On an Analogy between the Conductivity for Heat and the Induction-Balance Effect of Copper-Tin Alloys

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XXII. *On an Analogy between the Conductivity for Heat and the Induction-Balance Effect of Copper-Tin Alloys.* By W. CHANDLER ROBERTS, F.R.S.*

IN a paper submitted to the Society in June last, I pointed out that the results obtained when copper-tin alloys are examined by the aid of the induction-balance does not correspond with Matthiessen's determinations of the electric conductivities of the same alloys. The nature of the induction-curve remained therefore more or less obscure; but I have recently observed a remarkable resemblance between my own results† and those given by Calvert and Johnson‡ for the conductivity of heat, which had hitherto escaped me, as the authors did not plot their figures. The following diagram shows the relation of the curve published by me in July last with those of Calvert and Johnson and Matthiessen respectively, which I find for the first time placed in juxtaposition in a valuable report on the copper-tin alloys recently issued by the United-States Government§.

Note.—The curves for the conductivity of heat and electricity are taken from Plate xiv. of the Report on Copper-Tin Alloys, above referred to. The latter curve should, however, be moved slightly to the left, as Matthiessen's numbers represent *volumes*, and not weights, per cent. of copper.

* Read November 8th.

† Phil. Mag. (5) vol. viii. p. 57, 1879.

‡ Phil. Trans. vol. cxlviii. 1858, p. 340.

§ Report made under the Direction of the Committee on Metallic Alloys. Washington, 1879.

The earlier results, which were obtained by observations on blocks of alloy 18 millims. square and 7 millims. thick, have since been verified (except in the case of pure copper, which as originally given is too low) by a series of disks 24 millims. in diameter and 3 millims. thick, formed in the lathe, or, in the case of the very brittle ones, by filing.

The close agreement between the conductivity for heat and electricity has, as is well known, been pointed out by Wiedemann and Franz*; but as the similarity has hitherto, I believe, only been observed in isolated cases, the above results on an extended series of alloys may be of interest.

Calvert and Johnson claim a high degree of accuracy for their results; but they were subjected to adverse criticism, as Wiedemann† objected to the apparatus they adopted and to the small size of the bars employed. It is therefore the more important to point to the almost absolute identity of the two curves representing phenomena of which the manifestations are so different.

The respective values of the alloys were ascertained by placing the metal to be examined on one side of the balance and by superposing a graduated wedge-shaped scale of zinc over the opposing coil, as has already been described by Prof. Hughes‡. The figures given, can however, only be considered to represent the general relation among themselves of the various alloys in the series, as the zinc scale does not give absolute values.

The induction-balance curve, as I have previously pointed out, bears an evident relation to the curve representing the density of the same alloys; but its divergence from Matthiessen's curve§ of conductivity is singular. This may perhaps be explained by the fact that Matthiessen does not appear to have examined any alloy between those which contain respectively 16·4 and 85·1 volumes per cent. of copper, probably because the alloys between these points are too brittle to permit their being formed into wire. It may be noted, however, that the curve of the tin-gold alloys, which belong to

* Poggenдорff's *Annalen*, vol. lxxxix. [1853], pp. 497-531.

† *Ibid.* vol. cviii. [1859], pp. 393-407.

‡ *Phil. Mag.* (5) vol. viii. p. 50.

§ *Brit. Assoc. Report*, 1863, p. 37. and *Chem. Soc. Journ.* 1867, p. 212.

the same group as the copper-tin, is given in his well-known paper * in 1860, and does not show an unbroken line in the horizontal portion. Certain intermediate alloys, in the form of rods, are now being examined by Dr. Lodge, whose results will doubtless clear up the point.

The alloys which occupy the critical points of the induction-balance curve are very interesting. They may be represented by the formulæ SnCu_3 and SnCu_4 respectively; and although they only vary by a single equivalent, or by 6.49 per cent. of copper, their structure and appearance differ widely. The latter, SnCu_4 , is a speculum-metal. It has a large conchoidal fracture and a yellow-grey tint. SnCu_3 , on the other hand, has a blue-grey colour and a coarse surface of interrupted crystalline planes. By successive additions of copper, this alloy seems to pass into the other without any sharp break.

Possibly both alloys are chemical combinations; and the difference of their ordinates probably marks a different allotropic state. For further information on such questions, however, we may look with confidence to Prof. Hughes's beautiful and simple instrument, which will also help us to determine whether the relation between conductivity for heat and electricity is really as exact as it has hitherto been supposed to be.

XXIII. *Note on a Determination of the Specific Electrical Resistance of certain Copper-Tin Alloys.* By OLIVER J. LODGE, D.Sc., Assistant Professor of Physics in University College, London.

ON the 5th of November I received from Mr. Chandler Roberts three rods of certain very brittle copper-tin alloys which he had with some difficulty cast, in order that I might determine their specific resistance per unit of volume by ordinary processes, because the readings which the induction-balance gave for disks of these three metals indicated that their conductivities did not by any means agree with Matthiessen's curve of electric conductivity for copper-tin alloys, though, on the other hand, they did agree with some severely

* Phil. Trans. vol. cl. p. 161.