Recent developments in thermopiles as applied to optical instruments

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RECENT DEVELOPMENTS IN THERMO-PILES AS APPLIED TO OPTICAL INSTRUMENTS.

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These few notes on thermopiles are based on the results of some experiments carried out during the past year with a view to obtaining some means of accurately measuring radiation in the infra-red spectrum, but at the same time avoiding the bolometer and its attendant difficulties.

It is comparatively easy to adapt a thermopile to an existing spectrometer, and at no great cost; and a suitable galvanometer is generally to be found in the equipment of a laboratory, while the bolometer is in itself more costly, special apparatus is required to obtain the best results, and in addition to this the bolometer is more difficult to control.

One of the first points to decide in designing a sensitive thermopile is, which materials will be most suitable for the junctions? On reference to tables, bismuth and antimony will at first appear to give the greatest electromotive force for a given rise in temperature, viz., 112 microvolts per degree C.; but as it is also necessary to produce the greatest rise of temperature at the junctions for a given radiation, the materials forming the junctions must be reasonably small and thin in order that the heat capacity may be low. Bismuth can be obtained in the form of wire in various sizes from 0.06 mm. up to 2.0 mms. in diameter, but up to now it has not been possible to produce antimony wire, so that a sensitive thermopile constructed of Bi Sb junctions is at present out of the question.

The material next in the list for use instead of antimony is iron, giving an E.M.F. against bismuth of 81 m.v. per degree C., but on account of its high electrical resistance, and great liability to rust, iron is passed over in favour of silver, which gives 72 m.v. per degree.

Thermopiles have been constructed of constantan (which is an alloy of 60% Cu and 40% Ni) and iron, but as the E.M.F. developed is only 50 m.v. per degree, up to the present bismuth and silver would seem to be the most suitable junction to use.

In a paper in the 'Annalen der Physik,' 1910, E. H. Johansen has given several important rules governing the construction of a sensitive thermopile of only one junction for use in vacuo, and it is on these lines that the thermopile about to be described is constructed.

Johansen has found that for a vacuum thermopile the loss of heat by conduction should be equal to that lost by radiation, and for a thermopile for use in air, that the conduction loss should be equal to the sum of the losses by radiation and convection, also that the resistance of the galvanometer must be equal to that of the thermo-element.

The first experiments were undertaken with a single junction to determine the percentage of the heat lost in the various ways. This junction consisted of a thin piece of silver foil with the two wires crossing near the centre, as recommended by Johansen. This silver foil receiver-plate was bent into the form of a V, as in the Féry single junction pile, the concave side being directed towards the source of radiation. By shaping the receiver in this way, the loss of heat by reflexion will be negligible.

The whole junction was then sealed up in a glass tube, suitable lead wires being provided for connection to a potentiometer. The tube was then exhausted to a pressure of .001 mm. of mercury, when the convection loss ceases. The junction was exposed to radiation from a

Nernst lamp at a suitable distance, and the E.M.F. measured on the potentiometer. Air was then admitted and a fresh measurement of the E.M.F. taken. From these measurements the rise of temperature of the junction was obtained, and knowing the lengths and diameters of the wires the heat lost by conduction can be calculated. One other reading was taken, this time with a known incident radiation, the junction being exposed to a Hefner standard lamp at a distance of one meter. The amount of radiation received by a surface of one square centimeter at a meter distance from a Hefner lamp is accurately known, and multiplying this by the area of the junction gives the energy received by that junction.

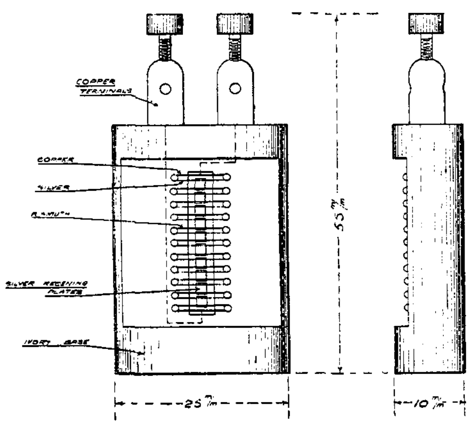
These readings give three equations, from which values for the convection and radiation losses are extracted. Having established the amount of heat lost in various ways, it is only a question of finding the best practical dimensions of the wires and sensitive area. The range of wires is naturally limited, and the most usual size of sensitive area for spectroscopic work is about 20 x 1.5 mms.; also on account of the very small E.M.F. available, it is desirable to keep the resistance of the thermopile as low as possible.

Taking all these points into consideration it was found that the most sensitive thermopile was one consisting of 10 junctions occupying a space of 20 x 1.5 mms., the diameters and lengths of wires being so chosen that they fulfilled as nearly as possible the conditions previously mentioned. (See illustration below.)

These junctions are mounted in a slot milled out in an ivory block, the wires being soldered to pegs placed on either side of the slot, and to the silver foil strips at the centre. It will be noted that there are really two "cold" junctions to each "hot" one, the two cold ones being connected in parallel with each other, but in series with the corresponding hot junction.

This arrangement is carried on throughout the thermopile, copper wires being soldered to the first and last pairs of pegs, and connected to terminals fixed in the top of the ivory block. The resistance of such a thermopile is only about 3 ohms, and it can be used with any sensitive low resistance galvanometer. The double set of cold junctions, coupled with their relatively large mass, prevents zero creep of the galvanometer to a great extent, while admitting of a rigid mechanical construction.

This troublesome zero creep is particularly noticeable with the familiar type of thermopile



in which the cold junctions are arranged alternately and on each side of the hot junctions. The small mass of the cold junctions and their proximity to the hot ones, renders them liable to heat up by convection and conduction, even when carefully shielded from direct radiation, with the result that a reliable galvanometer reading is difficult to obtain. It is interesting to note that for a given sensitive area there is a correct number of junctions; and a thermopile constructed with twice that number of junctions is less sensitive than one with the correct number, although the resistance is still low.

There is one other junction which has been tried, viz., bismuth and tellurium; this gives an E.M.F. about eight times as great as bismuth-silver, but tellurium, owing to its crystalline structure, cannot be drawn into wire, and even were such wire obtainable, it could not be soldered, in fact thin copper and silver foil completely disappear when touched by heated tellurium. Nevertheless single bismuth-tellurium junctions have been constructed, and further experiments are in course of progress, but at present they are not of sufficient mechanical soundness, or permanence, to justify hopes that their great sensitiveness will be available in the near future for spectroscopic work.

Mr. Twyman said the subject of the paper was one to which Mr. Bellingham had devoted a very great amount of work during the past nine months, and the series of experiments which he had briefly described, had taken a very long while to carry out. Those experiments had been most carefully done, and he was distinctly of opinion that Mr. Bellingham had arrived at a most efficient thermopile, composed of bismuth and silver, for use in air.

The Chairman said he very much appreciated the labour Mr. Bellingham had devoted to the subject, and the very great skill with which he must have carried out his experiments in order to obtain the results he had described. The construction of that type of thermopile would, he was sure, be of very great importance to English opticians, whose backwardness in this department was no doubt due to the fact that English instrument makers had not up to the present furnished the requisite apparatus. Of course, foreign instrument makers had the advantage that the initial work was done abroad, but he was very glad that one of our own instrument makers had now turned his attention to the matter, and that there was now a prospect that the work of spectroscopy would be developed in England as much as abroad. He hoped the enterprise of the maker would be well repaid, and that his apparatus would in many cases be used in preference to foreign ones.