A REPETITION OF THE TROUTON-NOBLE ETHER DRIFT EXPERIMENT

By Carl T. Chase

Abstract

Experimental reasons are given showing that previous failures of this experiment to detect motion of the earth in the ether have not been conclusive. The experiment has been repeated with apparatus free from the sources of error described and sufficiently sensitive to detect a motion in the ether of 4 km/sec. No such motion was found.

Introduction

If a parallel plate condenser, moving with respect to a stationary ether, is charged, it can be shown[1] that under certain conditions there will exist a couple tending to rotate the condenser. If the condenser is suspended by means of a delicate fiber in such a manner that the plates are in a vertical plane, the couple will be given by the expression

$$K=\tfrac{1}{2}CV^2\beta^2\sin 2\psi \sin^2 Z$$

where C is the capacity of the condenser; V, the potential to which it is charged; β, the ratio of the velocity of the moving condenser to the velocity of light; ψ, the angle between the direction of motion and the plane of the plates; and Z the angle between the direction of motion and the suspending fiber (the zenith distance). The couple is a maximum when $\psi=45°$ and $Z=90°$. Knowing the elastic constants of the fiber, the rotation that will be produced by this couple can easily be computed.

There are some who maintain that the right side of this expression should still be divided by the dielectric constant of the dielectric used in the condenser. The effect of such a factor on the sensitivity of the apparatus will be considered later in connection with the experimental observations.

Discussion of Previous Results

The first attempt to detect this turning of the condenser was made about 1902 by Trouton and Noble,[2] who looked for the effect due to the orbital velocity of the earth combined with the proper motion of the solar system. Their experiment gave what was at that time considered a negative result; there was no effect of the size that they sought. However, in view of the recent more accurate performances of the Michelson-

[1] Fitzgerald & Lorentz, Scientific papers, p. 556.
Lorentz, Proc. Acad. Amst., **6**, 809 (1904).
Laue, Ann. d. Phys., **38**, 370 (1912).
Kennard, Bull. Nat. Res. Council, Dec. 1922.

[2] Trouton and Noble, Proc. Roy. Soc., 1903.

Morley experiment by D. C. Miller[3] and the velocity of 10 km/sec that seems to be measurable, it became desirable to repeat this experiment, using more sensitive apparatus and continuing the observations over longer periods of time, to see just how negative the results of Trouton and Noble really were. They observed merely a few deflections each time the experiment was tried.

The experiment was also performed by Tomaschek[4] in 1925 with apparatus apparently having sufficient sensitivity to detect a motion of 10 km/sec and no motion was observed. However, it has been found that there were serious sources of error in the apparatus that would have produced a negative result in any case. The arrangement consisted essentially of a condenser surrounded by metallic shielding and suspended on a wire of phosphor-bronze, 50 cm long and .0015 cm in diameter. Since two connections are necessary to charge the condenser, a fine wire connected to the bottom of the condenser and dipping into a solution of sulfuric acid served as the second electrical connection. The period of the swinging condenser was 8 minutes, such a large period being caused chiefly by the great mass of shielding that was used. This was at a considerable distance from the axis of the suspension and had a large moment of inertia.

A similar arrangement was set up by the author in order to determine whether the surface tension of the liquid, which was suspected of exerting frictional forces on the submerged wire, would cause any frictional couple comparable in size to the couple that would result from a motion in the ether. A suspended system of condenser and shielding was used having a small moment of inertia and a period of 80 seconds when hung on a phosphor-bronze wire 90 cm long and .0015 cm in diameter. A fine wire attached to the bottom of the condenser dipped 2 mm below the surface of a dilute solution of salt in water. It was found that when the condenser was initially at rest, the top of the suspending wire could be turned through two or three complete revolutions without any resulting motion of the condenser. Clearly, then, there were frictional forces in the liquid surface that would prevent any rotation of the size computed for a velocity in the ether of 10 km/sec (a few degrees at most). By bodily disturbing the condenser, it could be made to oscillate, but only about some position of equilibrium determined by the horizontal forces exerted on the submerged wire by the surface tension, pulling the wire to one side or another depending on the initial adjustment. To remove the condenser from such a position of equilibrium it was always necessary to turn the top of the suspending wire through several revolutions.

[3] D. C. Miller, Science, Apr. 30, 1926.

[4] R. Tomaschek, Ann. d. Phys., **78**, 743, (1925).

The condenser used by Tomaschek was charged by means of a small static machine, the voltage being read on a Braun electrometer. It is difficult to see how the potential could have been kept at all constant with such an arrangement. This would be extremely important, since rotations of the condenser due to electrostatic forces were always present, and could not be accurately allowed for unless the potential was kept constant.

Description of Apparatus

In the present apparatus, the two sources of error described above were eliminated in the following way. The lower connection to the condenser consisted of a duplicate of the upper suspension, each being of phosphor-bronze, 90 cm long and .0015 cm in diameter. The potential was supplied by a generator in series with batteries, was read by means of a voltmeter, and was kept constant to a half of one percent, the limit of accuracy of the calibration of the voltmeter scale. The potential was 600 volts. During the whole time that the condenser was charged, it was continuously connected to the source of potential, thus preventing any change of conditions that would result if the charge leaked away and the potential decreased.

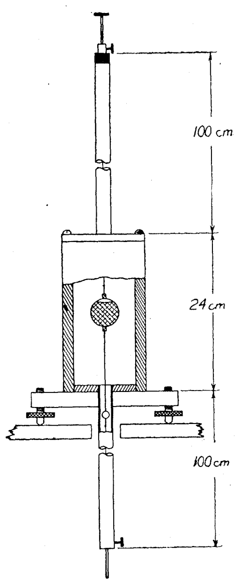

Fig. 1. Diagram of apparatus

The condenser was built up of mica discs $4\times.003$ cm and aluminum discs $2\times.003$ cm provided with connecting tabs 2 mm wide. Sixty such elements were assembled in a press, with connecting tabs brought out on opposite sides; the whole was boiled in paraffin and the condenser allowed to cool under pressure. The thickness was 3 mm, the weight 10 grams, the measured capacity .04 microfarad.

The experimental arrangement is shown in Fig. 1. The condenser is completely enclosed by a steel cylinder 23 cm long, 9 cm inside diameter, with walls $1\frac{1}{2}$ cm thick. Besides serving as an excellent electrostatic shield, the large heat capacity of the steel eliminated all disturbances from convection currents except under such extreme temperature conditions as could easily be avoided. The cylinder was provided with caps of brass 1 cm thick. The suspensions were supported and enclosed by brass tubes 1 m long and 2 cm in diameter. The condenser was closely wrapped with a layer of aluminum foil for an electrostatic shield, the area of the metallic plates being completely covered. The foil coating was connected to the lower terminal of the condenser, a small space being left around the upper terminal. The lower terminal was connected to the case through the lower suspension. A small mirror for observing deflections was fixed to a piece of 16 aluminum wire, one end of wh ich was securely fastened to the lower terminal of the condenser, the other end holding the lower phosphor-bronze wire. In order not to disturb the symmetry around the condenser, the mirror was placed below the steel cylinder in the lower brass tube, and could be seen through a small hole in this tube, the hole being covered by mica to prevent the entrance of air currents. Insulation of the upper suspension was effected by a cylinder of paraffin, and means were provided for adjusting the two suspensions. The period of oscillation of the condenser was 40 seconds, and when set oscillating it would continue for from 20 to 30 minutes.

Thus it will be seen that conditions inside the cylinder were very symmetrical. The metallic covering of the condenser, the mirror, and the case were all at the same potential, the only parts at high potential with respect to the case being the upper suspending wire and the upper terminal of the condenser (and of course the condenser plates, but these were completely covered by the foil coat). The upper brass tube was accurately concentric with the steel cylinder. In this way electrostatic disturbances were reduced to a minimum.

Method of Observation

Observations were made every five minutes for twenty-four consecutive hours in the following manner. The condenser is initially uncharged and swinging. Five consecutive turning points are taken, reading to tenths of millimeters the position of a galvanometer lamp image thrown on a ground glass scale by the mirror attached to the condenser. The scale distance was 2 m. The image was always sharp and accurate readings were easy to make. These five turning points were averaged to obtain a single "resting point." The condenser was then charged, allowed to swing for two or three minutes to overcome any possible shock or effect of a ballistic throw caused by the sudden charging, and five more turning points observed. Care was taken to have observations equally spaced in time so that any drift of the zero position on the scale could be accurately allowed for.

Thus one resting point was obtained for each five minutes during the run, alternately with the condenser charged and uncharged. To obtain the deflections resulting from charging the condenser, any three consecutive resting points were taken, say two for the condenser uncharged and one for the condenser charged. The mean of the two uncharged positions was subtracted from the charged position; thus any zero drift was eliminated. For the next deflection, two charged positions and one uncharged position were used, and so on, obtaining one deflection for each five minutes during the run. The temperature was read once every hour. The total change in temperature was never more than one degree and often much less.

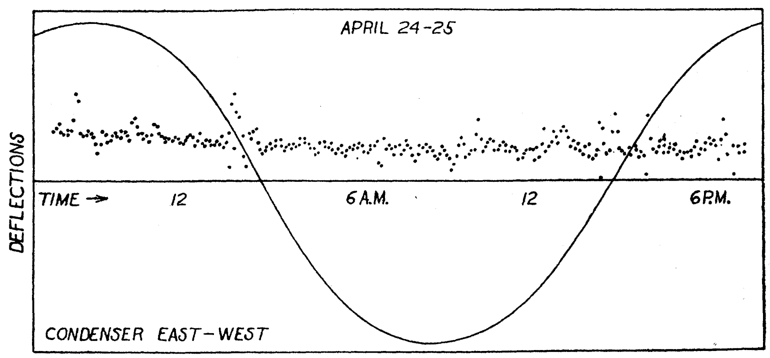

Fig. 2. The points are observed deflections. The solid curve is computed for a velocity of 9 km/sec toward a point whose right ascension is 260° and whose declination is +65°.

Results

The deflections observed during two runs are plotted in Figs. 2 and 3, and for comparison a curve is computed for the velocity that Miller obtains, and is plotted in the same diagrams; the vertical distance from maximum to minimum of this curve corresponds to a deflection of 28 mm. The deflections that are at first apparent are due to electrostatic forces and depend on the initial adjustment of the apparatus (level, etc.) but are constant as long as these adjustments are unchanged. The downward trend of the observed points is due to elastic fatigue in the suspending wires. Lord Kelvin has shown that if a system is suspended on a wire and made to oscillate continuously about the axis of the wire, it becomes increasingly difficult for a given force to produce a given twist in the wire; in other words, the wire becomes stiffer. If the wire is allowed to rest for a time, it regains its original elastic properties. In the present experiment the condenser makes over two thousand oscillations during a single run. The downward trend of the observed points appeared in every curve that was taken, the slope depending on the amplitude of oscillation. In one case where the amplitude was relatively large the slope was about 30°. Changes of slope always occur simultaneously with changes in temperature.

There is no periodic change in the size of the deflections that is the same on any two curves. Sometimes a small maximum will occur at a given time, sometimes a small minimum, and often there will be no sign of either. Such maxima or minima as do occur correspond to a velocity of not more than 2 km/sec, and there is nothing periodic or systematic about such deviations. The mean of several runs is nearly a straight line, with no deviations corresponding to a velocity greater than 1 km/sec. If the size of the deflections must be divided by the dielectric constant

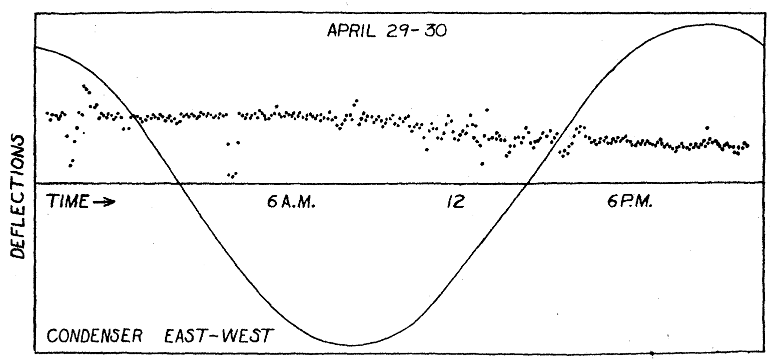

Fig. 3. Same as Fig. 2 but for a different date.

as mentioned in the introduction, the greatest velocity that could remain undetected in any one run of twenty-four hours would be 5.5 km/sec, and in the mean of several runs, 4 km/sec.

Conclusion

Thus the experiment has been repeated with the elimination of sources of error that have previously prevailed, and under more controllable conditions than have heretofore been obtained. The apparatus could detect a motion relative to the ether of 4 km/sec and no evidence of such a motion is found.

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