ideal method for producing chilled metal. If any object has been covered in this way with "zinc", this layer is in a *metastable* condition after cooling to ordinary temperature.

In consequence such a layer will disintegrate in the long run. That the metal made in this way is not in the ordinary condition is proved by experience. NEUBURGER [1]) says about it (in the case of tin):

"....ebenso erleiden diese unter Umständen auch eine teilweise Veränderung ihrer physikalischen Eigenschaften, die in einer Vergrösserung der Härte besteht. ....Während gegossenes Zinn nach der BRINELLSCHEN Kugeldruckprobe einen Härtegrad von 9.5 aufweist, zeigt gespritztes einen solchen von 14.2".

We hope to be able to report shortly on the metastability of these "atomized" metals.

VAN 'T HOFF—*Laboratory.*

Utrecht, November 1913.

Physics. — *"A rapid Thermopile."* By Dr. W. J. H. MOLL. (Communicated by Prof. W. H. JULIUS.)

Among the many instruments, which have been devised for the quantitative investigation of visible and invisible radiation, the thermopile occupies the foremost place in order of both priority and merit. Though for special researches and under particular circumstances the bolometer and the radiometer may be deemed more suitable, the thermopile has never ceased to find its application, for the most delicate measurement as well as for the simple demonstrative experiment.

It is particularly of late years, that it has once again attracted the attention of a number of investigators, and that numerous improvements in its construction have been tried. All of these had the same purpose, namely to increase the *sensitiveness* of the instrument.

Another property, however, is by no means of less importance, viz. the *rapidity* with which, after the radiation has been admitted or intercepted, thermal equilibrium is reached in the pile. The greater this rapidity, the better is the instrument adapted to the investigation of all sorts of radiation-phenomena of short duration and of rapid variability, and also to those researches which require a long series of successive readings, and which with a slow instrument

[1]) Die Naturwissenschaften, 1, 465 (1913).

become extremely wearisome. But besides all this, great rapidity of the thermopile implies, as is easily conceivable, great stability of the zero, and its indications will therefore be the more certain, the more quickly they are arrived at.

The common thermopile, as is generally known, is a rather slow instrument.

In the original form, devised by MELLONI, it consists of a number of metal bars, joined so as to form a bundle, at the terminals of which the two sets of junctions are found. The great heat-capacity of such a system causes the rise in temperature of the exposed junctions to continue a long time, and thus a considerable delay occurs before equilibrium of temperature is reached.

The thermopile of RUBENS is built up from metal wires, arranged zig-zag wise in the same plane. A slit is adjusted so as to admit the radiation only to the "odd" junctions. The much smaller heat-capacity of this pile is to the advantage of both its rapidity and its sensitiveness. The rapidity, nevertheless, is still comparatively small; in the case of a specimen which I examined the thermo-electric current took 6 seconds to reach 99 $^0/_0$ of its definitive value.

The improvements, which in recent years the thermopile has undergone, relate to small details of construction only, viz. the number, the dimensions, and the material of the wires. It is true, that sometimes the sensitiveness was thus improved, but invariably at the cost of the rapidity.

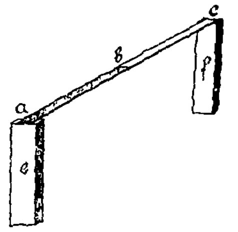
The rapidity of a thermopile is determined by the rapidity with which a difference in temperature of the junctions comes to an equilibrium; a process in which not only the heat-capacity of the junctions plays a rôle, but also, and chiefly, the heat-exchange by conduction, radiation, and convection.

Heat-exchange also takes place while the instrument is being exposed to the radiation, and will thus have a directly prejudicial effect on the sensitiveness. If therefore this exchange be furthered in order to increase the rapidity, we shall have to expect a diminution of the sensitiveness, unless we arrange so as to compensate for it in some other way.

Now, for various applications of the thermopile (in particular, when it is employed not for spectral work, but for the measurement of "total radiation") the narrowness of the exposed surface is of no advantage. A wider surface, which receives a greater part of the radiation, would appear more suitable for the work in hand.

In the following lines a thermopile will be briefly described, which has been constructed according to a wholly different principle. In its construction the two conditions — a prompt heat-exchange and a wide surface exposed to radiation — are satisfied, and consequently *a high degree of both rapidity and sensitiveness* has been attained.

The *thermopile* is built up of a great number of metal strips. Each of these consists partly (*ab*) of constantan, and partly (*bc*) of copper, and is soldered at both ends on two copper bars (*e* and *f*).



This constantan-copper strip can be exposed to the radiation throughout its entire length. Then, on account of the great difference in heat-capacity of the two junctions *a* and *b*, *b* will attain a higher temperature than *a*; the equilibrium of temperature being attained in a very short time, in consequence chiefly of the good heat-conduction between the junctions.

As copper and constantan differ considerably in heat-conductivity, the two metals which form the strip are taken of different thickness (and length), so as to have the temperature highest at *b*, while the strip is exposed to radiation.

Elements, as described, may be readily combined to form a pile. Thus I built a *surface thermopile* of 80 elements, which, being arranged in three rows (of 24, 32, and 24 elements respectively), practically fill a circular surface of 2 cm. in diameter. The total resistance is about 9 ohms. The sensitiveness and the rapidity of this thermopile may be inferred from the following data. The radiation from a standard candle at a distance of 1 metre produces an electromotive force of 18 microvolts, the current reaching 99 % of its definitive value within $1^1/_2$ seconds.

The heat-capacity of the bars *e* and *f* is still further increased by clamping them (with the insertion of a thin sheet of mica) to a heavy piece of copper, this piece of copper occupying the space between the bars as far as just below the strip *abc*. When the pile has been exposed for some time, and therefore has absorbed heat, the temperature of this metal mass will certainly have risen somewhat, but both the junctions will undergo its influence practically to the same degree. The thermopile therefore displays an uncommonly great zero-stability.

Similar elements may also be combined so as to form a thermopile for spectral investigation, but, since in this case the exposed surface must be narrow, such an instrument will be less sensitive. I have compared a *linear thermopile* of this kind, consisting of 30 elements, with a RUBENS pile. Their resistance is the same (3—5 ohms), and in the case of equal surface (20 × 1 mm.) my thermopile exhibits a sensitiveness some 20 %, smaller. This disadvantage, however, is amply compensated for by its rapidity, which is 4 times as great [1]).

Thermopiles of this construction are manufactured by Messrs. KIPP & SONS of Delft.

Physiology. — *"Experiments on the atonical muscle."* II. By Prof. J. W. LANGELAAN. (Communicated by Prof. H. ZWAARDEMAKER.

(This communication will not be published in these Proceedings).

[1]) A rapid and sensitive galvanometer of low resistance, adapted for use in combination with these thermopiles, has been described in the proceedings of the meeting of June 28, 1913, p. 149.

(December 27, 1913).