

A SENSITIVE THERMOPILE.

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AMONG the various types of thermopiles for use in the study of spectral distributions and radiation in general, the Rubens thermopile, consisting of junctions of fine iron and constantin wire seems to be the most efficient. The line thermopile described by Rubens¹ consisted of twenty junctions of constantin and iron each 0.5 mm. in width and formed a line of 20 mm. in length. The thermo-electromotive force per junction as given by Rubens is 53×10^{-6} volts per degree difference of temperature between the hot and cold junctions, thus giving a total of 1.06×10^{-3} volts per degree difference of temperature between the twenty hot and twenty cold junctions. The resistance of the thermopile was 3.5 ohms.

Rubens using a galvanometer of 2.77×10^{-10} amperes, and a resistance of 5 ohms would have obtained a deflection of about 0.5 mm. for a difference of temperature of one millionth of a degree. No data were given for the sensibility of the thermopile-galvanometer combination in terms of a "candle at a distance of a meter" from the thermopile.

Rubens however does not claim for his thermopile an absolute sensibility equal to that of the bolometer. It has been the desire of the writer to construct a thermopile of an absolute sensibility equal to that of the best bolometer of equal area upon which to receive radiation, and hence possessing a much higher effective sensibility, effective in the sense that a bolometer and thermopile of equal absolute sensibility, the thermopile is the more steady. The bolometer, while a very efficient instrument in itself possesses a very serious drawback and difficulty attending its use, namely battery drift and unsteadiness.

The bolometer and thermopile are alike in that they are ex-

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tremely susceptible to minute changes in surrounding temperature unless properly encased. The thermopile as a rule possesses a difficulty which is foreign to the bolometer. The thermopile does not respond so quickly to thermal charges or return to its initial zero position as rapidly as does the bolometer, owing to its larger thermal capacity. Hence in constructing a thermopile, two things must be borne in mind—first it must possess a high sensibility, and second it must have a very small thermal capacity.

In order to attain the first it is necessary to obtain metals or alloys which possess high thermo-electromotive forces, and at the same time have comparatively low thermal capacity. It is likewise necessary that the metals or alloys be not too brittle, so that it becomes an unmanageable task to handle them.

The writer was referred to the work of Hutchins,¹ which gives a description of alloys of bismuth and tin and bismuth and antimony. The alloy of bismuth and tin contained approximately 5 per cent. tin, and the alloy of bismuth and antimony contained approximately 3 per cent. antimony. A single pair of junctions of these alloys gave a thermo-electromotive force of 120×10^{-6} volts per degree difference of temperature over a wide range of average temperatures, *i. e.*, between the hot and cold junctions.

In order to prepare the alloys for use, they were melted and while in a liquid state pressed between two pieces of plate glass. This method of preparation gave them a smooth surface and almost any thickness desired could thus be obtained. Sheets of these alloys were selected which had a thickness of about 0.25 mm. They were then cut into bars about 2.5 mm. long and 0.5 mm. wide. The most convenient and economical method of procedure was to rule lines on the sheets of alloy with a knife, and then by a further use of the knife the bars could be readily cut.

The bars were then mounted on a piece of ivory about 22 mm. long and of slightly less width than the length of the bars of alloy. The mounting was so done that the cold junctions came on one edge of the ivory piece and the hot junctions on the other edge. The bars were insulated from each other by thin paper and shellac, the shellac serving a double purpose, namely, as an insulation and

¹Am. Jour. Science, 48, 226.

also as an adhesive with which to bind the bars together and also to bind them to the ivory piece. As little shellac as possible was used owing to the difficulty it gave when the soldering of the junctions was attempted.

The ends of the rows of hot and cold junctions were filed with a very fine file and the junctions were properly made by means of a soft solder consisting of lead, tin and bismuth. The remaining flat side of the thermopile was then shellaced and covered with ivory of the same dimensions as the first.

By this means a pile of thirty to forty junctions was obtained having a resistance of 3.5 ohms to 5 ohms, according to the number of junctions. The pile was then mounted in a circular disc of hard rubber, having a thickness of about 1 cm. Copper leads were fixed into the disc and fine copper wires from the terminals of the pile wire soldered to these leads. The whole was then enclosed in a cylindrical water jacket open at the ends. The cylindrical jacket contained suitable blends to prevent convection currents, and stray radiation from affecting the thermopile.

For a description of the complete thermopile, one having 37 hot junctions will be chosen. It possessed a length of 21 mm. and a width of 0.5 mm. The bars were 2.5 mm. long. The thermal electromotive force per degree difference of temperature between hot and cold junctions for the complete thermopile was 4.4×10^{-3} volts, and had a resistance of 5 ohms. This thermopile connected to a galvanometer having a resistance of 3 ohms and a sensibility of 4×10^{-10} amperes would give, for a difference of temperature of one millionth of a degree, a galvanometer deflection of 1.4 mm. as compared to a deflection of .4 mm. given by the Rubens thermopile with a much more sensitive galvanometer.

A much more satisfactory way of determining the sensibility of the thermopile is to find the sensibility in terms of the "candle at a distance of a meter" and perhaps at the same time compare the deflection given by the thermopile with that of the bolometer of equal area, using the same galvanometer for each. The sensibility of the galvanometer in this case was 4×10^{-10} amperes. For a candle at a distance of 3 meters from the thermopile a deflection of 260 mm. was obtained, giving a deflection of 2,340 mm. at a

distance of one meter. A bolometer gave a deflection for a candle at a distance of a meter of 1100 mm. The bolometer had a rock salt window to protect it from air currents while the thermopile did not possess a window. The comparison in this case is not so important for it was evident that the bolometer did not possess the sensibility in this test that a good bolometer usually does, namely about 2,500 mm. for a deflection from a candle at a meter's distance. Yet it must be borne in mind that no bolometer will give a maximum of sensibility with a galvanometer of sensibility of only 4×10^{-10} amperes, yet in the case of the thermopile we have a deflection of 2,340 mm. with this galvanometer for the sensibility in terms of the "candle at a meter's distance."

In the above comparison the thermopile was much more steady in its action than the bolometer. Both possessed drift due to temperature changes, but the thermopile lacked the unsteadiness peculiar to the bolometer. The thermopile was, on the other hand, somewhat sluggish, a feature which the bolometer rarely possesses. Yet the sluggishness was not so pronounced as to be annoying.

In conclusion it may be said that this particular type of thermopile has overcome the usual objections applied to thermopiles in general, namely lack of sensibility and sluggishness. On the other hand, it possesses a sensibility superior to the best bolometers and lacks the annoying unsteadiness of the bolometer due chiefly to batteries. It possesses a slow drift, which likewise is common to the bolometer, and is more sluggish than the bolometer.

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