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The Thermal Conductivity of Tellurium

Arthur R. Fortsch
The State University

THE THERMAL CONDUCTIVITY OF TELLURIUM.

ARTHUR R. FORTSCH.

Until September, 1915, when this research was undertaken, no work had been done on the thermal conductivity of tellurium. During the year 1915-1916, however, King[1] in collaboration with Wold[2] published some work on tellurium in which values were given for its thermal conductivity. In this article will appear: (1) A brief outline of the method used by the author, which was entirely different from that of Wold[3] and King[4]; (2) A summary of the results obtained by this method; and (3) A comparison between these results and those of Wold[5] and King.[6]

The method is based on that of Christiansen[7] with a guard ring idea of Sieg.[8] Imagine two parallel planes in a body of area A a distance d apart, the respective temperatures being e_1 and e_2. The quantity Q of heat conducted across in the time t is given by the equation: $Q = \frac{K(e_1 - e_2)At}{d}$ where K is the thermal conductivity. Now suppose that we have two disks of different materials arranged as in figure 31 below, with a heating device above and a cooling device beneath the disks. After a certain time a condition of equilibrium is established. We make the following assumptions:

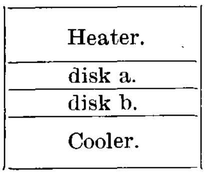

FIGURE 31

(1) The quantity of heat flowing down through the disks a and b is the same.
(2) The areas of the disks are equal.
(3) The end losses from the edges of the disks are negligible.

[1] Phys. Rev., Dec., 1915, p. 437.
[2] Phys. Rev., Feb., 1916, p. 169.
[3] Loc. cit.
[4] Loc. cit.
[5] Loc. cit.
[6] Loc. cit.
[7] Ann. d. Phys. u. Chem. 14, 1881, p. 23.
[8] Phys. Rev., Sept., 1915, p. 213.

Then with these assumptions in mind:

$Q = \frac{K_1(e_3-e_2)\,At}{d_1} = \frac{K_2(e_2-e_1)\,At}{d_2}$ where the symbols are defined as follows:

e_3 = temp. of upper surface of disk a.
e_2 = " " lower " " " ".
= " " upper " " " b.
e_1 = " " lower " " " ".
K_1 = thermal conductivity of disk a.
K_2 = " " " " b.
d_1 = thickness of disk a.
d_2 = thickness of disk b.

From the above equation we deduce at once:

$$\frac{K_2}{K_1} = \frac{d_2\,(e_3-e_2)}{d_1\,(e_2-e_1)}$$

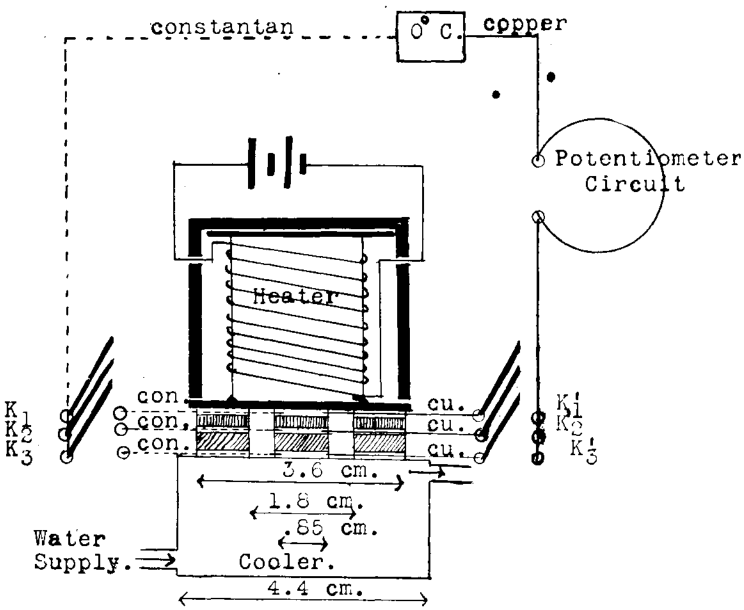

Fig. 32. Arrangement of apparatus for experiment.

Figure 32 is a diagram of the apparatus used. The guard ring to prevent end losses is clearly shown. The temperatures e_3, e_2, and e_1 were obtained by means of thermo-couples embedded in copper disks with insulated guard rings of the same material and thickness. They were made very thin and copper being a far better conductor of heat than the lead or tellurium the effect was found to be negligible. One of these was placed above disk a, a second between disk a and disk b, and a third below disk

b. The heat was supplied by a small heating coil while the cooler was connected to the water supply. The E. M. F.'s were measured with a potentiometer and since these were directly proportional to the temperatures the ratio K_1/K_2 was obtained by using them in place of e_3, e_2, and e_1.

It was at first intended to compare the tellurium disk directly with a lead disk but in some preliminary work with lead and tin using lead as a standard the results for tin were consistent but were about one-third of the value given by the latest tables. By increasing the ratio of the surface to the area of the edges, the values became more nearly those of the tables. This indicated a constant error due to end losses which the guard ring did not prevent. Although the guard ring did not prevent end losses it insured constant equilibrium conditions and as these were more important in the plan used than prevention of end losses the guard ring was maintained. The plan used was as follows. Let K_g, K_l, K_{sn}, K_t denote the respective conductivities of glass, lead, tin, and tellurium. First we may compare a lead disk with a glass disk. We find: $K_l / K_g = A$. Also comparing tellurium with glass: $K_t / K_g = B$.

By dividing these equations as they stand we obtain:

$$K_l / K_t = A / B.$$

In a similar way we may find the ratio $K_{sn} / K_t = A_1 / B$. or $K_{sn} / K_l = A_1 / A$.

This latter test of lead and tin agreed with the tables to within 11 per cent. Considering that this method was designed primarily for poor conductors these results can be considered very satisfactory. Different thicknesses of lead and glass disks were used with the tellurium and the agreement of the results was sufficient to point to the conclusion that the value of K_t obtained was in the neighborhood of the true value. The combinations (thickness expressed in millimeters) and the ratios were as follows:

SET. I.

Pb. 2.47	glass	.93	;	K_l / K_g	= 13.1
Te. 2.24	glass	.93	:	K_t / K_g	= 1.41

$$K_l / K_t = 13.1 / 1.41 = 9.3$$

SET II.

Sn. 2.51	glass	.93	;	K_{sn} / K_g	= 22.8
Te. 2.24	glass	.93	;	K_t / K_g	= 1.41

$$K_{sn} / K_t = 22.8 / 1.41 = 16.2$$

SET III.

Pb. 1.96	glass	2.40	;	K_l / K_g	= 14.2
Te. 2.24	glass	2.40	;	K_t / K_g	= 1.39

$$K_l / K_t = 14.2 / 1.39 = 10.2$$

SET IV.

Pb. 2.47	glass	4.54	;	K_l / K_g	≡ 14.5
Te. 2.24	glass	4.54	;	K_t / K_g	= 1.33

$$K_l / K_t = 14.5 / 1.33 = 10.9$$

Reducing the ratio K_{sn}/K_t to terms of lead by multiplying by the fraction .082/.150 (the conductivities of lead and tin at the temperature of experiment) gives $K_l/K_t = 8.9$. The average of these four values gives $K_l/K_t = 9.6$.

The greatest variation from this average is 13.5 per cent. At the temperature of the experiment (25 to 35 degrees C.) the value of K_t is .082/9.6=.0085.

The value as given by Wold[9] and King[10] is .0135. There is thus a difference of 59 per cent between the two values. However, this is not at all surprising with the poorer conductors. Ingersoll and Zobel[11] make this statement in regard to them: "While the values of K for the metals are probably correct to about 1 per cent, no such accuracy can be claimed for the poorer conductors, as the disagreement between different observers is frequently 50 per cent or even more." It should be particularly noted, also, that the method used by the author was designed primarily for the poorer conductors while that of Wold[12] and King[13] is best suited to the better conductors.

THE PHYSICAL LABORATORY,
THE STATE UNIVERSITY.

[9]Loc. cit.
[10]Loc. cit.
[11]Math. Theory of Heat Conduction, p. 161.
[12]Loc. cit.
[13]Loc. cit.