

heater, which is placed in the interior of an iron plate cylinder, *m*, is in contact with the flames of burners, *n*.

The hot water flows to the carbureter through the pipe, *J*, while the pipe, *J*, leads cold water to the heater. A constant circulation is thus set up. The burners, *n*, receive gas from the reservoir, *C*, through the pipes, *n'* and *n''*, which are connected by the regulator, *E*.

The Temperature Regulator.—The object of this is to regulate the entrance of the gas into the burners, *n*, so that when the water in the receiver, *C*, has reached its normal temperature of 14° or 15°, the burners shall go out of themselves. As soon as the temperature drops in *C*, the regulator allows the gas to pass again, and the burners are relighted by a small burner with a low flame placed near them.

This regulator is provided with a copper tube, *O*, which is filled with glycerine, and enters the water in *C*.

From this new arrangement of the various parts there results an absolutely automatic apparatus. In fact, the gas engine, through the intermedium of the air pump, furnishes the air that is converted into gas. A portion of the gas formed, being sent to the motor through the pipe, *p*, and pocket, *P*, serves to actuate the engine; so that the latter produces gas in the carbureter, and the carbureter actuates the motor through the intermedium of this same gas.

Carbureted air gas gives an agreeable, white light, which does not fatigue the eyes. It is perfectly pure, being free from those sulphurous and ammoniacal products that render coal gas so injurious to the respiratory organs, and that spoil paintings, gildings, etc.—*Annales Industrielles*.

THE POSOMETRICAL DROP-COUNTER.

ALL those who have had to make chemical analyses or prepare pharmaceutical products well know how difficult it is to accurately measure the number of drops of a liquid that it is desired to add to another one, in small quantity, in a precise and definite proportion. Mr. Alfred Jannin, a pharmacist of Chalon-sur-Saône, has devised a very practical drop-counting bottle, which we think is deserving of a description.

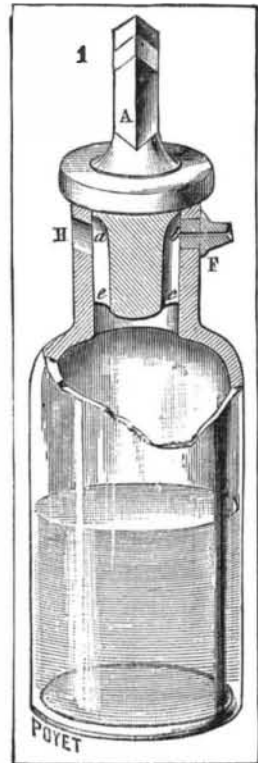


FIG. 1.—JANNIN'S DROP-COUNTER.

The liquid, finding an exit through the aperture in the nozzle, falls drop by drop by virtue of its own weight, and air enters the bottle through the aperture, *H*, in measure as the dropping proceeds.

If we turn the stopper (which may be compared to a quarter-circle cock-plug), the grooves no longer being in communication with the apertures, the bottle will be hermetically closed. We would call attention to the form of the nozzle, which contains an aperture 6 mm. in length, that communicates with a very divergent cone. It is this latter that constitutes the principal part of the instrument, since it has a great influence upon the regularity with which the liquid flows.

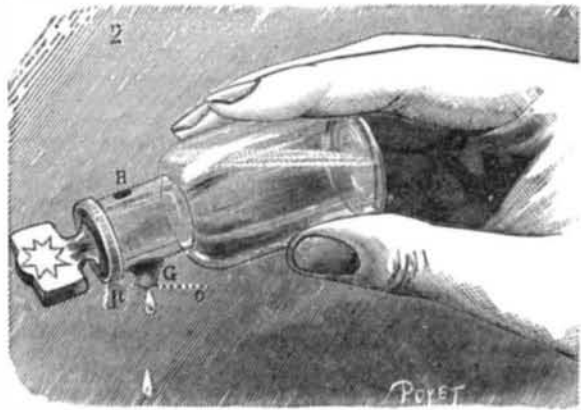


FIG. 2.—METHOD OF USING THE DROP-COUNTER.

As the entire conical surface is immediately wet, every drop has exactly the same weight as the first, and the drops detach themselves better, and never run over the external edges, as they do in most of the drop-counters that have hitherto been constructed.

The nozzle may be changed, as there are four different models of it that answer to the various requirements of therapeutical preparations. There is one for distilled water and aqueous solutions, one for Fowler's solution, one for laudanum, and one for

tinctures or alcoholic preparations. Mr. Jannin has had to greatly modify the nozzle.

The cone, which may be called a cone of adherence, must vary in diameter in wide proportions. While the extremity of the cone of the nozzle must have a diameter of 3.2 mm. to give drops of distilled water of the weight of 5 centigrammes, it must have one of 3.7 mm. for Fowler's solution, one of 4.1 mm. for laudanum, and one of 7.9 for tinctures.

As the rate of flow is proportional to the internal diameter of the tube through which the liquid comes, the inventor has had to make the aperture 6 mm. in diameter, so as to give nearly sixty drops per minute. Under such circumstances, the drops come neither slowly nor rapidly, and the eye can follow and easily count them.

This process of dropping is very accurate, almost mathematically so, for the weight of the drops does not vary by one five-hundredth. Mr. Jannin calls his bottle a *posometrical* (size-measuring) drop-counter.—*La Nature*.

NEW APPARATUS FOR THE ESTIMATION OF CARBONIC ACID IN THE AIR.

By THOMAS C. VAN NUYS.

FROM results of the estimation of carbonic acid in the air since Pettenkoffer* published his method, it is evident that either the amount of carbonic acid in the air varies greatly at different times or the methods employed are defective. Later investigations tend to prove that the methods are not reliable, the estimations being too high. Truchot's† maximum quantity found in forty-nine estimations made during fine weather was 4.2 volumes in 10,000 volumes of air, and where the ground was covered with snow his maximum quantity was 8.7 volumes. H. and A. Schlaginweit‡ found from 3.2 to 5.8 volumes in 10,000 volumes of air, according to altitude. Mene§ found 7 volumes in 10,000 volumes of air. On the contrary, G. F. Armstrong|| claims that the quantity of carbonic acid in the air does not exceed 3.5 volumes in 10,000 volumes of the air, and J. Reiset's¶ maximum quantity in ninety-one estimations was 3.415 volumes in 10,000 volumes of air, the average number of volumes being 2.978. Generally considered, the methods for the estimation of carbonic acid in the air, whether by passing air through tubes containing a solution of barium hydrate or by shaking up a definite quantity of a standardized solution of barium hydrate with a measured quantity of air, do not provide sufficiently for preventing contact of the external air containing CO₂ with the Ba(OH)₂ when titrated with oxalic acid or when filtered and washed.

By the apparatus illustrated by the figure, it is intended to overcome this difficulty. The capacity of the apparatus, A, ascertained by having determined its weight when empty and dry, and its weight when filled with distilled water at 4° C., is 6,177 c. c. The diameter of the mouth, *a*, of the apparatus is from 22.5 to 25 mm. The inside diameter of the end, *b*, of the apparatus is 65 mm. This drawn out, part of the apparatus is provided with a glass stop-cock, *c*. The stopper, *d*, fits in the mouth of the apparatus by a ground surface so as to be perfectly air-tight. A hole 4.5 mm. in diameter passes through the stopper, closed above by the rubber tube, and below the stopper is drawn out so as to form a tube which is bent and is connected to a piece of glass tubing by means of a rubber tube. The attached piece of tubing is bent upward and drawn out so its orifice is 4 mm. in transverse diameter and 1.5 mm. perpendicular diameter.

When the stopper is in place, with a small quantity of grease it can be readily turned with the thumb and one finger. The capacity of the flask, B, is 400 c. c., and it is provided with a rubber stopper having three holes. Through one of these holes passes the bent glass tube, *e*, which is connected with the apparatus; through another hole the tip or dropper of the burette; and through the third hole the bent end of the chlor-calcium tube, *f*. This tube is filled with pieces of pumice saturated with a strong solution of natr. hydrate. In estimating the carbonic acid in the air with this apparatus, I use a solution of oxalic acid standardized according to Pettenkoffer,** and a solution of barium hyd. of one-half the strength of that of Pettenkoffer, thereby avoiding an excess of barium oxalate, which makes the disappearance of the red color of the rosolic acid more obscure. 2.8636 grammes pure oxalic acid which has neither effloresced nor deliquesced are dissolved in 1,000 c. c. distilled water. 1 c. c. of this solution has the same saturating power as 1 milligramme CO₂. About 3.5 grammes pure barium hydr. and 0.5 gramme barium chlor. are dissolved in 1,000 c. c. water. If the solution is not clear, it should be filtered. The solution should be kept in an aspirator bottle, the stopper of which is connected with a large chlor-calcium tube having its end bent, and the tube filled with pieces of pumice saturated with a strong solution of natr. hydrate. In titrating the Ba hydr. solution with the solution of oxalic acid, contact with the external air is avoided by employing Pettenkoffer's†† method in filling a pipette. The flask, B, may be employed in this titration. Two or three drops of an alcohol solution of rosolic acid are introduced into it, the rubber tube, *g*, is removed from the end of the apparatus and is connected with a wash-bottle containing a solution of natr. hydrate, and a U shaped tube containing soda-lime. The end of the chlor-calcium tube, *f*, is connected with an aspirator bottle filled with water, and air is drawn through the apparatus until the flask is filled with air free of CO₂. The end of the rubber tube, *g*, is taken between the thumb and finger and carefully disconnected, and placed over the tip or dropper of a 50 c. c. pipette containing the Ba solution, and when the solution has run into the flask, the end of the tube is removed from the pipette, with the precaution that no outside air enter the tube. It is fitted over the mouth-piece of a wash-

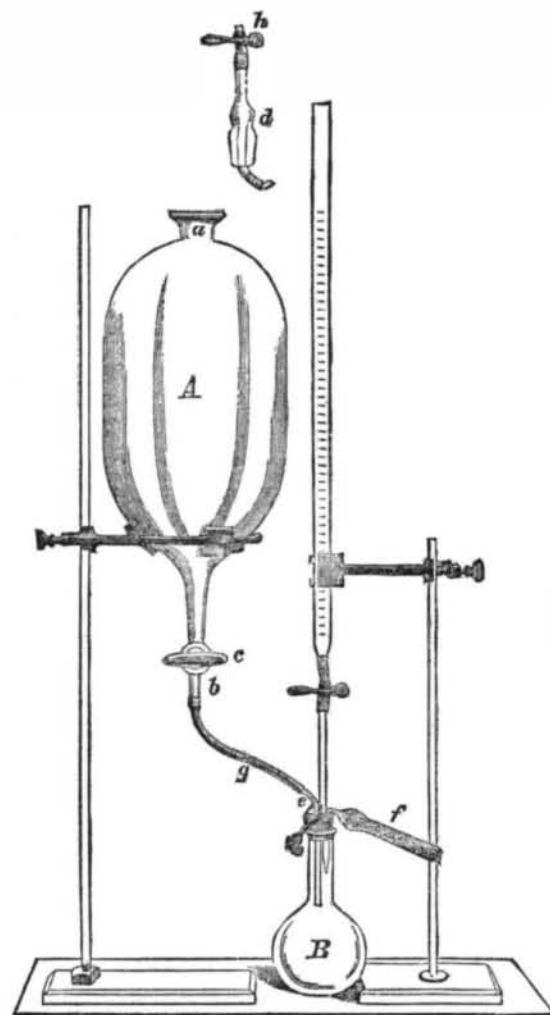
bottle filled with water.* About 100 c. c. water is passed into the flask through the rubber tube, when it is secured by the pinch-cock. The oxalic acid solution is added until the red color disappears. Titrations should be repeated until an agreement is reached. As the oxalic acid solution is liable to change, titrations should be made every two or three days to avoid the uncertainty of results owing to decomposition of the acid in solution.

The stopper, *d*, is prepared for use by filling the canal passing through its entire length with water, as a pipette is filled when the rubber tube is secured by the pinch-cock. The ground surface of the stopper is then rubbed with grease.

The inside surface of the apparatus, A, is dried, either by washing with absolute alcohol and ether, and let remain open in a warm place until dry, or by attaching the tube, *b*, to a foot bellows by means of a rubber tube, and pumping air into it until dry. In this way the apparatus is filled with the air, the CO₂ of which it is intended to estimate.

The flask, B, is dried, and into it are put two or three drops of an alcohol solution of rosolic acid. Air is introduced into it, having its carbonic acid separated as before, when the rubber tube, *g*, is secured by the pinch-cock.

The apparatus having been filled with the air, the carbonic acid of which it is intended to estimate, a thermometer is suspended in the apparatus and let remain thirty minutes, so the temperature may become constant, when the temperature and barometric pressure are noted. Fifty c. c. of the barium solution are



NEW APPARATUS FOR ESTIMATING CARBONIC ACID.

introduced into the apparatus, A, the glass stop-cock having been closed. The stopper is put in place and secured by means of a rubber band. The apparatus, A, is turned on its side, placed on a table, and by frequent turning the inside surface is kept wet with the solution, and after the lapse of two hours all of the carbonic acid will have been absorbed. The lower end, of the apparatus is raised a short distance from the table, and the tube, *b*, is filled with water from the glass stop-cock to the end. The apparatus is returned to its place on the stand, the water remains in the tube, and the end of the rubber tube, *g*, which is attached to the glass tube, *e*, is filled with water from the part of tube secured by the pinch-cock to the end and fitted over the tube, *b*, carefully excluding any air. The pinch-cock is removed to its place, as shown in the figure, and the glass stop-cock is carefully turned. If the air in the apparatus is under less pressure than the outside air, bubbles will pass through the barium solution into the apparatus, in which case the stop-cock should be turned so that the air may pass into the apparatus slowly, and all the carbonic acid of the air be absorbed as it comes in contact with the natr. hydrate solution in the chlor-calcium tube. In a short time all of the barium hydrate solution will have passed into the flask. The rubber band or cord which secured the stopper in place is removed. An aspirator bottle containing water is placed one meter above the apparatus, and by means of a rubber tube 6 mm. internal diameter, connection is made between it and the rubber tube, *h*, attached to the stopper and secured by the pinch-cock. The rubber tubing making this connection should be filled with water to the exclusion of any air. As the pinch-cock is removed from the rubber tube at the stopper, the water will flow into the apparatus and is thrown against its surface. By means of the thumb and finger the stopper is turned slowly, so every part of the surface is washed. If the rubber tube should become twisted, it can be prevented from turning with the other hand, provided the tube does not fit too tight. By careful washing, not more than

* Every case in which water is used which will subsequently come in contact with the Ba solution, distilled water having been boiled is employed.

* Sitzungsberichte der k. bayerischen Acad. d. Wissenschaft, 1860, 291.

† Ann. agronomiques, 1877, 69.

‡ Pogg. Annalen 76, 442.

§ Ann. de la société des sciences industrielles de Lyon, Nos. 1-3, in Rep. Chim. App. iv., 473.

|| Proceedings Royal Society, 30, 343.

¶ Comptes Rendus, 90, 1,144.

** Annalen der Chemie, Suppl. Band 2, 25.

†† Mohr's Titrimethode, Vierte Auf., 140.

250 c. c. water will be required, which was determined by introducing 2 c. c. strong hydrochloric acid and 40 c. c. water, and washing until the acid disappears from the wash-water. The rubber tube, *g*, is secured by the pinch-cock, and the end is removed from the tube, *b*. The bent tube, *e*, is drawn up so its end comes within 3 cm. of the stopper, and the long tip of the burette is carefully pushed further into the flask, and the barium hydrate is titrated by letting 20.5 c. c. of the oxalic acid solution run in from the burette at once, and after gently shaking, one or two drops are added, and so on until the red color disappears. The data of one estimation are here given:

50 c. c. of the barium hydr. = 24.5 c. c. of the oxalic acid sol. Temperature, 4° C. Barometric pressure, 743.5 mm.

Capacity of apparatus..... 6,177 c. c.
Deduct 50 c. c. volumes Ba solution.. 50
6,127 c. c.

This volume, when subjected to normal pressure, would be $\frac{6127 \cdot 743.5}{760} = 5993.9$ c. c., and when reduced from

4° C. to zero would be $\frac{273 \cdot 5993.9}{277} = 5907.3$ c. c. It

required 21.1 c. c. oxalic acid solution, hence 3.4 milligrammes CO₂ (the equivalent of 3.4 c. c. oxalic acid solution) found in 5907.3 c. c. air at zero and 760 mm. pressure; 1 milligramme CO₂ at zero and normal pressure measures 0.5084 c. c., hence $3.4 \times 0.5084 = 1.72869$ c. c. CO₂ found. To find the number of volumes of CO₂ in 10,000 volumes air, we have the following equation:

$$5907.3 : 1.72869 :: 10,000 : x.$$

$$x = \frac{1.72869}{5907.3} = 2.926 \text{ volumes in 10,000 volumes air.}$$

Estimations of carbonic acid in the air have been made in this laboratory several weeks under my direction, by Mr. B. F. Adams, who found that the principal source of error is the difficulty of ascertaining the correct temperature. If the apparatus is placed where it is thinly shaded, the temperature will vary ten or fifteen degrees C. in thirty minutes, according as the rays of the sun pass through the apparatus or as reflecting bodies are warmed. Even the temperature varies in different parts of the apparatus. When estimations are made, the temperature being below the freezing-point, and the barium solution is run into the apparatus, which necessarily has a temperature above the freezing-point, the air in the apparatus is warmed unequally. The difficulty is not removed by waiting until the fluid freezes, for during this time some air free of CO₂ may pass out of the apparatus by diffusion, and a false result be reached. With this apparatus, exercising the greatest care in determining the temperature and the atmospheric pressure, we have found that the quantity of CO₂ in the air is subject to slight variation at different times, but at present the number of estimations made is not sufficient to establish the maximum and minimum quantities during night and day, and during different seasons.

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—*American Chemical Journal*, vol. viii., No. 3.

[NATURE.]

PROFESSOR NEWCOMB'S DETERMINATION OF THE VELOCITY OF LIGHT.*

THE method selected for the important experiments described in the present memoir† is that known as Foucault's. The idea fundamental to it is that of the determination of the interval occupied by light in flashing from a revolving to a fixed mirror and back, by the amount of deviation produced in its return path through the change meantime effected in the position of the revolving mirror. The angle of deviation of the ray is double the angle of displacement of the reflector; to this angle corresponds (since the mirror rotates at a known rate) a definite fraction of a second, which is the time of luminous transmission across twice the measured distance between the mirrors.

But this theoretically simple means of ascertaining the velocity of light is complicated, in practice, with innumerable difficulties. A choice demanding the utmost nicety of judgment must be made between various conflicting conditions; sacrifice in one direction is the price of advantage in another; a balance has to be struck, giving the largest sum-total of facilities with the fewest and least intractable drawbacks. The plan finally decided upon by Prof. Newcomb was the result of much anxious deliberation; we hope to render it, in its main outlines, intelligible to our readers.

A fundamental condition of the problem is to get an image of the light-source absolutely coincident with the light-source itself, so long as the movable mirror is at rest; and this, whatever be the position the mirror is at rest in, provided only that it be such as to permit the rays sent out by it to return, after due triple reflection, to the eye. This requisite is secured by locating the center of curvature of the distant concave mirror in the axis of the revolving plane one. All rays emitted from this point toward the former will return along the same paths; differences of direction due to differing positions of the movable mirror will be eliminated by the return reflection; and there ensues a "stationary image" of the light-source, occupying, when visible at all, an invariable situation.

So far, all the operators by Foucault's method have been unanimous; but in the placing of the lens indispensable for the management and concentration of the light employed, a material distinction obtained between the plan of experiment chosen by Prof. Newcomb and that pursued by Prof. Michelson in his similar investigation at the Naval Academy in 1879 (see *Nature*, vol. xxi., pp. 94, 120). Fig. 1 represents in principle the arrangement adopted by the former,

which was also that used by Foucault. In it the lens, *L*, is placed between the light-source, *S*, and the revolving mirror, *A*. Fig. 2 shows the disposition preferred by Michelson, in which the lens is interposed between the revolving and fixed mirrors. In both equally, *S* and *M* are, and for the purpose in view necessarily must be, in conjugate foci of the lens.

A disadvantage of the first form is that the measurement of any considerable deviations will be attended by uncertainties caused by the oblique passage through the lens of the return beams. It was, however, obviated in the experiments under consideration by the use of two lenses, one for the outgoing, the other for the incoming, rays. The second method (Michelson's) promises increased brilliancy of the image, which may, nevertheless, be regarded as outweighed by atmospheric and other impediments to its distinctness, as well as by the illumination of the field of view produced by the passage through it of some part of the lens with every revolution of the mirror. The method exemplified in Fig. 1 was then chosen by Prof. New-

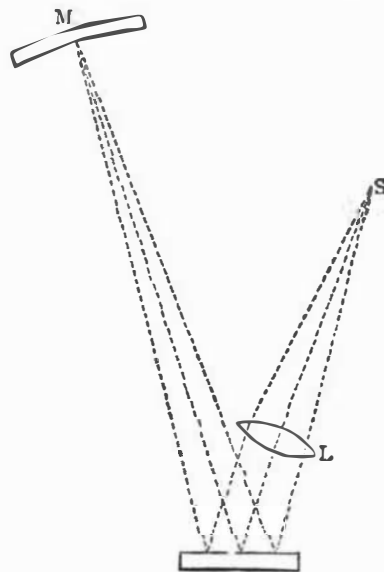


Fig. 1.

comb as affording more or less calculable conditions; while No. 2 involved all the uncertainties of definition habitually besetting astronomical observations.

Let us now endeavor to realize the nature of the experimenter's immediate task. The precise measurement of an angle actually constitutes it. From the mirror, *A*, so long as it remains at rest, an image is reflected in a certain direction; but no sooner is *A* set rapidly rotating, than the same image is reflected in a slightly different direction. The amount of this difference—in other words, the angle of deviation—is the object to be ascertained.

Obviously, the first desideratum is to render the inevitable error of measurement comparatively small, by making the quantity to be measured large. Two roads are open toward this end. A high velocity can be given to the mirror, *A*, or a great distance can be interposed between *A* and *M*. By the first means, the angle rotated through in a given time will be augmented; by the second, the time available for the displacement of the reflector will be prolonged by the lengthening of the journey imposed upon the rays to be reflected. The difficulties hampering increased speed are purely mechanical, though none the less formidable; those in the way of a lengthened path are optical.

The preservation of light enough to keep the image

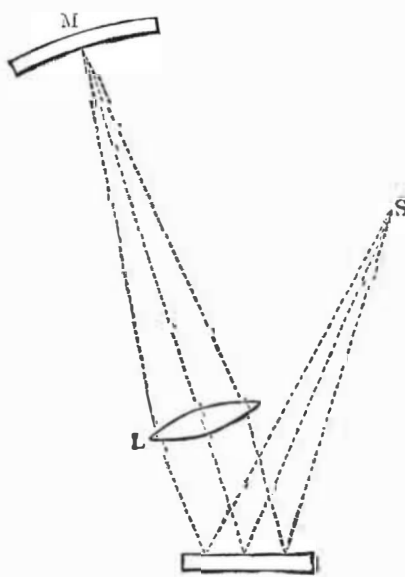


Fig. 2.

bright and distinct is of paramount necessity for the avoidance of ruinous uncertainties in its measurement. Now, in Foucault's experiments, the object affording the image was the line of a reticule. It was dark upon a bright ground—a platinum wire relieved against a sheaf of sunbeams. But no perfectly defined image of such an object could be formed at any considerable distance; and we find accordingly that the utmost length by which he ventured to separate his mirrors was twenty meters. His entire apparatus was, in fact, contained in a single room. Hence, notwithstanding a speed given to his mirror of from 600 to 800 revolutions per second, the actual linear deflection of the return ray amounted to no more than seven-tenths of a millimeter. Chiefly by employing as his light-source an illuminated slit, the lucent image of which on a dark ground bore the enormous loss of light ensuing from the transportation of the fixed mirror to a distance of close upon 2,000 meters, Michelson was enabled

to augment this deflection some two hundredfold. The resulting velocity for light of 299,910 kilometers per second was proportionately trustworthy, the error of the angular measurement upon which it immediately depended being estimated to be one hundred times less than in Foucault's determination. Prof. Newcomb's improvements carried him still further toward absolute accuracy.

The details of construction of his "phototachometer" were decided on in the summer of 1879, and the instrument was completed by the Messrs. Clark in May, 1880. It consisted essentially of four parts—a sending and a receiving telescope, a revolving and a fixed mirror. Sunlight, thrown from a heliostat through an adjustable vertical slit at the eye-end of the sender, passed down the tube, which was bent at right angles to get it out of the way of the observing telescope, and, after reflection by a plane mirror at the elbow, passed out through the objective toward the revolving mirror. This was formed by a rectangular prism of polished steel, 85 millimeters in height, and with a cross-section of 37.5 square millimeters. The vertical faces constituting the reflecting area were nickel-plated, and proved of a remarkably durable, though not very high, polish. Motion in opposite directions at will was com-

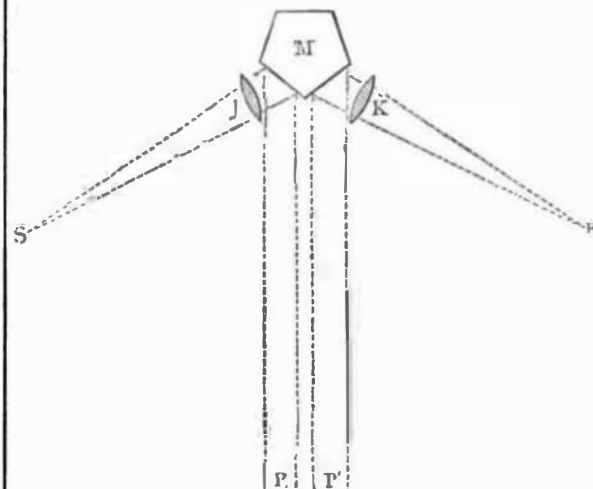


Fig. 3.

municated by two air-turbines, acting one at the top, the other at the bottom, of the mirror, and serving, by a simple contrivance, each for the regulation of the contrary velocity imparted by the other. A wheel-work arrangement, by which an electric current was broken once for every twenty-eight revolutions of the mirror, gave the means of obtaining a chronographic record of its rate of going. Two fixed mirrors, mounted side by side on cast-iron stands, were employed to return the light sent to them by the revolving mirror. Each was about 40 centimeters in diameter, and had a radius of curvature of some 3,000 meters. The object-glass of the receiving telescope was (in the first instance) placed immediately under that of the sender, the former thus directly facing the lower, the latter the upper, section of the movable mirror. The two tubes, however, owing to the "broken" form given, as already mentioned, to that of the sender, made with each other an angle of 90°. Horizontal movement round a vertical axis coincident with that of the rotating mirror was possessed by the observing telescope, to which was attached a pair of microscopes for reading off the divisions on a horizontal divided arc fixed to a stiff frame at its further end. The amount of this horizontal motion of the telescope measured the deviation of the thrice-reflected sunbeam, and, by an immediate deduction, its velocity.

The site chosen for the erection of the apparatus was Fort Myer, on the south side of the Potomac, overlooking the city of Washington. The stationary mirrors, to and from which the carefully guarded rays performed their trips, were placed, to begin with, in the grounds of the Naval Observatory, at a distance of 2,551 meters from Fort Myer, but were in 1881 removed to a point at the base of the Washington Monument, at a distance increased to 3,721 meters. Some tentative experiments were undertaken on June 22, 1880; after a few days' trial, however, it was found that the wheel-work for counting the revolutions of the mirror was destroyed by the rapidity of the impressed movements. New wheels were out almost before a set of readings could be obtained with them; until at length the Messrs. Clark, finding that no metal would stand the inflicted wear and tear, substituted *raw hide* as the material for the first wheel, a device which proved wholly successful. With the instrument thus modified, work was begun on August 9, and continued without interruption until September 20. The transportation of the fixed mirrors to the Monument station in the spring of 1881 postponed the commencement of operations to August 8; and their effective prosecution was then impeded by the discovery of a source of systematic error in a "torsional vibration" of the rotating mirror. That is to say, the steel prism employed to reflect the light, no longer, when its speed attained a certain point, revolved as an absolutely rigid whole, but *tended toward* the possession of different velocities in its different parts. Hence a slight twisting of its mass, producing vibrations round the axis of rotation, the effect of which was visible in the breaking up of the image of the slit into four separate images, one due to each of the faces of the prism. The persistence of this baffling symptom compelled a modification of the instrument, by which the sending and receiving telescopes could be respectively depressed and raised so as to alternate their positions, and the portions of the mirror they were directed toward. The mean of any two complete sets of observations made with the telescopes thus interchanged would be free, as Prof. Newcomb shows, from the effects of any probable form of torsional vibration.

No such effects, however, were apparent in the observations of 1882. This last series extended from July 24 to September 5, and were so nearly free from accidental differences that the probable error of a complete determination was scarcely more, under good conditions, than the ten-thousandth part of the whole.

* "Measures of the Velocity of Light made under the direction of the Secretary of the Navy during the years 1880-82," by Simon Newcomb, Professor, U. S. Navy. Astronomical Papers prepared for the use of the American Ephemeris and Nautical Almanac, vol. ii., parts, iii. and iv. (Washington: Bureau of Navigation, 1885.)

† For the historical notice serving as an introduction to it, see *Nature*, May 13, p. 29.