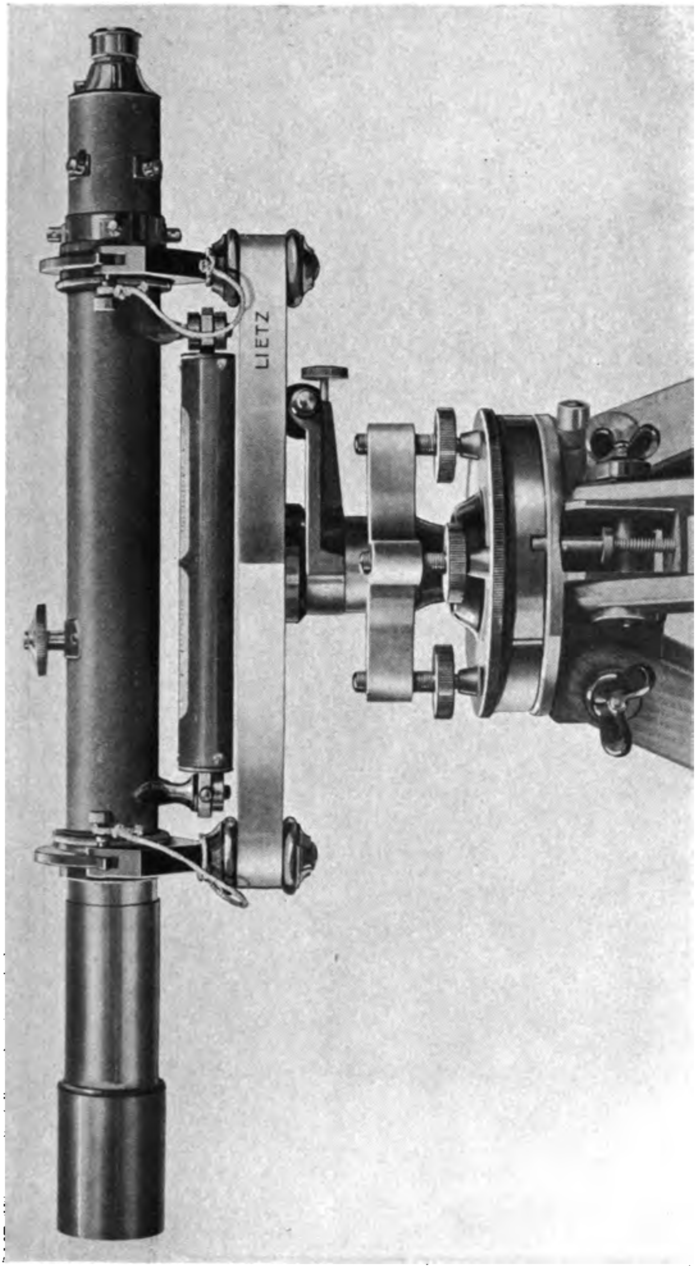
TELESCOPIC SOLAR ATTACHMENT.

Price, $50.00.



BURT, SOLAR ATTACHMENT.

Price, $50.00.



No. 19.

ENGINEERS' Y-LEVEL.

Price, $140.00.

☞ For details see the following page.

No. 19. Engineers' Y-Level.

Possesses all recent improvements. Long center; star-shaped construction of the guide for the foot-screws; clamp and tangential movement; sensitive spirit level. The telescope has definition, light and power in a high degree; best achromatic Jena glass lenses (erect vision) and stadia hairs if desired; is provided with a slide-protector, and either cloth, bright or bronze finished. Fastened to the tripod by means of the Lietz coupling.

The whole is packed in a neat case containing all the usual accessories.

Dimensions and Weight.

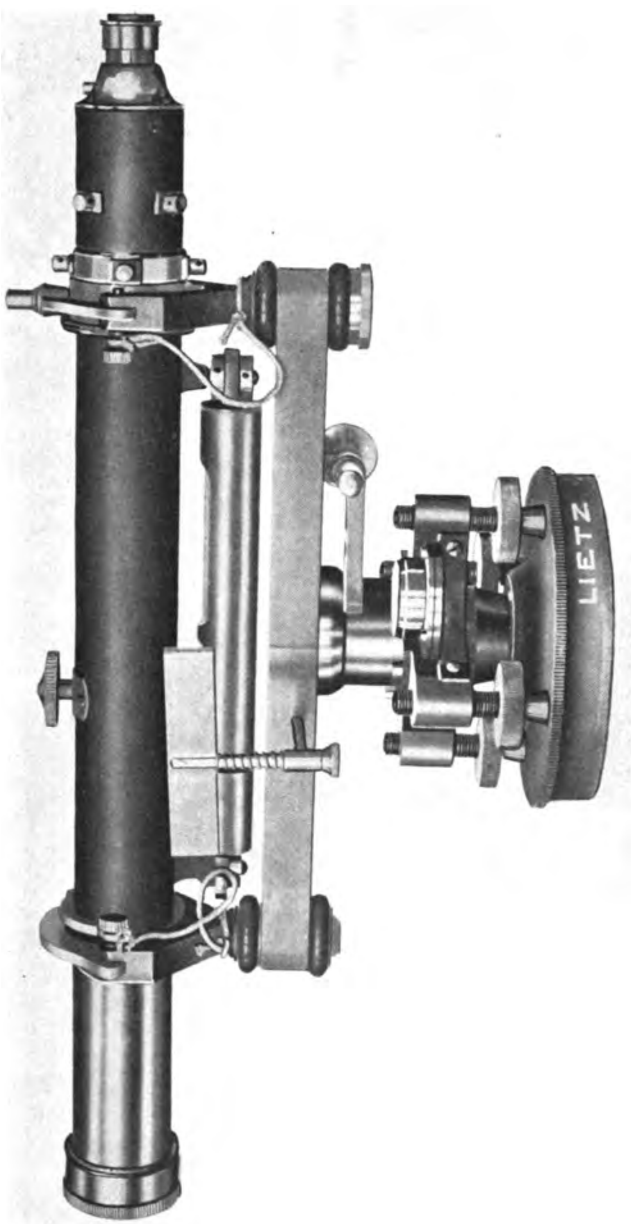
Length of telescope	18	inches
Diameter of objective	1⅜	"
Magnifying power	33	
Weight of instrument	10½	lbs.
" tripod	8	"
" box	7½	"
Weight of this instrument if made of hard aluminum	6¼	"
The price of this instrument is		$140 00

And if made of hard aluminum, 15 per cent is added.

The Extras, for which additional charge is made, are as follows:

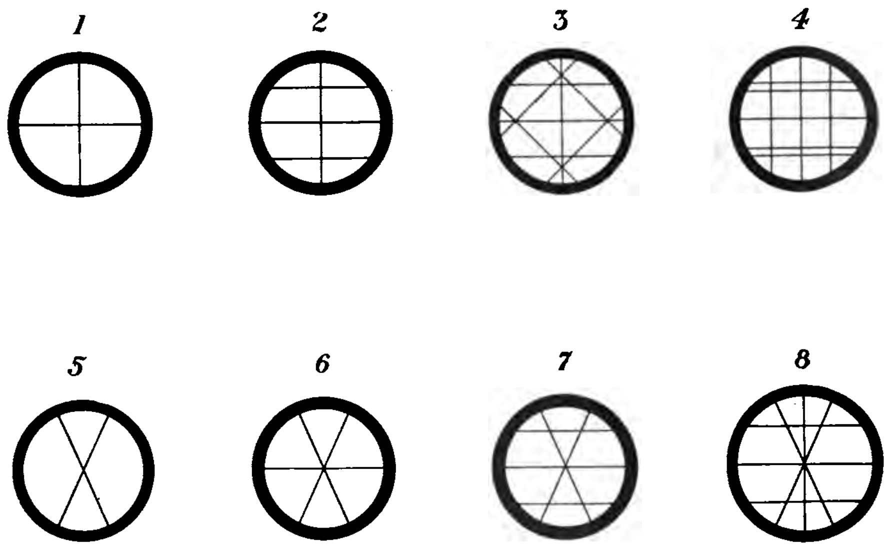
Mirror, to control the bubble at eye end	$10 00
Stadia hairs, fixed	3 00
" " adjustable	10 00
Reversion level to telescope (see footnote on page 130)	15 00
Three leveling screws on base-plate, instead of four	10 00
Protection bag	1 00
Bottle of fine watch oil	25

☞ If this instrument is provided with a micrometer screw for the vertical control of one of the Y's, and an additional spirit level, set normal to the line of collimation, it becomes a HYDROGRAPHIC Y-LEVEL. The charges for these additions are $40.00. See page 133.



HYDROGRAPHIC LEVEL.

☞ For details see page 132.



The cut shows the different cross wires we set in our instruments as ordered. When ordering please state number of cross wire wanted, as shown above.

No. 20.
15-Inch Dumpy Level
Price, $100.00.

No. 20a.
15-Inch Dumpy Level
With mirror attachment folded down*
Price, $110.00.

A. Lietz Company
Makers
San Francisco, Cal.
No. 20a.
With mirror raised

* The mirror, when folded down, serves as a protection to the spirit level; when raised, it indicates the position of the bubble at the eye-end of the telescope, so that the observer may control it without changing his position. ☞ For details of the Dumpy Level, see following page.

No. 20. Engineers' Dumpy Level.

Long center and most approved construction of the lower parts. Sensitive spirit level, placed over the telescope, to lower the center of gravity. The telescope has definition, light and power in a high degree; best achromatic Jena glass lenses, erect vision and stadia hairs if desired. Is provided with a slide-protector and cloth finished. Screw coupling.

Packed in a neat case containing all the usual accessories.

This is an elegant instrument, fit for the best class of engineers' work, and is guaranteed in every detail.

Dimensions and Weight.

Length of telescope	15 inches
Diameter of objective	1⅜ "
Magnifying power	28
Weight of instrument	9 lbs.
" tripod	8 "
" box	5½ "
The price of this instrument is	$100 00

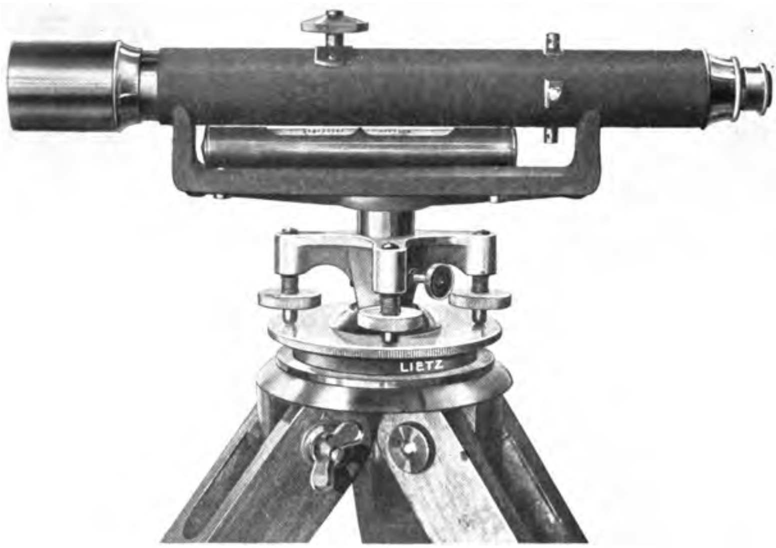
No. 20 A.

Is the same as No. 20, but provided with a mirror to indicate the position of the bubble to an observer at the eye end.

Price $110 00

The Extras to Nos. 20 and 20a, for which additional charge is made, are as follows:

Stadia hairs, fixed	$3 00
Clamp and Tangent screws	10 00
Horizontal circle, reading to minutes	25 00
Protection bag	1 00
Bottle of fine watch oil	25



No. 21.
BUILDERS' LEVEL.
☞For price and details, see the following page.

A. LIETZ COMPANY
MAKERS
San Francisco, Cal.

No. 21.

Fitted with a Right-Angle Bracket and Control Level for Vertical Sights.

Extra Charge, $15.00.

No. 21. Builders' Level.

Constructed by us for the use of architects, builders, contractors, and for general engineering work not requiring the highest degree of accuracy. The instrument is very substantially made, and not liable to get out of order easily; an important feature, because instruments of this kind occasionally have to be intrusted to men whose duties will not permit to take the greatest amount of care. The instrument is far superior to the so-called architects' level, which is built on the principle of the Y-level, having other so-called patented features, which make the instrument complicated and unreliable, difficult to manipulate, and which decrease its strength considerably. Our instrument No. 21 is built for the special purpose of obtaining the simplest form of an accurate and reliable tool. Packed in a neat case containing all the usual accessories.

Dimensions and Weight.

Length of telescope	12 inches
Diameter of objective	1⅛ "
Magnifying power	18
Weight of instrument	4½ lbs.
" tripod	6 "
" box	3¼ "
The price of this instrument is	$45 00

When supplied with a horizontal circle graduated to ½ degrees $5.00 additional is charged.

This instrument can also be supplied with our Patent Angle Bracket, as shown in the previous page.

Extra for this attachment, $15.00.

No. 22. LIETZ PRELIMINARY TRANSIT.
[Patented.]

Price of instrument as shown with extension tripod stadia hairs and box, containing all the usual accessories, $80.00.

Dimensions and Weight.

Length of telescope	6	inches
Diameter of objective	¾	inches
Length of needle	3	inches
Diameter of horizontal plate	3	inches
Magnifying power to telescope (diameters)	8	
Weight of the instrument	2½	lbs.
Weight of the case	2	lbs.
Weight of the tripod	2	lbs.

This Transit when used as a needle instrument admits to lay off the magnetic variation, so that the combination incorporates a variation plate.

No. 22. Lietz Preliminary Transit.

For many purposes where great accuracy is not required, it is often far more convenient to use some small instrument which will admit of measurements within practical limits. The irrigator, farmer, ditcher, grader, building contractor, gardener, forester, road builder, etc., often require means of obtaining heights and relative positions, for which higher grade instruments would be unnecessarily refined.

It is for such purposes that we have constructed the Lietz Preliminary Transit. This combines portability with accuracy and reliability, within a reasonable limit, at a minimum expenditure. In appearance it is identical to an engineer's transit. It possesses four leveling screws, but no shifting center. The lower axis moves in the star piece which carries the four leveling screws. It is readily clamped in any position by means of a milled-head screw, working directly on the center. The second spindle carries the top plate, together with the standards and telescope. The compass is centrally located, and has a diameter of 3 inches. The plate is graduated into quadrants, in the regular way, and this graduation is utilized for reading horizontal angles, by means of a vernier to 2 minutes of arc. The vertical arc is graduated from 0 degree to 100 degrees each way, reading to 2 minutes by a vernier which is clamped readily into any position on the telescope axis by a milled-head screw, so that the position of the arc, which is stationary on the standard, admits of reading any vertical angle, by means of repetition, if over 90. The telescope is 6 inches long, has erect lenses, magnifying 8 diameters. The telescope possesses a level 2½ inches in length, and a tangential movement, so that the instrument represents a complete transit of modern construction, having, of course, a limited degree of accuracy, but capable of carrying out preliminaries where high-grade instruments would otherwise have to be used. Its cost is within the reach of all, and we know of no instrument better adapted to the use of the student than one of these complete little field instruments with which so much can be accomplished and so much can be learned. Every feature of the transit is represented here, and it admits of obtaining results approaching those of the surveyor's transit and level.

Crude instruments are placed on the market to supply the demand for a fairly reliable measuring tool of small cost. These are usually worthless, as they are made without any regard for the underlying principles that should govern the make of such an article. But with the Lietz Preliminary Pocket Instrument, for which patent has been granted, the object has been attained. Every part is carefully made and neatly finished, and its cost is less in comparison than the inferior articles that are usually offered for sale in the market.

NOS. 23 AND 24.

☞ For details and price see following page.

Lietz Universal Transit No. 23.

It possesses double centers, lower clamp and tangent movement, plate movement with clamp and tangent screw, two ground and graduated plate levels, horizontal circle graduated on solid silver with two double opposite verniers, provided with a shade, reading to single minutes, placed conveniently for reading without stepping from the eye end. Compass needle and graduated compass ring, with variation plate. One of the standards provided for vertical adjustment carrying an achromatic erect telescope, with fixed stadia hairs, it has a long ground and graduated level, clamp and tangent movement, a full vertical circle graduated on solid silver reading to single minutes by double full vernier, with guard (not shown in illustration).

The instrument complete packed in fine mahogany case with all usual accessories $225.00

Dimensions and Weight.

Horizontal Circle (measured to edge of graduation)	5	in. diam.
Vertical Circle (measured to edge of graduation)	4	in. diam.
Compass Needle	3½	in. long.
Telescope	8½	in. long.
Object Glass	1	in. diam.
Weight of Instrument	8	lbs.
Weight of Tripod	6	lbs.
Weight of Box	6	lbs.

No. 23A. The same as No. 23 but with the following changes: Horizontal circle graduated on heavy silver plate instead of solid silver. It has only one double vernier reading to single minutes and no guard for vertical circle.

Complete, packed in fine mahogany case with all usual accessories...... $175.00

Lietz Universal Transit No. 24.

It possesses a double center, lower clamp and tangent movement, plate movement with clamp and tangent screw, two ground and graduated plate levels, horizontal circle graduated on solid silver with two double opposite verniers, provided with a shade, reading to half minutes, placed conveniently for reading without stepping from the eye end. Compass needle and graduated compass ring, with variation plate. One of the standards provided for vertical adjustment carrying an achromatic erect telescope, with fixed stadia hairs, it has a long ground and graduated level, clamp and tangent movement, a full vertical circle graduated on solid silver reading to single minutes by double full vernier with guard (not shown in illustration).

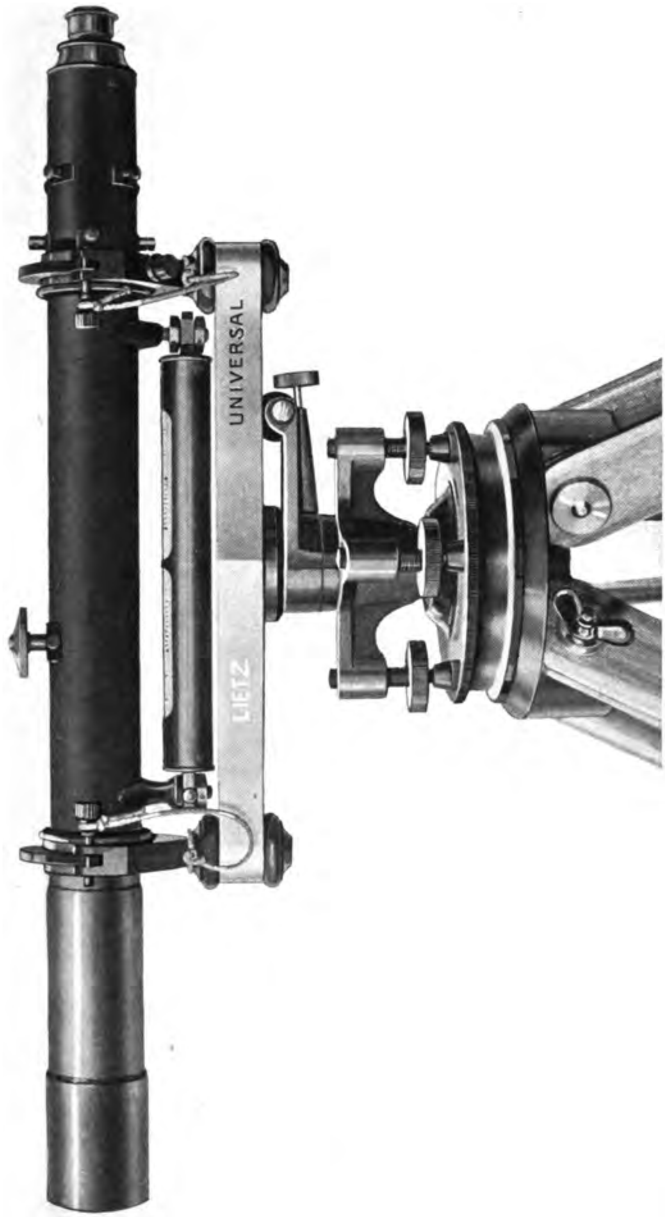
The instrument complete packed in fine mahogany case with all usual accessories $235.00

Dimensions and Weight.

Horizontal Circle (measured to edge of graduation)	6¼	in. diam.
Vertical Circle (measured to edge of graduation)	5	in. diam.
Compass Needle	4½	in. long.
Telescope	11½	in. long.
Object Glass	1⅛	in. diam.
Weight of Instrument	14	lbs.
Weight of Tripod	8	lbs.
Weight of Box	8	lbs.

No. 24A. The same as No. 24 but with the following changes: Horizontal circle graduated on heavy silver plate instead of solid silver. It has only one double vernier reading to single minutes and no guard to vertical circle.

Complete, packed in fine mahogany case with all usual accessories...... $185.00



No. 25.
ENGINEER'S Y LEVEL.
☞For details and price see following page.

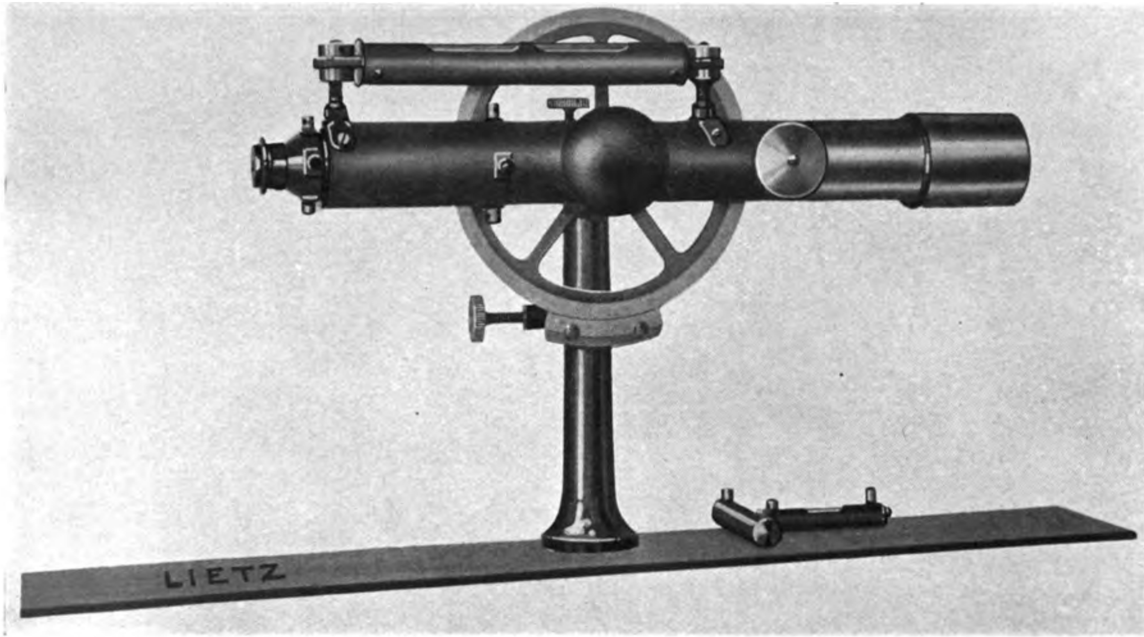
LIETZ UNIVERSAL Y LEVEL. No. 25.

It possesses a long center, star-shaped construction, clamp and tangent movement, a semi-trace spirit Level, 18 inch Achromatic Telescope, with slide protractor.

Price, complete, with all usual accessories, in mahogany case, $110.00.

Dimensions and Weight.

Length of Telescope	18 inches
Diameter of Objective	1⅜ inches
Weight of Instrument	10½ lbs.
Weight of Tripod	8 lbs.
Weight of Box	7 lbs.

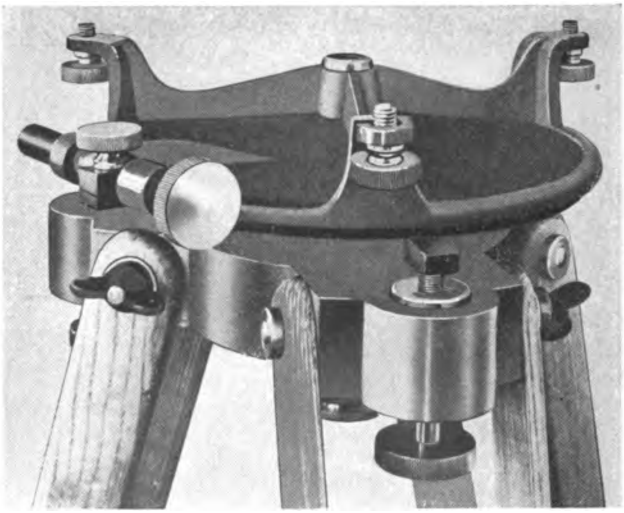


The Johnson Plane Table Outfit, No. 30.

Johnson's improved plane-table movement, mounted on large tripod.....	$ 45 00
Plane-table drawing board, 31x24 inches, fitted with screw sockets and clamps for paper	5 00
Plumbing arm and plummet	4 00
Combined compass and levels........	15 00
Alidade with 11-inch Telescope, with stadia, 4½-inch vertical circle and vernier to one minute, ground level, clamp and tangent screw........	90 00
Total	$159 00

☞ For illustrations of plane-table movement and extras see the following page.

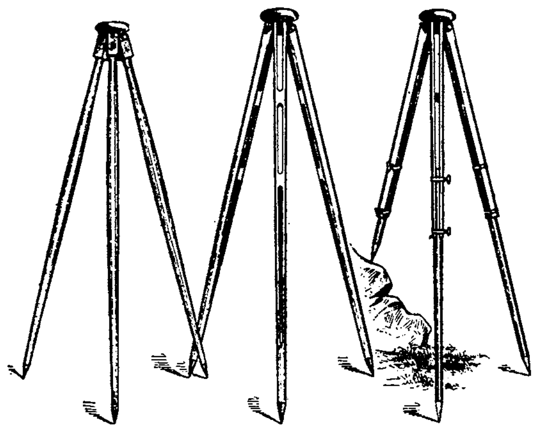
JOHNSON PLANE TABLE HEAD.



Head with leveling screws and tangent movement in lieu of Johnson head $20.00

Extra rollers for mounting continuous paper or Plane Table, each....... 10.00

TRIPODS.



35 Hardwood Tripod, for Preliminary Transit, No. 22................ $ 5.00

36 Hardwood Tripod, for Builders' Levels, No. 21.................... 10.00

37 Hardwood Tripod, split leg, for Transits Nos. 6 to 13.............. 15.00

38 Hardwood Tripod, split leg, for Transits Nos. 1 to 5, Levels Nos. 19 and 20.. 15.00

39 Extension Metal Tripod, for Preliminary Transit, No. 22........... 5.00

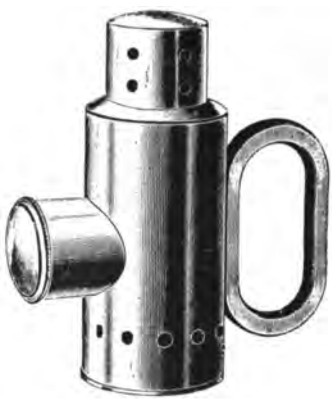
40 Extension Hardwood Tripod, for Transits Nos. 6 to 13............ 17.50

41 Extension Hardwood Tripod, for Transits Nos. 1 to 5, Levels Nos. 19 and 20.. 17.50

NOTE.—One extension leg on tripods Nos. 37 and 38, add $1.25 to list price.

Illuminating Lamps.

No. 45.



No. 43

No. 42. Lamp for illuminating graduations, cross-wires, etc., for use in underground work, common .... $ 4.00

No. 43. Lamp of brass, with ground lens 7.00

No. 44. Small Plummet Lamp of brass, steel point, 16 oz. 8.00

No. 45. Large Plummet Lamp of brass, steel point, 24 oz. 10.00

COMPASSES.

No. 46. Surveying Compass, with folding sights, graduated to ½ degrees on raised ring, variation plate, two level bubbles, ball joint and socket for Jacob staff mountings, needle about 3½ in., in polished mahogany case............................each $16.00

No. 47. Same as No. 46, but without variation plate.................... 10.50

No. 48. Same as No. 46, but 4½-inch needle 20.00

No. 49. Same as No. 48, but without variation plate.................... 13.00

Leather case with shoulder strap for either of the above instead of mahogany box ....extra 2.50

No. 50. Surveying Compass, like No. 46, without level bubbles; needle about 3 inches.. 9.00

No. 51. Surveying Compass, like No. 46, without level bubbles; needle about 3½ inches 11.00

No. 52. Surveying Compass, like No. 46, without level bubbles; needle about 4 inches 11.50

Sight Compasses.

No. 53. Pocket Compass, bronzed, 2½-inch bar needle, with stop, silvered metal dial, with cover ....each $5.25

No. 54. Pocket Compass, bronzed, 3-inch bar needle, with stop, silvered metal dial, with cover ....each 6.25

No. 55. Pocket Compass, watch pattern, with folding sights, silvered metal dial, 1¾-inch bar needle, with stop, graduations on raised ring ....each 4.00

No. 56. Pocket Compass, watch pattern, with folding sights, silvered metal dial, 2-inch bar needle, with stop, graduations on raised ring ....each 4.60

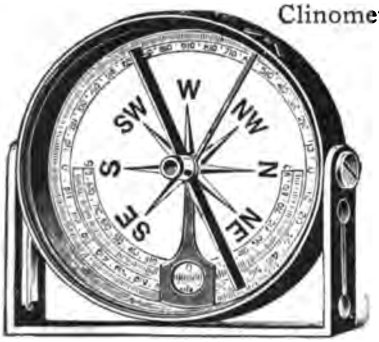
No. 57. Pocket Compass, watch pattern, with folding sights, silvered metal dial, 2½-inch bar needle, with stop, graduations on raised ring ....each 5.10

No. 58. Pocket Compass, watch pattern, with folding sights, silvered metal dial, 2-inch bar needle, with stop, graduations on raised ring, with clinometer attachment....................each 6.50

No. 60. Pocket Compass, hunting case, self-acting stop, bar needle, 1½-inch, silvered metal dial....................each 2.95

No. 61. Pocket Compass, hunting case, self-acting stop, bar needle, 1¾-inch needle, silvered metal dial....................each 3.20

Clinometer Compass.



No. 70. Clinometer Compass, bar needle, with stop, 2½-inch, silvered metal dial, having a clinometer, in leather case.........each $ 7.25

No. 71. Clinometer Compass, bar needle, with stop, 3-inch, silvered metal dial, having a clinometer, in leather case................each 8.75

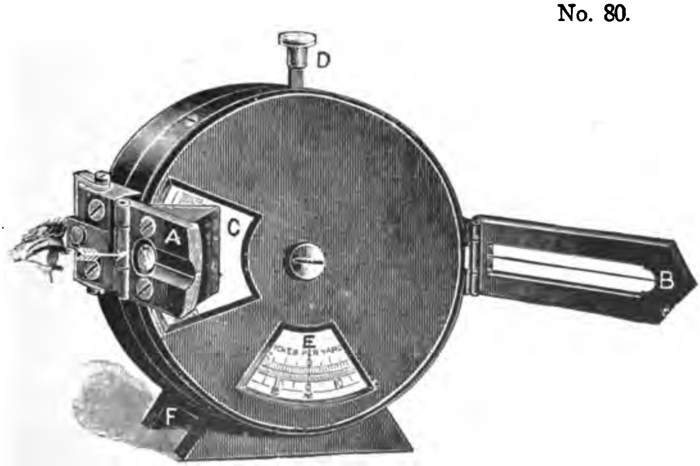
No. 72. Clinometer Compass, bar needle, with stop, 4-inch, silvered metal dial, having a clinometer, in leather case..........each 10.50

Prismatic Compass.

No. 80. Hutchinson's Improved Prismatic Compass, 3-inch floating card dial, jeweled center, top nearly enclosed, in leather sling case ....each $16.00

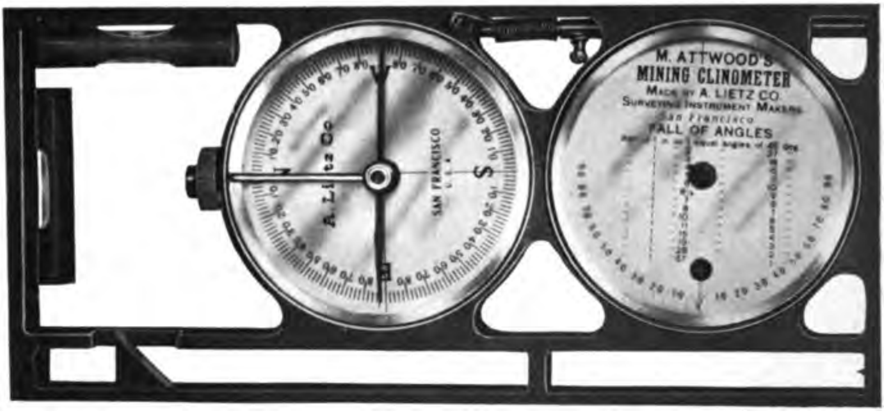
No. 82. Prismatic Compass and Clinometer, 3-inch floating aluminum ring compass, jeweled center, gravity clinometer, giving inches per yard and degrees ....each 23.00

No. 80.



No. 82.

M. Attwood Mining Clinometer and Compass.



A NEW POCKET INSTRUMENT.

No. 87. The accompanying cut represents a new universal measuring tool, including Attwood's Mining Clinometer. It combines the most sensitive clinometer with two levels, a compass and a sighting arrangement, with reflecting metal mirror, which permits its use as a hand leveling instrument (similar to Lock's hand level), while inclines can be measured by the use of the sight as well as the base of the instrument. When held horizontal, the sight also admits of taking compass bearings.

The instrument is especially constructed for the use of miners, to take the underlay of any metalliferous vein, 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.

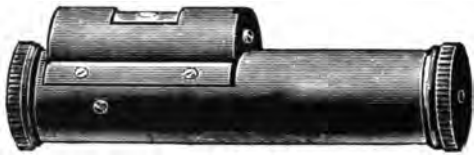
It can also be used in quartz mills, to give the proper angle to the silvered plates, blanket, trays, and sluice boxes.

The instruments are extensively used in our mining districts, as well as in South Africa. The late improvements make it a universal measuring tool adaptable to the many uses, underground as well as surface work, which the engineer as well as the superintendent or foreman has to perform.

It is made of aluminum alloy, and weighs, inclusive of leather case, eight ounces.

Price, complete $15.00

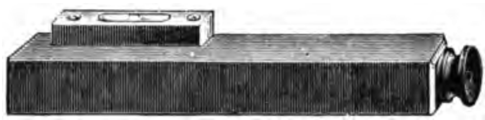
Hand Levels.



No. 90.

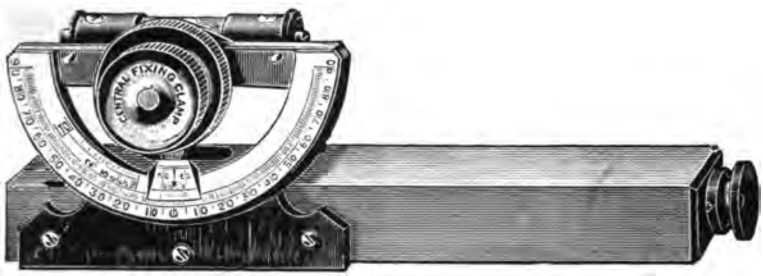
No. 89. Lietz Special Hand Level..$10.00

No. 90. Lock's Hand Level, bronze, with prism and magnifying lens, for bubble, 5 inch, in case.................................... 7.00



No. 92.

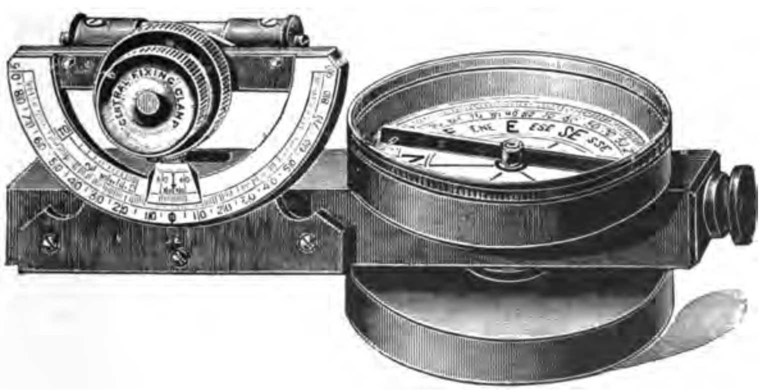
No. 92. Square Hand Level, 5-inch, in case............................ 4.50



No. 95.

No. 95. Abney Level and Clinometer, 5-inch, in case.................... 13.50

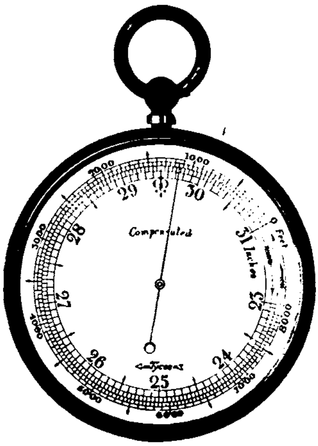
Consisting of a hand level similar to Locke's; the bubble is mounted on a vertical arc, graduated, which is used to obtain angles, slopes, etc.



No. 96.

No. 96. Abney Level, like No. 95, with compass, etc.................... 18.00

Aneroid Barometers, for Measuring Altitudes and Atmospheric Pressure.



No. 100.

No. 106.

No. 100. Watch pattern, gilt, 1¾-inch silvered metal dial, compensated for temperature, revolving altitude scale, 3,000 feet, in morocco case ....each $20.00

No. 102. Watch pattern, gilt, 1¾-inch silvered metal dial, compensated for temperature, revolving altitude scale, 10,000 feet, in morocco case ....each 19.00

No. 104. Watch pattern, gilt, 1¾-inch silvered metal dial, compensated for temperature, revolving altitude scale, 15,000 feet, in morocco case ....each 20.00

No. 106. Watch pattern, gilt, 1¾-inch silvered metal dial, compensated for temperature, revolving altitude scale, 10,000 feet, hunting case ....each 22.00

No. 108. Watch pattern, gilt, 1¾-inch silvered metal dial, compensated for temperature, revolving altitude scale, 15,000 feet, hunting case ....each 24.00

No. 110. Watch pattern, gilt, 2½-inch silvered metal dial, compensated for temperature, revolving altitude scale, 3,000 feet, in morocco case ....each 21.00

No. 111. Watch pattern, gilt, 2½-inch silvered metal dial, compensated for temperature, revolving altitude scale, 10,000 feet, in morocco case ....each 20.00

No. 112.

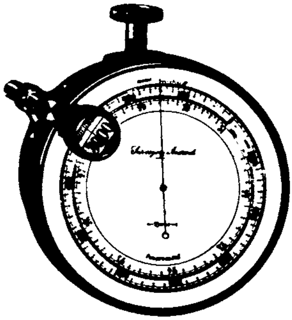
No. 115.

No. 112. Watch pattern, gilt, 2½-inch silvered metal dial, compensated for temperature, revolving altitude scale, 15,000 feet, in morocco case ....each $21.00

No. 115. Pocket Aneroid, 2½-inch silvered metal dial, fixed altitude scale, 5,000 feet, in single 5-foot divisions, in repeating circle of divisions, making it possible to read even closer than 5 feet, compensated for temperature, in case..................each 50.00

A portable form of Surveying Aneroid.

Surveying and Mining Aneroid.



No. 120. Mining Aneroid, 3-inch silvered metal dial, fixed altitude scale, 2,000 feet below and 4,000 feet above sea-level, vernier with rack and pinion, reading to 2 feet, adjustable reading lens, compensated for temperature, in leather sling case ....each $50.00

No. 120.

No. 121. Mining Aneroid, 3-inch silvered metal dial, fixed altitude scale, 2,000 feet below and 4,000 feet above sea-level, vernier with rack and pinion reading to 2 feet, adjustable reading lens, compensated for temperature, in aluminum case.........each 60.00

No. 122. Surveying Aneroid, as above, 10,000 feet, with vernier reading to 5 feet ....each 48.00

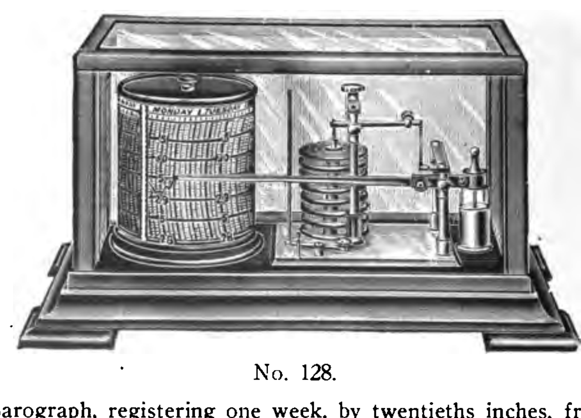
No. 123. Surveying Aneroid, as above, 10,000 feet, with vernier reading to 5 feet, aluminum case..............................each 58.00

No. 124. Surveying Aneroid, as above, 16,000 feet, with vernier reading to 5 feet ....each 50.00

No. 125. Surveying Aneroid, as above, 16,000 feet, with vernier reading to 5 feet, aluminum case..............................each 60.00

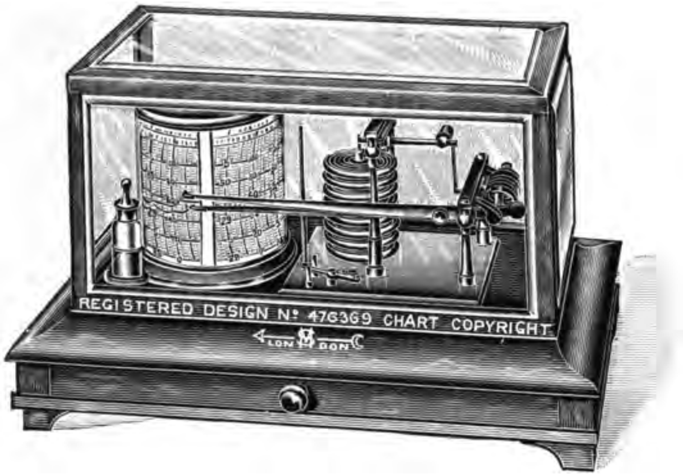
No. 126. Pocket Thermometer, 5-inch, glass scale, reading to 2 degrees Fah., in hard rubber or nickel-plated case...............each 1.00

Barographs and Thermographs.



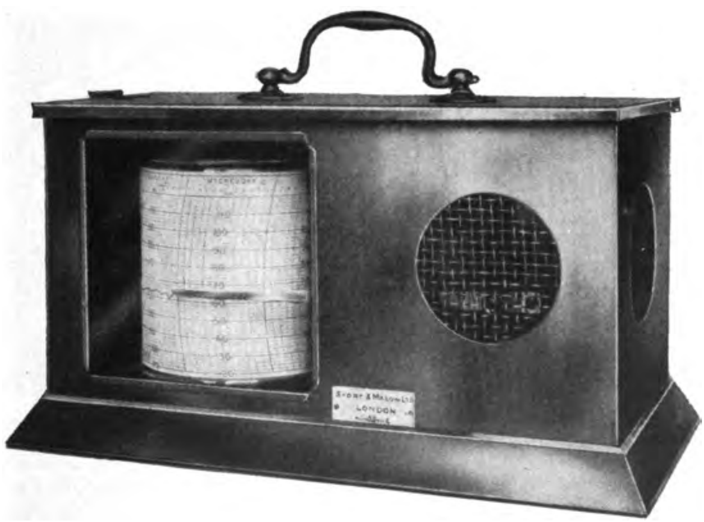
No. 128.

No. 128. Barograph, registering one week, by twentieths inches, from 28 to 30.5, movement operated by a large vacuum pan concealed in the base of the instrument, 8-day clock movement jeweled, oak case, with glass sides, top and ends, complete with charts for one year, pen and ink.............................each $40.00



No. 130.

No. 130. Barograph, large size, all working parts exposed, 8 vacuum boxes ....each $50.00



No. 135.

No. 135. Thermograph, registering for one week, from 1 to 100 degrees Fahrenheit, by 2 degrees, in metal weather-proof case, with handle, glass front, eight-day jeweled clock movement, with charts for one year, ink and pen........................each 43.00

No. 137. Thermograph, registering for one week, from 1 to 100 degrees Fahrenheit, by 2 degrees, in oak case, with handle, glass front, eight-day jeweled clock movement, with charts for one year, ink and pen..each $40.00

No. 139. Thermograph, large size, in oak case.......................each 50.00

Anemometers.

No. 142.

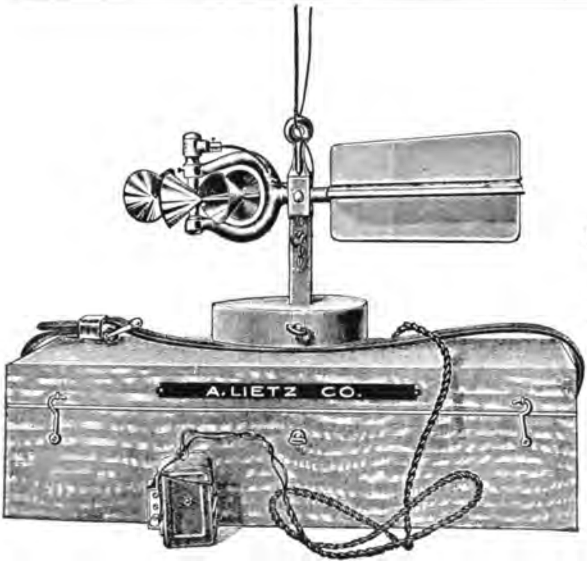
No. 142. Biram Anemometer, 3-inch diameter, reading to 1,000 feet, with disconnector, in polished mahogany case................each $20.00

No. 144.

No. 144. Watch Pattern Anemometer, 2-inch diameter, registering to 1,000 feet, with disconnector, hunting case, in velvet-lined morocco case ....each $30.00

No. 150. U. S. Weather Bureau Standard Rain Gauge.............each 10.00

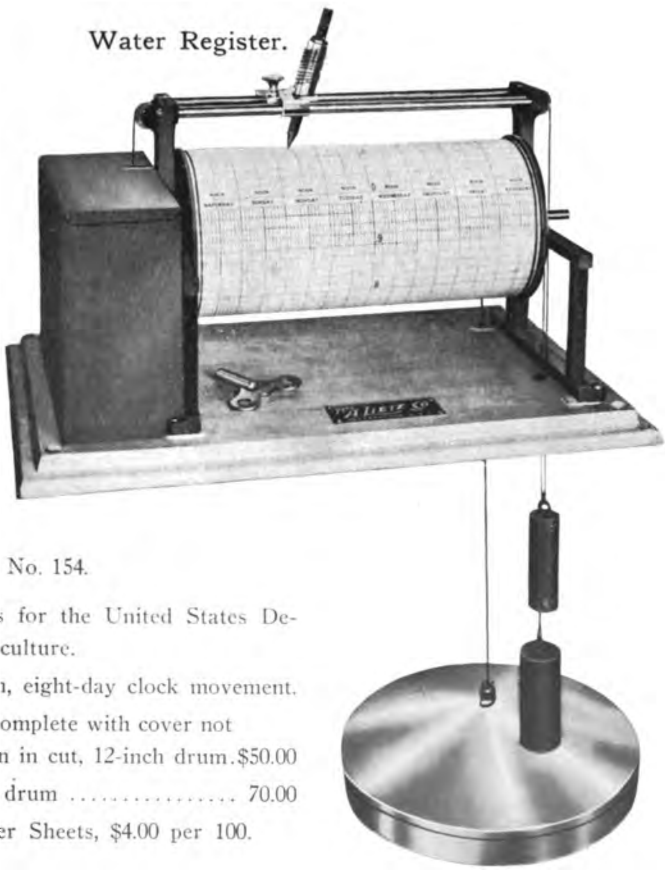
No. 151. U. S. Weather Bureau Standarl Rain Gauge, small size....each 4.50



Price Electric Current Meter.

For use in small streams.
Price, $63.50.

Water Register.



No. 154.

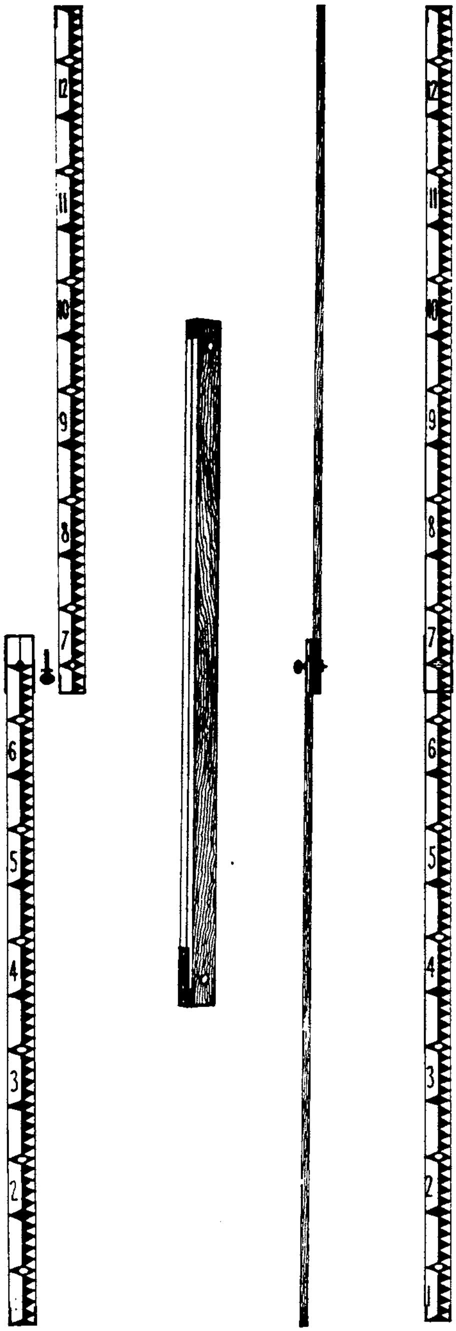
As made by us for the United States Department of Agriculture.

Recording drum, eight-day clock movement.

No. 154. Price, complete with cover not shown in cut, 12-inch drum. $50.00

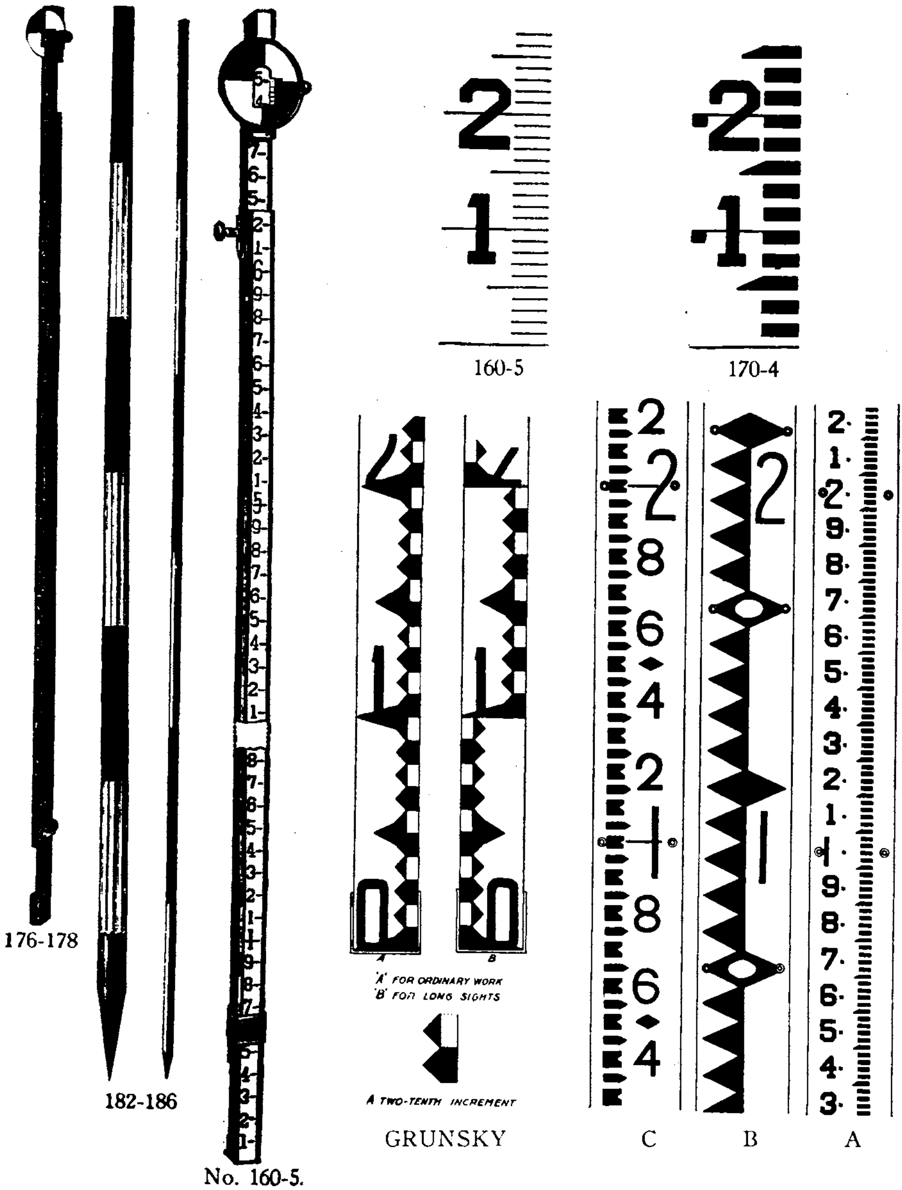
No. 156. 18-inch drum 70.00

Extra Register Sheets, $4.00 per 100.



LIETZ FOLDING STADIA ROD.

☞ For price and design of marking see pages 161-162.



Leveling Rods.

☞ NOTE.—The leveling rods (160-5) are our own make, graduated to hundredths, by uniform, clean divisions. The black numerals corresponding to the tenths, have an exact height of 0.06 foot and the red or foot numerals are 0.08 foot high. This affords a rod reading at distances where graduation lines disappear. The wood is the best, thoroughly seasoned. The target and all connecting metal parts are cast in one piece; the vernier made to thousandths, the scale is brass, and the face of the target is japanned. We recommend this rod as the best in the market. It is a self-reading rod, similar to the Philadelphia pattern.

Philadelphia Leveling Rods.

Line Graduation 160-5, Page 161.

No.	160	161	162	163	164	165
Length in feet	8 to 15	7 to 13	6½ to 12	5 to 9	4 to 7	3 to 5
Price	$17.00	$16.00	$13.00	$12.75	$12.75	$12.00

Block Graduation 170-4, Page 161.

No.	170	172	174	176		
Length in feet	7 to 13	6½ to 12	3 to 5	Architects 5½–10 Decimal or inches		
Price	$15.00	$13.00	$12.00	$6.00		

177 Lietz Stadia Rod 12 ft. 2 fold ... $12.00
178 Lietz Stadia Rod 14 ft. 3 fold ... 15.00
179 Lietz Stadia Rod, Grunsky markings, 12 ft. 2 fold ... 16.00
179A Lietz Stadia Rod, Grunsky markings, 15 ft. 3 fold ... 19.00

When ordering, state what kind of markings are wanted (see page 161). B is best adapted for long distance work; C as a combination for stadia and leveling; A for leveling only. For markings after Grunsky see also page 99.

For construction see page 160.

Flexible Rods.

No. 180.

For Leveling and Stadia Work.

Painted on canvas, with a legible design, see page 161. May be rolled up in a package 2½ to 3 inches long (the width of the canvas), and less than 1½ inches in diameter, weighing less than 3 ounces. A very handy requisite on a long trip.

When ordering, please state which design is wanted. See page 161.

180 Flexible Level Rod, 12 ft. long ... $4.00

Ranging Poles.

No. 182. Wooden pole, 6 and 8 feet long, with steel pointed shoe, divided in feet, red and white alternately ....each $2.25

No. 184. Octagonal steel spear, 6 to 8 feet long, divided in feet, red and white alternately ....each 2.75

Rod Level.

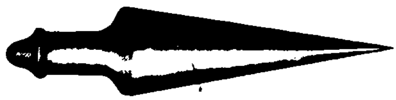
No. 190.

No. 190. Improved Rod Level......................................each $2.50

This Rod Level is an *improved* type, used to hold rod or pole of any shape perpendicular. The level bubbles are sunk in the casting at right angles to each other, thereby lessening the possibility of breakage, as well as making it easier for the rodman to hold the bubbles in the center, than the old form of circular spirit levels. The latter are continually leaking and it is impossible to keep them in order.

The Improved Rod Level can either be fastened to the rod by means of a flat-head screw, for which there is a key slot provided, or pressed against the rod or pole while holding. Indispensable for stadia work.

Plumb-bobs.



8 oz. No. 192 $1.75

12 oz. No. 194 $2.25

16 oz. No. 195 $3.25

18 oz. No. 200 $2.75

20 oz. No. 201 $3.00

24 oz. No. 202 $3.25

48 oz. No. 204 $5.00

Plumb-bob Cord.

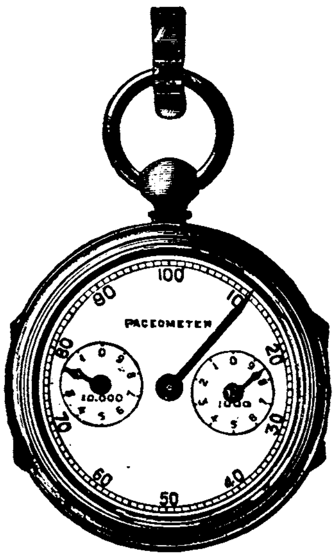
No. 210. Best Braided Linen Cord, thick, medium or thin..........per yd. $0.02

No. 211. " " Silk " ....per yd. .06

Stake Tacks.

No. 215. Stake Tacks, galvanized, with indentation on top for guiding the point of plumb-bob ....per lb. $0.60

Pedometers.



Nos. 219-20.

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.

No. 219. Pedometer registering every step to 25,000.................... $5.25

No. 220. Pedometer registering steps to 100,000........................ 6.50

Odometers.

No. 224. Odometer, for measuring distances by wagon. It is enclosed in a brass box, 4½ inches diameter, furnished with leathern case and double straps to fasten to the center of the wheel. It is the most correct instrument for practical use. Price....$15.00

Chain Pins and Markers.

No. 230. Steel Arrows, 14-inch, 11 in set..................................$1.25

No. 235. Iron Arrows, 14-inch, 11 in set.................................. .60

No. 240. Marking Tool, timber scribe.................................. 1.25

Surveyors' Chains.

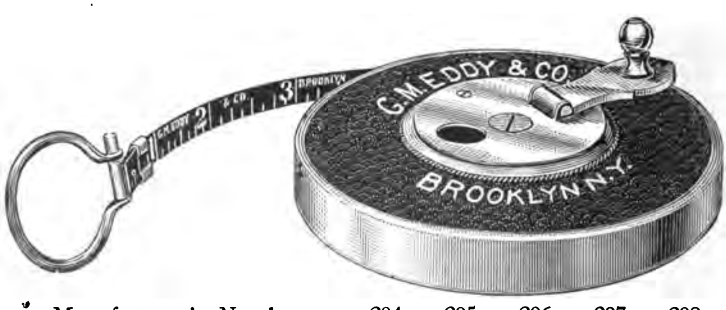
No. 245.	Iron Chain, brass handles,	No. 8 wire,	33 feet			$ 2.60
No. 246.	" "	" "	50 "			3.25
No. 247.	" "	" "	66 "			4.00
No. 248.	" "	" "	100 "			5.25
No. 249.	Steel Chains, "	No. 10 "	33 "			3.50
No. 250.	" "	" "	50 "			4.25
No. 251.	" "	" "	66 "			6.50
No. 252.	" "	" "	100 "			8.00
No. 253.	Steel Chains, brazed links and ring,	No. 12 wire,		33 feet		5.50
No. 254.	" " "	" "		50 "		6.00
No. 255.	" " "	" "		66 "		10.00
No. 256.	" " "	" "		100 "		11.00

Paine's Patent Standard Steel Tapes.

¼ Inch Wide.

In iron cases, brass bound, morocco covered, improved handle.

All orders for Steel Tapes will be filled marked in 10ths unless otherwise directed. These tapes are marked in links on the other side, if so ordered.



	Manufacturer's Number	204	205	206	207	208	209
	Feet	25	33	50	66	75	100
No. 290.	Price, each	$4.00	4.25	5.25	7.00	8.75	10.50

These tapes are detachable from the case, and are furnished with detachable rings to avoid breakage.

Meters and 10ths or 12ths, add 2 cents per foot.

Graduated Compensating Handles.

FOR VARIOUS TEMPERATURES.

No. 292. Per pair $2.25

No. 293. Pocket Thermometers ....each 1.15

No. 294. Grummon's Balance and Level.............................each 3.00

Steel Spring Tapes, German Silver Cases.

GRADUATED IN 10THS OR 12THS.

		DESCRIPTION.	PRICE, EACH.
No. 298.	Manufacturer's No. 220.	3-foot steel tape, ¼ inch wide	$1.00
	" " 221.	4 " " " "	1.15
	" " 222.	5 " " " "	1.30
	" " 223.	6 " " " "	1.40
	" " 224.	8 " " " "	1.60
	" " 225.	12 " " " "	2.25
	" " 226.	15 " " " "	2.65

Eddy's Improved Standard Steel Tapes.

In Leather-Covered Cases, Flush Handle.

No. 300.

Nos. 302-4.

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

No. 300.	Manufacturer's Number............	210	211	212	213	214
	Feet	33	50	66	75	100
	Price, each	$4.15	6.00	8.00	9.50	12.00

⅜ Inch Wide in Red Leather-Covered Cases.

No. 302.	Manufacturer's Number.	300	301	302	303	304	305	306
	Feet	25	33	40	50	66	75	100
	Price, each............	$4.50	5.20	6.00	7.20	9.20	10.40	12.80

Eddy's Improved Standard Steel Tapes.

½ Inch Wide in Red Leather-Covered Cases.

No. 304.	Manufacturer's Number.......	400	401	403	404	405	406
	Feet	25	33	50	66	75	100
	Price, each	$5.10	5.85	8.10	10.35	11.70	14.40

Metallic Warp Tapes.

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

Metallic Tape, ⅝ Inch Wide.

No. 307.	Manufacturer's Number	137	138	139	140	141	142	143
	Feet	25	33	40	50	66	75	100
	Price, each	$1.75	2.05	2.25	2.45	2.90	3.15	4.00

Friend Steel Tape, ⅜ Inch Wide, in Russet Leather Case, with Brass Trimmings.

Manufacturer's Number	600	601	602	603
Feet long	50	66	75	100
Each	$4.00	5.00	5.25	7.00

Star Steel Tapes.

A cheap but accurate and reliable steel tape. The line is made of the best steel, marked and finished in the best style and mounted in a brass case, handsomely nickel-plated. It is light and durable, and easily carried in the pocket, and having an improved new handle, winds freely.

Send for a 4-inch sample piece of the tape.

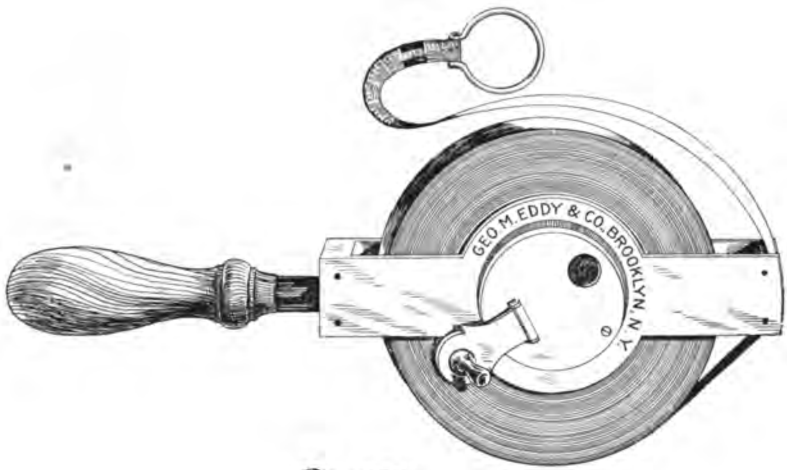
When ordering, state if divisions in 10ths or 12ths are desired.

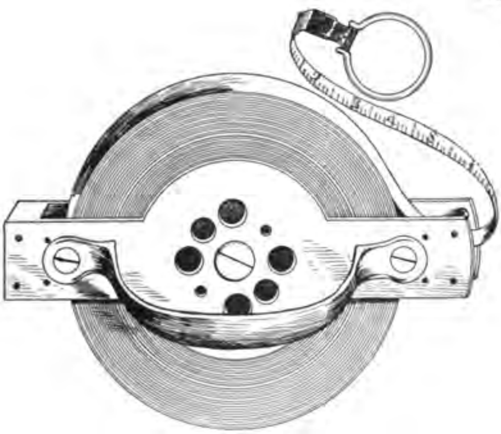
⅜ Inch Wide.

Manufacturer's Number,	497.	25 feet	each	$3.25
" "	500.	50 feet	each	4.00
" "	501.	66 feet	each	5.00
" "	502.	75 feet	each	5.25
" "	503.	100 feet	each	7.00

Eddy's Improved Standard Steel Tapes.

Empire Steel Tapes.





With compact brass reel and wooden handle.

Tapes ¼ or ⅜ inch wide, as desired. ¼-inch tapes will be sent unless otherwise ordered.

No. 315.	Manufacturers' Number	700	701	702	703
	Feet	50	66	75	100
	Price, each	$5.65	6.50	9.00	10.15

Roe's Steel Tape on Patent Electric Reel.

(Patented May 24, 1892.)

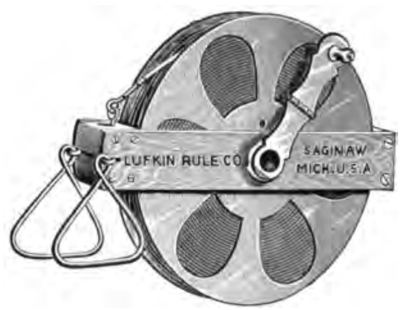
No.	Length	Description	PLAIN.	NICKEL PLATED.	ALUMINUM PLATED.
1 A,	100	ft. long, every ft. End ft. in tenths			
1 B,	100	“ “ “ “ “ inches	$ 5.00	$ 6.00	$ 7.00
2,	100	“ “ 5 “ “ “ tenths			
3,	100	“ “ 5 “ “ “ inches	4.00	5.00	6.00
4,	66	“ graduated in links			
5,	66	“ in rods and tenths of a rod	5.00	6.00	6.50
6,	66	“ every 5 lks. Each end every lk.			
7 A,	50	“ “ foot. End ft. in tenths	4.00	5.00	5.50
7 B,	50	“ “ “ “ “ inches			
8,	50	“ “ 5 feet. “ “ tenths			
9,	50	“ “ 5 “ “ “ inches	3.00	4.00	4.50
10,	33	“ graduated in links			
12.	33	“ every 5 lks. Each end every lk.	2.50	3.00	3.50
11 A,	200	“ “ foot End ft. in tenths			
11 B,	200	“ “ “ “ “ inches	7.50	9.00	10.50
16 A.	200	“ “ 5 feet. “ “ tenths			
16 B,	200	“ “ 5 “ “ “ inches	6.00	7.50	9.00
17,	10	meters long. Each meter in decimeter	2.40	3.00	3.50
18,	15	“ “ “ “ “	2.70	3.50	4.00
19,	20	“ “ “ “ “	3.00	4.00	4.50
20 A,	25	“ “ “ “ “	3.50	4.50	5.00
20 B,	50	“ “ “ “ “	5.00	6.50	7.50
21,	40	varas long, every vara End vara in 10ths	4.00	5.00	6.00
22,	20	“ “ “ “ “ “ “	3.00	4.00	4.50
23,	10	“ “ “ “ “ “ “	2.40	3.00	3.50
30,	300	ft. long, every ft. End ft. in 10ths or 12ths	10.00	12.00	14.00
31,	300	“ “ 5 ft. “ “ “	8.00	10.00	12.00
32,	400	“ “ ft. “ “ “	12.50	15.00	17.50
33,	400	“ “ 5 ft. “ “ “	10.00	12.00	15.00
34,	500	“ “ ft. “ “ “	15.00	18.00	21.00
35,	500	“ “ 5 ft. “ “ “	12.00	15.00	18.00

Price of 100 foot Electric Reel, without Tape.......................... 1.50

“ 200 “ “ “ “ “ 2.00

Brass Detachable Handles, per pair.......................... .30

Surveyors' Chain Tape.



4100

5100

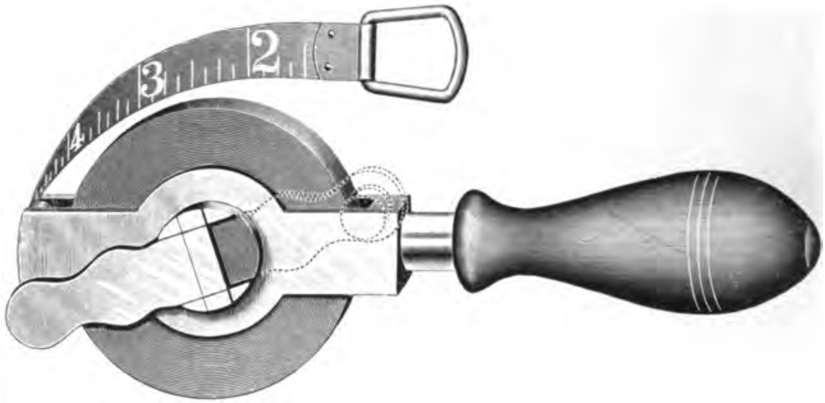
¼-inch heavy Steel Tape, graduated every foot. End foot in 10ths on raised surface, etched in.

No. 320.	Manufacturer's Number,	5100.	100	feet.	Price each	$ 6.00
	“ “	5150.	150	“	“ “	7.50
	“ “	5200.	200	“	“ “	9.00
	“ “	5066.	100	links.	“ “	5.00
	“ “	5132.	200	“	“ “	7.00
	“ “	5198.	300	“	“ “	9.00
	“ “	5082M.	25	meters.	“ “	5.75
	“ “	5100M.	30	“	“ “	6.50
	“ “	5164M.	50	“	“ “	9.50
	“ “	5328M.	100	“	“ “	17.00
	Tape only, without reels, deduct					2.00
	Rings only					.50

Surveyors' Ribbon Steel Tapes.

Heavy ribbon, ⅛-inch steel tape, graduated every foot, end foot in 10ths. Links have end foot in 10ths of links. Meters have first decimeter in millimeters, balance of first meter in centimeters, balance of tape in decimeters, on raised surface, etched in.

No. 325.	Manufacturer's Number,	4100.	100	feet.	Price each	$ 7.50
	“ “	4150.	150	“	“ “	9.00
	“ “	4200.	200	“	“ “	10.50
	“ “	4300.	300	“	“ “	14.00
	“ “	4500.	500	“	“ “	21.50
	“ “	4066.	100	links.	“ “	6.50
	“ “	4132.	200	“	“ “	8.50
	“ “	4198.	300	“	“ “	10.50
	“ “	4330.	500	“	“ “	15.50
	“ “	4082M.	25	meters.	“ “	7.25
	“ “	4100M.	30	“	“ “	8.00
	“ “	4164M.	50	“	“ “	11.00
	“ “	4328M.	100	“	“ “	18.50
	Tape only, without reel, deduct					3.50
	Extra rings					.50



Germania Steel Tapes.

¼ Inch Wide.

Marked Feet and 12ths, Inches and Eighths	Marked Feet 10ths and 100ths of Feet, for Surveyors' use	Length	Each
No. 1273	1273 D	50 ft.	$5.25
" 1275	1275 D	75 "	7.50
" 1276	1276 D	100 "	9.00

THREE-EIGHTH INCH GERMANIA

No. 1283	1283 D	50 ft.	$4.50
" 1285	1285 D	75 "	6.25
" 1286	1286 D	100 "	7.75

ONE-HALF INCH GERMANIA

No. 1293	1293 D	50 ft.	$5.25
" 1295	1295 D	75 "	7.50
" 1296	1296 D	100 "	9.00

The "Cripple Creek" Reel.

The Cripple Creek Reel is the neatest, lightest, most convenient, easiest working, and most durable reel for long steel tapes made.
Price of Cripple Creek Reel, each, $12.50.

Reliable Junior Tapes.

¼ inch Tapes.

Marked Feet and 12ths	Marked Feet 10ths and 100ths	Length	Each
No. 100	No. 100 D	25 ft.	$3.75
" 103	" 103 D	50 "	4.60
" 105	" 105 D	75 "	6.60
" 106	" 106 D	100 "	7.00

No. 370.

Above cut shows the new "Punch and Set" combined for repairing steel tapes. It cuts a clean hole through two thicknesses of Chesterman or Lufkin Tape (or any other of same thickness) one-sixteenth of an inch in diameter, without drawing the temper. There is absolutely no filing required by this method except to round off the rough corners of the break. Place the tape under a small steel spring on the rubber, and it is held in place for punching. It is riveted as quickly as the hole is cut. The first rivet or eyelet holds the tape in position for cutting or riveting the rest. Five minutes is average time to make a good repair. The holes can be cut extremely near the ends or edges of repair **without any danger of splitting the tape,** thus avoiding any chance of dirt collecting under the splice or cutting the fingers when drawing the tape through the hands or catching in rags, etc., when cleaning.

The tool is small, light, durable, and cheap. It can be carried in the instrument box; thus a corps having it with them can repair broken tapes with loss of but a few minutes at any time. The cut shows tool, tape, and a four-minutes' repair in latter. They are in use and recommended by various railroad companies, city engineers, etc., throughout the country.

Price of Punch and Set Combined, $2.75, and 1,000 eyelets, $1.25—$4.00 for outfit. Postage, 16 cents.

McCullough Tape Level.

No. 380.
(Pat. July 26, 1892.)

Insures accuracy in measurements with steel tapes. Above cut full size. Weight, one ounce. It is used by clamping to the tape, about one foot from the handle, by means of the two springs shown, and can be attached and detached instantly.

Price $1.00

Hensoldt Improved Prism Binoculars.

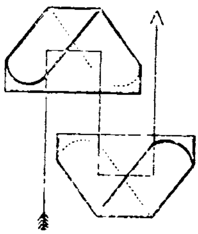
☞For price and details see page 179.

HAVE

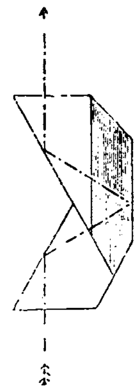
1. Greatest brightness of image.
2. Wide field of view.
3. Perfect definition, flatness of field, and equal illumination up to the margin of the image.
4. Rigid construction to protect optical parts from any possible derangement.
5. Most compact, light and graceful shape.
6. Easy access to internal optical parts for cleaning by the user.

There are a number of prismatic glasses on the market of which some have a few of the advantages above mentioned, but **only in Hensoldt Improved Prism Binoculars are all the above points embodied,** as may be judged by actually comparing the Hensoldt glass with those of other makes.

Construction.



Other Construction



Hensoldt

The novel combined prism of the Hensoldt Binocular is shown in the above illustrations, being compared with the other constructions. This improved arrangement allows the employment of object glasses of larger aperture (up to 2 inches, thereby giving a higher degree of brightness than other glasses. It also permits the reduction of the Aluminum Frame to the slender shape of a telescope. as well as securing the optical elements more rigidly in proper relation to each other.

The prism can be removed easily for cleaning.

Prices and Specifications (with Solid Leather Sling Case).

No.	Magnification Diameter	Object Glass	Field at 1000 Yards	Relative Brightness	Width and Height	Price
1 Prism Binocular	3½	5-8 in.	220 yds.	18	3½ x 3¾ in.	$40.00
2 " "	6	1 1-32 "	125 "	18	5 x 4¼ "	46.00
3/4 " "	8	1 1-32 "	100 "	12	5 x 4¼ "	52.00
5 " "	12	1 1-32 "	64 "	5	5 x 4¼ "	62.00
6 " "	6	1 3-8 "	148 "	34	6 x 5 "	60.00
7 " "	10	2 "	90 "	25	7½ x 5⅝ "	90.00
8 " "	12	2 "	70 "	17	7⅞ x 5⅝ "	95.00
1 " Monocular	3½	5-8 "	220 "	18	3⅝ x 1 3/16 "	14.00
2 " "	6	1 1-32 "	125 "	18	5¼ x 1¾ "	18.50
3/4 " "	8	1 1-32 "	100 "	12	5¼ x 1¾ "	20.50
5 " "	12	1 1-32 "	64 "	5	5¼ x 1¾ "	25.00
6 " "	6	1 3-8 "	148 "	34	6¼ x 2 "	22.00
7 " "	10	2 "	90 "	25	7⅞ x 2½ "	35.00
8 " "	12	2 "	70 "	17	7⅞ x 2½ "	40.00

OTHER FIELD GLASSES OF THE ORDINARY CONSTRUCTION.

Best Quality.

382 Field glass, with objectives 2 inches in diameter, leather case and strap, low form $15.00

383 Field glass, with objective 2 inches diameter, leather case and strap, high form, with sunshades 16.00

384 Field glass, with objective 2¼ inches diameter, leather case and strap, high form, with sunshades 18.00

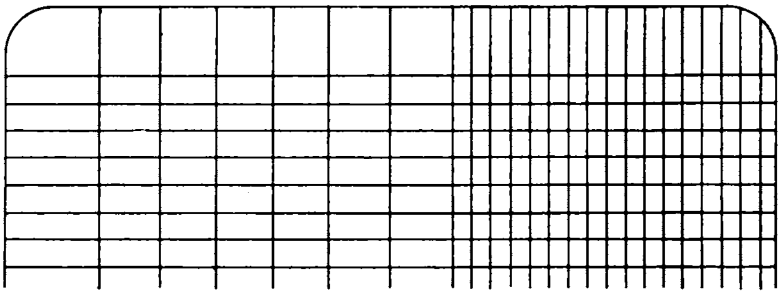
385 Field glass, with objective 2¼ inches diameter, leather case and strap, low form, with sunshades (NIGHT GLASS)........................ 20.00

386 Field glass (the smallest), with objective 1¼ inches diameter, measuring 4 x 3 inches, with rapid focusing arrangement, complete in leather case with strap, with sunshades............................. 15.00

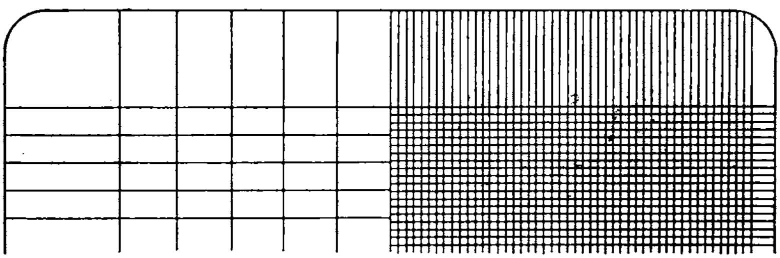
Drawing Materials

ENGINEERS' FIELD BOOKS.

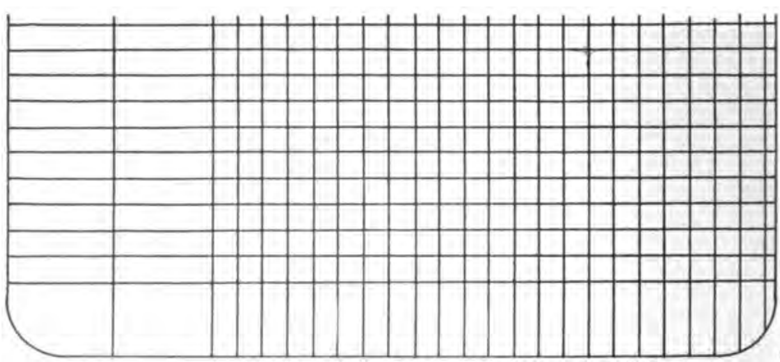
All our Field Books contain Stadia Reduction Tables, etc.



460 Field Book, 4 x 7 inches, 80 leaves.................Each $0.55 Doz. $5.40
461 Field Book, 5 x 8 inches, 80 leaves.................Each .60 Doz. 6.00

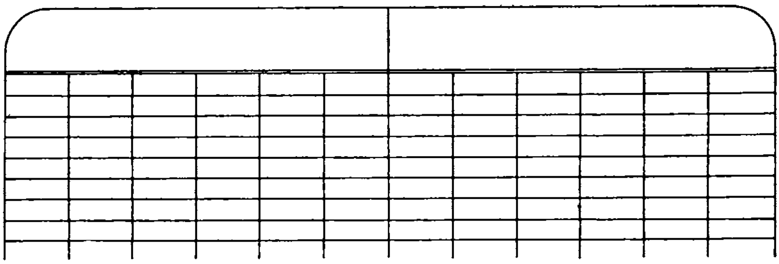


463 Mining Transit Book, 4 x 7 inches, 80 leaves, right hand page 10 x 10 to one inch ....Each $0.60 Doz. $6.00



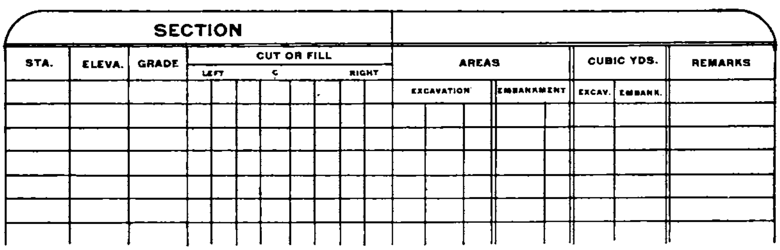
465 Transit Book, 4 x 7 inches, 80 leaves...............Each $0.55 Doz. $5.40
466 Transit Book, 5 x 8 inches, 80 leaves...............Each .60 Doz. 6.00

All our Field Books contain Stadia Reduction Tables, etc.

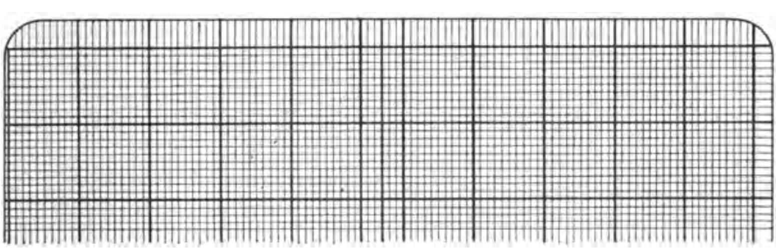


470 Level Book, 4 x 7 inches, 80 leaves.................Each $0.55 Doz. $5.40

471 Level Book, 5 x 8 inches, 80 leaves.................Each .60 Doz. 6.00



474 Field Book, 5¼ x 8 inches, 80 leaves, printed headings. Each........$ 1.00
Dozen 10.00



478 Cross-Section Book, 5½ x 7½ inches, 80 leaves, ruled 10 x 10 to one inch
Each ....$ 0.75
Dozen 7.00

479 Cross-Section Book, 6½ x 8½ inches, 80 leaves, ruled 10 x 10 to one inch
Each 1.00
Dozen 10.00

480 German White Drawing Paper.

480 German White Drawing Paper. Slightly grained surface. Well adapted for pencil, crayon, water color and ink.

		Per Quire.
Cap	14 x 17 inches	$0.20
Demy	15 x 20 inches	.35
Medium	17 x 22 inches	.45
Royal	19 x 24 inches	.55
Super Royal	19 x 27 inches	.65
Imperial	22 x 30 inches	.95
Double Elephant	27 x 40 inches	1.80

485 Finest Cream Drawing Paper.

485 Finest Cream Drawing Paper. Is tough and has a hard grained surface.

		Per Quire.
Royal	19 x 24 inches	$1.10
Imperial	22 x 30 inches	1.50
Atlas	24 x 36 inches	2.25
Double Elephant	27 x 40 inches	2.60

490 Drawing Paper.

490 Drawing Paper. A very tough pure white Drawing Paper having a smooth, hard surface. An excellent paper for fine drawings in ink or pencil.

		Per Quire.
Royal	19 x 24 inches	$1.65
Imperial	22 x 30 inches	2.35
Double Elephant	27 x 40 inches	3.60

Samples of any of our Papers will be mailed upon application.

DRAWING PAPERS.

500 Whatman's C. P. (Grained) or H. P. (Smooth) Surface.

		Per Quire.
Cap	13 x 17 inches	$0.60
Demy	15 x 20 inches	.90
Medium	17 x 22 inches	1.25
Royal	19 x 24 inches	1.55
Imperial	22 x 30 inches	2.60
Double Elephant	27 x 40 inches	4.80
Antiquarian	31 x 53 inches	14.75

501 Whatman's R (Rough) Surface.

		Per Sheet	Per Quire
Royal	19 x 24 inches	$0.08	$1.55
Imperial	22 x 30 inches	.12½	2.60
Double Elephant	27 x 40 inches	.25	4.80

540 Manila Detail Paper—Medium Weight.

In Original Rolls weighing about 75 lbs.

	Per Yard	Roll	Per Roll	Original Rolls Per Lb.
36 in. wide	$0.05	10 yds.	$0.45	$0.10
42 in. wide	.06	10 yds.	.55	.10
48 in. wide	.07	10 yds.	.65	.10

542 Manila Detail Paper—Heavy Weight.

In Original Rolls weighing about 75 lbs.

	Per Yard	Roll	Per Roll	Original Rolls Per Lb.
36 in. wide	$0.06	10 yds.	$0.50	$0.10
42 in. wide	.08	10 yds.	.60	.10
48 in. wide	.09	10 yds.	.70	.10

546 Climax Detail Paper—Medium Weight.

In Original Rolls weighing about 100 lbs.

	Roll	Per Roll		Original Rolls Per Roll	Original Rolls Per Lb.
36 in. wide	50 yds.	$2.25	Per roll, 100 yds.	$4.00	$0.12
42 in. wide	50 yds.	2.60	Per roll, 100 yds.	4.70	.12
48 in. wide	50 yds.	2.95	Per roll, 100 yds.	5.35	.12

Samples of any of our papers will be mailed upon application.

DRAWING PAPERS.

547 Climax Detail Paper—Heavy Weight.

In Original Rolls weighing about 100 lbs.

	Roll	Per Roll		Original Rolls Per Roll	Original Rolls Per Lb.
36 in. wide	50 yds.	$2.75	Per roll, 100 yds.	$5.00	$0.12
42 in. wide	50 yds.	3.10	Per roll, 100 yds.	5.75	.12
48 in. wide	50 yds.	3.65	Per roll, 100 yds.	6.75	.12

550 Cream Drawing Paper.

In Original Rolls weighing about 40 lbs.

	Per Yard	Roll	Per Roll	Original Rolls Per Lb.
30 in. wide	$0.13	10 yds.	$1.15	$0.28
36 in. wide	.15	10 yds.	1.35	.28
42 in. wide	.20	10 yds.	1.70	.28

551 Cream Drawing Paper—Mounted.

	Per Yard	Roll	Per Roll
36 in. wide	$0.60	10 yds.	$5.00
42 in. wide	.75	10 yds.	6.25
54 in. wide	1.00	10 yds.	8.50

562 White German Drawing Paper.

In Original Rolls weighing about 40 lbs.

	Per Yard	Roll	Per Roll	Original Rolls Per Lb.
30 in. wide	$0.15	10 yds.	$1.35	$0.33
36 in. wide	.20	10 yds.	1.60	.33
42 in. wide	.23	10 yds.	1.90	.33

563 White German Drawing Paper—Mounted.

	Per Yard	Roll	Per Roll
36 in. wide	$0.75	10 yds.	$6.00
42 in. wide	.90	10 yds.	7.50
54 in. wide	1.40	10 yds.	11.10

570 Eggshell Drawing Paper—Medium.

	Per Yard	Roll	Per Roll	Original Rolls Per Lb.
36 in. wide	$0.35	10 yds.	$3.10	$0.50
42 in. wide	.40	10 yds.	3.60	.50
36 in. wide mounted	.90	10 yds.	8.00	....
42 in. wide mounted	1.00	10 yds.	9.00	....

Samples of any of our Papers will be mailed upon application.

DRAWING PAPERS.

585 Transparent Sketching Paper.

36 in. wide, per roll of 50 yards	$2.00
60 in. wide, per roll of 50 yards	3.25

TRACING PAPERS.

590 Detail Tracing Paper.

40 in. wide, per roll of 50 yards	$1.50
48 in. wide, per roll of 50 yards	2.00
40 in. wide, per roll of 100 yards	2.50
48 in. wide, per roll of 100 yards	3.00

600 Bond Tracing Paper.

42 in. wide, per yard	$0.10	Per 20 yard roll	$1.50

602 Light Parchment Tracing Paper.

42 in. wide, per yard	$0.10	Per 20 yard roll	$1.75

604 Parchment Tracing Paper.

42 in. wide, per yard	$0.22½	Per 20 yard roll	$3.50

This paper is very transparent and has a pleasing color. It is very tough and stands erasing well, takes color, and is highly recommended as a perfect tracing paper,

AND IS THE BEST SUBSTITUTE FOR TRACING CLOTH

618 Albus Tracing Paper. Unglazed.

42 in. wide, per yard	$0.10	Per 44 yard roll	$3.60
57 in. wide, per yard	.15	Per 44 yard roll	4.60

A thin, white, natural tracing paper, adapted for pen and ink perspectives.

620 Vellum Tracing Paper.

36 in. wide, per yard	$0.22½	Per 20 yard roll	$3.50
42 in. wide, per yard	.25	Per 20 yard roll	4.00

This paper is waterproof; very transparent; atmospheric changes do not affect it; makes clear, sharp blue prints. Three or four erasures of ink can be made; ink will not spread on erased surface. Perfectly adapted to use of Architects, Engineers, Surveyors and users of tracing cloth and tracing papers generally. A fair test will convince that Vellum Tracing Paper is superior to anything of the kind hitherto offered.

Samples of any of our Papers will be mailed upon application.

Tracing Cloth in Sheets.

On account of the large demand for Tracing Cloth in sheets we have equipped ourselves so that we can supply at SHORT NOTICE sheets cut any size, and print the border lines and titles with opaque black ink. The border lines and titles can be made any width or style. Prices will be quoted upon submitting the style desired.

TRACING CLOTH.

650 Imperial Tracing Cloth.

Inches wide	30	36	42	48	54
Per roll of 24 yards	$8.10	$9.00	$12.10	$16.00	$17.00
Per yard	.40	.45	.60	.80	.85

651 United States Tracing Cloth.
A Superb Article.

An American product which is equal to any of the imported tracing cloths, possesses excellent erasing and transparent qualities.

Inches wide	30	36	42
Per roll of 24 yards	$6.50	$7.50	$10.00
Per yard	.35	.40	.55

652 Tracing Cloth Powder

For powdering Tracing Cloth to make it take ink more readily.

In tin shakers, each.......... $0.15

Blue Printing in all its branches attended to at short notice.

670 Blue Print Paper.

Inches wide	30	36	42
Per 10 yard roll	$0.70	$0.80	$0.90
Per 50 yard roll	3.00	3.50	4.00

In ordering, kindly state whether Regular or Rapid Solution is wanted.

671 Blue Print Paper.

Inches wide	30	36	42
Per 10 yard roll	$0.90	$1.00	$1.10
Per 50 yard roll	4.00	4.50	5.00

In ordering, kindly state whether Regular or Rapid Solution is wanted.

672 Blue Print Paper.

This paper is especially adapted for export trade on account of its excellent keeping qualities and fine results.

Inches wide	30	36	42
Per roll of 10 yards	$1.30	$1.50	$1.70
Per roll of 50 yards	5.25	6.25	7.25

In ordering, kindly state whether Regular or Rapid Solution is wanted.

Samples of any of our Papers will be mailed upon application.

673 Blue Print Cloth.

Inches wide	30	36	42
Per 10 yard roll	$3.00	$3.75	$4.75

In ordering, kindly state whether Regular or Rapid Solution is wanted.

675 Solar Paper—Thin for Negatives.

Inches wide	30	36	42
Per 10 yard roll	$1.80	$2.20	$2.70
Per 50 yard roll	9.00	10.50	12.50

676 Solar Paper—Thick for Positives.

Inches wide	30	36	42
Per 10 yard roll	$1.80	$2.20	$2.70
Per 50 yard roll	9.00	10.50	12.50

677 Solar Cloth—Thin for Negatives.

Inches wide	30	36	42
Per 10 yard roll	$5.00	$6.00	$7.00

678 Solar Cloth—Thick for Positives.

Inches wide	30	36	42
Per 10 yard roll	$4.50	$5.00	$6.00

679 Fixing Salts.

For permanently fixing and intensifying prints.

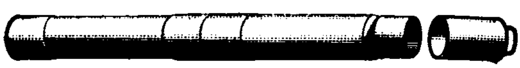
Per 4 ounce box	$0.15
Per 1 pound	.40

Samples of any of our Papers will be mailed upon application.

683 Erasing Fluid for Altering Prints.

White, Yellow, Red, per bottle $0.20

Metal Preserving Tubes.



Made of tin for storing prepared papers or cloths, excluding light and moisture.

	Inches	30	36	42
685	For 10 yard rolls, each	$0.95	$1.00	$1.10
686	For 50 yard rolls, each	1.10	1.25	1.35
689	Spring clips for holding prints, per doz.			$0.25

PROFILE PAPERS AND CLOTHS.

Our Profile Papers and Cloths are printed from an engraving on specially selected stock. The lines are perfectly distinct, and we guarantee them to be of uniform quality and absolutely continuous, and not in pieces as is often the case.

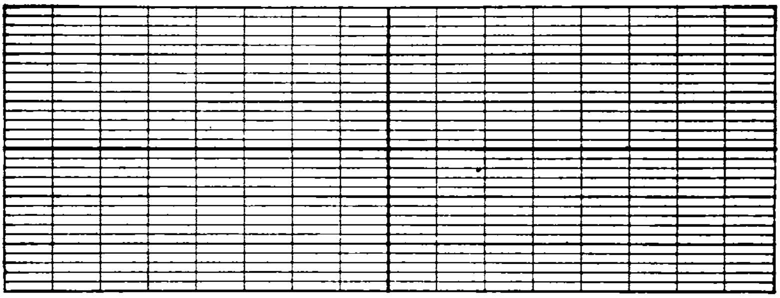


Plate "A" 4 x 20 to 1 Inch.

		Per Roll	Yard
700	Plate A, on Drawing Paper, 20 in. wide, 50 yard rolls..... Printed in Orange or Green.	$10.00	$0.24
701	Plate A, Mounted on Muslin, 20 in. wide, 20 yard rolls.... Printed in Orange or Green.	10.00	.75
702	Plate A, on Opaque Cloth, 20 in. wide, 20 yard rolls...... Printed in Orange or Green.	10.00	.60
703	Plate A, on Tracing Cloth, 20 in. wide, 20 yard rolls...... Printed in Orange or Green.	12.50	.75
704	Plate A, on Tracing Paper, 20 in. wide, 50 yard rolls...... Printed in Orange only.	10.00	.24

When ordering please state color.

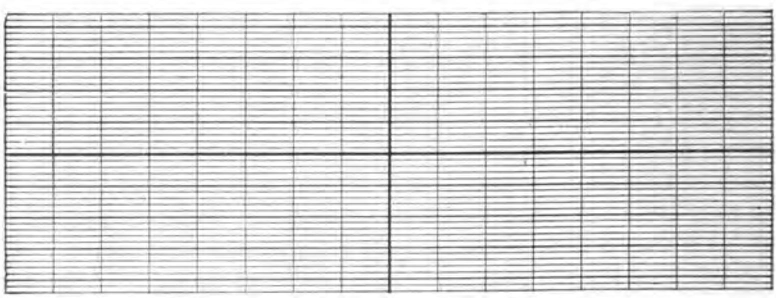
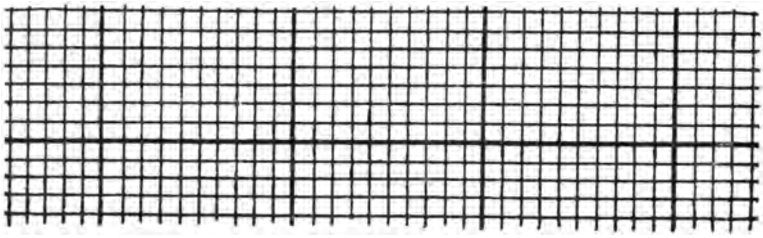


Plate "B" 4 x 30 to 1 Inch.

		Per Roll	Yard
705	Plate B, on Drawing Paper, 20 in. wide, 50 yard rolls.... Printed in Orange or Green.	$10.00	$0.24
706	Plate B, Mounted on Muslin, 20 in. wide, 20 yard rolls.... Printed in Orange or Green.	10.00	.75
707	Plate B, on Opaque Cloth, 20 in. wide, 20 yard rolls....... Printed in Orange or Green.	10.00	.60
708	Plate B, on Tracing Cloth, 20 in. wide, 20 yard rolls...... Printed in Orange or Green.	12.50	.75
709	Plate B, on Tracing Paper, 20 in. wide, 50 yard rolls...... Printed in Orange only.	10.00	.24

Samples of Profile Papers and Cloth mailed on application.

CROSS SECTION AND MILLIMETER PAPERS.



Cross Section Paper 10 x 10 to 1 Inch.

No.	Description	Per Roll	Yard
715	Cross Section, on Drawing Paper, 20 in. wide, 50 yard rolls Printed in Orange or Green.	$10.00	$0.24
716	Same Pattern, Mounted on Muslin, 20 in. wide, 20 yd. rolls Printed in Orange or Green.	10.00	.75
717	Same Pattern, on Opaque Cloth, 20 in. wide, 20 yard rolls Printed in Orange or Green.	10.00	.60
718	Same Pattern, on Tracing Cloth, 20 in. wide, 20 yard rolls Printed in Orange or Green.	12.50	.75
719	Same Pattern, on Tracing Paper, 20 in. wide, 50 yard rolls Printed in Orange only.	10.00	.24
		Quire	Sheet
720	In sheets 16 x 20 in. on Drawing Paper, 10 x 10 to 1 inch... Printed in Orange or Green.	$3.50	$0.20
721	In sheets 16 x 20 in. on Tracing Paper, 10 x 10 to 1 inch.... Printed in Orange only.	3.50	.20
722	In sheets 16 x 20 inches on Drawing Paper, 8 x 8 to 1 inch.. Printed in Orange or Green.	3.50	.20
723	In sheets 16 x 20 inches on Tracing Paper, 8 x 8 to 1 inch... Printed in Orange only.	3.50	.20
		Per Roll	Yard
725	Millimeter on Drawing Paper, 50 cm. wide, 50 yard rolls.. Printed in Orange or Green.	$10.00	$0.24
726	Millimeter Mounted on Muslin, 50 cm. wide, 20 yard rolls.. Printed in Orange or Green.	10.00	.75
727	Millimeter on Tracing Paper, 50 cm. wide, 50 yard rolls.. Printed in Orange only.	10.00	.24
728	Millimeter on Tracing Cloth, 50 cm. wide, 20 yard rolls... Printed in Orange or Green.	12.50	.75

When ordering, please state color.

Samples of Cross Section Papers mailed on application.

CROSS SECTION AND MILLIMETER PAPERS.

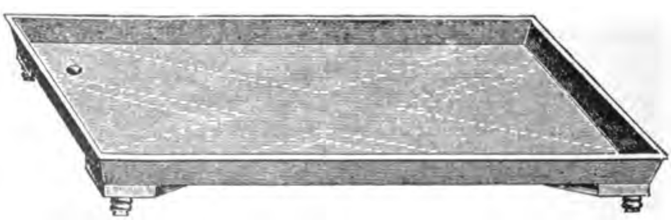
		Per Quire.
775	Ruled Cross Section Paper, 10 x 10 to 1 inch, in sheets 16 x 21 in., blue	$1.00
776	Ruled Cross Section Paper, 8 x 8 to 1 inch, in sheets 16 x 21 in., blue.	1.00
777	Ruled Cross Section Paper, 4 x 4 to 1 inch, in sheets 16 x 21 in., red and blue	1.00

BLUE PRINT FRAMES.

Best Quality.

These frames are made of hardwood seasoned, shellac finished, steel springs and metal corners.

	Printing Surfaces	Inside Dimensions		Frames Only	With Felt Pad	Complete With Pol. Plate Glass
800	20 x 26 inches	21½ x 27½	Each,	$ 7.00	$ 8.00	$12.00
801	24 x 30 inches	25½ x 31½	Each,	9.00	10.00	16.00
802	30 x 42 inches	32 x 44	Each,	14.00	16.00	24.00
803	36 x 60 inches	38 x 62	Each,	22.00	25.00	43.00



Made of Galvanized Iron, with Wooden Braces and Drain Pipe.

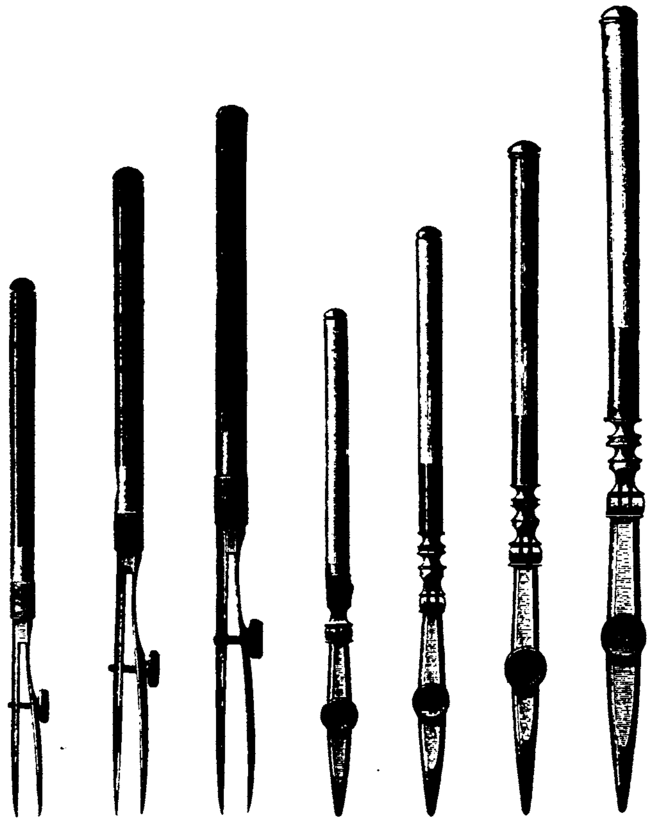
805	20 x 24	Each	$ 4 50
806	24 x 30	Each	5.50
807	30 x 42	Each	7.00
808	36 x 60	Each	9.50

Genuine Superior Swiss Drawing Instruments

BY reason of the great care in the selection of material and the attention given to the perfection of all the details in their manufacture have during the last half century become recognized all over the world as the standard.

In order to enable everyone to distinguish KERN'S GENUINE SWISS DRAWING INSTRUMENTS, as a guarantee of their perfection in workmanship, the instruments are stamped KERN & CO., AARAU, SWISS, or K. & CO., A SWISS.

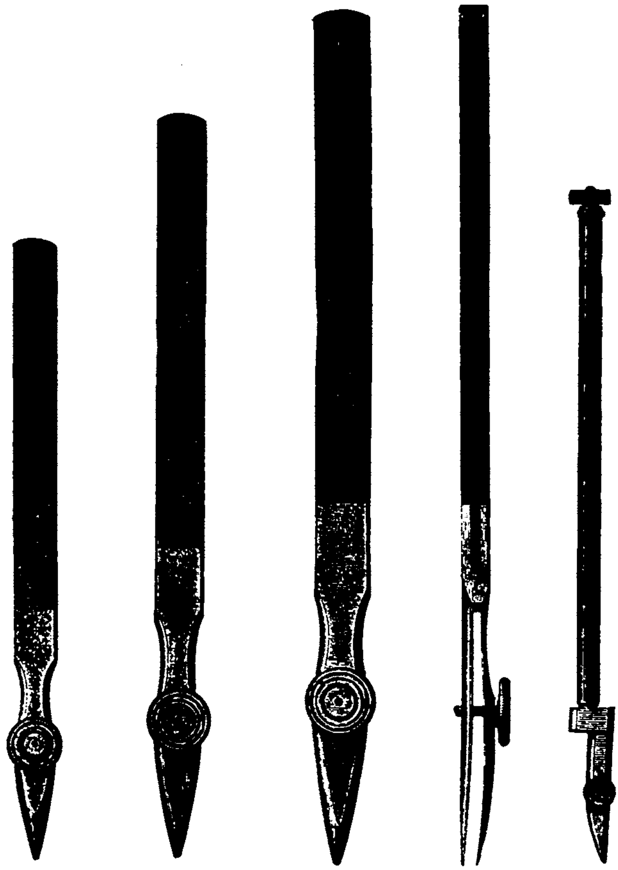
GENUINE SUPERIOR SWISS DRAWING INSTRUMENTS.



1000 1002 1004 1006 1007 1008 1009

1000	Drawing Pen, upper blade with spring, ebony handle, 4½ in.	$0.95
1001	Drawing Pen, upper blade with spring, aluminum handle, 4½ in.	1.05
1002	Drawing Pen, upper blade with spring, ebony handle, 5 in.	1.00
1003	Drawing Pen, upper blade with spring, aluminum handle, 5 in.	1.15
1004	Drawing Pen, upper blade with spring, ebony handle, 5½ in.	1.10
1005	Drawing Pen, upper blade with spring, aluminum handle, 5½ in.	1.25
1006	Drawing Pen, with joint ivory handle, 4 in.	1.15
1007	Drawing Pen, with joint ivory handle, 4¾ in.	1.40
1008	Drawing Pen, with joint ivory handle, 5½ in.	1.60
1009	Drawing Pen, with joint ivory handle, 6 in.	1.65

GENUINE SUPERIOR SWISS DRAWING INSTRUMENTS.



1010 1011 1012 1013

1010	Swedish Drawing Pen for broad lines, ebony handle, 5 in.	$1.50
1011	Swedish Drawing Pen for broad lines, ebony handle, 6 in.	1.60
1012	Swedish Drawing Pen for broad lines, ebony handle, 7 in.	1.75
1013	Curved Pen, German silver handle, 5½ in.	1.80

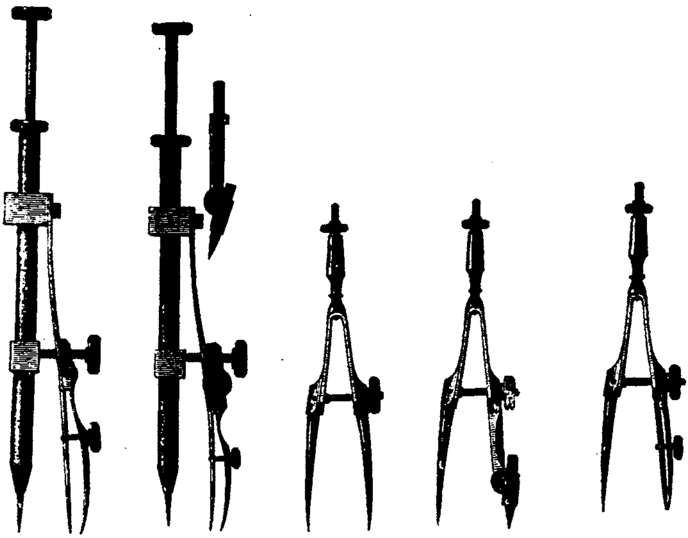
GENUINE SUPERIOR SWISS DRAWING INSTRUMENTS.

1014 1015 1016 1017 1018 1019 1019A

1014	Dotting pens with six wheels, improved, with reservoir for ink, ivory handle	$3.75
1015	Border Pen for broad lines, ivory handle, 6½ in.	2.60
1016	Border Pen for broad lines, ivory handle, 6½ in., may also be used for a railroad pen	3.00
1017	Pricker, ivory handle	1.10
1018	Tracer, ivory handle	.80
1019	Railroad Pen, with joints to blades and in shanks, improved, having both pens bent in the same direction, ivory handle, 5½ in.	3.25
1019A	Universal Dotting Pen	6.50

No interchange of wheels is necessary, the thumbscrew sets for the various dots.

GENUINE SUPERIOR SWISS DRAWING INSTRUMENTS.



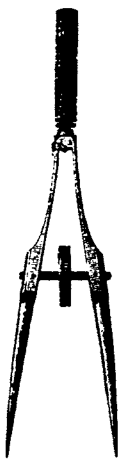
1019B 1020 1020A 1022 1021

1019B	Spring Bow Pen, self-adjusting	$3.75
1020	Spring Bow Pen, self-adjusting, with pencil point	5.00
1020A	Minute Steel Bow Divider, 2½ in. metal handle	1.75
1021	Minute Steel Bow Pen, 2½ in. metal handle	2.50
1022	Minute Steel Bow Pencil, 2½ in. metal handle	2.50

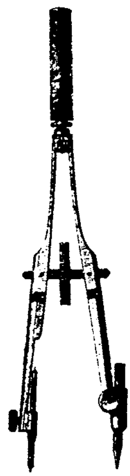
1023 1025 1024

1023	Steel Spring Bow Divider, 3 in., German silver handle	$1.75
1024	Steel Spring Bow Pen 3 in., German silver handle	2.40
1025	Steel Spring Bow Pencil, 3 in., German silver handle	2.40

GENUINE SUPERIOR SWISS DRAWING INSTRUMENTS.



1026



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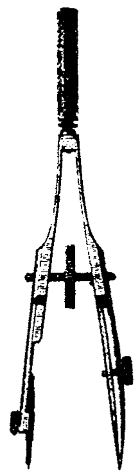
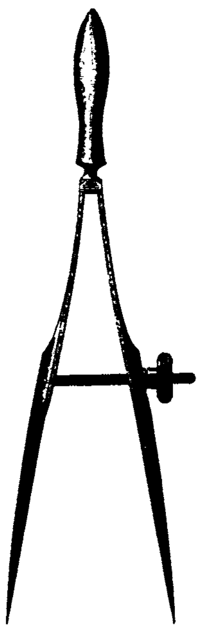


1027

1026	Steel Spring Bow Divider,	3½ in., German silver handle..........	$2.00
1027	Steel Spring Bow Pen,	3½ in., German silver handle..........	2.50
1028	Steel Spring Bow Pencil,	3½ in., German silver handle..........	2.50

These bows have a screw on right and left thread.

GENUINE SUPERIOR SWISS DRAWING INSTRUMENTS.



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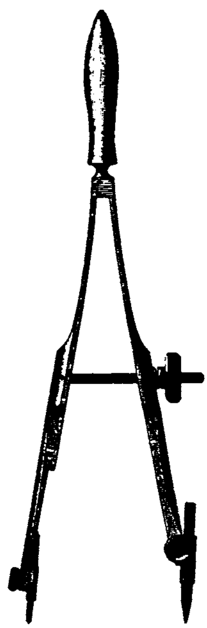
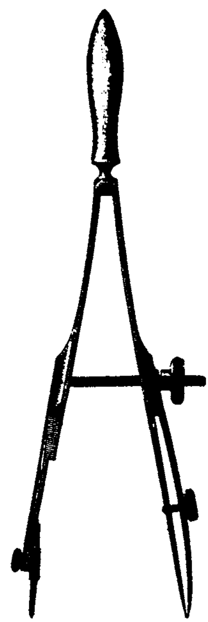


1031

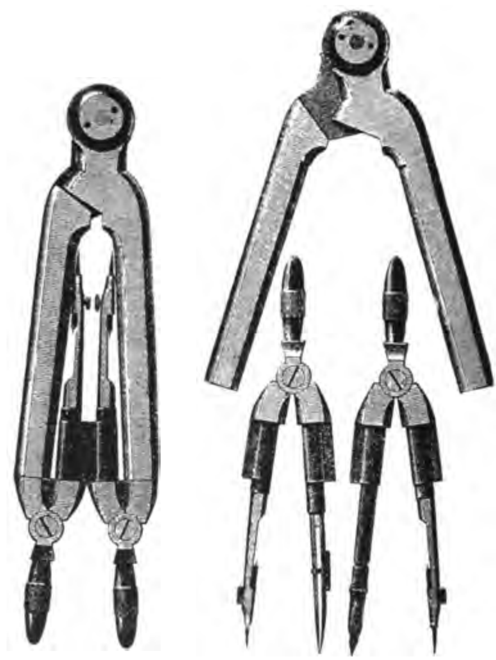


1030

1029	Steel Spring Bow Divider,	4¾ in., ivory handle..................	$1.90
1030	Steel Spring Bow Pen,	4¾ in., ivory handle..................	2.40
1031	Steel Spring Bow Pencil,	4¾ in., ivory handle..................	2.40

GENUINE SUPERIOR SWISS DRAWING INSTRUMENTS.

1032



1033

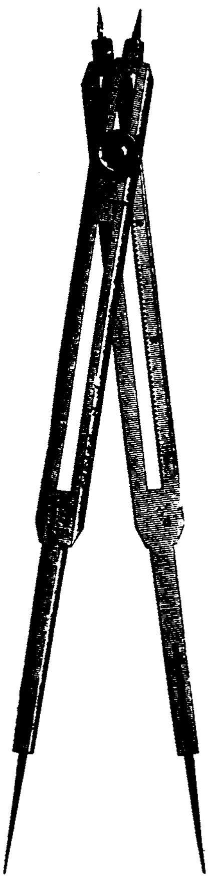
1032 Pocket Dividers with sheath, 5 in. . . . . $ 2.80

1033 Pillar Compasses, with handles, 2 needle points, pen and pencil point, which can be withdrawn from the compasses and used as small Bow Pen and Pencil respectively. 10.00

GENUINE SUPERIOR SWISS DRAWING INSTRUMENTS.

1034

1034 Proportional Divider, finely divided for lines and circles, 7½ in..... $9.00

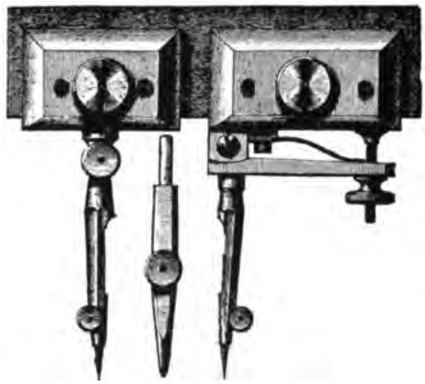


1035 1036

1035 Proportional Dividers, finely divided for lines and circles, 9 in. with rack movement and movable points...................... $14.50

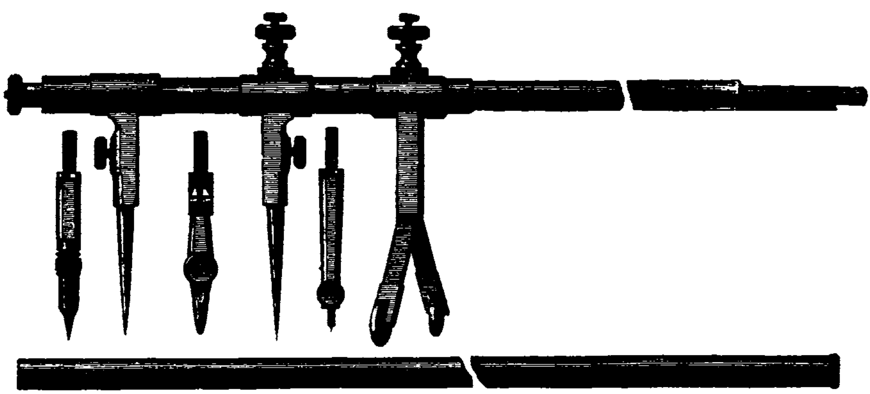
1036 Proportional Divider, finely divided for lines and circles, planes and solids, 9 in., with micrometer adjustment.................. 16.75

GENUINE SUPERIOR SWISS DRAWING INSTRUMENTS.



1040

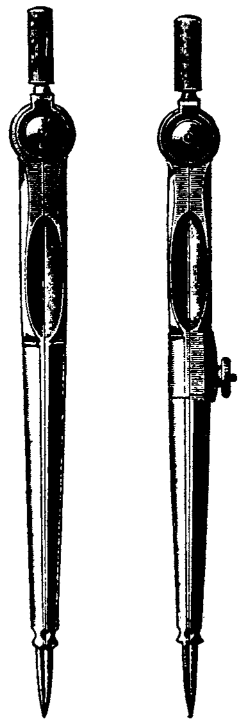
1040 Beam Compass, to fit any straight edge, with 2 needle points exchangeable for lead, pen point, with micrometer adjustment.... $ 7.50



1041

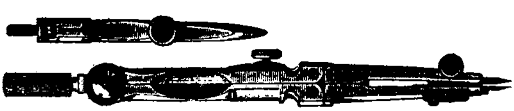
1041 Tubular Beam Compass, 36 in. with 2 steel points, pen, pencil and needle point, 3 bars $14.00

GENUINE SUPERIOR SWISS DRAWING INSTRUMENTS.



1042 1043

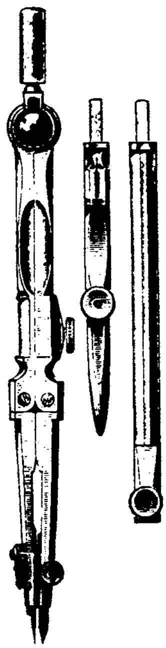
1042 Plain Divider, 5 in., rounded steel points........................... $ 2.35
1043 Hairspring Divider, 5 in., rounded steel points.................. 3.25



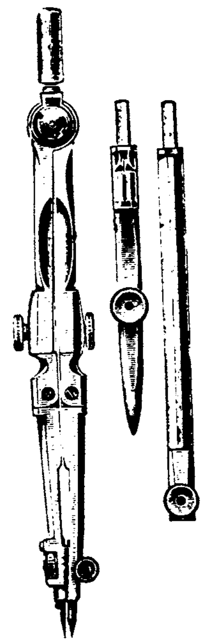
1044

1044 Compass 3½ in., with fixed needle point, pen and pencil point...... $ 5.75
1045 Compass 3½ in., as No. 1044, with hairspring................... 6.75

GENUINE SUPERIOR SWISS DRAWING INSTRUMENTS.



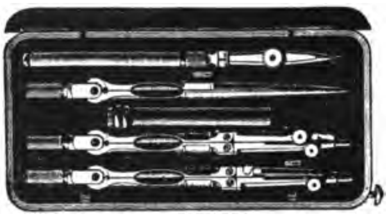
1046



1047

1046	Compass 5½ in., with patent fixed needle point, pen, pencil point and lengthening bar	$ 7.15
1047	Compass 5½ in., as No. 1046, with hairspring	8.25
1048	Combination Needle Points for Drawing Compasses, each	.15

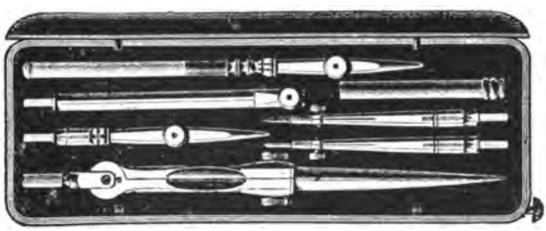
SETS OF GENUINE SUPERIOR SWISS DRAWING INSTRUMENTS.



1060

1060 Set contains:

Drawing Pen, with joint, ivory handle, 4 in....................
Hairspring Divider, 3½ in....................................
Compass, 3½ in. with fixed needle and pen point...............
Compass, 3½ in. with fixed needle and pencil point............
Box for Leads $13.00

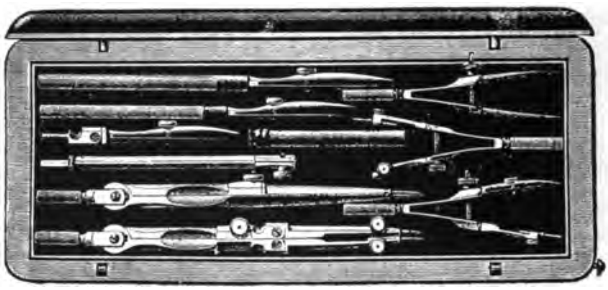


1061

1061 Set contains:

Drawing Pen, with joint, ivory handle, 5½ in..................
Compass 5½ in. with 2 steel points, pen, pencil and needle points and lengthening bar ....
Box for Leads $12.00

SETS OF GENUINE SUPERIOR SWISS DRAWING INSTRUMENTS.



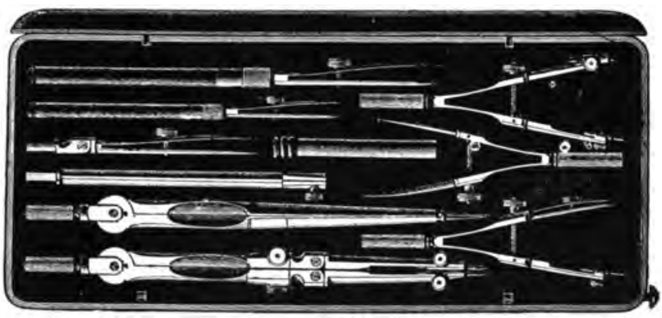
1062

1062 Set contains:

Drawing Pen, upper blade with spring, ebony handle, 4½ in....
Drawing Pen, upper blade with spring, ebony handle, 5 in......
Steel Spring Bow Divider, 3½ in., metal handle...............
Steel Spring Bow Pen, 3½ in., metal handle..................
Steel Spring Bow Pencil, 3½ in., metal handle.................
Hairspring Divider, 5 in., rounded steel points.................
Compass, 5½ in., with fixed needle point, pen, pencil point and lengthening bar ....
Box for Leads $21.50

1063 Set contains:—1062 in Leather Pocket Book Case................. 24.50

SETS OF GENUINE SUPERIOR SWISS DRAWING INSTRUMENTS.



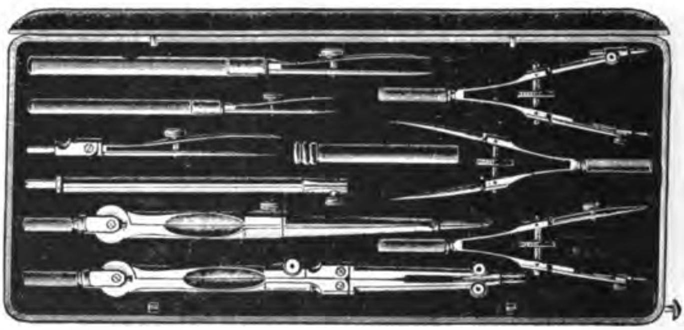
1064

1064 Set contains:

- Drawing Pen, upper blade with spring, ebony handle, 4½ in.....
- Drawing Pen, upper blade with spring, ebony handle, 5 in.......
- Steel Spring Bow Divider, 3½ in., metal handle................
- Steel Spring Bow Pen, 3½ in., metal handle..................
- Steel Spring Bow Pencil, 3½ in., metal handle................
- Plain Divider, 5 in., rounded steel points......................
- Hairspring Compass, 5½ in., with fixed needle point, pen, pencil point and lengthening bar ....
- Box for leads.. $22.00

1065 Set contains:—1064 in Leather Pocket Book Case................ 25.00

SETS OF GENUINE SUPERIOR SWISS DRAWING INSTRUMENTS.



1066

1066 Set contains:

Drawing Pen, upper blade with spring, aluminum handle, 4½ in.

Drawing Pen, upper blade with spring, aluminum handle, 5 in...

Steel Spring Bow Divider, 3½ in. metal handle, center screw....

Steel Spring Bow Pen, 3½ in. metal handle, center screw.......

Steel Spring Bow Pencil, 3½ in. metal handle, center screw.....

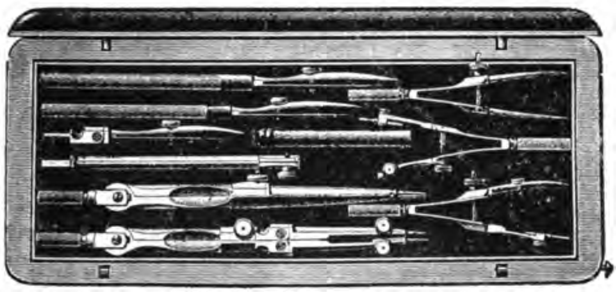
Hairspring Divider, 5 in., with rounded steel points..............

Compass, 5½ in., with fixed needle point, pen, pencil point and lengthening bar ....

Box for leads $22.50

1067 Set contains:—1066 in Leather Pocket Book Case................. 25.50

SETS OF GENUINE SUPERIOR SWISS DRAWING INSTRUMENTS.



1068

1068 Set contains:

Drawing Pen, upper blade with spring, aluminum handle, 4½ in.
Drawing Pen, upper blade with spring, aluminum handle, 5 in...
Steel Spring Bow Divider, 3 in., metal handle.................
Steel Spring Bow Pen, 3 in., metal handle......................
Steel Spring Bow Pencil, 3 in., metal handle...................
Hairspring Divider, 4½ in., rounded steel points..............
Compass, 4½ in., with fixed needle point, pen, pencil point and lengthening bar ....
Box for leads $20.00

1069 Set contains:—1068 in Leather Pocket Book Case..................23.00

SETS OF GENUINE SUPERIOR SWISS DRAWING INSTRUMENTS.

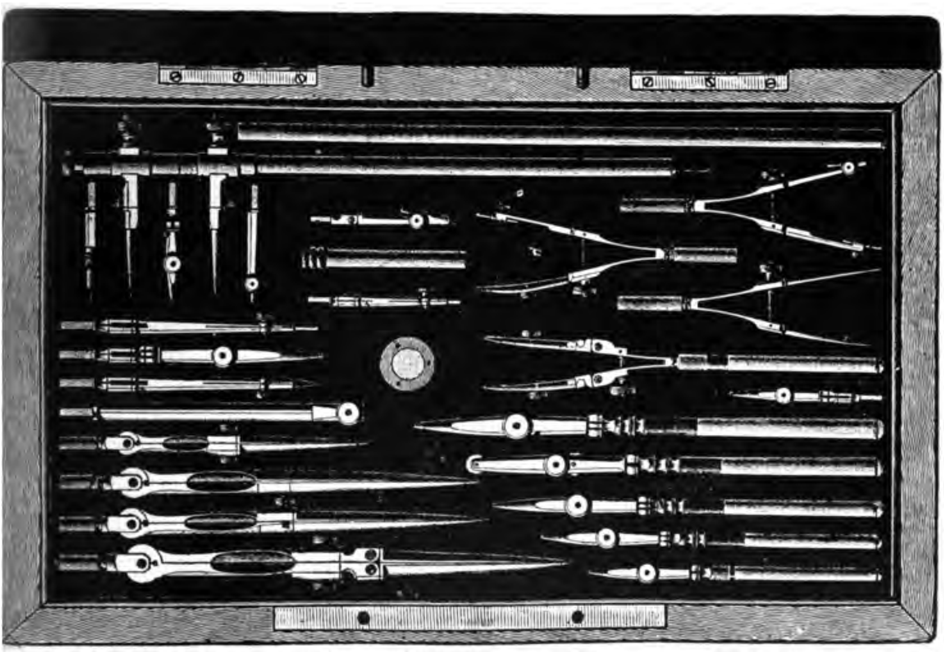
OPEN.

CLOSED.

Pocket Book Cases Illustrated.

SETS OF GENUINE SUPERIOR SWISS DRAWING INSTRUMENTS.

Fine polished Palysander wood case, with ebony corners. Lock and tray and ample space for colors, brushes, etc.



1070

1070 Set contains:

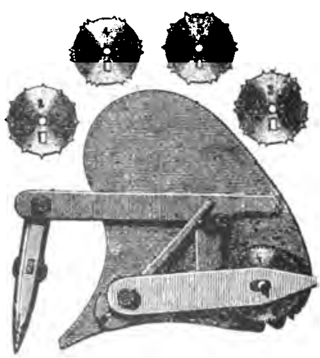
- Drawing Pen, with joint, ivory handle, 4 in....................
- Drawing Pen, with joint and pin, ivory handle, 4¾ in...........
- Drawing Pen, with joint and pin, ivory handle, 5½ in...........
- Drawing Pen, with joint and pin, ivory handle, 6½ in...........
- Railroad Pen, with joints to blades and in shanks, improved, 5½ in. ....
- Dotting Pen, with six wheels, improved with reservoir for ink, 6 in. ....
- Steel Spring Bow Divider, 3½ in., metal handle................
- Steel Spring Bow Pen, 3½ in., metal handle..................
- Steel Spring Bow Pencil, 3½ in., metal handle................
- Tubular Beam Compass, 18 in., 2 bars, 2 steel points, pen, pencil and needle point ....

SETS OF GENUINE SUPERIOR SWISS DRAWING INSTRUMENTS.

Compass, 3½ in., with 2 steel points, pen, pencil and needle point
Plain Divider, 5 in. ....
Hairspring Divider, 5 in. ....
Compass, 6 in., with 2 steel points with joint in each leg, pen, pencil, needle point and lengthening bar......................
Box for leads ....
Horn center with German silver edges........................ $64.00

1071 Special University set contains:
Drawing Pen, upper blade with spring, aluminum handle, 4½ in.
Drawing Pen, upper blade with spring, aluminum handle, 5 in...
Steel Spring Bow Divider, 3½ in., metal handle, center screw....
Steel Spring Bow Pen, 3½ in., metal handle, center screw......
Steel Spring Bow Pencil, 3½ in., metal handle, center screw....
Self Adjusting Spring Bow, No. 1020, with pen and pencil point
Hairspring Divider, 5 in., with rounded steel points............
Compass, 5½ in., with fixed needle point, pen, pencil point and lengthening bar ....
Box for leads 27.00

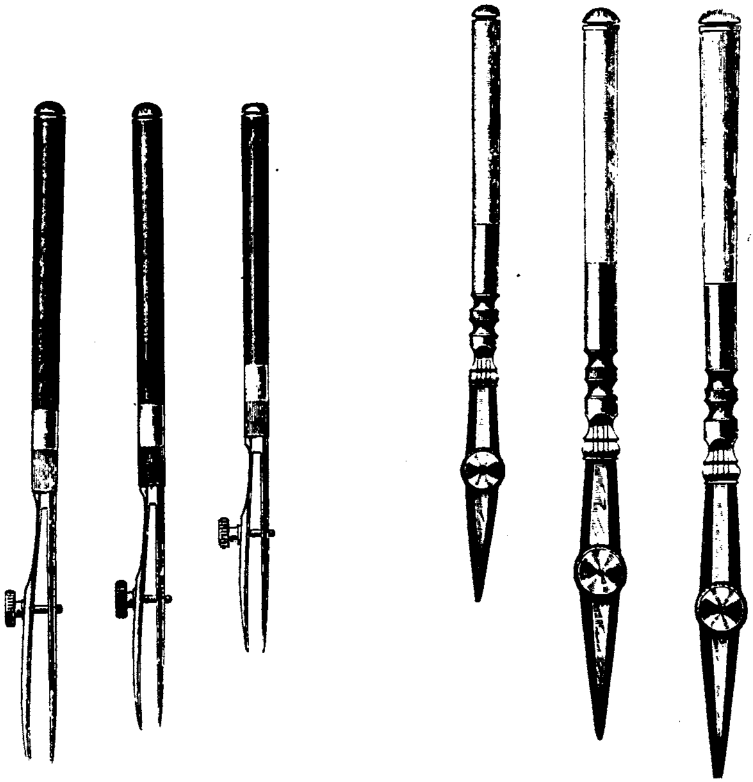
1072 Set contains:—1071 in Leather Pocket Book Case................ 30.00



1075

1075 Swiss Dotting Pen, with 6 wheels, in case........................ $ 4.50

IMPERIAL DRAWING INSTRUMENTS.



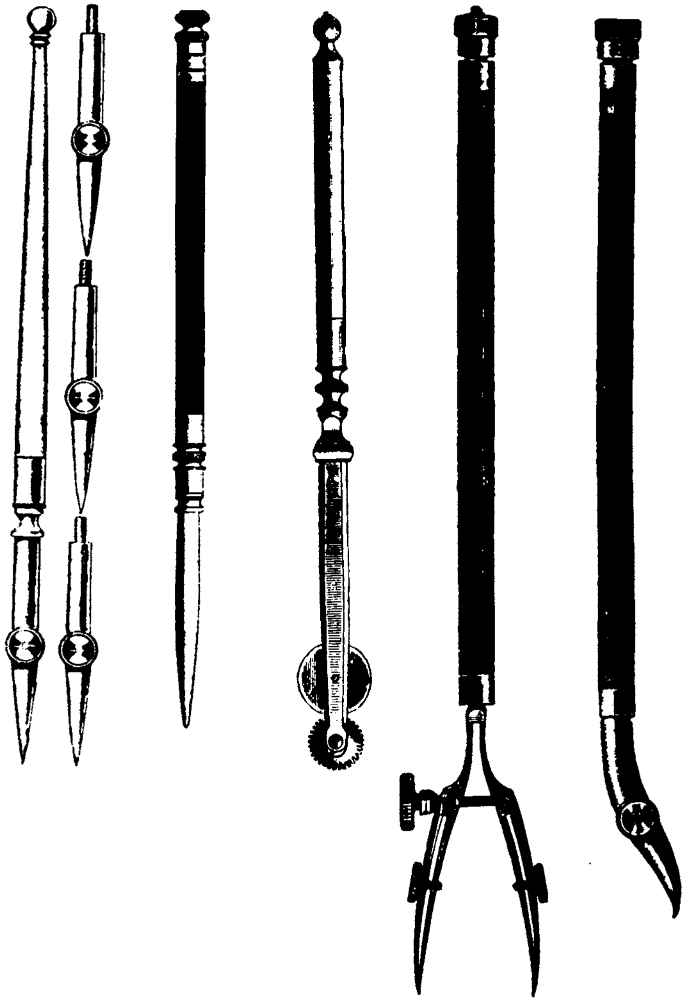
1102 1101 1100 1103 1104 1105

1100 Ruling Pen, ebony handle, upper blade with spring, 4½ in......... $0.60
1101 Ruling Pen, ebony handle, upper blade with spring, 5 in........... .65
1102 Ruling Pen, ebony handle, upper blade with spring, 5½ in......... .70
1103 Ruling Pen, ebony or ivory handle, with joint and pin, 4¾ in....... .95
1104 Ruling Pen, ebony or ivory handle, with joint and pin, 5½ in....... 1.00
1105 Ruling Pen, ebony or ivory handle, with joint and pin, 6 in......... 1.10

1115 and 1116

1115 Improved Ruling Pen, cross joint, ebony handle, 4½ in........... $1.10
1116 Improved Ruling Pen, cross joint, ebony handle, 5 in............. 1.20

IMPERIAL DRAWING INSTRUMENTS.



1125 1126 1127 1129 1128

1125 Hatching Pen, with push screw, 3 extra pens...................... $3.00
1126 Ruling Pen, 5½ in., opens and shuts by screw in upper end handle 1.25
1127 Dotting Pen, with extra wheel, ivory handle...................... 1.85
1128 Improved Curve Pen, 5½ in.................................... 1.25
1129 Improved Railroad Pen, 5½ in.................................. 3.25

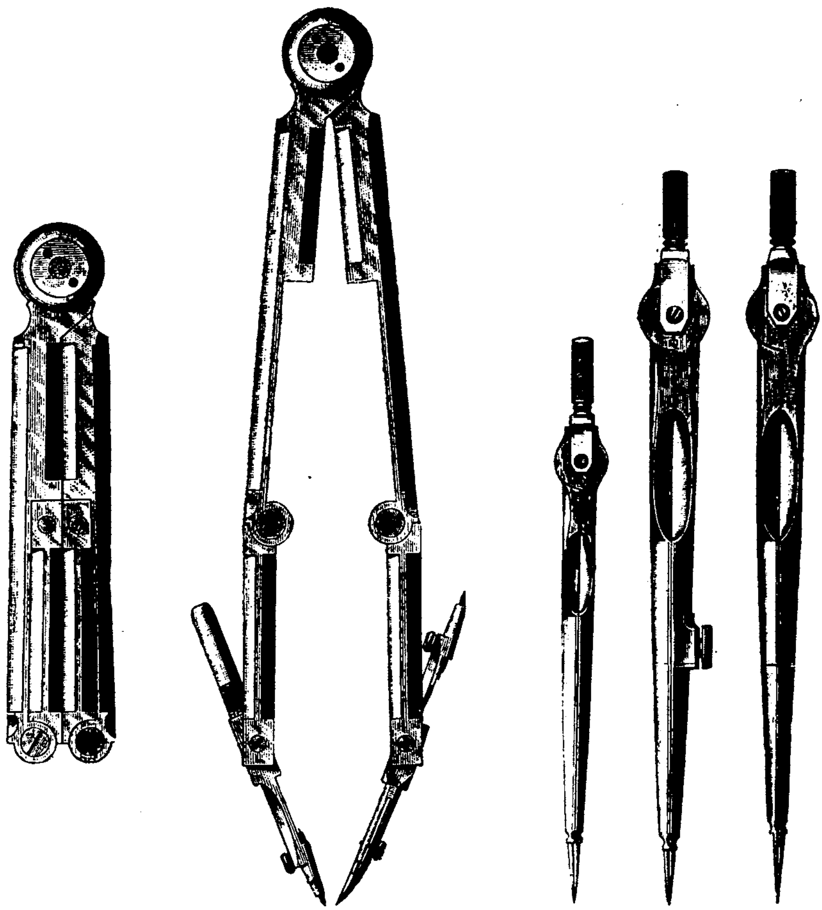
Pens 1128 and 1129 are fastened to a rod which swivels in the hollow handle and thus follows the smallest curve with precision. The rod may be locked by means of a nut at the upper end, and the instrument may be used as an ordinary drawing or railroad pen.

IMPERIAL DRAWING INSTRUMENTS.

1130 1133 1134 1135 1136 1137

1130	Swedish Ruling Pen, ebony handle, 5 in.	$0.85
1131	Swedish Ruling Pen, ebony handle, 6 in.	.95
1132	Swedish Ruling Pen, ebony handle, 7 in.	1.15
1133	Railroad Pen, 5½ in., ivory handle	3.15
1134	Pricker	.25
1135	Pocket Divider, 5 in.	1.45
1136	Three legged Divider, 5 in.	3.70
1137	Whole and Half Divider, 6½ in.	3.15

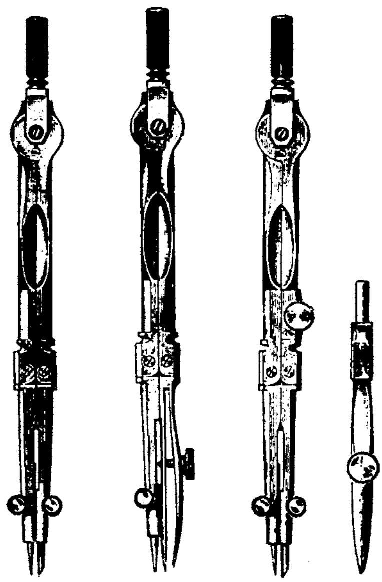
IMPERIAL DRAWING INSTRUMENTS.



1138 Closed 1138 Open 1139 1140 1141

1138	Pocket Compass, with folding points	$5.60
1139	Plain Divider, 3½ in.	1.15
1140	Hairspring Divider, 5 in.	2.15
1141	Plain Divider, 5 in.	1.35

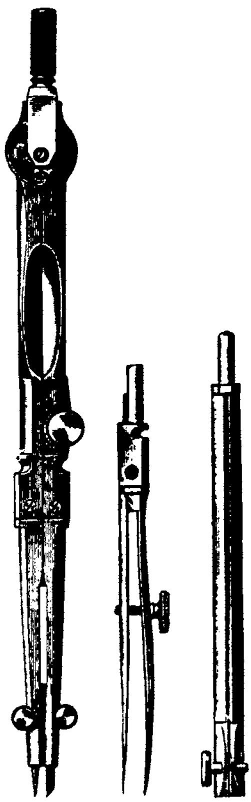
IMPERIAL DRAWING INSTRUMENTS.



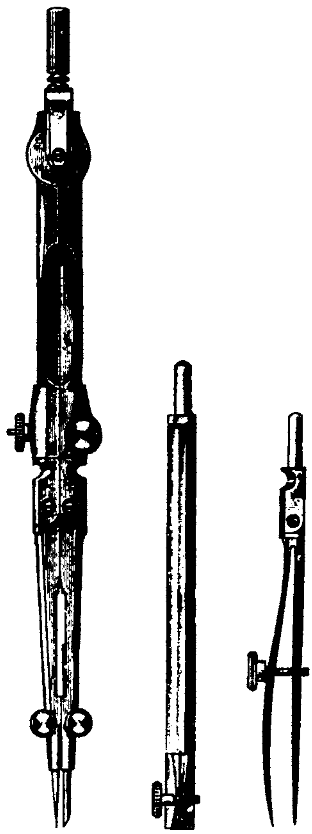
1146 1145 1147

1145	Compass, 3½ in., with fixed needle and pen point.................	$2.60
1146	Compass, 3½ in., with fixed needle and pencil point...............	2.60
1147	Compass, 3½ in., with fixed needle point, pen and pencil point......	3.05

IMPERIAL DRAWING INSTRUMENTS.



1150

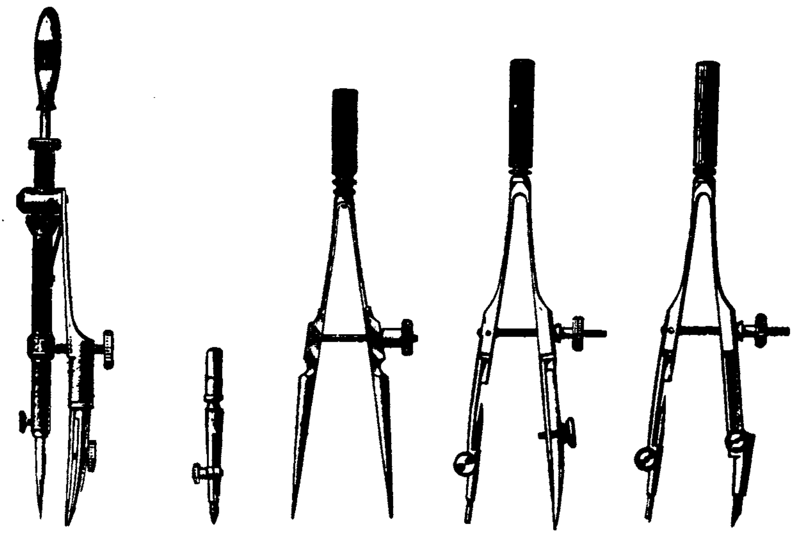


1151

1150 Compass, with fixed needle point, pen and pencil point and lengthening bar $4.00

1151 Compass, with hair spring, fixed needle point, pen and pencil point and lengthening bar.. 5.00

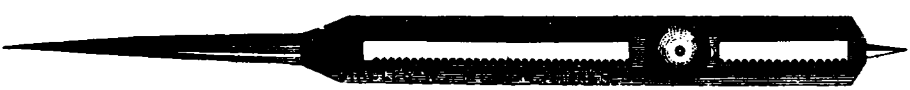
IMPERIAL DRAWING INSTRUMENTS.



1160 1161 1162 1163

1160	Spring Bow, self adjusting, with pencil point, in leather case	$3.25
1161	Steel Spring Bow Divider, 3½ in	1.00
1162	Steel Spring Bow Pen, 3½ in	1.25
1163	Steel Spring Bow Pencil, 3½	1.25
1164	Steel Spring Bow Divider, center screw, 3½ in	1.50
1165	Steel Spring Bow Pen, center screw, 3½ in	1.75
1166	Steel Spring Bow Pencil, center screw, 3½ in	1.75

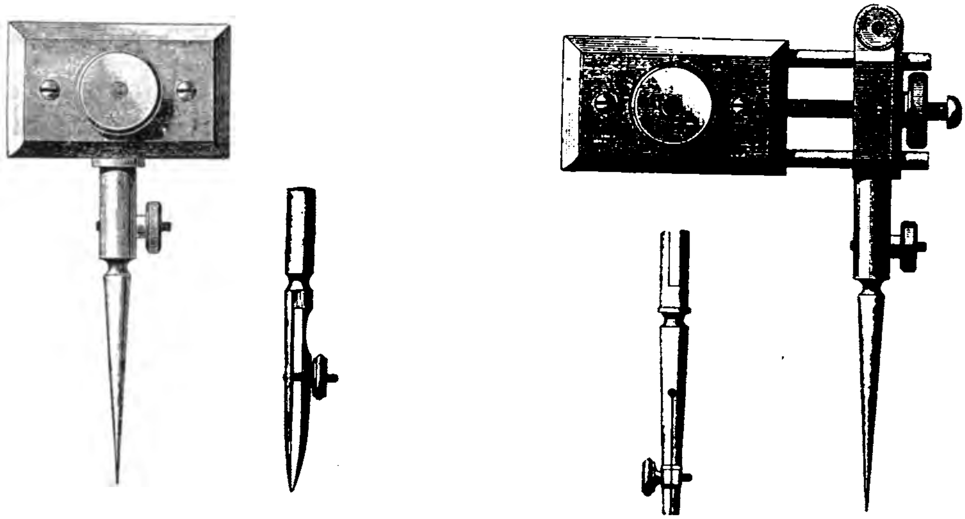
1164-5-6 have screw with right and left hand thread like 1161-2-3.



1167

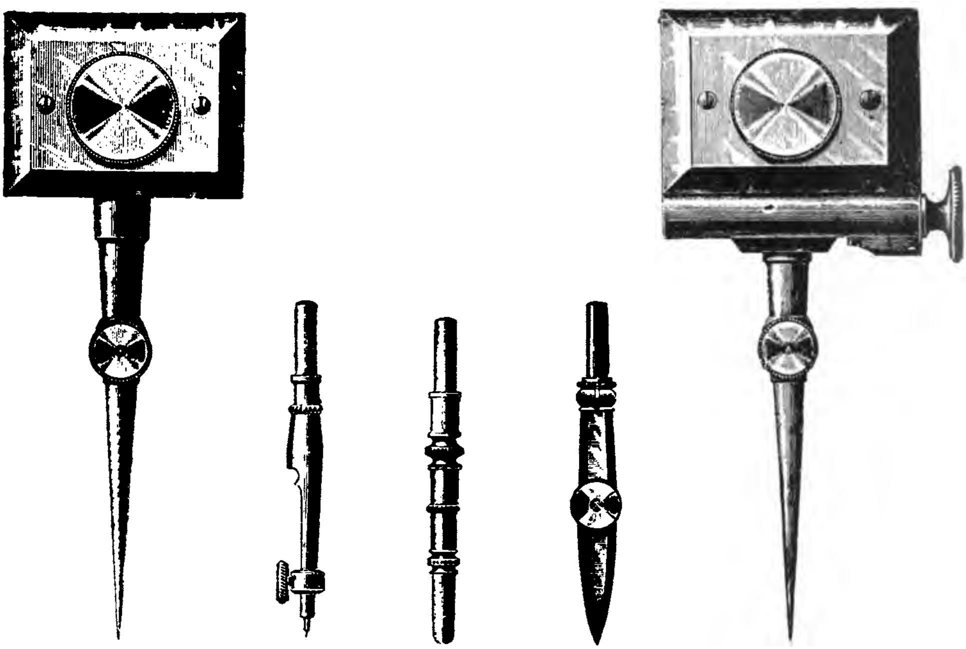
1167 Proportional Divider, finely divided for lines and circles, with micrometer adjustment $12.70

IMPERIAL DRAWING INSTRUMENTS.



1170

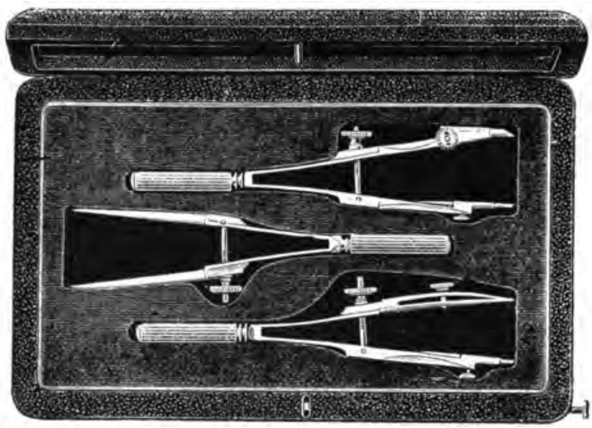
1170 Beam Compass, small size, to fit any straight edge, 2 steel points, pen and pencil point, micrometer adjustment, in case............ $6.50



1171

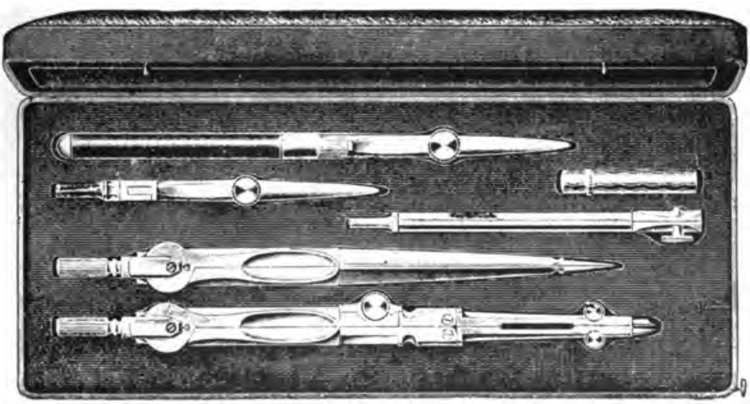
1171 Beam Compass, large size, with 2 steel points, pen, pencil and needle point, micrometer adjustment, in case........................... $7.85

IMPERIAL DRAWING INSTRUMENTS.



1180

1180	Nos. 1161-2-3 in leather case, silk velvet lined....................	$3.70
1181	Nos. 1164-5-6 in leather case, silk velvet lined....................	4.55



1182

1182 Set contains:

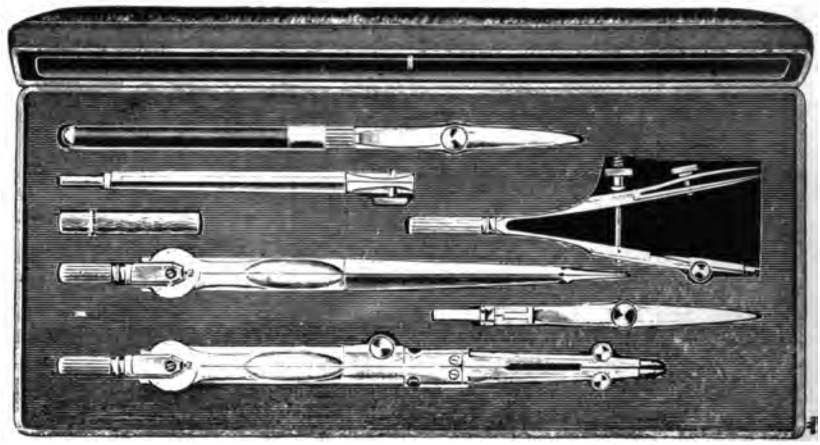
Drawing Pen, ebony handle, upper blade with spring, 5 in.......

Plain Divider, 6 in..

Compass, 6 in., with pen, pencil and needle point, and lengthening bar ....

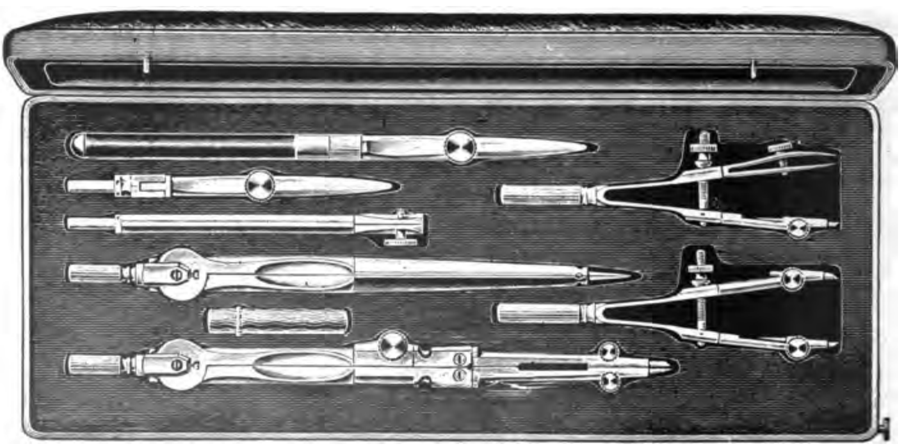
Box for leads $6.75

IMPERIAL DRAWING INSTRUMENTS.



1183

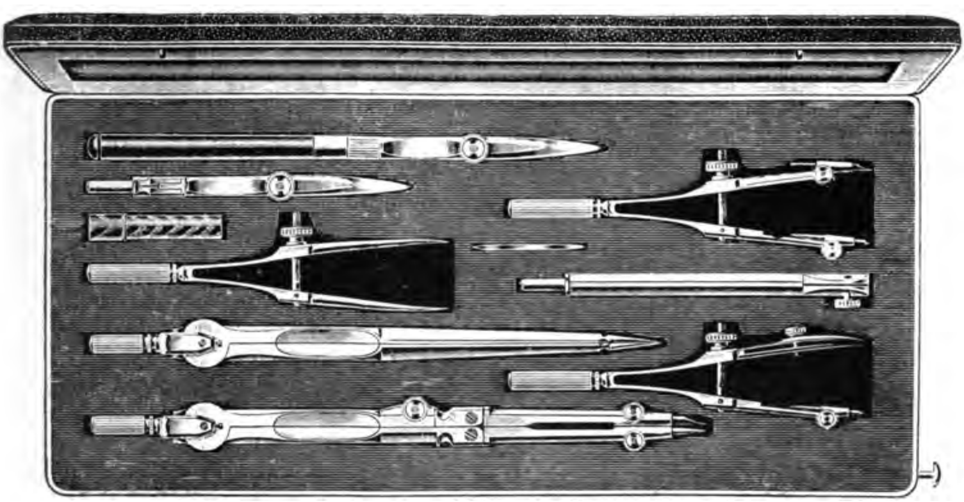
1183 Set contains:
- Drawing Pen, ebony handle, upper blade with spring, 5 in.......
- Steel Spring Bow Pen, metal handle, 3½ in...................
- Plain Divider, 6 in..
- Compass, 6 in., with pen, pencil, needle point and lengthening bar
- Box for leads $8.10



1184

1184 Set contains:
- Drawing Pen, ebony handle, upper blade with spring, 5 in.......
- Steel Spring Bow Pen, metal handle, 3½ in....................
- Steel Spring Bow Pencil, metal handle, 3½ in..................
- Plain Divider, 5½ in..
- Compass, 6 in., with pen, pencil, needle point and lengthening bar
- Box for leads $9.60

IMPERIAL DRAWING INSTRUMENTS.



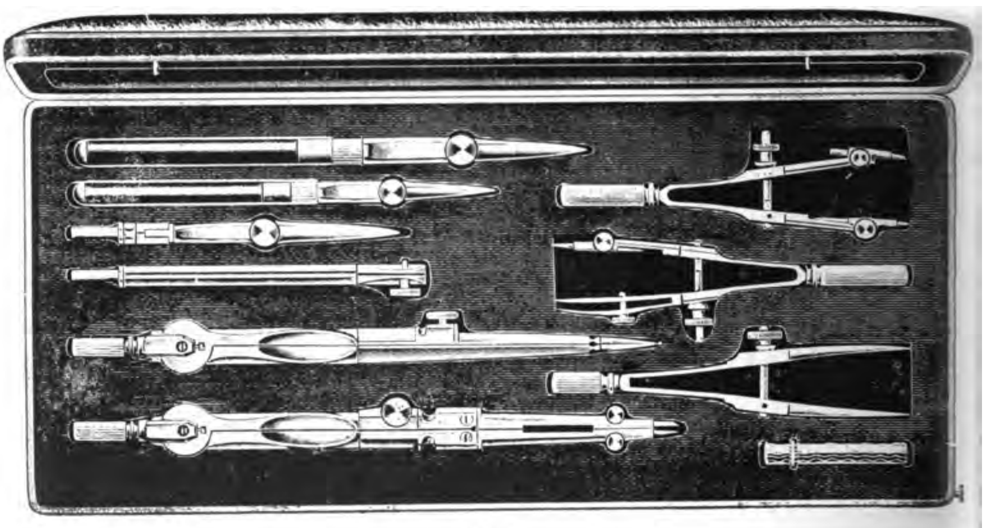
1185

1185 Set contains:

Drawing Pen, ebony handle, upper blade with spring, 5 in.......
Steel Spring Bow Divider, metal handle, 3½ in..................
Steel Spring Bow Pen, metal handle, 3½ in......................
Steel Spring Bow Pencil, metal handle, 3½ in...................
Plain Divider, 6 in...
Compass, 6 in. with pen, pencil, needle point and lengthening bar
Box for leads..$11.55

1186 Set contains:—Like 1185, in Pocket Book Leather Case............ 12.30

IMPERIAL DRAWING INSTRUMENTS.



1187

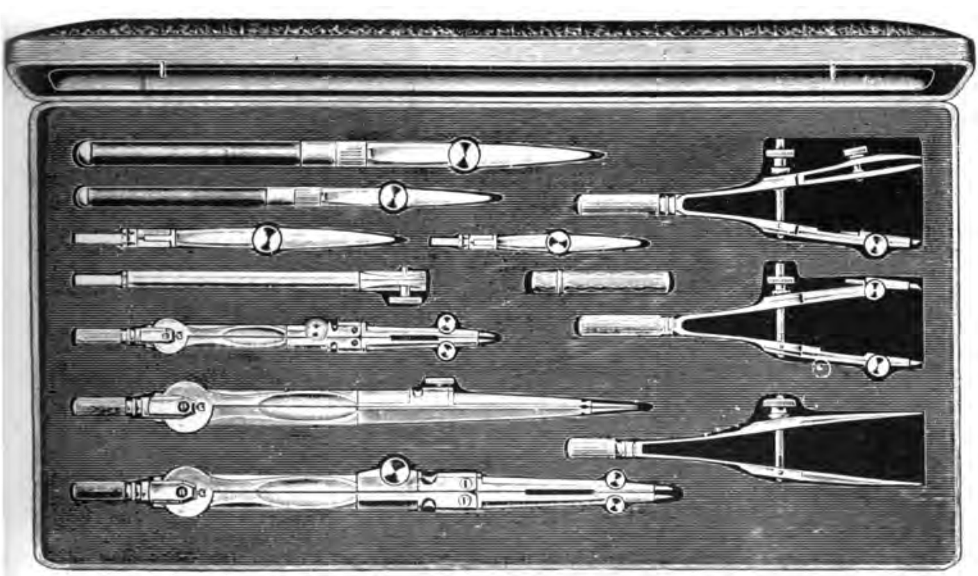
1187 Set contains:

Drawing Pen, ebony handle, upper blade with spring, 5 in.......
Drawing Pen, ebony handle, upper blade with spring, 4½ in......
Steel Spring Bow Divider, metal handle, 3½ in.................
Steel Spring Bow Pen, metal handle, 3½ in....................
Steel Spring Bow Pencil, metal handle, 3½ in..................
Hairspring Divider, 6 in. ....
Compass, 6 in., with pen, pencil, needle point and lengthening bar
Box for leads. $12.45

1188 Set contains:—1187 in Leather Pocket Book Case................ 13.20

1189 Set contains:—1188 in Leather Pocket Book Case with center wheel Bow instruments like No. 1164-5-6............................ 15.00

IMPERIAL DRAWING INSTRUMENTS.

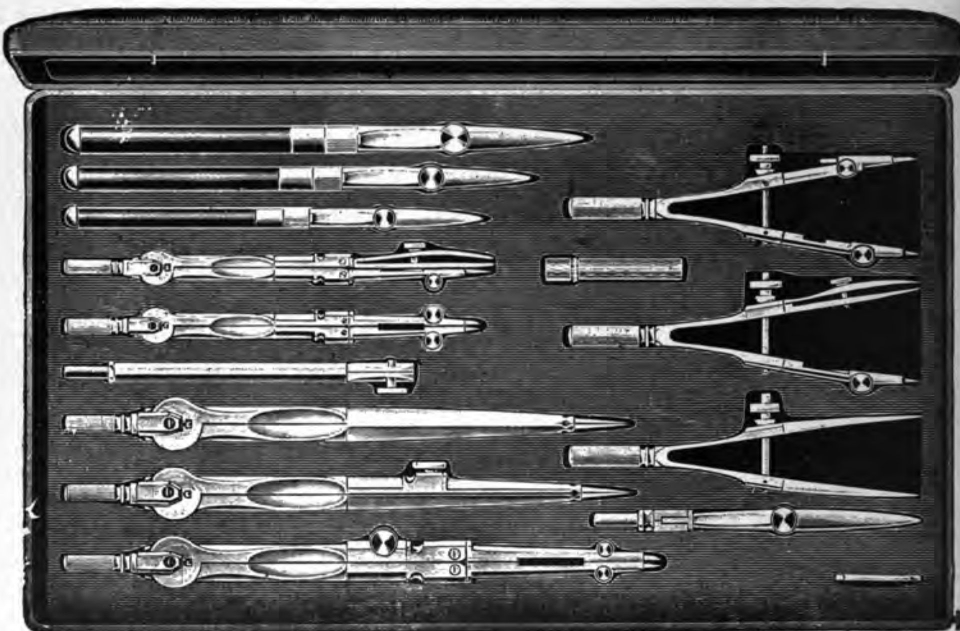


1190

1190 Set contains:

Drawing Pen, ebony handle, upper blade with spring, 5 in.......
Drawing Pen, ebony handle, upper blade with spring, 4½ in.....
Steel Spring Bow Divider, metal handle, 3½ in..................
Steel Spring Bow Pen, metal handle, 3½ in....................
Steel Spring Bow Pencil, metal handle, 3½ in..................
Hairspring Divider, 6 in.......................................
Compass, 3½ in., with pen, pencil and needle point..............
Compass, 6 in., with pen, pencil and needle point and lengthening bar ....
Box for leads $15.75

IMPERIAL DRAWING INSTRUMENTS.



1191

1191 Set contains:

Drawing Pen, ebony handle, upper blade with spring, 5½ in.....
Drawing Pen, ebony handle, upper blade with spring, 5 in.......
Drawing Pen, ebony handle, upper blade with spring, 4½ in.....
Steel Spring Bow Divider, metal handle, 3½ in..................
Steel Spring Bow Pen, metal handle, 3½ in......................
Steel Spring Bow Pencil, metal handle, 3½ in...................
Compass, 3½ in., with fixed needle and pen point...............
Compass, 3½ in., with fixed needle and pencil point.............
Plain Divider, 6 in..
Hairspring Divider, 6 in. ....
Compass, 6 in., with fixed needle point, pen, pencil point and lengthening bar ....
Box for leads $20.00

SUPERIOR DRAWING INSTRUMENTS.

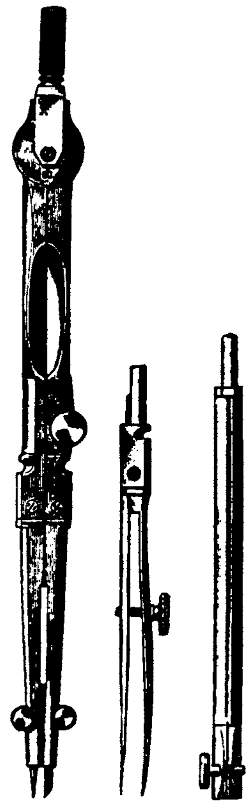
1200 1201 1202 1205 1204 1203

1200	Ruling Pen, ebony handle, with joint, 4½ in.	$0.50
1201	Ruling Pen, ebony handle, with joint, 5 in.	.55
1202	Ruling Pen, ebony handle, with joint, 5½ in.	.60
1203	Ruling Pen, ebony handle, upper blade with spring, 4½ in.	.50
1204	Ruling Pen, ebony handle, upper blade with spring, 5 in.	.55
1205	Ruling Pen, ebony handle, upper blade with spring, 5½ in.	.60

SUPERIOR DRAWING INSTRUMENTS.

1211

1210



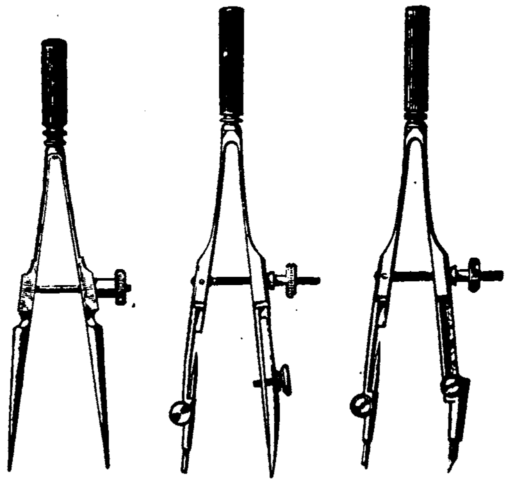
1215

1210 Plain Divider, 5 in. $1.00

1211 Hairspring Divider, 5 in. 1.65

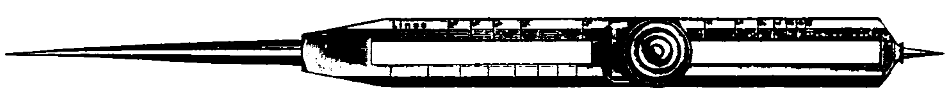
1215 Compass, with fixed needle point, pen and pencil point and lengthening bar 2.40

SUPERIOR DRAWING INSTRUMENTS.



1225 1226 1227

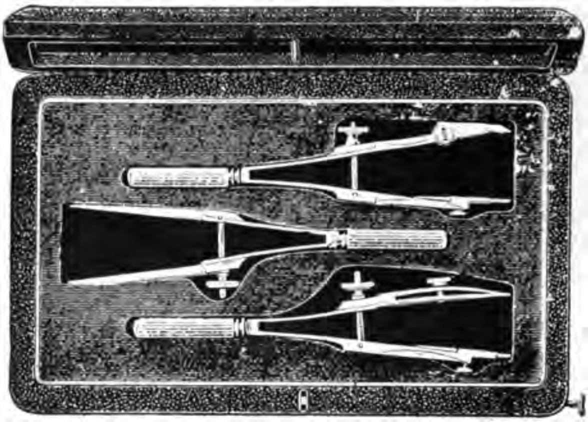
1225 Steel Spring Bow Divider, 3½ in. $0.75
1226 Steel Spring Bow Pen, 3½ in. 1.00
1227 Steel Spring Bow Pencil, 3½ in. 1.00



1230

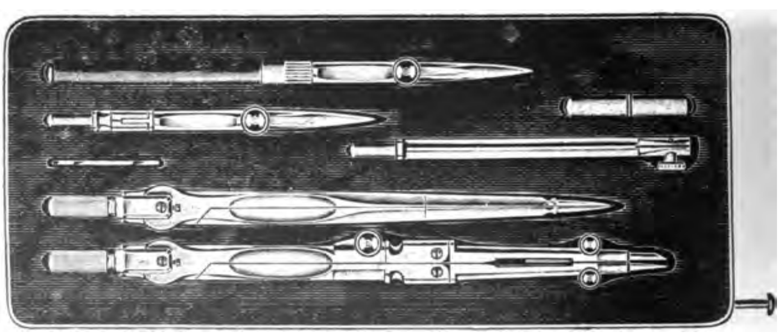
1230 Proportional Divider, finely divided, for lines and circles. $9.25

SUPERIOR DRAWING INSTRUMENTS.



1240

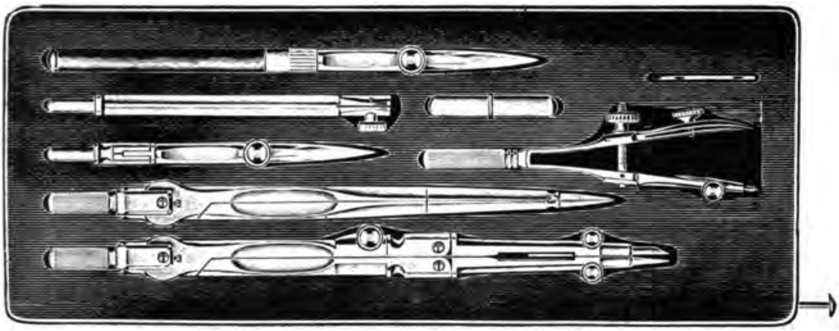
1240 Nos. 1225-6-7 in case, velvet lined................................ $3.0C



1241

1241 Set contains:
- Drawing Fen, ebony handle, upper blade with spring, 5 in.......
- Plain Divider, 6 in...
- Compass, 6 in., with pen, pencil and needle point, and lengthening bar ....
- Box for leads $5.10

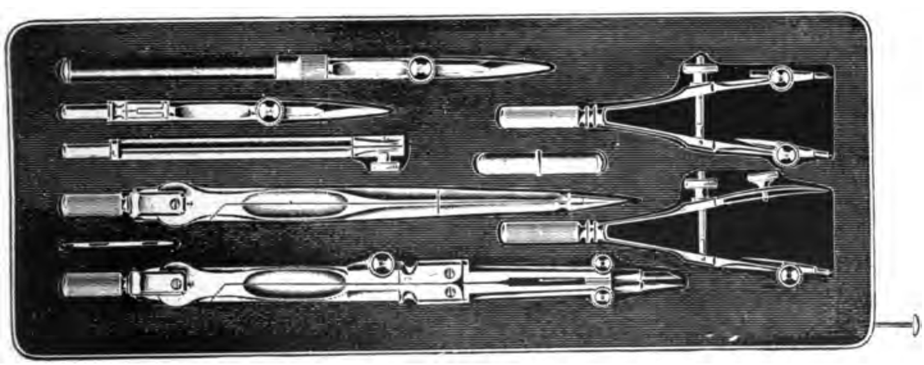
SUPERIOR DRAWING INSTRUMENTS.



1242

1242 Set contains:

Drawing Pen, ebony handle, upper blade with spring, 5 in.......
Steel Spring Bow Pen, metal handle, 3½ in....................
Plain Divider, 6 in..
Compass, 6 in., with pen, pencil, needle point and lengthening bar
Box for leads $6.15

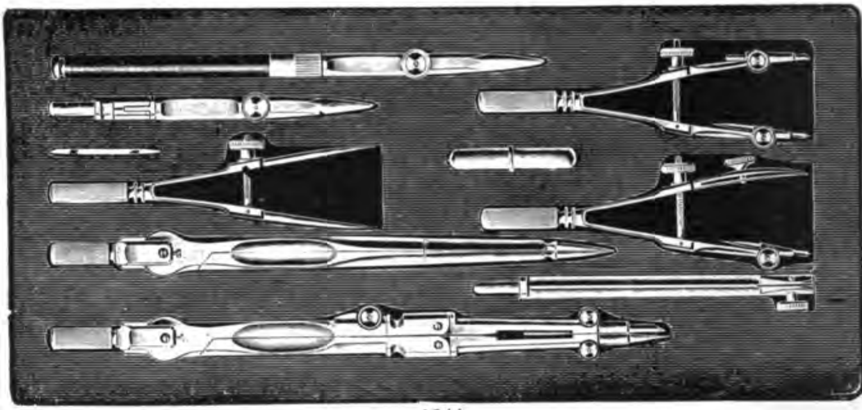


1243

1243 Set contains:

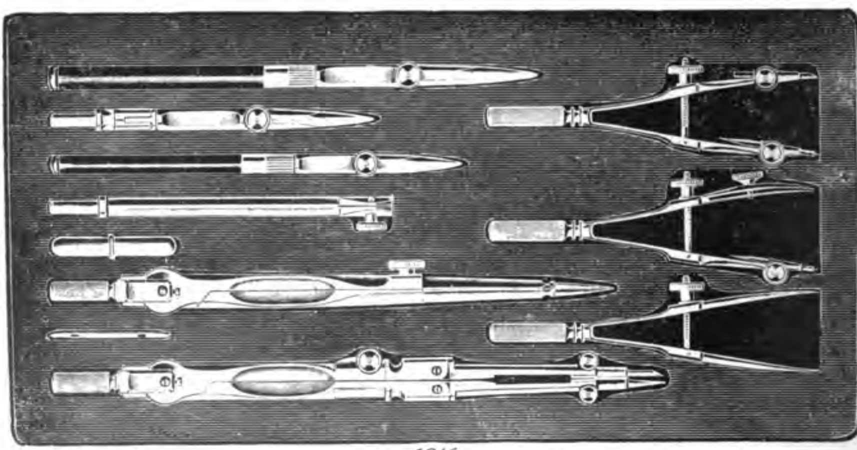
Drawing Pen, ebony handle, upper blade with spring, 5 in.........
Steel Spring Bow Pen, metal handle, 3½ in.....................
Steel Spring Bow Pencil, metal handle, 3½ in..................
Plain Divider, 5½ in...
Compass, 6 in., with pen, pencil, needle point and lengthening bar
Box for leads $7.05

SUPERIOR DRAWING INSTRUMENTS.



1244

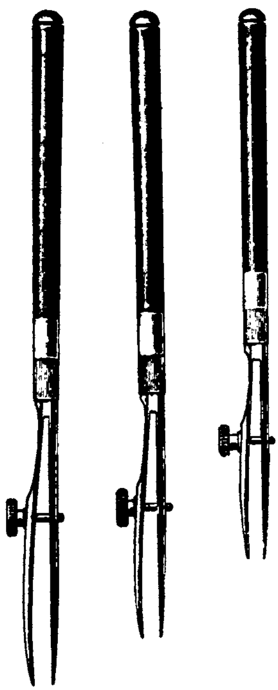
1244 Set contains:
Drawing Pen, ebony handle, upper blade with spring, 5 in........
Steel Spring Bow Divider, metal handle, 3½ in.................
Steel Spring Bow Pen, metal handle, 3½ in....................
Steel Spring Bow Pencil, metal handle, 3½ in..................
Plain Divider, 6 in. ....
Compass, 6 in. with pen, pencil, needle point and lengthening bar
Box for leads $7.80
1245 Set contains:—1244 in Pocket Book Leather Case................. 8.55



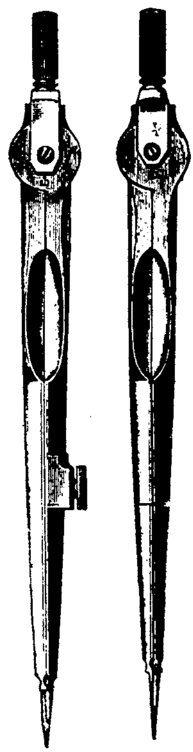
1246

1246 Set contains:
Drawing Pen, ebony handle, upper blade with spring, 5 in........
Drawing Pen, ebony handle, upper blade with spring, 4½ in.....
Steel Spring Bow Divider, metal handle, 3½ in................
Steel Spring Bow Pen, metal handle, 3½ in...................
Steel Spring Bow Pencil, metal handle, 3½ in..................
Hairspring Divider, 6 in. ....
Compass, 6 in., with pen, pencil, needle point and lengthening bar
Box for leads $9.00
1247 Set contains:—1246 in Leather Pocket Book Case................ 9.75

ELITE DRAWING INSTRUMENTS.



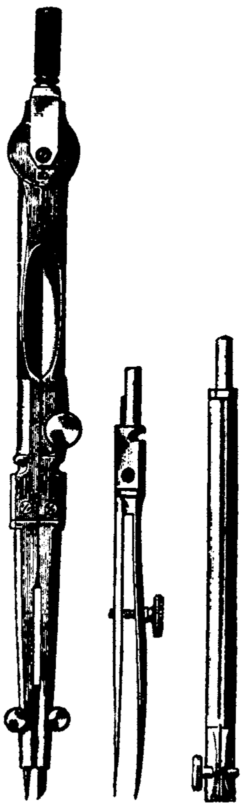
1302 1301 1300



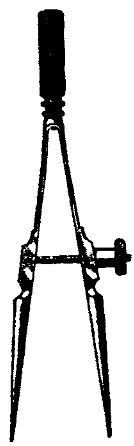
1311 1310

1300	Ruling Pen, ebony handle, upper blade with spring, 4½ in.	$0.35
1301	Ruling Pen, ebony handle, upper blade with spring, 5 in.	.40
1302	Ruling Pen, ebony handle, upper blade with spring, 5½ in.	.45
1310	Plain Divider, 5 in.	.70
1311	Hairspring Divider, 5 in.	1.10

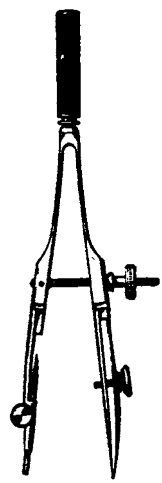
ELITE DRAWING INSTRUMENTS.



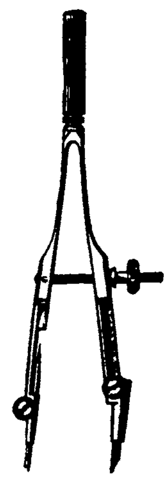
1315



1320



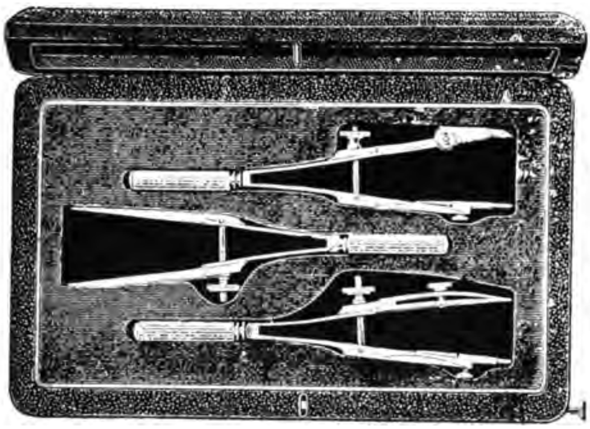
1321



1322

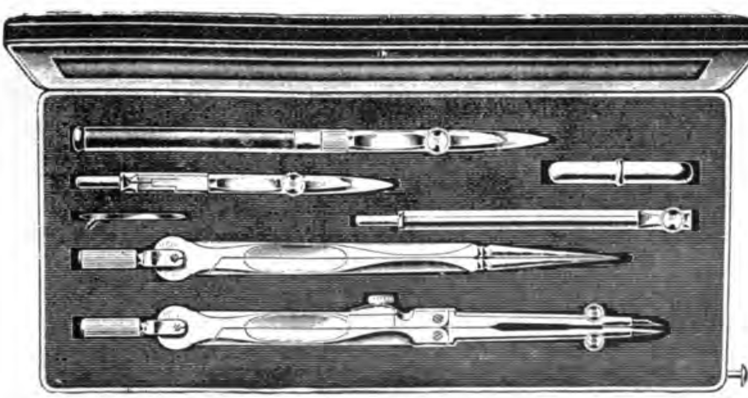
1315	Compass, with fixed needle point, pen and pencil point and lengthening bar	$2.00
1320	Steel Spring Bow Divider, 3½ in.	.50
1321	Steel Spring Bow Pen, 3½ in.	.75
1322	Steel Spring Bow Pencil, 3½ in.	.75

ELITE DRAWING INSTRUMENTS.



1330

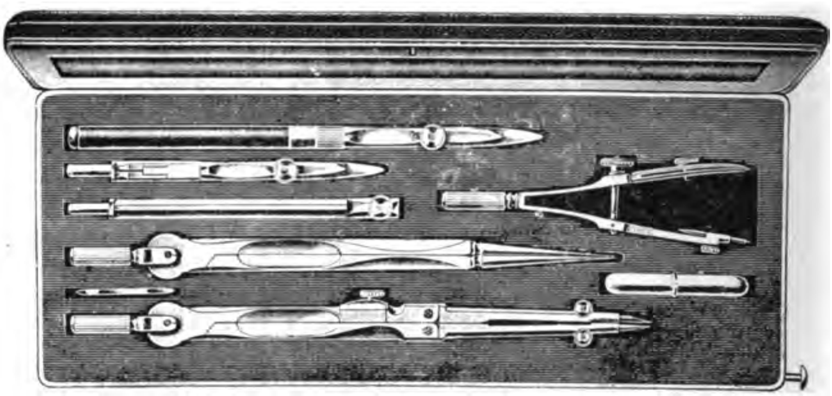
1330 Nos. 1320-1-2 in case, velvet lined.............................. $2.50



1331

1331 Set contains:
- Drawing Pen, ebony handle, upper blade with spring, 5 in........
- Plain Divider, 6 in..
- Compass, 6 in., with pen, pencil and needle point, and lengthening bar ....
- Box for leads.. $3.45

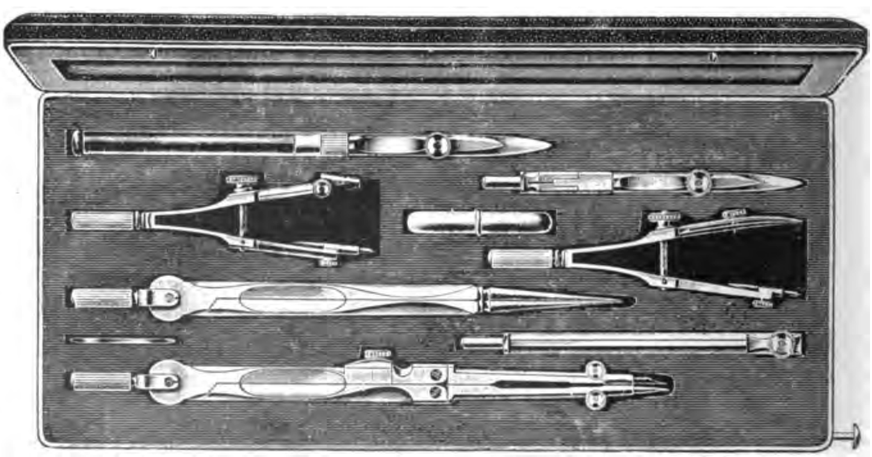
ELITE DRAWING INSTRUMENTS.



1332

1332—Set contains:

Drawing Pen, ebony handle, upper blade with spring, 5 in........
Steel Spring Bow Pen, metal handle, 3½ in....................
Plain Divider, 6 in..
Compass, 6 in., with pen, pencil. needle point and lengthening bar
Box for leads $4.20

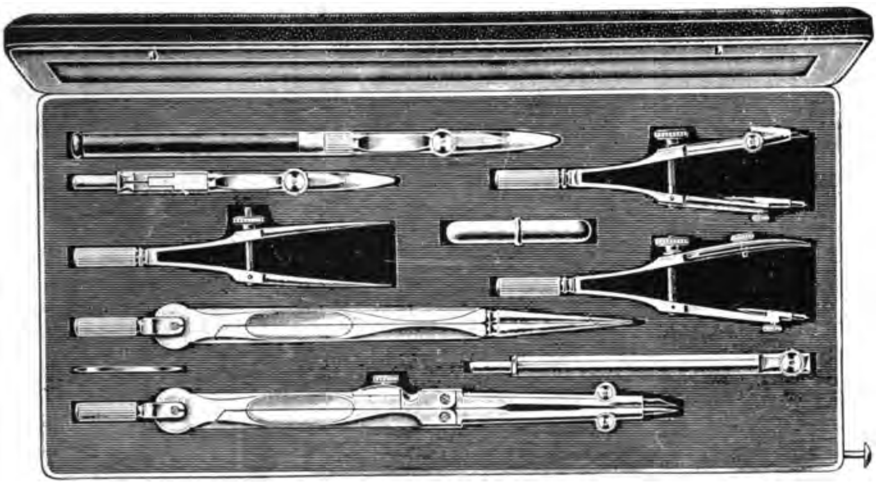


1333

1333 Set contains:

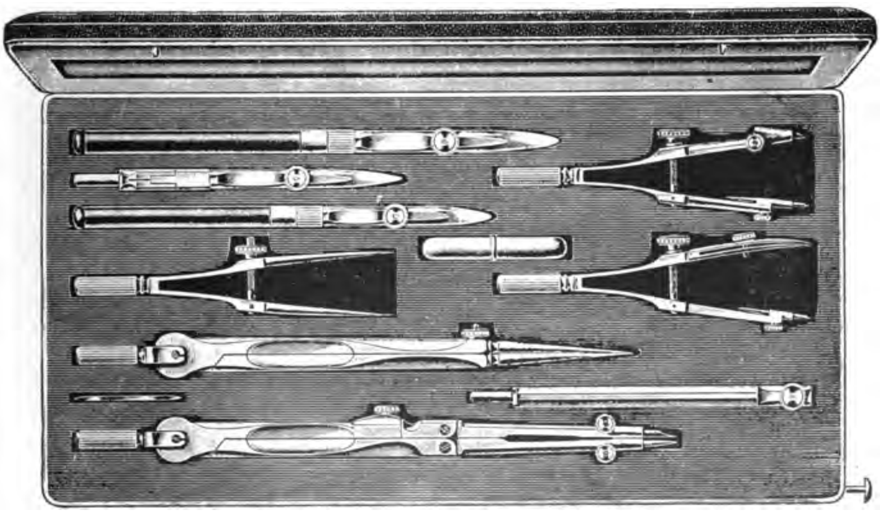
Drawing Pen, ebony handle, upper blade with spring, 5 in.......
Steel Spring Bow Pen, metal handle, 3½ in....................
Steel Spring Bow Pencil, metal handle, 3½ in..................
Plain Divider, 5½ in..
Compass, 6 in., with pen, pencil, needle point and lengthening bar
Box for leads $4.80

ELITE DRAWING INSTRUMENTS.



1334 Set contains: 1334

Drawing Pen, ebony handle, upper blade with spring, 5 in.......
Steel Spring Bow Divider, metal handle, $3\frac{1}{2}$ in.................
Steel Spring Bow Pen, metal handle, $3\frac{1}{2}$ in. ....
Steel Spring Bow Pencil, metal handle, $3\frac{1}{2}$ in..................
Plain Divider, 6 in. ....
Compass, 6 in., with pen, pencil, needle point and lengthening bar
Box for leads $5.25



1335 Set contains: 1335

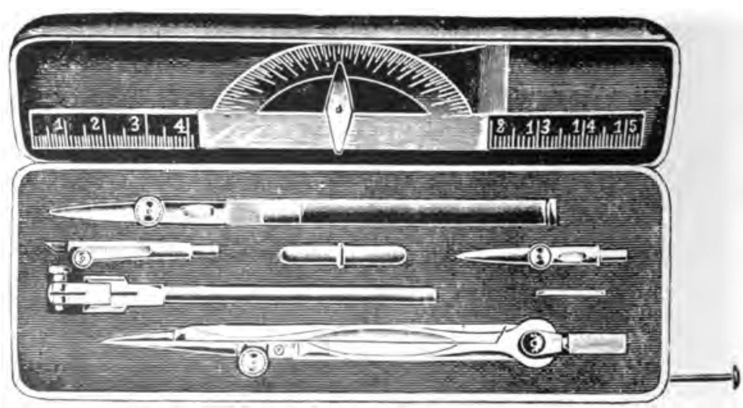
Drawing Pen, ebony handle, upper blade with spring, 5 in........
Drawing Pen, ebony handle, upper blade with spring, $4\frac{1}{2}$ in......
Steel Spring Bow Divider, metal handle, $3\frac{1}{2}$ in.................
Steel Spring Bow Pen, metal handle, $3\frac{1}{2}$ in....................
Steel Spring Bow Pencil, metal handle, $3\frac{1}{2}$ in..................
Hairspring Divider, 6 in. ....
Compass, 6 in., with pen, pencil, needle point and lengthening bar
Box for leads $6.15

NICKEL-PLATED DRAWING INSTRUMENTS.

1375

1375 Set contains:

Compass, 5 in., with pencil, pen and needle point................
Drawing Pen, ebony handle, upper blade with spring, 5 in........
Box for leads $1.15

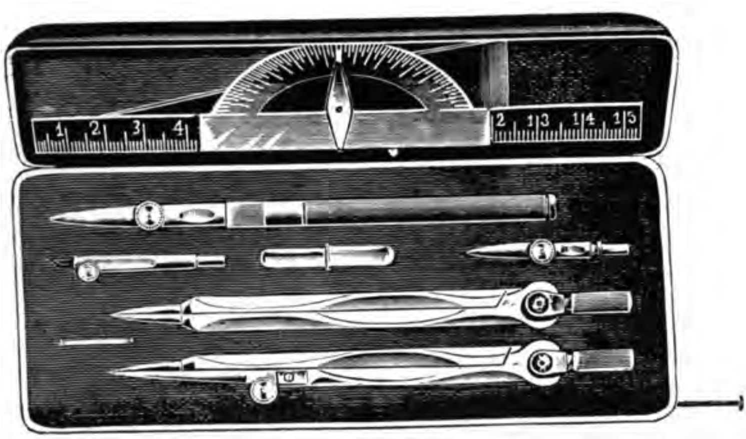


1376

1376 Set contains:

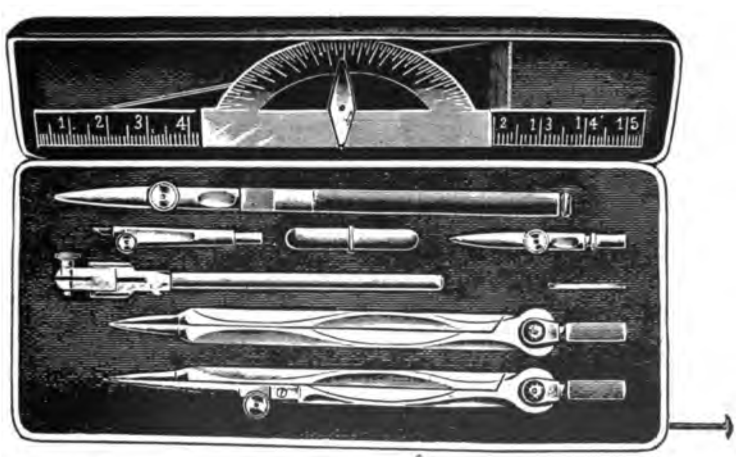
Compass, 5 in., with pencil, pen and needle point, lengthening bar
Drawing Pen, ebony handle, upper blade with spring, 5 in.......
Box for leads $1.30

NICKEL-PLATED DRAWING INSTRUMENTS.



1377

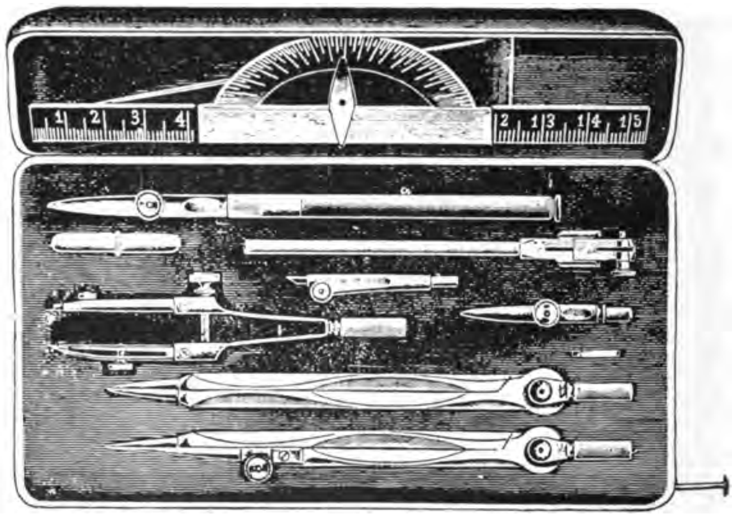
1377 Set contains:
Compass, 5 in., with pencil, pen and needle points................
Divider, 5 in. ....
Drawing Pen, ebony handle, upper blade with spring, 5 in.......
Box for leads $1.65



1378

1378 Set contains:
Compass, 5 in., with pen, pencil, needle points and lengthening bar
Dividers, 5 in. ....
Drawing Pen, upper blade with spring, ebony handle, 5 in........
Box for leads $1.80

NICKEL-PLATED DRAWING INSTRUMENTS.



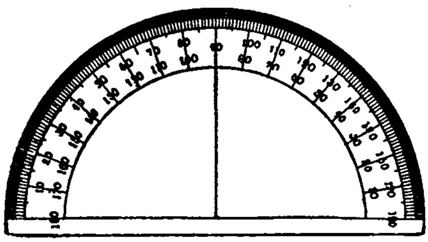
1379

1379 Set contains:

Compass, 5 in., with pen, pencil, needle points and lengthening bar
Dividers, 5 in. ....
Drawing Pen, upper blade with spring, ebony handle, 5 in........
Spring Bow Pen, 3½ in...
Box for leads $3.00

PROTRACTORS.

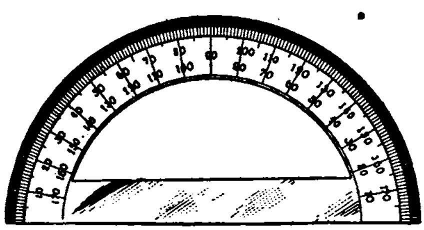
		Each
1400	Circular Protractor on Drawing Paper, 8 in. dia. in ½°	$0.20
1401	Circular Protractor on Drawing Paper, 14 in. dia. in ¼°	.30
1402	Circular Protractor on Bristol Board, 8 in. dia. in ½°	.20
1403	Circular Protractor on Bristol Board, 14 in. dia. in ¼°	.40
1404	Circular Protractor on Tracing Paper, 8 in. dia. in ½°	.20
1405	Circular Protractor on Tracing Paper, 14 in. dia. in ¼°	.30



1410-1424

1410	Semicircular Horn Protractor, 4 in., divided to 1 °	$0.15
1411	Semicircular Horn Protractor, 5 in., divided to ½°	.30
1412	Semicircular Horn Protractor, 6 in., divided to ½°	.35
1413	Semicircular Horn Protractor, 7 in., divided to ½°	.50
1414	Semicircular Horn Protractor, 8 in., divided to ½°	.70
1420	Semicircular Celluloid Protractor, 4 in., divided to ½°	.35
1421	Semicircular Celluloid Protractor, 5 in., divided to ½°	.45
1422	Semicircular Celluloid Protractor, 6 in., divided to ½°	.60
1423	Semicircular Celluloid Protractor, 7 in., divided to ½°	.75
1424	Semicircular Celluloid Protractor, 8 in., divided to ½°	1.20
1430	Semicircular Transparent Amber Protractor, 4 in., divided to ½°, open center	.75
1431	Semicircular Transparent Amber Protractor, 5 in., divided to ½°, open center	.90
1432	Semicircular Transparent Amber Protractor, 6 in., divided to ½°, open center	1.00
1433	Semicircular Transparent Amber Protractor, 8 in., divided to ½°, open center	1.75
1434	Semicircular Transparent Amber Protractor, 10 in., divided to ½°, open center	2.50

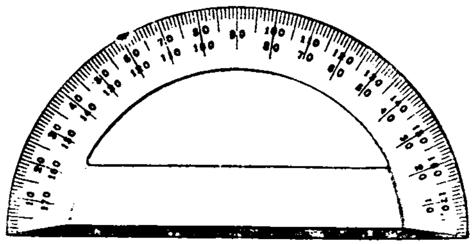
1430 to 1434 are engine divided and a very superior article.



1440-1444

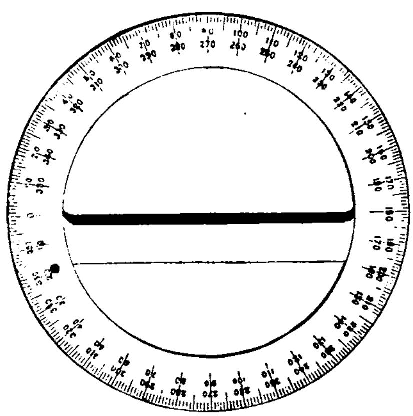
1440	Semicircular German Silver Protractor, 4 in., divided to 1 °	$0.60
1441	Semicircular German Silver Protractor, 5 in., divided to ½°	.80
1442	Semicircular German Silver Protractor, 6 in., divided to ½°	1.00
1443	Semicircular German Silver Protractor, 7 in., divided to ½°	1.20
1444	Semicircular German Silver Protractor, 8 in., divided to ½°	1.60

GENUINE SUPERIOR SWISS PROTRACTORS.



1450

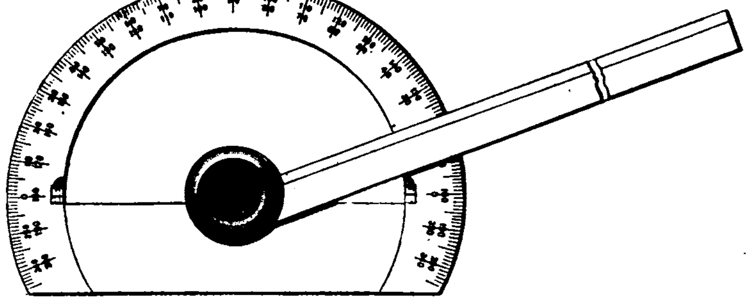
1450	Semicircular German Silver Protractor, beveled edge, 5 in.—½°...	$3.50
1451	Semicircular German Silver Protractor, beveled edge, 6 in.—½°...	4.25
1452	Semicircular German Silver Protractor, beveled edge, 6 in.—¼°...	5.25
1453	Semicircular German Silver Protractor, beveled edge, 7 in.—½°...	6.50
1454	Semicircular German Silver Protractor, beveled edge, 8 in.—½°...	7.90



1460

1460 Circular German Silver Protractor, 5 in., beveled edge, divided to ½° $8.00

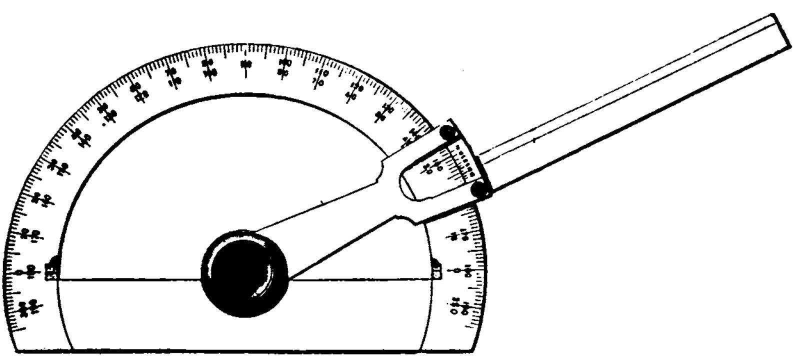
GENUINE SUPERIOR SWISS PROTRACTORS.



1465

1465 Semicircular German Silver Protractor, 6 in., with horn center and movable arm, divided ½° $11.25

1466 Semicircular German Silver Protractor, 7 in., with horn center and movable arm, divided ½° 13.50



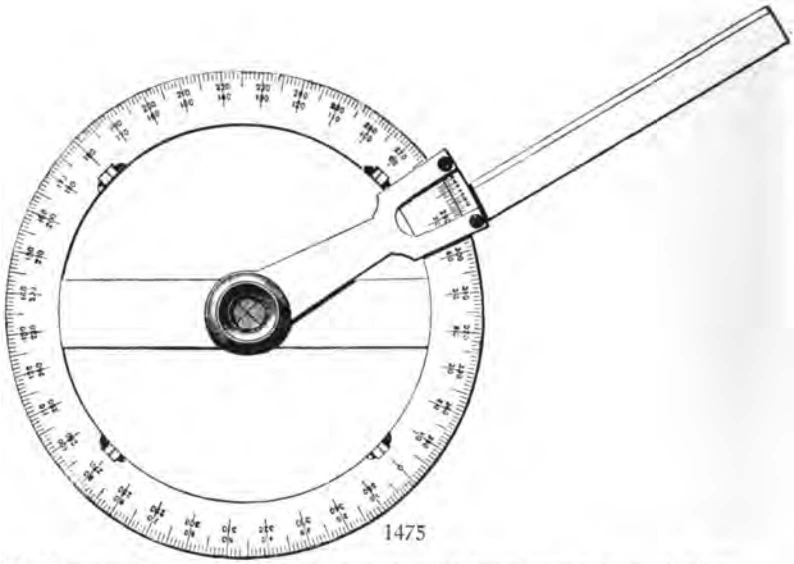
1470

1470 Semicircular German Silver Protractor, 5½ in., with horn center, divided to ½°, with Vernier reading to 3 minutes $15.75

1471 Same, 8 in., Vernier reading to single minutes 21.00

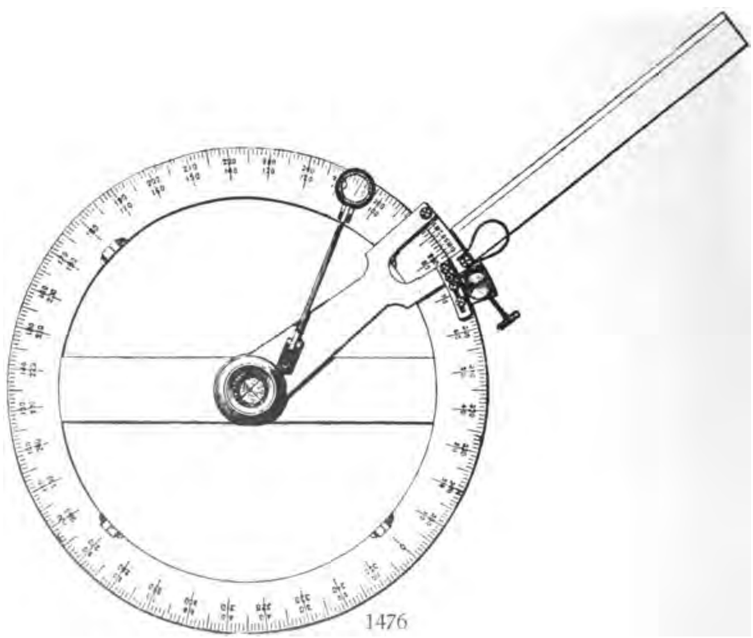
1472 Same, 10 in., Vernier reading to single minutes 26.25

GENUINE SUPERIOR SWISS PROTRACTORS.



1475

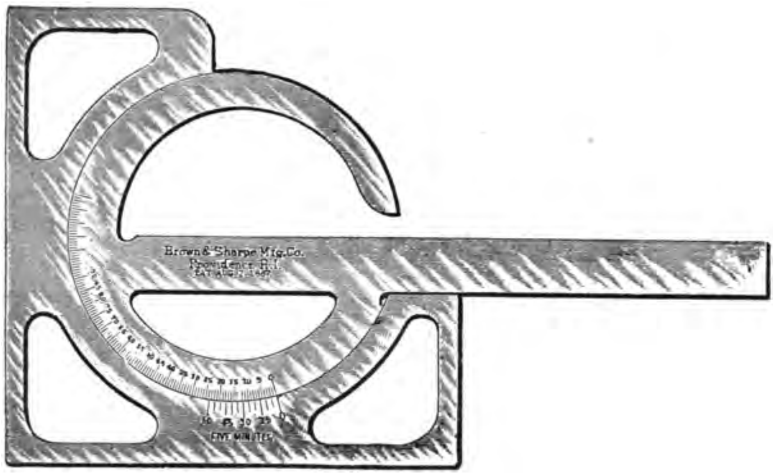
1475 Circular German Silver Protractor, with horn center, 8 in., divided to ¼°, with Vernier reading to minutes, in a Morocco case, silk velvet lined $30.00



1476

1476 Is 1475 with clamp and tangent, in case.......................... $37.50

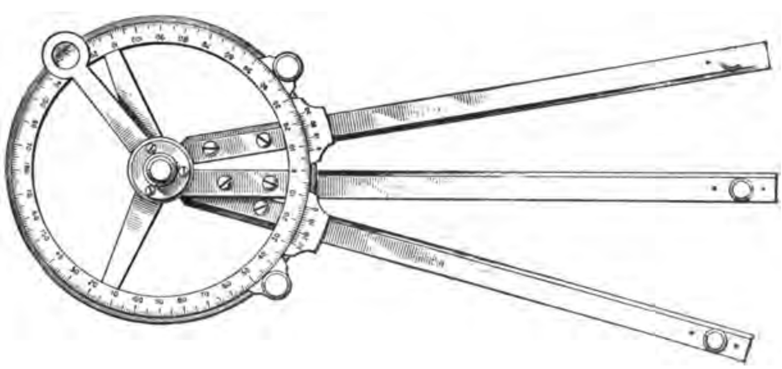
PROTRACTORS.



1480

1480 Brown & Sharp Protractor, steel.................................. $6.50

This Draftsman's Protractor is used in conjunction with T square or straight edge; has Vernier reading to five minutes.

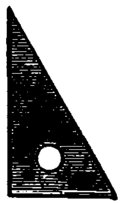


1485

1485 Three Arm Protractor as made by us for the U. S. Navy, U. S. Coast and Geodetic Survey, and U. S. A. Transport Service.... $90.00

TRIANGLES.

Every article in transparent amber, hard rubber, and wood is made of the very best and finest material that can be procured, and we guarantee every article sold to be true and reliable.



1500

1501

Cherry Triangles, Solid, 30 x 60°.

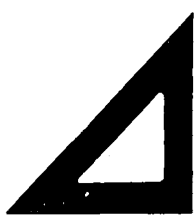
1500	Size, 7 in., each	$0.08
	Size, 9 in., each	.10

Cherry Triangles, Solid, 45°.

1501	Size, 6 in., each	$0.08
	Size, 8 in., each	.10

Cherry Triangles, Open Center, Mortise Corner Joints.

1502

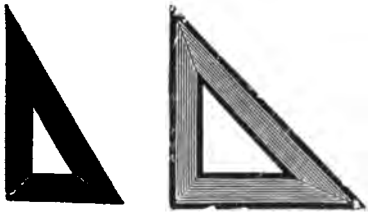


1503

	Sizes, inches	6	8	10	12	14
1502	30 x 60°		$0.12	$0.16	$0.20	$0.24
1503	45°	$0.12	.16	.20	.24	.30

TRIANGLES.

Mahogany, Ebony Lined, Triangles, Mortise Corner Joints.



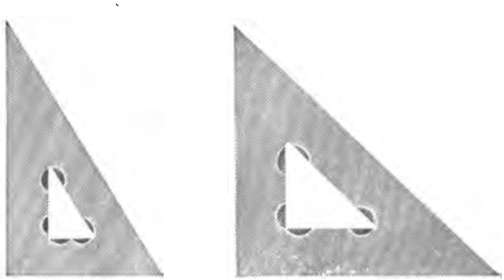
1504 1505

	Size, inches	6	8	10	12	14	17	20
1504	30 x 60°	....	$0.35	$0.40	$0.55	$0.75	$1.20	$1.50
1505	45°	$0.35	.40	.55	.75	1.20	1.50	....

Hard Rubber Triangles.

	Size, inches	4	6	8	10	12	14	15
1506	30 x 60°	$0.15	$0.25	$0.35	$0.45	$0.60	....	$1.25
1507	45°	.25	.35	.45	.60	1.00	$1.50	....

Transparent Amber Triangles.



1508 1509

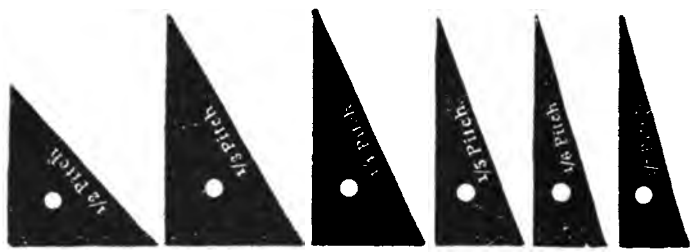
	Size, inches	4	5	6	7	8	9	10
1508	30 x 60°	$0.20	$0.30	$0.35	$0.40	$0.50	$0.60	$0.70
1509	45°	.30	.40	.50	.60	.70	.90	1.05

	Size, inches	11	12	14	15	16	18
1508	30 x 60°	$0.80	$0.95	$1.55	$2.00	$2.35	$3.20
1509	45°	....	1.55	2.10	2.65	3.00	....

TRIANGLES.

Steel Triangles, Nickel-Plated.

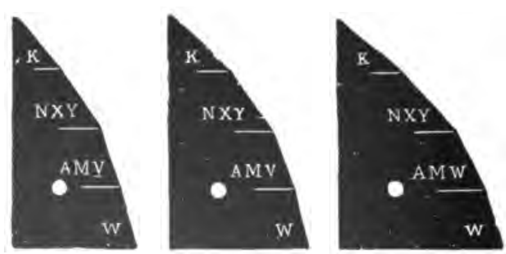
	Size, inches	6	8	10	12	15
1510	30 x 60°	$3.20	$3.85	$4.25	$5.50	$6.50
1511	45°	3.50	4.25	5.50	6.50	....



1512

1512 Hard Rubber Triangles for roof pitch, set of 6.................... $2.40

1513 Transparent Amber Triangles for roof pitch, set of 6.............. 4.50



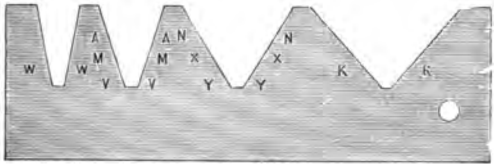
1514

1514 Hard Rubber Lettering Triangles, 3½ in., set of 3................. $1.20

1515 Transparent Amber Lettering Triangles, 3½ in., set of 3........... 1.50

1516 Wooden Lettering Triangles, 3½ in., set of 3..................... 1.00

LETTERING TEMPLETS.



1518

1517	Hard Rubber Lettering Templets, set of 3	$1.50
1518	Transparent Amber Lettering Templets, set of 3	1.80

STRAIGHT EDGE.

Cherry.

	Size, inches	15	24	30	36	42	48
1530	Square edge	$0.10	$0.20	$0.25	$0.25	$0.35	$0.40
1531	Beveled edge	.12	.25	.30	.35	.45	.50

Mahogany, Ebony Lined, Straight Edge.

	Size, inches	15	24	30	36	42	48
1532	Square, thin edge	$0.30	$0.50	$0.60	$0.80	$1.00	$1.25
1533	Beveled, thick edge	.35	.55	.65	.85	1.15	1.35

STRAIGHT EDGE.

Maple, Transparent Amber Lined, Beveled Edge.

	Size, inches	15	24	30	36	42	48
1534	....	$0.85	$1.00	$1.25	$1.50	$1.80	$2.20

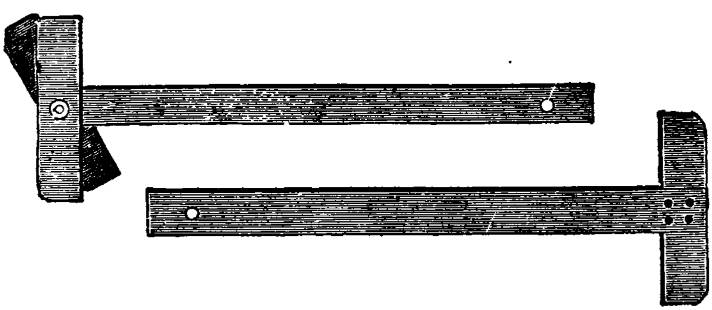
Steel Straight Edge, Nickel-Plated.

One Edge Beveled, Other Square.

	Size, inches	18	24	30	36	42	48	60
1535	....	$2.00	$3.00	$4.00	$5.00	$6.50	$8.00	$11.00

T SQUARES.

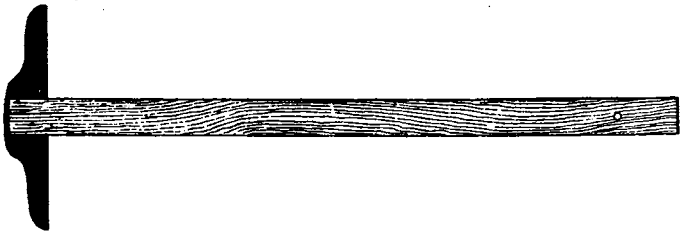
Cherry.

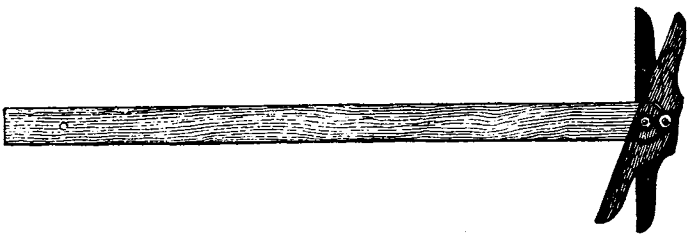


	Size, inches	15	24	30	36	42	48
1540	Fixed head	$0.20	$0.35	$0.40	$0.45	$0.55	$0.65
1541	Shifting head	.50	.80	.90	1.00	1.10	1.20

T SQUARES.

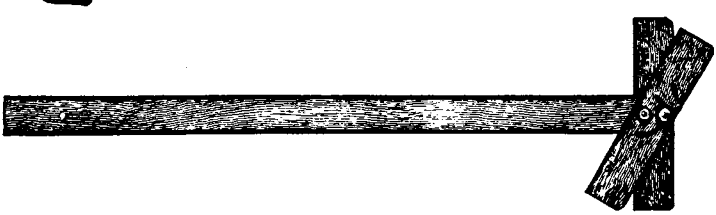
Pearwood.





	Size, inches	15	24	30	36	42	48
1542	Fixed head	$0.25	$0.35	$0.45	$0.55	$0.65	$0.90
1543	Shifting head	.70	.90	1.00	1.15	1.25	1.50

Mahogany, Ebony Lined.

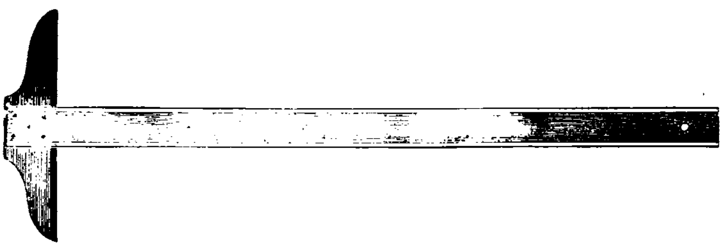


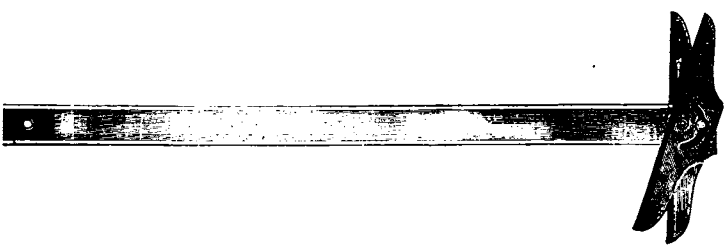
	Size, inches	15	24	30	36	42	48	60
1544	Fixed head	$0.70	$0.90	$1.10	$1.30	$1.50	$1.75	$2.60
1545	Shifting head	1.45	1.75	2.00	2.25	2.50	2.80	3.90

Mahogany, Ebony Lined Blade and Fixed Head, Beveled Edge.

	Size, inches	30	36	42	48
1546	....	$1.20	$1.40	$1.60	$1.85

Maple Blade, Amber Lined, T Squares.





	Size, inches	15	24	30	36	42	48
1547	Fixed head	$1.00	$1.50	$1.85	$2.15	$2.50	$3.00
1548	Shifting head	1.75	2.45	2.80	3.20	3.60	4.20

RAILROAD CURVES.

1560 Set of 10 Curves, from 12 in. to 120 in. radius, varying 12 in., made of amber, in wooden box, per set.............................. $ 9.00
1561 Do, made of hard rubber, in wooden box, per set................. 6.50
1562 Set of 17 Curves, from 12 in. to 60 in. radius, varying 3 in., made of amber, in wooden box.................................... 15.00
1563 Do, made of rubber, in wooden box............................. 12.00

Set of 41 with Tangent, made in rubber, wood and amber. Marked in degrees and inches to 100 feet scale, viz.:

0° .30′=114.59 in.	3° .30′=16.37 in.	6° =9.55 in.	8° .30′=6.75 in.
1° = 57.30 in.	3° .45′=15.28 in.	6° .15′=9.17 in.	8° .45′=6.55 in.
1° .15′= 45.84 in.	4° =14.33 in.	6° .30′=8.82 in.	9° =6.37 in.
1° .30′= 38.20 in.	4° .15′=13.48 in.	6° .45′=8.49 in.	9° .15′=6.20 in.
1° .45′= 32.74 in.	4° .30′=12.73 in.	7° =8.19 in.	9° .30′=6.04 in.
2° = 28.65 in.	4° .45′=12.07 in.	7° .15′=7.91 in.	9° .45′=5.88 in.
2° .15′= 25.47 in.	5° =11.46 in.	7° .30′=7.64 in.	10° =5.74 in.
2° .30′= 22.92 in.	5° .15′=10.92 in.	7° .45′=7.40 in.	10° .30′=5.48 in.
2° .45′= 20.84 in.	5° .30′=10.42 in.	8° =7.17 in.	11° =5.22 in.
3° = 19.10 in.	5° .45′= 9.97 in.	8° .15′=6.95 in.	11° .30′=4.99 in.
3° .15′= 17.63 in.			

1567 In wooden box, rubber, per set $30.00
1568 In wooden box, amber, per set 40.00

Single Railroad Curves with Tangent, rubber, each.................... 1.00
Single Railroad Curves with Tangent, amber, each..................... 1.20

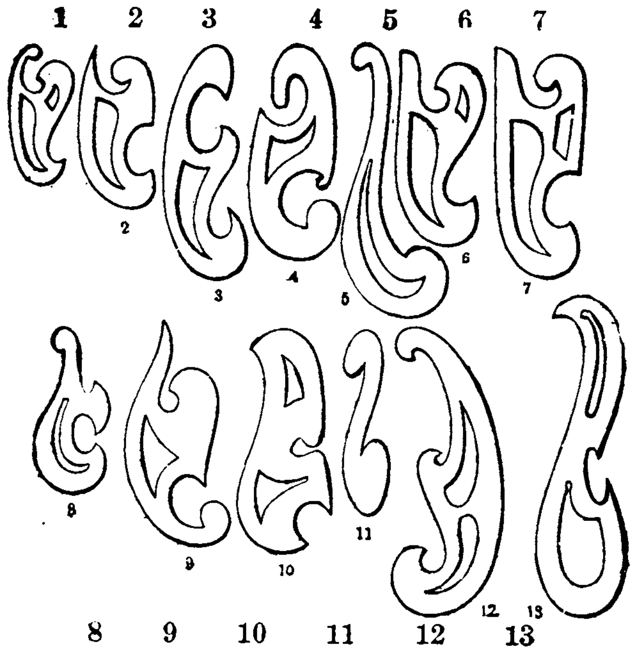
CURVES.

Irregular Curves in Amber, Wood and Hard Rubber.

	Numbers	1	2	3	4	5	6	7	8
1575	Wood	$0.10	$0.20	$0.20	$0.20	$0.20	$0.25	$0.25	$0.25
1576	Hard Rubber	.25	.30	.25	.35	.35	.35	.40	.40
1577	Amber	.45	.45	.45	.50	.50	.50	.55	.55

	Numbers	9	10	11	12	13	14	15	16	17
1575	Wood	$0.25	$0.30	$0.25	$0.20	$0.25	$0.25	$0.30	$0.30	$0.30
1576	Hard Rubber	.40	.45	.40	.30	.40	.50	.50	.50	.50
1577	Amber	.60	.65	.60	.75	.85	.85	.85	.75	1.20

CURVES.



	Numbers	1	2	3	4	5	6
1578	Wood	$0.20	$0.25	$0.30	$0.30	$0.30	$0.25
1579	Rubber	.35	.40	.50	.50	.50	.45
1580	Amber	.45	.55	.60	.60	.60	.55

	Numbers	7	8	9	10	11	12	13
1578	Wood	$0.30	$0.25	$0.30	$0.35	$0.20	$0.35	$0.45
1579	Rubber	.50	.35	.50	.60	.40	.75	1.00
1580	Amber	.60	.45	.60	.75	.50	.90	1.50

Mechanical Engineers' Curves.

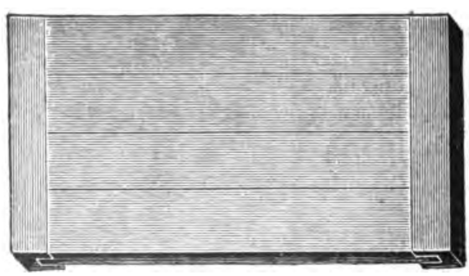
1585 Wood, 10 in set .... $ 4.00
1586 Rubber, 10 in set.. 6.00
1587 Amber, 10 in set 10.00

CURVES.

1588 Special Amber Curve $1.00

1589 Spiral Amber Curve $1.75

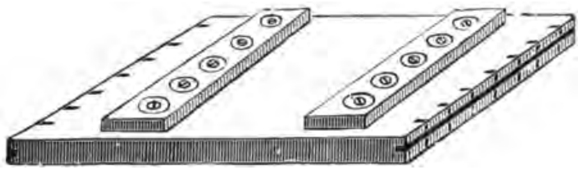
Drawing Boards.



Dovetailed, End Battens.

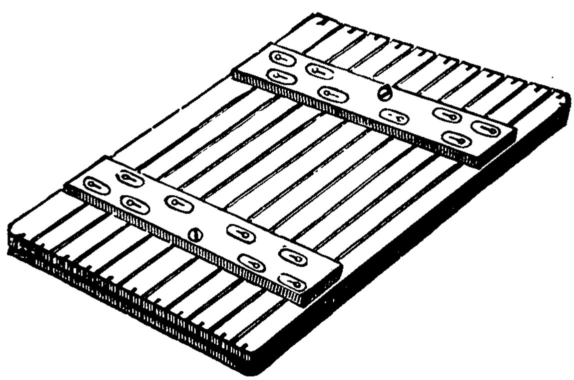
1600	12x17 ½ in., Pine Wood..	$0.90
	16x21 ½ in., Pine Wood..	1.00
	18x24 ½ in., Pine Wood..	1.15
	19x25 ½ in., Pine Wood..	1.25
	20x26 ⅞ in., Pine Wood..	1.50
	22x28 ⅞ in., Pine Wood..	1.63
	23x31 ⅞ in., Pine Wood..	1.88
	31x42 ⅞ in., Pine Wood..	3.15

DRAWING BOARDS.



1603 Made of ⅞ in. pine wood with ¾ in. hardwood ledges screwed to the back, running in oval metal washers, the end of board is secured with hardwood strips and cut in.

18x24	$1.90	23x31	$3.35
19x25	2.15	27x34	3.75
20x26	2.50	31x42	5.63
22x28	2.80	33x55	8.38



Super Extra.

For Draftsman's Use.

1605	18x24	$2.15	23x31	$3.75
	19x25	2.50	27x34	4.15
	20x26	3.00	31x42	6.25
	22x28	3.35	33x55	9.35

HORSES.

1610 Pine Wood Horses, without slanting top $4.75
1611 Pine Wood Horses, with slanting top 5.60

1612 Pine Wood Horses, with adjustable top..........................$12.00

TRESTLES.

1613 Ashwood Trestles, shellac finish, 37 in. long by 38 in. high......... $5.60

NORMAL ADJUSTABLE DRAWING TABLE.

1620

1620 The Normal Adjustable Drawing Table can be raised, lowered, or set at an inclination instantly by loosening the nut of the central rod which moves in slots of legs, as is readily seen from the illustration.

The drawing board can be detached and the trestles folded up, occupying little more space than an ordinary drawing board,—a great advantage if the table is not used constantly, as it can be put out of the way or set up in a few minutes.

Trestles are made of ash wood, fine shellac finish, drawing boards are made of clear and well-seasoned pine.

Size of board	27x31,	7/8 in. Pine	$ 9.00
Size of board	27x34,	7/8 in. Pine	10.00
Size of board	31x42,	7/8 in. Pine	11.50
Size of board	33x55,	7/8 in. Pine	17.50
Size of board	36x48,	7/8 in. Pine	16.50
Size of board	42x60,	1 1/8 in. Pine	20.00

1625

This is one of the most popular iron based tables. Either for school or for commercial work, its efficiency is unequaled. It is extremely strong and rigid. The tilting movement is horizontal and perpendicular. The perpendicular motion has a rack and pinion adjustment, giving a height of from 30 to 42 inches.

The tops are carefully constructed by methods derived from years of experience, and are made of selected clear Michigan cork pine.

1625 Size of boards:

31x42 inches	$25.00
36x48 inches	29.50
36x54 inches	31.00
36x60 inches	32.50
36x72 inches	37.00
42x60 inches	36.50
42x72 inches	39.00
48x72 inches	43.00

1626. ATTACHMENT FOR DRAWING TABLE. 1625.

Fig. 1

To enable the draughtsman to work with *greater rapidity* and with increased accuracy we handle an improved Automatic T Square or Parallel Ruler Attachment. It will pay for itself in a few weeks by the time saved. It is a device that can be attached in five minutes with no tool but a small screw-driver since it requires no cutting of the board or table. It consists of six brass pulleys held by nickel plated brackets, two brass binding posts, steel piano wire and a steel spring. The movement of the T Square is from back to front of the drawing board always having exact parallel motion. It permits the free use of both hands, thus enabling the operator to work with greater speed and accuracy. The four brackets are screwed to the corners of the board, or top, as shown, with the top of the bracket flush with the top of the board. The steel wire is then passed over the pulleys from one front corner to the other, crossing the wires at the back so that the upper wires on each side move forward or back simultaneously. The two ends of the wire are brought to the center of the board and attached to the steel spring. Attach a binding post to the upper wire on each side by passing the wire between B and C behind the pin on C. Take off the washer and thumb screw, D. and E, and screw them down on the straight edge so that the latter comes between C and D. The T Square is now ready for use. Draw a number of lines across the paper and then one about one thirty-second of an inch from the first one drawn and you will find them exactly parallel. Price, $5.00.

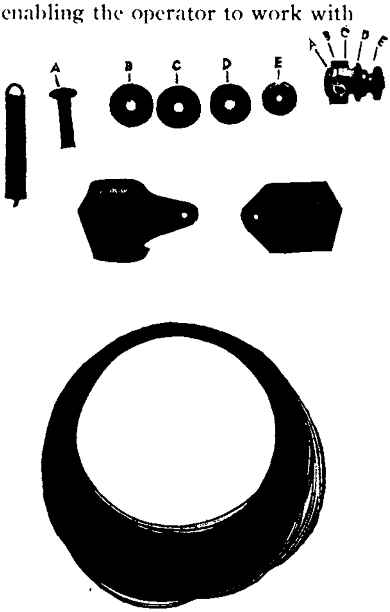


Fig. 2

Automatic T Square or Parallel Ruler is fitted ready to attach, from 4 to 6 inches longer than the top. This is only used in connection with No. 1625.

		Mahogany Ebony-lined	Maple Transparent Amber-lined
1627	Length of top 42 inches	$1.60	$2.75
1628	Length of top 48 inches	1.85	3.50
1629	Length of top 54 inches	2.25	4.50
1630	Length of top 60 inches	2.75	5.50
1631	Length of top 72 inches	3.30	6.50

In ordering, kindly state whether mahogany, ebony-lined or maple transparent amber-lined is desired.

FOLDING HARDWOOD TRESTLE WITH BOARD.

1640

1640 Size of boards:

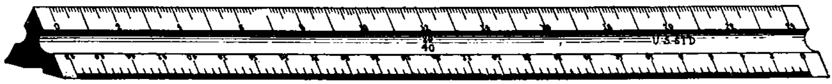
23x31, ⅞ inches	$12.50
31x42, ⅞ inches	14.00
33x55, ⅞ inches	20.00
36x60, 1⅛ inches	28.00
48x72 1⅛ inches	38.00

The Folding Hardwood Trestles are of a firm construction and the range of adjustments are from 31 to 41 inches in height and from level to 45° slant of board. When folded these trestles occupy very little space.

DRAWING ROOM CABINET.

1645 Made of well seasoned oak with fine shellac finish. Size of Cabinet 44 inches long, 36 inches high, 32 inches deep, with 10 drawers measuring inside 30x40x2½ in. $55.00

SCALES.



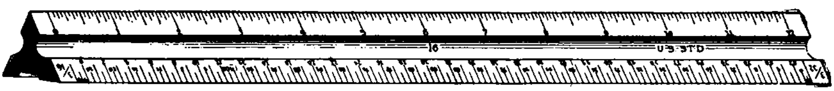
Triangular Boxwood Scales.

Graduated in 10, 20, 30, 40, 50 and 60 parts to the inch.

1700	6 in.	$0.60
1701	12 in.	.90
1702	18 in.	2.25
1703	24 in.	4.00

Triangular Boxwood Metric Scales.

		Each
1704	Triangular Boxwood Scale, 20 cm., div. to mm. and ½ mm.	$1.20
1705	Triangular Boxwood Scale, 30 cm., div. to mm. and ½ mm.	1.50
1706	Triangular Boxwood Scale, 50 cm., div. to mm. and ½ mm.	2.70



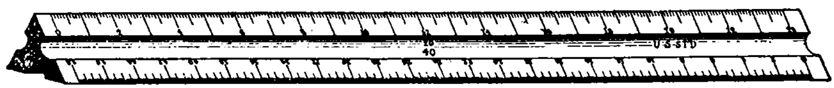
Graduated 3-32, 3-16, ⅛, ¼, ⅜, ½, ¾, 1, 1½ and 3 inches to the foot. One edge 16 to the inch.

1710	6 in.	$0.60
1711	12 in.	.90
1712	18 in.	2.25
1713	24 in.	4.00

⅛, ¼, ½, 1, ⅜, ¾, 1½, 2, 3 and 4 inches to foot

1714	6 in.	$0.60
1715	12 in.	.90
1716	18 in.	2.25
1718	24 in.	4.00

Triangular, White Edge Scales.



Graduated to 10, 20, 30, 40, 50, 60 parts to the inch.

1720	6 in.	$1.50
1721	12 in.	2.50
1722	18 in.	4.50
1723	24 in.	6.50

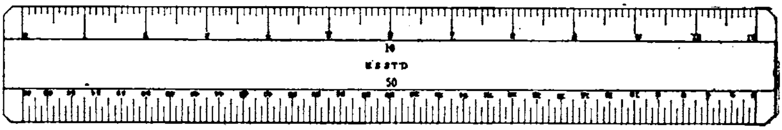
3-32, 3-16, ⅛, ¼, ⅜, ¾, ½, 1, 1½ and 3 inches to foot.

1725	6 in.	$1.50
1726	12 in.	2.50
1727	18 in.	4.50
1728	24 in.	6.50

⅛, ¼, ½, 1, ⅜, ¾, 1½, 2, 3 and 4 inches to foot.

1730	12 in.	$2.50
1731	18 in.	4.50
1732	24 in.	6.50

SCALES.



Flat Boxwood.

1735	6 in.	10x50	parts to inch	$0.50
1736	6 in.	10x20	parts to inch	.50
1737	6 in.	20x40	parts to inch	.50
1738	6 in.	30x60	parts to inch	.50
1739	6 in.	50x100	parts to inch	.75
1740	12 in.	10x50	parts to inch	.75
1741	12 in.	10x20	parts to inch	.75
1742	12 in.	20x40	parts to inch	.75
1743	12 in.	30x60	parts to inch	.75
1744	12 in.	50x100	parts to inch	1.25
1745	12 in.	100x500	parts to foot	.75
1746	12 in.	200x400	parts to foot	.75
1747	12 in.	300x600	parts to foot	.75
1748	12 in.	800x1000	parts to foot	1.35

Flat Boxwood, White Edge.

1750	6 in.	10x50	parts to inch	$0.75
1751	6 in.	10x20	parts to inch	.75
1752	6 in.	20x40	parts to inch	.75
1753	6 in.	30x60	parts to inch	.75
1754	6 in.	50x100	parts to inch	1.00
1755	6 in.	80x100	parts to inch	1.00
1756	12 in.	10x50	parts to inch	1.25
1757	12 in.	10x20	parts to inch	1.25
1758	12 in.	20x40	parts to inch	1.25
1759	12 in.	30x60	parts to inch	1.25
1760	12 in.	50x100	parts to inch	1.50
1761	12 in.	80x100	parts to inch	1.50
1762	12 in.	100x500	parts to foot	1.25
1763	12 in.	200x400	parts to foot	1.25
1764	12 in.	300x600	parts to foot	1.25
1765	12 in.	800x1000	parts to foot	1.75

Flat Boxwood Metric Scales.

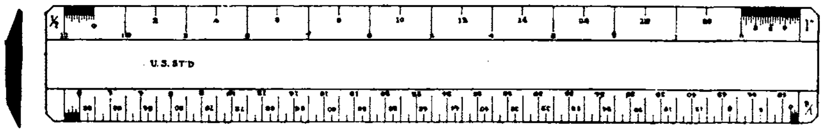
1770	10 CM long div. MM and half MM	$0.50
1771	20 CM long div. MM and half MM	.60
1772	30 CM long div. MM and half MM	.75
1773	50 CM long div. MM and half MM	1.40

SCALES.

Flat Boxwood, White Edge, Metric Scales.

1774	10 CM long div. MM and half MM	$0.75
1775	20 CM long div. MM and half MM	1.00
1776	30 CM long div. MM and half MM	1.25
1777	50 CM long div. MM and half MM	2.25

Flat Boxwood.



Graduated to 1/8, 1/4, 1/2 and 1 inch to the foot.

1780	6 in.	$0.50
1781	12 in.	.75
1782	18 in.	1.50
1783	24 in.	2.00

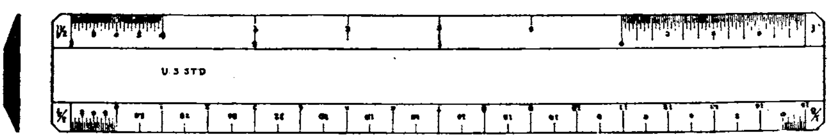
Flat Boxwood, White Edges.

Graduated to 1/8, 1/4, 1/2 and 1 inch to the foot.

1785	6 in.	$0.75
1786	12 in.	1.25
1787	12½ in.	1.35
1788	18 in.	2.25
1789	24 in.	3.00

No. 1787 reads 100 feet on 1/8; 50 feet on 1/4 and 25 feet on 1/2 inch.

Flat Boxwood.

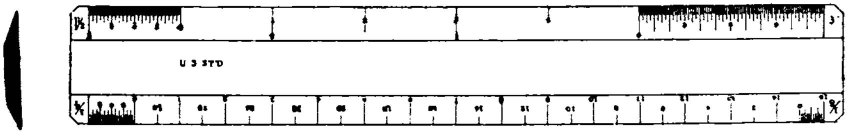


Graduated to 3/8, 3/4, 1½ and 3 inches to foot.

1790	6 in.	$0.50
1791	12 in.	.75
1792	18 in.	1.50
1793	24 in.	2.00

SCALES.

Flat Boxwood, White Edges.



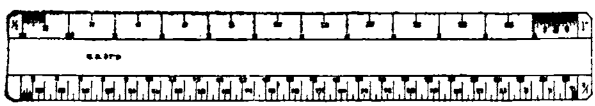
Graduated to ⅜, ¾, 1½ and 3 inches to foot.

1795	6 in.	$0.75
1796	12 in.	1.25
1797	18 in.	2.25
1798	24 in.	3.00

Flat Boxwood.

Beveled both sides, graduated to ⅛, ¼, ½, 1, ⅜, ¾, 2½ and 3 inches to the foot.

1800	6 in.	$0.75
1801	12 in.	1.25
1802	18 in.	2.25
1803	24 in.	3.00

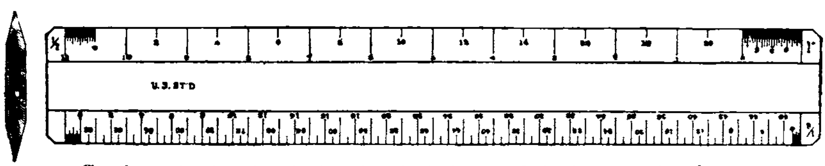


1805 Flat White Edge Pocket Chain Scale, 6 in., both sides beveled and divided 10x20 and 30x40 parts to the inch, in leather case........ $1.35

1806 Same as No. 1805, graduated ⅛, ¼, ½, 1, ⅜, ¾, 1½ and 3 inches to the foot........ 1.35

Flat Boxwood, White Edges.

Beveled Both Sides.



Graduated ⅛, ¼, ½, 1, ⅜, ¾, 1½ and 3 inches to the foot.

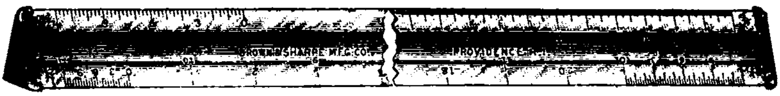
1810	12 in.	$2.00
1811	18 in.	3.40
1812	24 in.	4.60

Boxwood Plotting Scale.

1815 Boxwood Plotting Scale, 6 in........ $0.15

SCALES.

Steel, Triangular, Nickel-Plated.

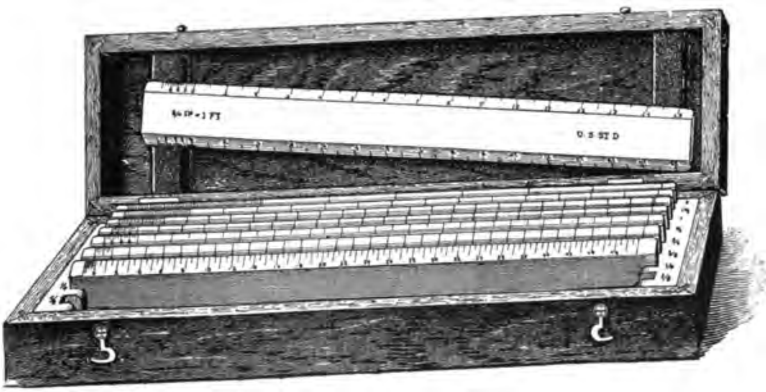


1818-1819

1818 12 in. Architects, graduated as 1726.............................. $2.50

1819 12 in. Engineers, graduated as 1721.............................. 2.50

Boxwood Scales in Sets.



1825 Set of 4 Boxwood Scales, 12 in., divided ⅛, ¼, ½, 1 in. to the foot, on both edges reading both ways, per set...................... $4.25

1826 Set of 8 Boxwood Scales, 12 in., divided ⅛, ¼, ½, 1, ⅜, ¾, 1½, 3 in. to the foot, on both edges reading both ways, per set......... 7.50

1827 Set of 12 Boxwood Scales, 12 in., divided ⅛, ¼, ½, 1, ⅜, ¾, 1½, 2, 4, 6, 12 in. to the foot on both edges reading both ways........ 11.00

1828 Set of 4 Boxwood Scales, 12 in., divided 10, 20, 30, 40, 50, 60, 80, 100 parts to the inch, different divisions on each edge, numbered and reading both ways, per set................................ 4.70

1829 Set of 6 Boxwood Scales, 12 in., divided 10, 20, 30, 40, 50, 60 parts to the inch on each edge, numbered to read both ways........... 6.00

1830 Set of 8 Boxwood Scales, 12 in., divided 10, 20, 30, 40, 50, 60, 80, 100 parts to the inch, on each edge, numbered to read both ways.... 9.00

Flat White Edge Boxwood Scales in Sets.

1831 Set of 4 White Edge Scales, 12 in., divided 1/8, 1/4, 1/2, 1 in. to the foot, same on both edges reading each way $6.25

1832 Set of 8 White Edge Scales, 12 in., divided 1/8, 1/4, 1/2, 1, 3/8, 3/4, 1 1/2, 3 in. to the foot, same on both edges reading each way 11.50

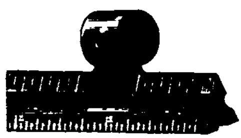
1833 Set of 12 White Edge Scales, 12 in., divided 1/8, 1/4, 1/2, 1, 3/8, 3/4, 1 1/2, 2, 4, 6 in. to the foot, same on both edges reading each way 17.00

1834 Set of 4 White Edge Scales, divided 10, 20, 30, 40, 50, 60, 80, 100 parts to the inch, different divisions on each edge, numbered to read both ways 6.75

1835 Set of 6 White Edge Scales, divided 10, 20, 30, 40, 50, 60 parts to the inch, one division on each edge, numbered to read both ways 9.00

1836 Set of 8 White Edge Scales, divided 10, 20, 30, 40, 50, 60, 80, 100 parts to the inch, one division on each edge, numbered to read both ways 13.00

Scale Guards.



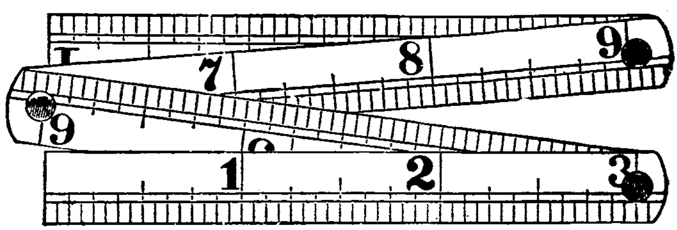
1840

1840 Triangular Scale Guards, nickel plated $0.20

1841 Map Measure, watch pattern 2.00

1842 Map Measure, 5 in., with handle, dial with two graduations, inches to miles and centimeters to kilometers 3.25

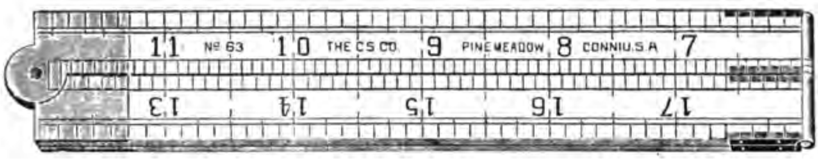
POCKET RULE



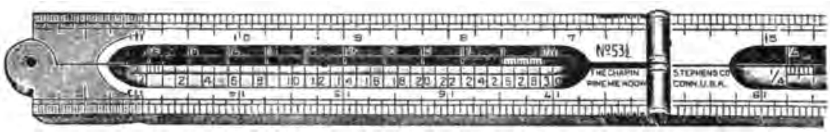
1843

1843 Surveyors Folding Steel Pocket Rule, divided in inches and 16ths on one side, 10ths and 100ths of foot on other side, in leather case, 2 ft., 6 fold 4 in. joints, each $0.75

RULES.

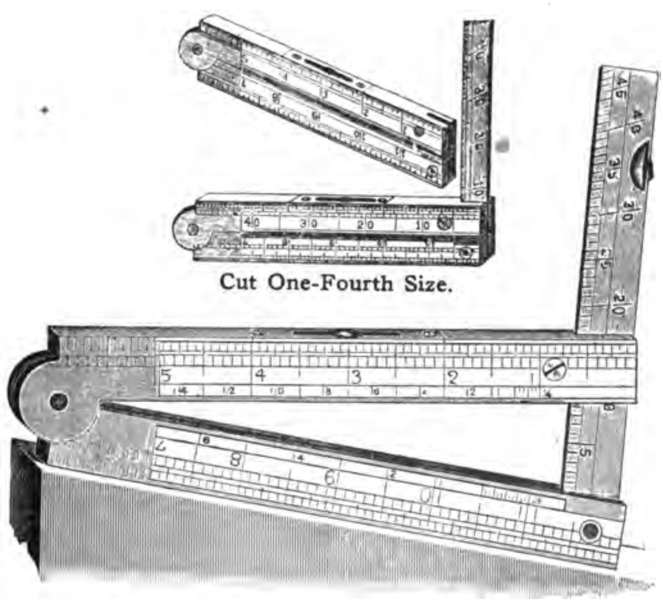


1845 Boxwood, four fold, two foot rules, full brass bound, arch joint graduated in 10th and 100ths of a foot, 16ths of an inch and drafting scale, each $0.50



1846 Ivory Rule, arch joint, edge plates, German silver, graduated to 8ths, 10ths, 12ths and 16ths of inch, with drafting scale.......... $8.00

1847 Ivory Rule, arch joint, edge plates. German silver, graduated to 8ths, 10ths, 12ths and 16ths of inch, and 100ths of foot, each...... 5.30



Cut One-Fourth Size.

1848 Clinometer Rule, combines carpenter's rule, splint level, square, plumb, drafting scale, brace scale, T square protractor, each..... $2.00

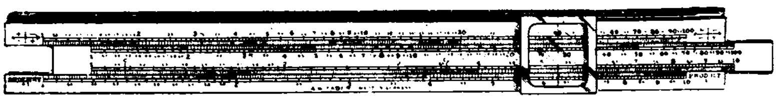
The Slide Rule.

The Slide Rule has been defined as "an instrument for mechanically effecting calculations by logarithmetic computation," (Pickworth, The Slide Rule), and it is said that "by its aid various arithmetical, algebraical, and trigonometrical process may be performed with ease and rapidity, the results obtained being sufficiently accurate for almost all practical requirements."

The A. W. Faber Calculating Rule consists of a "stock" or "body" about 10 inches in length, 1¼ inches in width, and ⅛ of an inch in thickness; a movable strip or "slide" inserted into the body surfaces level, and a "runner" about one inch square fitted with glass, which, sliding freely the entire length of the instrument, serves to connect the fine graduations of the several scales in the "body" and "slide."

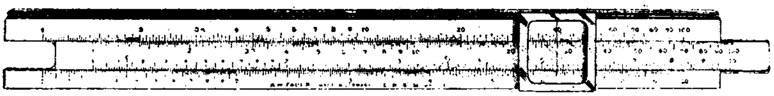
The rule is made of boxwood, with celluloid facings.

A Manual or Book of Instructions of 40 printed pages and 13 diagrams accompanies each rule, explaining the general principles which govern the instrument and furnishing practical illustrations of its usefulness.



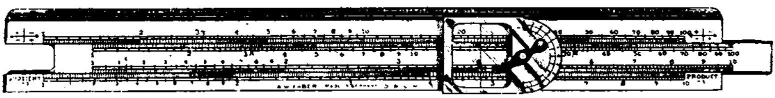
1850 Calculating Rule, 6 in. long.. $3.25

1851 Calculating Rule, 10 in. long.. $3.50



1852 Calculating Rule, 10 in. long, with spring.......................... $4.50

1852 Rule has inserted in its body, lateral to the slide, a boxwood adjuster which acts upon the slide like a spring and insures to its movement an even and adequate friction, safeguarding against becoming loose or tight under changes of temperature and atmospheric humidity.



1853 Calculating Rule, with self-adjusting slide and digit indicator...... $5.00

1854 Calculating Rule, with self-adjusting slide and digit indicator, 20 in. long 15.00

The above rule is made ⅜ in. longer at either end in order to afford a firmer purchase to the slide and cursor, when operated in those positions.

It is also provided with a ready reference reading mark, for determining the number of digits in a product or quotient; and with digit registering cursor for problems involving more than two factors.

BOUCHER CALCULATOR.

1860

The Boucher Calculator is made in form of a stem-winding watch. Compound calculations can be performed easily by means of the two pointers, operated by the "Stemwinder" and acting simultaneously on both dials.

1860	Boucher's Calculator, enameled dial, with directions, each	$8.50
1861	Same as No. 1860, but with silvered dial	14.00

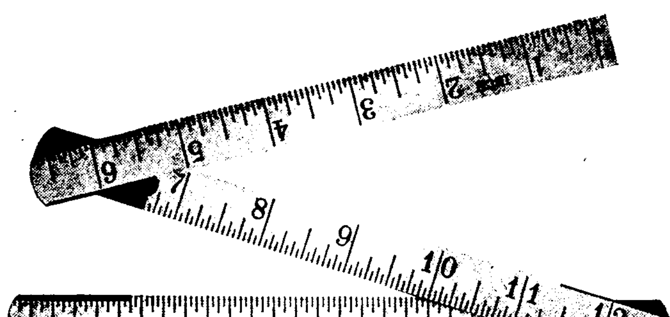
RULES.

Sundries for Slide Rules.

1865	Glass indicator with one hair line (as furnished with rules)	$0.50
1866	Glass indicator with two hair lines	.70
1867	Glass indicator with decimal pointer	1.00
1868	Sole Leather Case for 6 inch Slide Rule	.75
1869	Same, 10 inch	1.25
1870	Same, 20 inch	1.75

Folding Pocket Rules.

Yellow finish, brass tipped, boxwood, with self locking springs and invisible joints.



These Pocket Rules are thin and light, and more convenient than the common joint rules. By a peculiar preparation of the wood, shrinkage is entirely prevented.

1875	2 feet, 4 fold, inches both sides, each	$0.25
1876	4 feet, 8 fold, inches both sides, each	.50
1877	6 feet, 12 fold, inches both sides, each	.75

Folding Pocket Rules—Continued.

These Folding Rules are covered with a white enameled coating, the black graduations being more legible and distinct where shown on the white surface; no rivets shown on surface.

These rules are not affected by heat or moisture and are easily cleaned.

1880	Pocket Rule, 2 feet, 4 fold, with springs, each	$0.40
1881	Pocket Rule, 4 feet, 8 fold, with springs, each	.75
1882	Pocket Rule, 6 feet, 12 fold, with springs, each	1.00

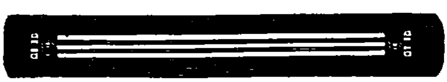
Parallel Rules.

1885	Ebony Parallel Rules, N. P. Bars, 6 in.	$0.30
1886	Ebony Parallel Rules, N. P. Bars, 9 in.	.60
1887	Ebony Parallel Rules, N. P. Bars, 12 in.	.75
1888	Ebony Parallel Rules, N. P. Bars, 15 in.	.90
1889	Ebony Parallel Rules, N. P. Bars, 18 in.	1.20
1890	Ebony Parallel Rules, N. P. Bars, 24 in.	1.80
1891	Hard Rubber Parallel Rules, N. P. Bars, 6 in.	.75
1892	Hard Rubber Parallel Rules, N. P. Bars, 9 in.	.90
1893	Hard Rubber Parallel Rules, N. P. Bars, 12 in.	1.20
1894	Hard Rubber Parallel Rules, N. P. Bars, 15 in.	1.50
1895	Hard Rubber Parallel Rules, N. P. Bars, 18 in.	1.80
1896	Hard Rubber Parallel Rules, N. P. Bars, 24 in.	2.40

Transparent Amber Parallel Rules.

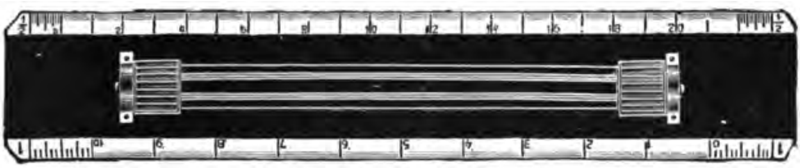
1900	6 inches	$1.35
1901	9 inches	1.80
1902	12 inches	2.40
1903	15 inches	3.00
1904	18 inches	3.75
1905	24 inches	4.90

Rolling Parallel Rules.



1910	Ebony, nickel plated mountings, 9 in.	$2.75
1911	Ebony, nickel plated mountings, 12 in.	3.25
1912	Ebony, nickel plated mountings, 15 in.	4.00
1913	Ebony, nickel plated mountings, 18 in.	5.00
1914	Hard Rubber, nickel plated mountings, 9 in.	4.00
1915	Hard Rubber, nickel plated mountings, 12 in.	4.50
1916	Hard Rubber, nickel plated mountings, 15 in.	5.50
1917	Hard Rubber, nickel plated mountings, 18 in.	6.50

RULES.



Hardwood Parallel.

Nickel plated mounting, white amber edges, divided ⅛, ¼, ½ and 1 inch to the foot.

1920	12 in.	$4.50
1921	15 in.	5.50
1922	18 in.	7.00

Brass Parallel, Nickel-Plated.

1925	9 in., weight about 18 oz.	$ 7.25
1926	12 in., weight about 23 oz.	8.50
1927	15 in., weight about 31 oz.	10.00
1928	18 in., weight about 40 oz.	12.00
1929	24 in., weight about 58 oz.	18.00

THUMB TACKS.

Steel Stamped Tacks.

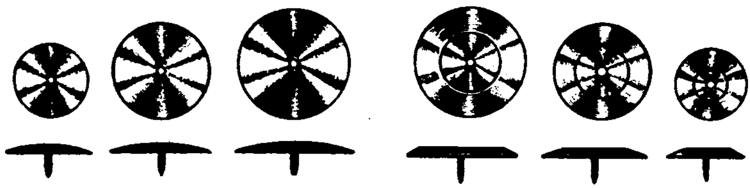
1935	Round Heads, ⅜ in. diameter, per gross............	$0.90 per doz.	$0.10
1936	Round Heads, 7-16 in. diameter, per gross..........	1.10 per doz.	.15
1937	Round Heads, 9-16 in. diameter, per gross..........	1.30 per doz.	.20
1938	Round Heads, ⅜ in. diameter, 100 in box..........................		.45
1939	Round Heads, 7-16 in. diameter, 100 in box........................		.55
1940	Round Heads, 9-16 in. diameter, 100 in box........................		.70

Nickel Covered Head.

1941	Capped, ⅜ in. diameter, per gross..................	$1.50 per doz.	$0.20
1942	Capped, 7-16 in. diameter, per gross................	1.80 per doz.	.25
1943	Capped, 9-16 in. diameter, per gross................	2.20 per doz.	.30

1944	German Silver, ⅜ in. diameter, per gross..........	$2.25 per doz.	$0.30
1945	German Silver, ½ in. diameter, per gross..........	2.45 per doz.	.35
1946	German Silver, ⅝ in. diameter, per gross..........	2.75 per doz.	.45
1947	Brass, ⅜ in. diameter, per gross...................	2.25 per doz.	.15
1948	Brass, ½ in. diameter, per gross...................	2.45 per doz.	.25
1949	Brass, ⅝ in. diameter, per gross...................	2.75 per doz.	.35

THUMB TACKS.



1951 1952 1953 1956 1955 1954

These Thumb Tacks are screwed in and riveted. The points are made of the best tool steel. They are turned and finished on their own point, a test that is twenty times more severe than any usage a Thumb Tack can be put to.

1951	German Silver, 7-16 in. diameter, per doz.	$0.65
1952	German Silver, ½ in. diameter, per doz.	.70
1953	German Silver, ⅝ in. diameter, per doz.	.90
1954	German Silver, beveled edge, 7-16 in. diameter, per doz.	.65
1955	German Silver, beveled edge, ½ in. diameter, per doz.	.70
1956	German Silver, beveled edge, ⅝ in. diameter, per doz.	.90

HORN CENTERS.

1960

1961

1960	Plain Horn Center, ½ in. diameter	$0.15
1961	German Silver Rim, horn center, ⅜ in. diameter	.50

HIGGINS' LIQUID DRAWING INKS.

		¾ Oz. Bottle
1965	Higgins' General Black Ink	$0.25
1966	Higgins' Water Proof Black Ink	.25
1967	Higgins' Water Proof Blue Ink	.25
1968	Higgins' Water Proof Brick Red Ink	.25
1969	Higgins' Water Proof Brown Ink	.25
1970	Higgins' Water Proof Carmine Ink	.25
1971	Higgins' Water Proof Green Ink	.25
1972	Higgins' Water Proof Indigo Ink	.25
1973	Higgins' Water Proof Orange Ink	.25
1974	Higgins' Water Proof Scarlet Ink	.25
1975	Higgins' Water Proof Vermilion Ink	.25
1976	Higgins' Water Proof Violet Ink	.25
1977	Higgins' Water Proof Yellow Ink	.25
1978	White Ink for Writing on Blue Prints, etc.	.25
1979	8 oz. bottles (½ pint)	2.00
1980	16 oz. bottles (1 pint)	3.75
1981	32 oz. bottles (1 quart)	7.00

1985 HIGGINS' PHOTO MOUNTER.

1985	3 oz. Screw Capped Jars, each	$0.15
1986	6 oz. Screw Capped Jars, each	.25
1987	14 oz. Screw Capped Jars, each	.50
1988	½ gal. Screw Capped Jars, each	2.00
1989	1 gal. Screw Capped Jars, each	3.50

1990 HIGGINS' DRAWING BOARD AND LIBRARY MUCILAGE.

1990	3 oz. Screw Capped Jars, each	$0.15
1991	6 oz. Screw Capped Jars, each	.25
1992	14 oz. Screw Capped Jars, each	.50
1993	½ gal. Screw Capped Jars, each	2.00
1994	1 gal. Screw Capped Jars, each	3.50

MOIST WATER COLORS.

Windsor & Newton's.

In Pans and Half Pans.

2000 1 Antwerp Blue
2 Bistre
3 Blue Black
x4 British Ink
5 Brown Ochre
6 Brown Pink
x7 Bronze
8 Burnt Sienna
9 Burnt Umber
10 Chinese White
11 Chrome Yellow
12 Cologne Earth
x13 Constant White
14 Deep Chrome
x15 Dragon's Blood
16 Emerald Green
x17 Flake White
18 Gamboge
19 Hooker's Green No. 1
20 Hooker's Green No. 2
21 Indigo
22 Indian Red
23 Italian Pink
24 Ivory Black
x25 King's Yellow
26 Lamp Black
27 Light Red
28 Naples Yellow
29 Neutral Tint
30 New Blue
31 Olive Green
32 Orange Chrome
33 Payne's Grey
34 Prussian Blue
35 Prussian Green
36 Raw Sienna
37 Raw Umber
40 Roman Ochre
41 Sap Green
42 Terre Verte
43 Van Dyke Brown
44 Venetian Red
45 Vermilion
47 Yellow Lake
48 Yellow Ochre

Full pans or cakes, each $0.25
Half pans or cakes, each .... .15

Colors marked x are put up in half cakes and cakes.

MOIST WATER COLORS.

Windsor & Newton's.

In Pans and Half Pans.

2001	x49 Black Lead	57 Roman Sapia
	50 Brown Madder	58 Ruben's Madder
	51 Carmine Lake	59 Scarlet Lake
	89 Cerulean Blue	90 Scarlet Madder
	52 Crimson Lake	60 Scarlet Vermilion
	55 Neutral Orange	61 Sepia
	64 Orange Vermilion	62 Warm Sepia
	56 Purple Lake	

Full pans or cakes, each.. $0.45

Half pans or cakes, each.. .25

2002	69 Cadium Orange	76 Lemon Yellow
	68 Cadium Yellow	87 Mars Orange
	63 Cobalt Blue	73 Oxide Chromum
	71 French Blue	77 Pale Cadium Yellow
	74 Indian Purple	79 Pure Scarlet
	53 Indian Yellow	65 Violet Carmine
	75 Intense Blue	81 Veridian

Full pans or cakes, each.. $0.65

Half pans or cakes, each.. .35

2003	66 Aureolin	78 Pink Madder
	91 Aurora Yellow	92 Primrose Aureolin
	67 Burnt Carmine	82 Purple Madder
	70 Carmine	80 Rose Madder
	x85 Field's Orange Vermilion	93 Yellow Carmine
	86 Madder Carmine	

Full pans or cakes, each.. $0.90

Half pans or cakes, each.. .45

2004	83 Smalt	84 Ultramarine Ash

Full pans or cakes, each.. $1.40

Half pans or cakes, each.. .70

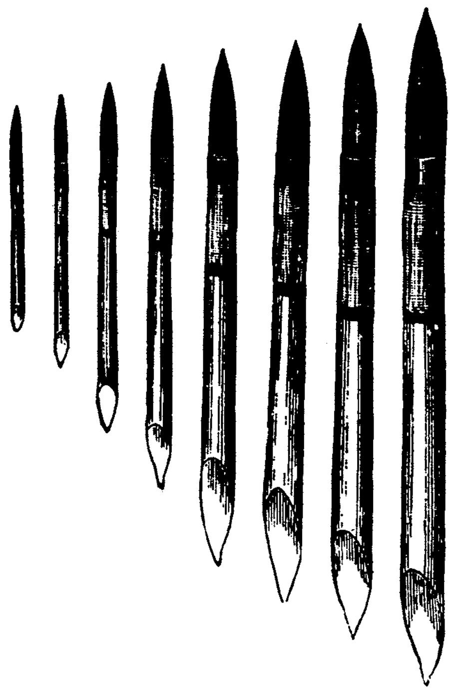
2005 88 Genuine Ultramarine

Quarter cakes, each.. $2.25

Colors marked x are put up in half cakes and cakes.

BRUSHES.

Quill Brushes of Camel's Hair.

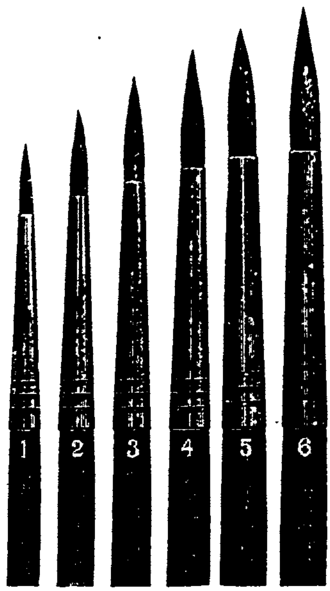


1 2 3 4 5 6 7 8

		1	2	3	4	5	6	7	8
2010	Each	$0.05	$0.05	$0.06	$0.06	$0.08	$0.08	$0.10	$0.10

BRUSHES.

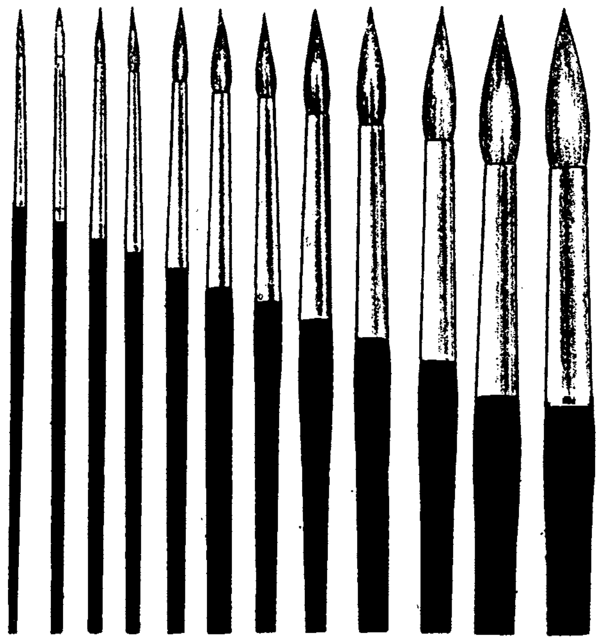
Camel's Hair Brushes in Tin with Handles.



	1	2	3	4	5	6	7
2011	$0.06	$0.08	$0.08	$0.10	$0.10	$0.12	$0.15

BRUSHES.

Red Sable Brushes in Albata with Handle.

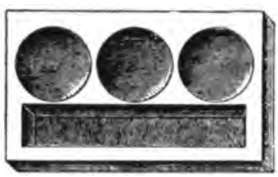


		1	2	3	4	5	6
2012	....	$0.15	$0.20	$0.25	$0.30	$0.40	$0.55
		7	8	9	10	11	12
	....	$0.70	$0.90	$1.20	$1.50	$2.00	$2.75

CABINET NESTS.

2015	2¼ in. diameter, 6 in set	$0.55
2016	2¾ in. diameter, 6 in set	.65
2017	3¼ in. diameter, 6 in set	.75

INK AND COLOR SLABS.



2018	3 wells and slope, 1½ x 2¾ in. each	$0.10
2019	3 wells and slope, 2⅜ x 3⅝ in. each	.20
2020	3 wells and slope, 2¾ x 4¼ in. each	.25
2021	3 wells and slope, 3 x 4¼ in. each	.30
2022	3 wells and 3 slope, 2½ x 4 in. each	.20
2023	5 wells and 5 slope, 4 x 7½ in. each	.55

A. W. FABER'S RUBBER BANDS.

Guaranteed the Best.

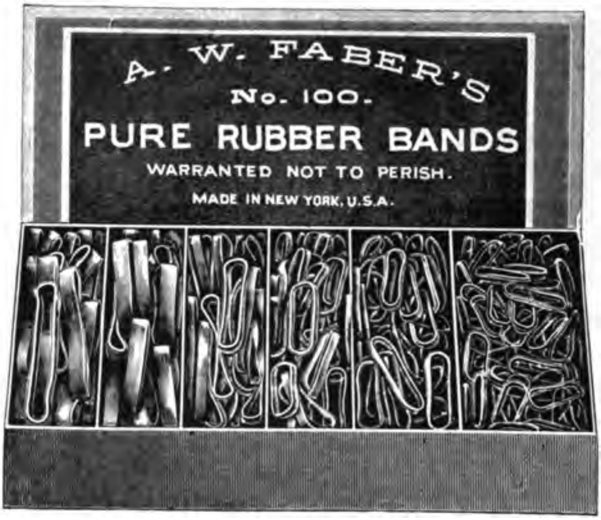
String Bands—1/16 In. Wide.

2025	Nos.	10	12	14	16
	Inches long	1¼	1⅝	2	2½
	Per gross	$0.25	$0.30	$0.35	$0.40

Narrow Bands—⅛ In. Wide.

2026	Nos.	28	30	32	33
	Inches long	1⅜	2	3	3½
	Per gross	$0.60	$0.70	$0.90	$1.00

Assorted Bands.



2027—100.

2027—200.

2027	Nos.	100	200	300	400
	Price	$1.75	$1.25	$0.85	$0.50

A. W. FABER'S PENCILS.

2030 A. W. Faber's Siberian Lead Pencils, Hexagon, in the following degrees: 2B, B, HB, F, H, 2H, 3H, 4H, 5H, 6H, 7H, 8H, per dozen.. $1.25

Hexagon Gilt Pencils

2031 Nos. 1, 2, 3, 4, 5, 6, per dozen.................................... $0.60
2032 "Velvet" Hexagon, with rubber tip, Nos. 2 and 3, per dozen........ .60

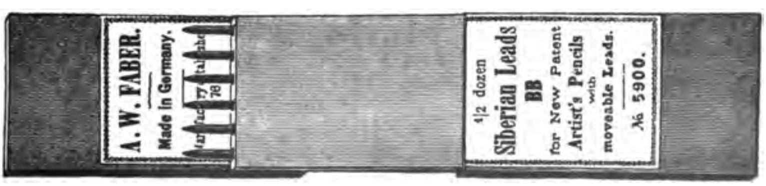
Round Gilt Pencils.

2033 Nos. 2, 3, 4, 5, per dozen.. $0.60

2034

Pencil Lengtheners.

2034 A. W. Faber Pencil Lengtheners, each............................ $0.10



2035 A. W. Faber's Siberian Leads, six in box, like 2030, 2B to 8H, per box $0.65

A. W. FABER'S PENCILS.

2036 A. W. Faber's Wax Crayons or Creta Laevis Pencils.

Blues

12 Prussian Blue
13 Ultramarine
50 Antwerp Blue, Deep
58 Antwerp Blue, Light
65 Indigo
88 Light Blue

Reds

16 Flesh Tint, No. 1
18 Flesh Tint, No. 2
20 Red Lead
38 Vermilion
42 Indian Red, No. 1
30 Indian Red, No. 2
46 Scarlet
72 Pink
75 Carmine

Yellows

2 Chrome Yellow, Pale
4 Chrome Yellow, Medium
62 Chrome Yellow, Deep
37 Yellow Ochre
59 Primrose Yellow
64 Italian Pink

Various

1 White
41 Black
51 Violet
54 Purple

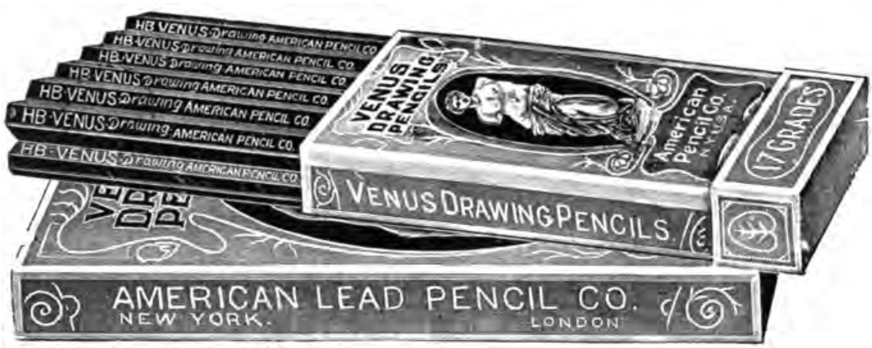
Browns

6 Roman Ochre
32 Burnt Umber
34 Burnt Sienna
43 Indian Brown, No. 1
28 Indian Brown, No. 2
35 Purple Brown
36 Brown Ochre
60 Red Brown
61 Raw Umber, No. 1
33 Raw Umber, No. 2
52 Raw Umber, No. 3
55 Raw Umber, No. 4
87 Vandyke Brown

Greens

29 Prussian Green, No. 1
45 Prussian Green, No. 2
39 Olive Green, No. 1
47 Olive Green, No. 2
40 Olive Green, No. 3
56 Olive Green, No. 4
53 Yellow Green
63 Chrome Green, No. 1
57 Chrome Green, No. 2
69 Chrome Green, No. 3

Price ....$0.10 each or per dozen $1.00
2037 Extra Fine Blue Pencils, 7 inches long.... .10 each or per dozen 1.00
2038 Faber Blue, Green and Red Pencils, per dozen.................... .60



Venus Drawing Pencils.

2039 Venus Drawing Pencils, 17 grades, 6B, 5B, 4B, 3B, 2B, B, HB, F, H, 2H, 3H, 4H, 5H, 6H, 7H, 8H, 9H.......$0.10 each—per dozen $1.00

2040 Venus Copying Pencils..................................per dozen .75

Koh-I-Noor Pencils.

2041 Koh-i-noor Pencils, hexagon, yellow polish, in the following degrees: 3B, 2B, B, HB, F, H, 2H, 3H, 4H, 5H, 6H, 7H, 8H, per dozen $1.25
4B 1.50
5B and 6B 1.80

"Mongol" Hexagon, Yellow Finish.

2042 "Mongol" Pencils are made in 12 grades. For a moderate priced Detail or Drawing Pencil it has no equal. Grade 6B, 3B, 2B, B, HB, F, H, 2H, 3H, 4H, 5H, 6H, per dozen...................... $0.60

Marking Pencils.

2043 Black, in white wood, per dozen................................ $0.60

2044 Carbon Marking Pencils .... .60

Lumberman's Pencils.

Extra Fine Quality.

2045 A. W. Faber's, black, per dozen................................ $1.00

2046 A. W. Faber's, red, per dozen................................ 1.00

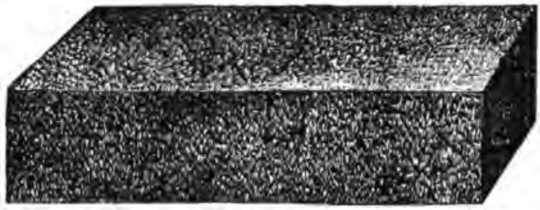
2047 A. W. Faber's, blue, per dozen................................ 1.00

2048 A. W. Faber's, green, per dozen................................ 1.00

Dixon Lumber Crayons.

2049 Blue, red and black, per dozen.................................... $1.00

RUBBER ERASERS.



2060	Sponge Rubber, medium rubber back, 2 x 2 x 1 in., each	$0.30
2061	Sponge Rubber, large size, 4 x 2 x 1 in., each	.60
2062	Sponge Rubber, mammoth size, 6 x 4 x 1 in., each	1.80

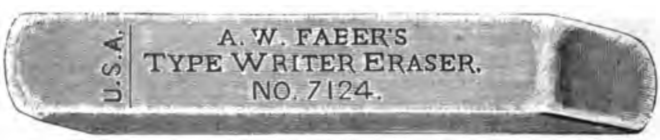
E. Faber Emerald Erasers.

2065	Small size	$0.05 each or per dozen	$0.60
2066	Large size	.10 each or per dozen	1.20

E. Faber Ruby Erasers.

2067	Small size	$0.05 each or per dozen	$0.60
2068	Large size	.10 each or per dozen	1.20

A. W. Faber's Typewriter Eraser.



2070	Small size	$0.05 each or per dozen	$0.60
2071	Large size	.10 each or per dozen	1.20

Circular Erasers.

2075	For both ink and pencil use	$0.05 each or per dozen	$0.60

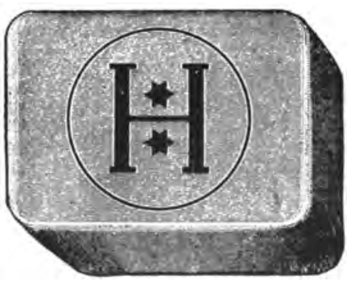
RUBBER ERASERS.

A. W. Faber's Soft Red Rubber—Square.

2080	Pieces to pound	12	24	36
	Per piece	$0.15	$0.10	$0.05
	Per pound			1.50

Faber's Ink Eraser and Paper Cleaner.

2085 Small size, each.. $0.05
2086 Large size, each.. .10



Hardtmuth's Pliable Rubber—Pink or Gray.

2090	Pieces to pound	40	24	16	8	4
	Per piece	$0.05	$0.10	$0.15	$0.25	$0.50

2095 Metal Erasing Shields, nickel plated, 2½ x 4½ inches, each......... $0.20
2096 Celluloid Erasing Shields, transparent, 2½ x 4½ inches, each....... .20

Pencil Pointers.

2097 Sand Paper Blocks, 1¼ x 4 inches, with handle, each............... $0.15

PENCIL SHARPENERS.

2100.

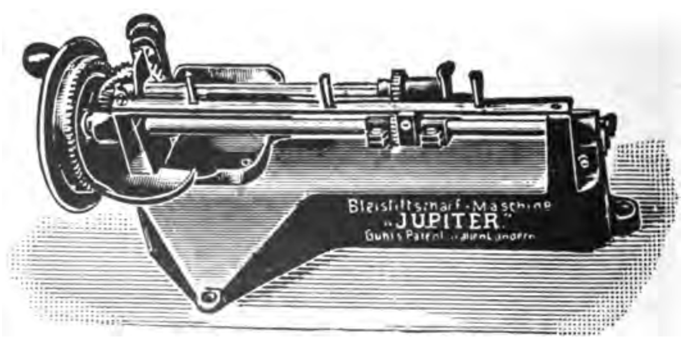
2101.

2100 The "Lakeside" Pencil Sharpener; cutter of case hardened steel, automatically holds pencil in place, requiring but one hand to operate; mechanically perfect, each $5.50

2101 Planetary Pencil Pointer, each 4.50

2102 Extra Knives for Planetary Pencil Pointer, pair .... .65

The Planetary Pencil Pointer is very durable and easily operated. It makes perfect points on any kind of pencil, can be attached to either wall or table.



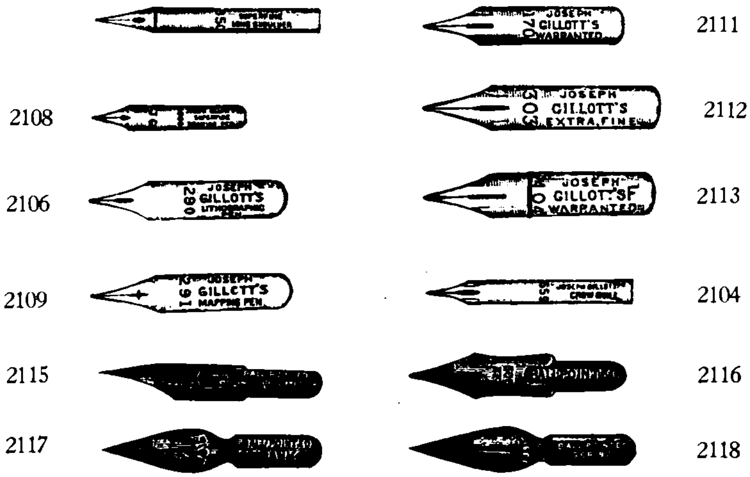
2103.

2103 "Jupiter" Pencil Sharpener, each $8.50

2104 New Cutting Wheel, each 1.50

The "Jupiter" Pencil Sharpener excels all others in workmanship and the ease with which it can be operated. The cutting wheel is made reversible, so that when one side is dull, the other can be used, after which a new cutting wheel can be furnished or the old one can be sharpened.

STEEL PENS.
For Draughtsmen's Use.



		Each	Per Doz.
2104	Gillott's Crow Quill (659) on card with holder	$0.05	$0.60
2105	Gillott's Crow Quill (659) loose in ¼ gross boxes	.05	.50
2106	Gillott's Lithographic (290) on card with holder	.05	.60
2107	Gillott's Lithographic (290) loose in 1 gross boxes	.05	.50
2108	Gillott's Drawing (1000) superfine, on cards	.10	1.00
2109	Gillott's Mapping (291) on cards with holder	.05	.60
2110	Gillott's Mapping (291) loose in 1 gross boxes	.05	.50
2111	Gillott's Mapping (170) loose in 1 gross boxes		.10
2112	Gillott's Mapping (303) loose in 1 gross boxes		.15
2113	Gillott's Mapping (404) loose in 1 gross boxes		.10
2114	Gillott's Tit Quill, on cards with holder	.15	1.25

Tit Quill is a recent invention, has a point as delicately fine as that of No. 1000 but is superior because it will make strokes up or down, or in any direction, with equal facility without sticking in paper.

2104.

		Per Gross
2115	Leonhardt's Ball Pointed Pens, 506F	$1.35
2116	Leonhardt's Ball Pointed Pens, 506EF	1.35
2117	Leonhardt's Ball Pointed Pens, 516F	1.35
2118	Leonhardt's Ball Pointed Pens, 516EF	1.35

PEN HOLDERS.

2125	Pen Holder for Crow Quill Pen (659), each	$0.10
2126	Pen Holders for Lithographic Pen (290), each	.10
2127	Natural Polish, tapered, 6¾ inches long, each	.05
2128	Maple, mottled finish, tapered, 7¾ inches long, each	.05
2129	Cedar, finely polished, 7 inches long, each	.10
2130	Cork, round, tapered, metal-lined tip, 6 inches long, each	.10

POLAR PLANIMETERS.

This very useful instrument for obtaining areas is so well known to the engineer that it need not be described in particular. A theoretical discussion of the principles underlying its operation will be found in almost any handbook on higher surveying.

Instructions how to use it are given below:

"Adjust the sliding-tube on the bar so that the index mark on the tube coincides with one of the marks on the bar.

"Needle Point Outside the Diagram.—Put the instrument on the drawing surface with the tracing point at a mark on the curve, the area of which is to be measured, press the needle point slightly into the paper outside the curve and read off the rolling wheel and the counting disk, taking the whole circumference of the recording roller as the unit of reading. (The roller need not be set to zero.) Then move the pointer (or tracer) around the area in the direction of the movement of the hands of a watch, and when you reach the starting point take a reading. Subtract the first from the second reading, and multiply the remainder by the coefficient of the scale.

"Example: Area required in square feet. Slide the tube on the bar so that the index of the former coincides with the mark denoted by 0.1 square feet. Suppose the dimensions of the diagram allow the needle-point to be placed *outside*. Then

Second reading (say) 8.311
First reading (say) 2.322

5.989 X 0.1 — 0.5989 square feet.

"Needle Point Inside the Diagram.—Circumscribe the diagram with the pointer in the direction of the movement of the hands of a watch, observing at the same time the counting disk, in order to see whether the total rotation is a forward or a backward motion.

"This preliminary rough operation completed, proceed as before explained, now following the curve *carefully* with the pointer. If the total rotation of the roller has been a *forward* motion, subtract the first reading from the second, and add the difference to the figure engraved on the top of the bar just over the mark.

"Thus, in a similar example:

Second reading (say) 5.423
First reading (say) 3.004

2.419
Figure on top of bar 20.741

23.160 X 0.1 — 2.316 square feet.

"The figures on the top of the bar are slightly different for different instruments.

"If the total rotation of the roller is a *back* motion, subtract the second reading from the first reading, and *subtract* the difference from the figure on the bar.

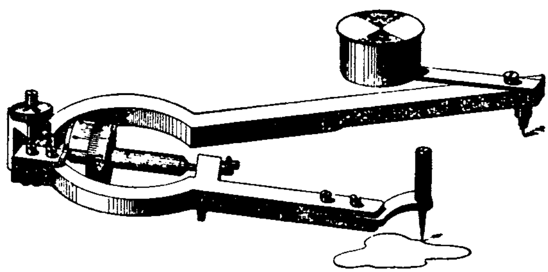
"Note: When the mark 0 on the roller is at the mark 0 of the vernier, a mark of the counting disk should be opposite the fixed index mark. Any slight non-coincidence due to play between roller and disk may readily be allowed for in taking readings."

The engineer finds this instrument most useful in determining the areas of profiles drawn upon cross-section paper, and it is there nearly always the case that the needle-point is placed outside of the diagram.

These profiles are generally drawn on an exaggerated scale, the vertical scale being considerably larger than the horizontal one.

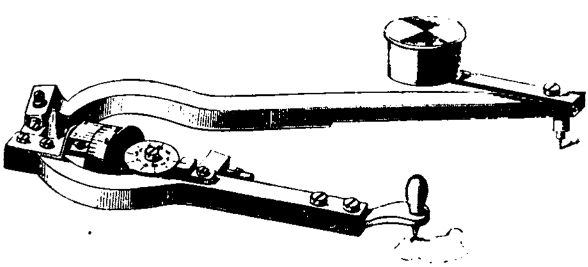
The best means of obtaining the area of such a profile is to draw a rectangular figure on the same scale, or scales, of a known area; to circumscribe that area with the planimeter set arbitrarily, but well fastened so that the bar cannot slip, and to read the disk, roller and vernier. The starting point may have been 0 or not; in the latter case we note the difference.

The figure may be circumscribed several times and the mean taken, should we desire greater accuracy. Knowing the area of this rectangular figure, it is an easy matter to compare it with the reading of the planimeter, and to find a coefficient by which every planimeter determination of the area of any profile drawn on the same scale, or scales, of the test figure must be multiplied to give the true result in square units represented by the scale. This is so apparent that it need not be demonstrated. It is by far the safest method, as it will recognize not only scale exaggeration, but any inaccuracies in the divisions of the cross-section paper. If we want to be very precise, we may determine a coefficient for every sheet of the cross-section paper used.



2150

2150 Polar Planimeter, German silver, fixed tracer arm, needle pole in case $15 00



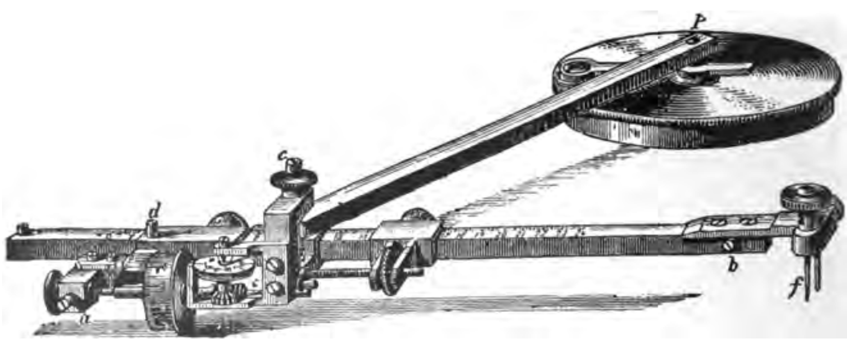
2151

2151 Polar Planimeter, German silver, fixed tracer arm, with wheel registering the revolutions, in case..........................$16 50

PLANIMETERS

2155

2155 Polar Planimeter, German silver, adjustable tracer arm, in Morocco case $28 00



2157

2157 Polar Planimeter, German silver, adjustable tracer arm with clamp and tangent screw, having a ball pole instead of needle, in Morocco case.. $33 25

2158 Polar Planimeter, like 2157, with 2 steel points for finding the mean height of indicator diagrams; the points protected by screw caps, in Morocco case.. 35 50

PLANIMETERS

2160

2160 Compensating Planimeter, German silver and bronze, adjustable tracer arm graduated, pole weight, testing rule, etc., in case...$36 00

2161 Compensating Planimeter, like 2160, with adjustable pole arm, in case 47 00

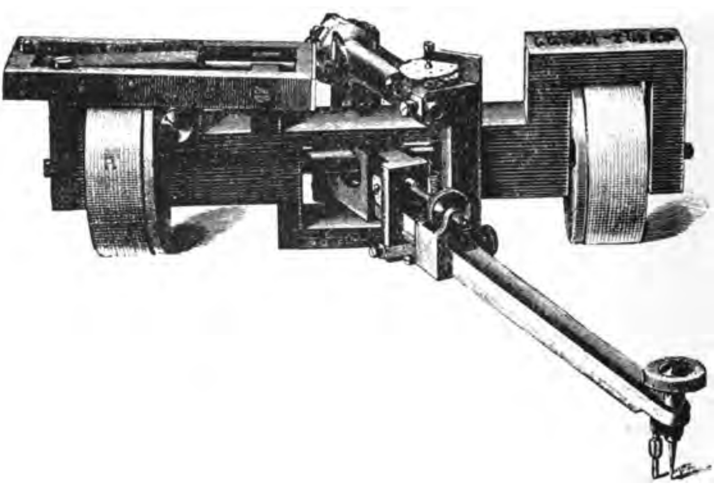
Planimeter No. 2160 is in two separate parts: One with tracer arm with measuring and recording wheels, and the other is a polar arm, having the pole weight at one end and a steel ball at the other, which forms a ball joint with the carriage. This construction gives the tracer arm a motion of 180° in either direction, thereby having greater scope than the ordinary planimeters. By measuring a diagram with the pole on the right, and then on the left side of the tracer arm, and taking the mean of the readings, compensating all errors of the instrument.

Planimeter No. 2161 has an adjustable polar arm having index marks for various settings furnished with the instrument, and when used with the pole inside of the area, the constant is a round number, 20,000 for any setting. Large areas can be measured with this instrument and can be used with the pole inside as well as outside of the diagram.

PLANIMETERS

2165

2165 Precision Disc Planimeter, diameter of pole disc 6 in., length of pole arm 6¾ in., length of tracer arm 8 in., with micrometer adjustment adjustable for vernier unit from .003 sq. in. to .0008 sq. in., with testing rule and lock case..............$95 00

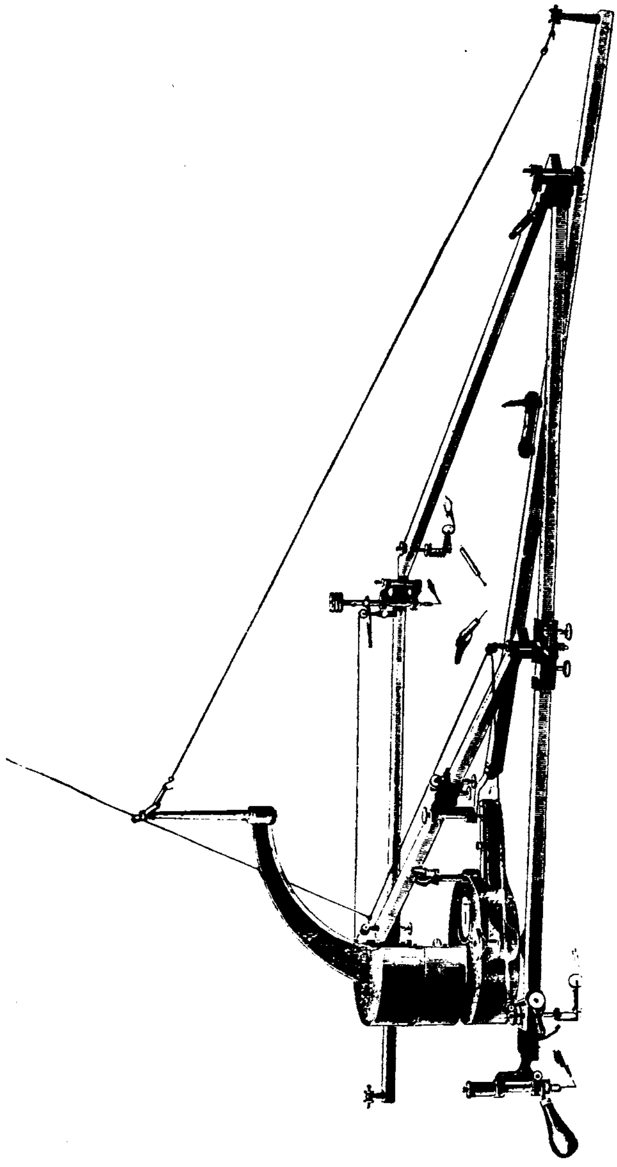


2167

2167 Rolling Planimeter, of German silver and brass, length of tracer arm, 8 in..$82 50

2168 Rolling Planimeter, like 2167 but larger, tracer arm 12 in. long... 95 00

PRECISION PANTOGRAPHS



2170 Suspended Precision Pantograph, square metal bars, for enlarging from 1:1 to 1:20 and reducing from 20:1 to 1:1, in all ratios, length of bars 33 in., extra supporting bar, with all usual accessories, in polished box..........................$160 00

2171 Do. Length of bars 38 in.............................. 170 00

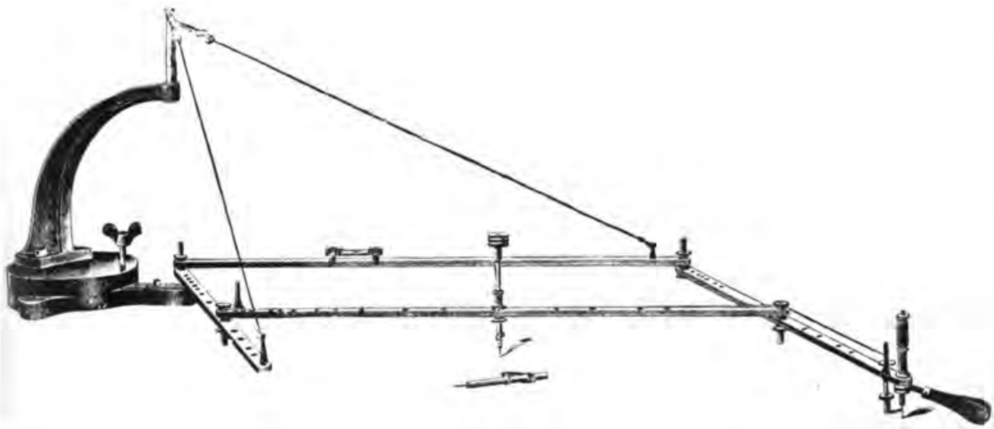
PRECISION PANTOGRAPHS

2172 Suspended Pantograph, square metal bars, for enlarging 1:20 to 4:5 and reducing 20:1 to 5:4, fully graduated, length of bar 28 in., with all the usual accessories, in polished box..........$75 00

2173 Length of bar 33 in.......................... 85 00

2174 Length of bar 38 in.......................... 92 50

PANTOGRAPHS



2180 Suspended Pantograph, pearwood bars, for enlarging and reducing in the following ratios: 1:20, 1:10, 1:8, 1:6, 1:5, 1:4, 1:3, 2:5, 1:2, 3:5, 2:3, 3:4, 4:5 and vice versa; length of bars 28 in., packed in polished box with all usual accessories............$35 00

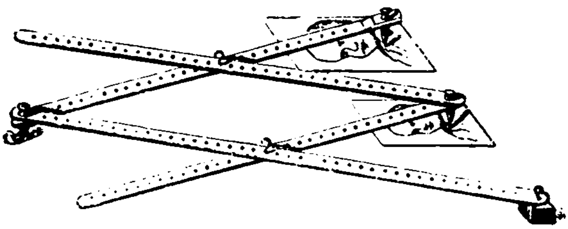
2181 Length of bars 33 in... 36 00

2182 Length of bars 38 in... 37 50

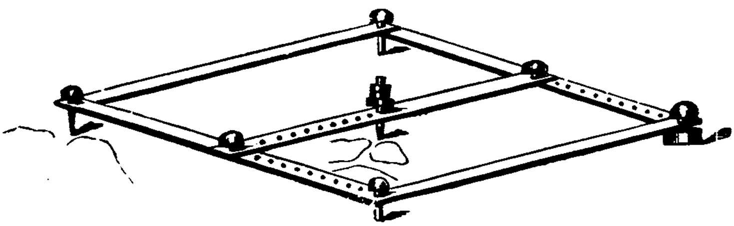
SCIENTIFIC BOOKS

We aim to carry a stock of books treating on all Scientific and Technical subjects, and by our up-to-date method of stock keeping we are able to always supply any book and of the very latest publication. Orders for books are sent by return mail.

PANTOGRAPHS



2185 Pantograph, small, common make, each.......................... $0.25
2186 Pantograph, long, clean cut figures, in box, each.................. .60
2187 Pantograph, brass mounted, movable point, in box, each........... 1.25
2188 Pantograph, nickel mounted, elbow joint wheel, in box, each....... 3.00

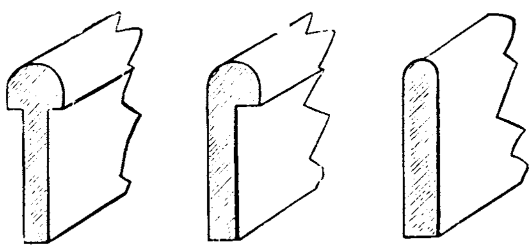


2189

2189 Pantograph, brass mounted, pearwood 22" arms, each.............. $5.00

BEAM COMPASS BARS

HARDWOOD



1 2 3

2195	Inches long......	24	30	36	42	48	54
	Each	$0 35	$0 40	$0 45	$0 50	$0 60	$0 65

RULES AND REGULATIONS FOR THE GENERAL GUIDANCE OF CIVIL ENGINEERS IN PROFESSIONAL PRACTICE.

Established in the Year 1891 by the

CALIFORNIA ASSOCIATION OF CIVIL ENGINEERS

Copied from Public Document.

Section 1. It is desirable, that whenever practicable, all engineering services should be charged for on a percentage basis.

Sec. 2. When no special agreement has been entered into between owner or employer and the engineer who is entrusted with work,the latter shall be entitled to compensation for services rendered at not less than the minimum percentage rates set forth in the schedule hereinafter contained; or, if the computation of the value of the services on a percentage basis is not practicable, then at not less than the minimum per diem rate.

Sec. 3. The various kinds of services rendered by the civil engineer are to be classified as follows:

Preliminaries,
Plans and Specifications,
Details
Supervision and progress estimates.
Superintendence,
Alterations,
Surveying,
Professional advice,
Expert work,
Consultation.

Sec. 4. Preliminary work is of such a variety of character that it is only then advisable to make a percentage charge for it when little or no field work has to be done to secure the necessary data on which the preliminary report, design or advice is to be based, and the schedule rate applies to such cases only.

In all other cases and for ordinary surveying, whether preliminary to construction or otherwise, a salary or a per diem charge should be agreed upon.

Sec. 5. Plans and specifications are required as the basis for the letting of contracts, or for the information of the owner, employer or consulting engineer, and afford a full description of the work. They are implied even when not required by the owner, and the charge therefor should not be less than the schedule rates, even when they are not actually furnished. They are presumed to include an estimate of the cost of the work when such estimate is required. Plans, when adopted and approved by owner, should be signed by both owner or his agent, and the engineer.

Sec. 6. Details are not always an essential feature of the engineer's construction work, and, as the amount of detail work may vary greatly, the rate to be charged therefor should be flexible, and rigid adherence to the schedule rate is not deemed desirable.

Sec. 7. Supervision and the making of progress estimates, is generally, and should always be required by the owner or employer, of the engineer who has furnished the plans and specifications, who is therefore presumed to be responsible for the work and its proper construction.

Supervision, in the sense in which the word is here used, means such inspection from time to time as may be required to satisfy the engineer that the specifications are fully complied with.

When the engineer who has furnished the plans and specifications for any work is also the superintendent of construction, as superintendence is defined in the next section, he shall be entitled to pay for superintendence and shall not be entitled to any additional charge for supervision.

Sec. 8. The engineer who designs any work should have a representative on the same as superintendent of construction, or should himself be superintendent of construction. But the owner or employer is generally, to a greater degree than the engineer, interested in a strict compliance by the contractor with the plans and specifications. Their interest in the selection of a superintendent of construction is mutual, and no person should be selected who is not acceptable to both.

The schedule rate for superintendence is intended to apply only when the engineer who has designed and planned the work superintends its construction. And this rate includes the compensation only of such assistants or deputies as may be necessary by reason of the great extent of any work to represent the engineer himself. All other employees are to be paid by the owner.

Sec. 9. Alterations may be required at any time by the owner of the work or may become necessary by reason of unforeseen conditions, or by reason of accidents.

The schedule rate applies only to such alterations as may be required by the owner after the original drafts of plans and specifications have been submitted and approved, or their approval has been implied by the commencement of construction. The planning of alterations which become necessary by reason of unforeseen conditions or accidents to the work are ordinarily covered by the percentage charges on the aggregate cost.

Sec. 10. Surveying covers every class of the engineer or surveyor's field work which is not necessarily a part of the preliminary work as covered by the schedule of minimum rates. It includes all location surveys for roads, canals, railroads, etc., besides every class of land surveying and land subdivision, and compensation therefor, except when services are covered by schedule rates, should be on a salary or a per diem basis.

Sec. 11. Schedule of minimum charges for civil engineers in professional practice:

TABLE OF MINIMUM CHARGES FOR CIVIL ENGINEERS.

	Less than $5,000	$5,000 to $10,000	$10,000 to $20,000	$20,000 to $50,000	$50,000 to $100,000	$100,000 to $200,000	$200,000 to $500,000	Over $500,000
Preliminaries	1.5	1.0	0.8	0.6	0.5	0.4	0.3	0.2
Plans and specifications	2.5	2.0	1.8	1.6	1.4	1.2	1.1	1.0
Details	1.0	1.0	0.8	0.6	0.4	0.3	0.2	0.1
*Supervision	1.0	0.5	0.4	0.4	0.3	0.3	0.2	0.2
Superintendence	3.5	3.0	2.5	2.3	2.1	1.9	1.7	1.5
†Alterations	6.0	5.0	4.5	4.0	3.4	3.2	3.2	3.0
Everything, including superintendence and alterations	9.5	7.5	6.5	5.5	4.8	4.2	3.6	3.0

*Supervision is to be omitted when superintendence is charged for.

†The percentages noted in the case of alterations are to be computed on the value of the work involved in the alteration, not on the cost of the whole work.

When employed on a per diem basis the charges for services should not be less than ten (10) dollars per day for self or representative and expenses.

When in charge of work as superintendent of construction the per diem should not be less than fifteen (15) dollars and expenses.

The several items of payment on the percentage basis become due when the class of service covered by each has been rendered.

All percentages are to be computed on the contract price or actual cost of the work. Pay for supervision or superintendence becomes due on the progress estimates made for contractors, or, if the work is done by day's labor, then on monthly appraisements of the value of the work done.

In submitting plans and specifications the preliminary work, which generally involves the presentation of a satisfactory design, is always presumed to have been done, and pay for preliminaries (except when such work has been undertaken at a salary or on a per diem basis), becomes due on presentation of plans and specifications, even when no actual field work nor the preparation of a preliminary design was necessary.

When work covered by plans and specifications is not carried out, then compensation for preliminaries, plans and specifications is to be computed on the estimated cost of the work.

The schedule rates are intended to cover compensation only for engineering services, i. e., compensation to the engineer for his services and for the services of his engineer assistants. The foregoing schedule rates do not include expenses, such as transportation, the hire of helpers, rod men, chain men, teamsters, living expenses when away from regular place of business, etc. All such expenses incurred by the engineer are a separate and additional charge against the owner.

The schedule rates do not include pay for legal or expert services required of the engineer in charge of work when his services as arbitrator or as expert witness in settlement of controversies, condemnation proceedings, etc., are required in the interest of the owner. For all such service and for every service not strictly included in the items specially enumerated in the schedule, the engineer is entitled to additional pay. Surveys which are not necessarily a part of superintendence, such as location surveys for canals, roads, etc., which precede the staking out of the work for the contractor, are not covered by any of the items in the rate schedule.

Sec. 12. Minimum rates for property subdivision and original townsite surveys, when the tracts to be subdivided do not lie within the corporate limits of cities or towns.

(This being a table of minimum rates; smooth surfaced, practically level, open ground and rectangular work has been made the basis thereof, and charges for subdivision work under less favorable conditions should be greater in proportion to the additional labor involved in field work, office computation and drafting.)

MINIMUM RATES FOR SUBDIVISION SURVEYS.

Area of Lot	Area in Acres of Tract to be Subdivided						
Acres	5 to 10	10 to 20	20 to 50	50 to 100	100 to 200	200 to 500	Over 500
20.0	$.....	$.....	$30.00	$20.00	$15.00	$12.50	$10.00
10.0	......	20.00	15.00	12.50	10.00	8.50	7.50
5.0	15.00	10.00	7.50	6.00	5.00	4.50	4.00
1.0	7.50	5.00	4.00	3.50	3.00	2.50	2.00
0.5	5.00	3.50	3.00	2.50	2.00	1.50	1.25
0.1	1.50	1.25	1.00	0.80	0.60	0.45	0.40

Rates for lots of sizes intermediate between those named in the foregoing schedule are to be ascertained by interpolation.

These rates do not include surveys of exterior boundaries of the tract to be subdivided, nor the cost of stakes or monuments to be set at corners or on base lines, which are to be furnished, marked or painted at owner's expense.

The cost of planning subdivisions is included in the schedule rates, only when the same can be made without reference to topographical features or local conditions requiring a preliminary survey.

The tabulated rates per lot include the preparation of one map and one tracing thereof.

In case of alterations, each such alteration is to be charged for as extra work, provided the alteration is ordered after the subdivision survey has been commenced. When subdivisions of a complicated nature are required, which involves special study of the ground, the establishment of grade or irregular lots, it will generally be advisable to charge for the same on an agreed per diem basis.

Sec. 13. The civil engineer should always charge for professional advice, regulating his charges according to the interests involved, whether his client be a private citizen, a corporation or a municipality.

Sec. 14. For services as an expert, whether before a court or as an arbitrator, special charges are to be made as may be mutually agreed upon by the employer and the engineer in accordance with the value of the service rendered, but in no case should the same, if fixed on a per diem basis, be less than twenty-five dollars per day.

Sec. 15. Consultation with engineers who have made certain branches of professional work a specialty, or who have acquired a pre-eminent standing in the profession, may be requested by the engineer having general charge of any work or may be required by the owner thereof. In either case the employment of the consulting engineer must be satisfactory to both owner and engineer and shall be at the expense of the owner.

No engineer should agree to act as consulting engineer except at the request or with the consent of the engineer in direct charge of the work;

and his reports and advice should be confined to the particular matters with reference to which he has been consulted.

Charges for consultation should be based on the value of the services rendered rather than on time required in arriving at conclusions or opinions.

Sec. 16. No reputable engineer should participate in competitive bidding against his colleagues to secure work at lowest prices; and calls for such competitive bidding should be discouraged.

Sec. 17. Participation by engineers in competitions for the adoption of plans according to merit, or where prizes are offered is always undesirable, and should be considered permissible only when the decision as to merit rests with persons technically educated and competent to pass judgment thereon.

Sec. 18. The owner's interests cannot be conserved when contracts for the construction of any work are let to the same person or firm which has furnished the plans and specifications therefor, and no reputable engineer should be interested in any contract for work to be executed according to plans and specifications furnished by himself.

Sec. 19. The foregoing sections are not intended to apply in case of the employment of assistants or deputies by members of the profession, nor is Section 13 intended to make advice given by any engineer to a colleague at the latter's request, basis for remuneration from the owner, except when the owner consents to have such advice called for; but it would certainly be unprofessional to call for advice from a colleague except after proper provision has been made to pay for the same.

SCHEDULE OF MINIMUM CHARGES AND PROFESSIONAL PRACTICE OF ARCHITECTS AS USUAL AND PROPER.

Adopted by the American Institute of Architects, October 23, 1884.

Adopted by the Western Association, November 14, 1884.

Reaffirmed by the American Institute of Architects, upon the consolidation of the Western Association of Architects, November 20, 1889, and added to, with reference to competitions and charges for preliminary studies, 1894.

For full professional services (including supervision), five per cent upon the cost of the work.

In case of the abandonment of the work, the charge for partial services is as follows:

Preliminary studies, as per table at the foot of schedule; preliminary studies, general drawings and specifications, two and one-half per cent; preliminary studies, general drawings, specifications and details, three and one-half per cent.

For work that costs less than $10,000, or for monumental and decorative work and designs for furniture, a special rate in excess of the above.

For alterations and additions, an additional charge to be made for surveys and measurements.

An additional charge to be made for alterations and additions in contracts and plans, which will be valued in proportion to the additional time and services employed.

Necessary traveling expenses to be paid by the client.

Time spent by the architect in visiting for professional consultation and in the accompanying travel, whether by day or night, will be charged for, whether or not any commission, either for office work or supervising work is given.

The architects's payments are successively due as his work is completed, in the order of the above classifications.

Until an actual estimate is received, the charges are based on the proposed cost of the work, and the payments are received as installments of the entire fee, which is based upon the actual cost.

The architect bases his professional charge upon the entire cost, to the owner of the building, when completed, including all the fixtures necessary to render it fit for occupation, and is entitled to extra compensation for furniture or other articles designed or purchased by the architect.

If any material or work used in the construction of the building be already upon the ground, or come into the possession of the owner without expense to him, the value of said material or work is to be added to the sum actually expended upon the building before the architect's commission is computed.

Supervision of Works.

The supervision or superintendence of an architect (as distinguished from the continuous personal superintendence which may be secured by the employment of a clerk of the works) means such inspection by the architect or his deputy, of a building or other work in process of erection, completion or alteration as he finds necessary to ascertain whether it is being executed in conformity with his designs and specifications or directions, and to enable him to decide when the successive installments or payments provided for in the contract or agreement are due or payable. He is to determine in constructive emergencies, to order necessary changes, and to define the true intent and meanings of the drawings and specifications, and he has authority to stop the progress of the work and order its removal when not in accordance with them.

Clerk of the Works.

On buildings where it is deemed necessary to employ a clerk of the works, the remuneration of said clerk is to be paid by the owner or owners, in addition to any commission or fees due to the architect. The selection or dismissal of the clerk of the works is to be subject to the approval of the architect.

Extra Services.

Consultation fees for professional advice are to be paid in proportion to the importance of the questions involved, at the discretion of the architect.

None of the charges above enumerated cover professional or legal services connected with negotiations for site, disputed party walls, right of light, measurement of work or services incidental to arrangements consequent upon the failure of contractors during the performance of the work. When such services become necessary, they shall be charged for according to the time and trouble involved.

Drawings and Specifications.

Drawings and specifications as instruments of service are the property of the architect.

Appointment of an Architect.

The American Institute of Architects is of the opinion that a better result is always obtained by the direct appointment of an architect for any given work than by the selection of an architect by the process of competition.

Soliciting Patronage.

The attempt to secure work by offering to prepare sketches or preliminary drawings, or to render full professional services at a less rate of compensation than another architect, is unprofessional conduct.

Competitions.

The charge for competition drawings is the same as for preliminary studies. All competitions should be conducted in accordance with the code governing competitions adopted by the A. I. A.

Table of Charges for Preliminary Studies.

Minimum Charge, $50.00.

For work to cost from

$ 5,000 to $50,000, 1% on proposed cost.

50,000	and	under	$ 75,000	$ 559.00
75,000	"	"	100,000	684.60
100,000	"	"	150,000	790.50
150,000	"	"	200,000	968.10
200,000	"	"	250,000	1,118.00
250,000	"	"	300,000	1,250.00
300,000	"	"	350,000	1,369.00
350,000	"	"	400,000	1,479.00
400,000	"	"	450,000	1,581.00
450,000	"	"	500,000	1,677.00
500,000	"	"	600,000	1,767.70
600,000	"	"	700,000	1,936.20
700,000	"	"	800,000	2,091.50
800,000	"	"	900,000	2,236.00
900,000	"	"	1,000,000	2,371.50
1,000,000	"	"	1,250,000	2,500.00
1,250,000	"	"	1,500,000	2,895.00
1,500,000	"	"	1,750,000	3,061.70
1,750,000	"	"	2,000,000	3,307.00
2,000,000	"	"	2,500,000	3,536.00
2,500,000	"	"	3,000,000	3,952.70
3,000,000	"	"	4,000,000	4,330.00
4,000,000	"	"	5,000,000	5,000.00

NOTE.—The ratio is equal to 2½ times the square root of the lowest cost.

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GRAND PRIZE

Award Ribbon

ALASKA-
YUKON-
PACIFIC
EXPOSITION

SEATTLE
1909