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About 25 years ago, as I was using a reflecting galvanometer by White of Glasgow, I noticed that when sunlight fell on its mirror a small deflection occurred without the flow of electric current. I found that this happened because the mirror was fastened to one of the groups of magnets of the suspension instead of lying between the coils as is now more usual. The system was in fact slightly twisted by the warmth of the sun ray. It occurred to me that if an astatic suspended system was purposely designed to be deformed by radiation, perhaps it might give large deflections with feeble rays. I constructed such an instrument about March, 1908, and tested it a few months later in the presence of Doctor Hale and Doctor Adams on Mount Wilson. It did indeed show high sensitiveness to radiation impulses but had too large a moment of inertia and a very long period of swing. I never used it for serious work.

In June, 1932, being again on Mount Wilson, and in need of a quick-acting radiation-measuring instrument of the highest sensibility, beyond what I could hope to get with the bolometer or even the radiometer, my thought recurred to this old instrument. It occurred to me that the two groups of magnets of the astatic system could be supported upon a stem made of two close curls of thin metallic ribbon, the two curls being of opposite senses to avoid distortion of the parallelism of the upper and lower magnet groups due to changes of surrounding temperature. I believed that when radiation should fall on one only of the two curls, the parallelism would be distorted and a tendency to rotate the system through 90° would ensue. Doctor Anderson, who encouraged me in this idea, suggested the obvious advantage of making the two curls of bimetallic strips. I constructed such an instrument, and found it to exceed my expectations as regards sensitiveness and satisfactory behavior.

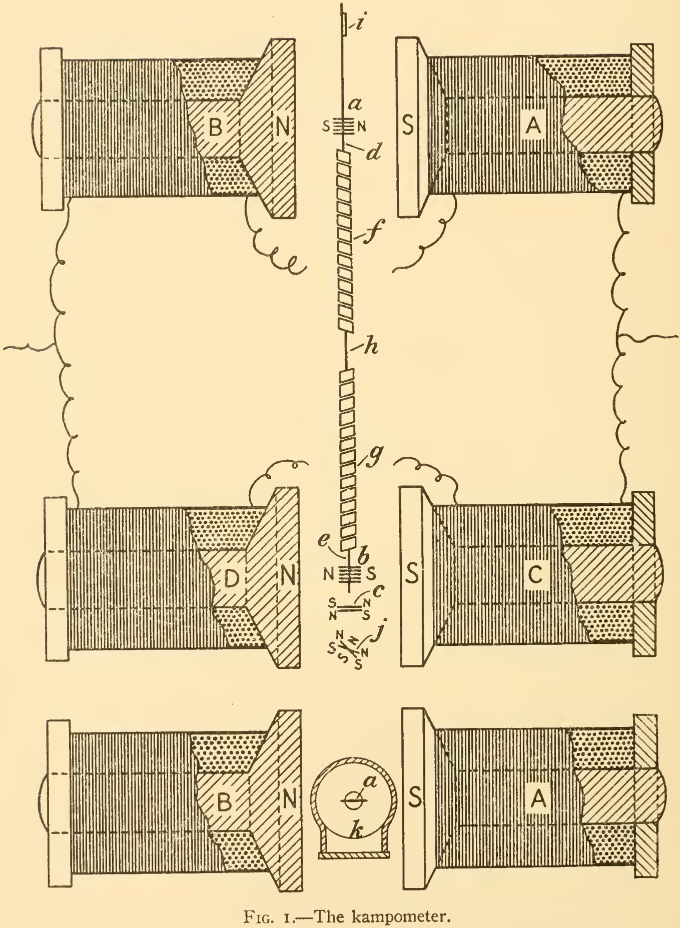

Fig. 1.—The kampometer.

The figure shows the principal features of the kampometer[1] in diagrammatic fashion. The two equal groups of suspended magnets, *a, b,* of opposite polarity, are fastened so to be as nearly as possible in parallel vertical planes, as indicated just below the suspension at *c,* where one is supposed to be viewing them nearly from above, but neglecting the curled stem which connects them. Each group is cemented to a short, thin, vertical rod of glass, *d, e,* and these two rods in turn are cemented to the ends of the bimetallic curled strips, *f, g,* of opposite curvature. The two curled bimetallic strips are connected by a third short, thin rod of glass, *h,* so that the whole forms a suspension similar to that of an astatic reflecting galvanometer. A small mirror, *i,* is affixed to the glass rod, *a,* in the usual way to indicate deflections of the system.

The suspended system hangs within a vacuum tube having a side window, as indicated in the plan view at *k.* On either side of the evacuated tube are electromagnets *A, B, C, D,* adapted as will be explained below to produce any desired degree of astatic sensibility.

Under the influence of a beam of radiation falling on the curl, *f,* the magnet groups, before parallel, are rotated with respect to one another. This changes the effective polarity of the system as indicated at *j.* Consequently the system tends to turn through 90° so that the new polarity may coincide with the direction of the magnetic field. Being opposed by the torsion of the quartz fiber and by inequalities of magnetization of the two fields the system actually takes up some such position as shown at *j.*

I find it more convenient to use electromagnets rather than permanent magnets to control the astatic condition of the system. It is necessary to change the relative strengths of the upper and lower fields, and also to rotate these two fields with reference to each other, in order to raise the astatic condition of the system to any desired degree. It is very easy with electromagnets to make relative alterations of the two fields in large or small steps by resistance-box changes. Both fields, of course, are operated in parallel from a common storage battery, and changes in the distribution of the current are produced by operating resistances in shunt circuits. In order to produce the relative rotation of fields which is required, quick and slow adjustments of the azimuth of the pair of magnets, *C, D,* are provided by means of tangent screws and a clamped tangent arm in the usual way. This rotation requires very fine adjustment to secure high sensibility.

[1] From the Greek words καμπή, a bend, and μετρέω, to measure.

In my first-constructed kampometer, I rolled a bimetallic strip, composed of brass and invar in about equal thicknesses, until the total thickness was reduced to 0.008 millimeter. I cut the strip as well as I could with scissors to a width of about 0.8 millimeter. I wound from it a pair of close spirals of opposite curvature, each of about 0.7 millimeter diameter. In each spiral there were 14 complete turns, with brass on the outside. Before cementing them to the glass rods, as described above, each spiral or curl was painted with lamp-black in alcohol and shellac suspension. The total weight of the suspension, including mirror, glass rods, and bimetallic curls, was approximately 4 milligrams.

The suspension was mounted, as stated above, in a glass tube. A ground-glass cone joint at the top enabled one to rotate the system with respect to the magnetic field. Opposite the upper bimetallic curl was a window of potassium iodide, a substance highly transparent to rays of great wave length. The glass work was very kindly blown for me by Doctor Smith of Mount Wilson Observatory, and the potassium iodide for the window was kindly given me by Doctor Strong of the California Institute of Technology. I found great difficulty at first in sealing the window onto the glass, because potassium iodide fractures so easily under the strain of slight inequalities of temperature. Tight sealing was at length secured by using " Arrowhead Cement," a quick-drying water-impervious cement manufactured by the Webb Products Company in San Bernardino, Calif.

With my colleague, L. B. Aldrich, I mounted the kampometer in the Smithsonian laboratory on Mount Wilson in direct connection through stop cocks and drying tubes with a mercury-vapor pump. We used it at a pressure of 0.003 millimeter of mercury.

Owing to the crude construction of the suspended system it was impossible to get it perfectly straight. Thus its moment of inertia was much greater than necessary. Moreover, because one of its metals, invar, was magnetic, the slightly crooked system gave in effect still another pair of suspended magnets besides the two principal groups in the control fields. Accordingly there was more than one position of equilibrium. At highly sensitive adjustments when illuminated by too strong a beam of radiation, the system would easily reverse itself and remain so.

Nevertheless, despite these drawbacks due to the crudeness of the construction, the kampometer proved highly sensitive. On August 11, 1932, with a time of single swing only $\frac{5}{8}$ of one second, a candle at 1 meter produced a deflection of 116 millimeters on a scale at 1.2

meters. As the damping was very slight, the sensitiveness was almost exactly proportional to the square of the time of single swing up to 2.0 seconds, which was the maximum we employed last autumn. Probably this proportionality would have held closely to much higher times of swing.

We are now proposing to construct a kampometer of molybdenum plated with cadmium. This combination gives about $1\frac{1}{3}$ times as great temperature-bending tendency as brass-invar, and is nearly nonmagnetic. We shall try different thicknesses of cadmium on molybdenum of 0.005 millimeter thickness until we find the best proportions. We shall use refined methods to give a perfectly straight and balanced stem, and shall use the best modern magnet steel for the magnet groups. This steel we believe will be not only of higher magnetic susceptibility, but also will be more resistive to demagnetization than that which we used last autumn. Thus we expect to be able to use stronger controlling fields without reversing the magnetization of the weaker of the two suspended magnet groups. In all these ways we expect to increase the sensitiveness for a given time of swing, and we expect to be able to control the system at 5 seconds single swing. If so, we believe we may reach 1,000 times the sensitiveness which we actually observed on August 11, 1932, with the first crude kampometer.

It will be noted that the kampometer has an advantage over both the bolometer and thermopile, in that there is no appreciable escape of heat from its sensitive part by metallic conduction. It has also an advantage over the radiometer in that there is no appreciable escape of heat by convection. Cooling only by radiation, it tends to assume a higher temperature under illumination by a beam of radiant energy than any of its three competitors. It lacks, of course, the capacity to be inclined to any angle with the vertical, which is an advantage of the bolometer and thermopile. With more robustly constructed kampometers the quartz fiber might perhaps be replaced by a jewelled bearing, and freedom for inclination to the vertical thus secured. Various forms of the instrument will perhaps suggest themselves to investigators. Anyone is at liberty to construct them as he pleases, and I hope the kampometer may have a useful future.