1897

Recent Determinations of the Electrical Conductivity of Aluminum

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RECENT DETERMINATIONS OF THE ELECTRICAL CONDUCTIVITY OF ALUMINIUM.

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Many and various values have been determined for the electrical conductivity of this metal. The causes have been as follows:

(1) The impurity of the metal used. Until 1886, the best commercial aluminium rarely surpassed 98 per cent. in purity, and it was not until 1889 that commercial metal of 99 per cent. was put on the market. As will be shown later, the effect, even within these narrow limits, is to change the conductivity nearly 10 per cent.

(2) The reference of the conductivity to copper or silver as standards. In such cases, the exact purity of the copper or silver and the physical condition of these metals, whether

hard or soft, must be known in order to give the comparison its proper value; but these were in most cases either unknown or neglected. Even at the present time, the absolute conductivity of pure soft copper or silver cannot be said to be fixed closer than within 1 per cent., so that figures for conductivity of aluminium, given only with reference to copper or silver, cannot, at best, have an accurate significance.

(3) Lack of an accurate standard of absolute resistance. The adoption of standard units of resistance, by international concert, and the consequent multiplication of registered copies, has made it an easy matter to use in experiments certified instruments of accurately-known resistance, and thus to dispense with self-constructed units of comparison in favor of more accurate standards.

(4) Imperfect methods of measurement. Of late years, several ingenious arrangements have been devised for eliminating from the calculations of experiments the resistance of connections, always an uncertain quantity, and more refined instruments for measuring and balancing electric currents have been constructed, thus permitting of increased accuracy in results.

In the following experiments, the specimens tested were kindly furnished by the Pittsburgh Reduction Company, and were all analyzed by Mr. Handy, of the Pittsburgh Testing Laboratory, so that their composition was accurately known. The conductivity is given in absolute measurement, so that no reference to any other metal as a standard can affect the results. This was rendered possible by the use of a certified standard resistance coil of 1 "International" ohm, whose possible error is not over 0·02 per cent., and by the use of the *Carey Foster* method of comparison. The metal was in wire, of 50-foot lengths, the diameter of which was measured by a micrometer and checked by weighing and determining the specific gravity. The wires were wound on wooden bobbins and immersed in oil, the temperature of which was given by a thermometer. The galvanometer used was a reflecting instrument, sufficiently delicate for all purposes. The standard coil was immersed in water, and the room was kept at a constant temperature. The bridge wire used was carefully calibrated, and all readings were taken several times. Two separate wires were tested in case of specimen 1, the result given being the mean of two results, which differed only one-hundredth of 1 per cent. from each other.

	Analysis.						Resistance at 0° C. of a Wire, 1 Meter Long by 1 Millimeter Diameter, in Ohms.	Specific Resistance at 0° C., *i. e.*, Resistance of 1 Cubic Centimeter in Absolute (C.G.S.) Units of Resistance.	
	Aluminium.	Iron.	Copper.	Silicon.	Sodium.	Zinc.	Hard.	Hard.	Annealed.
(1)	99·66	0·10	0·00	0·16	0·008	—	0·031245	2453·7	2432·2
(2)	99·58	0·25	0·00	0·16	0·052	—	0·03290	2584·0	2535·0
(3)	98·77	0·20	0·57	0·45	0·012	—	0·03627	2848·0	—
(4)	97·16	0·25	2·26	0·30	0·032	—	0·03590	2819·6	—
(5)	94·39	0·25	3·07	0·24	0·052	1·50	0·03583	3011·4	2984·7

For the reduction from the working temperature to 0° C. an experiment was made with wire No. (1), which showed that between 27° C. and 0° C. its temperature coefficient was 0·00392 per degree. This coefficient was used for the nearly pure wires, while for (4) and (5) a slightly lower coefficient, determined by Mr. Scott, was used. It appears that the purer the metal the greater its temperature coefficient.

Conductivity tests of a similar set of wires were made by Mr. C. F. Scott, electrician of the Westinghouse Electric Company, Pittsburgh. They were made by comparison with pure copper, with a Wheatstone bridge. These results can only be compared with ours by assuming a certain value for the conductivity of copper, and even then we cannot say how nearly the copper used by Mr. Scott would approach that standard. Sir W. Thompson's value for the specific resistance of copper is 1580, Dewar's 1562. In the following table we reduce our results to each of these standards, and add Scott's results for comparison:

RELATIVE CONDUCTIVITY (COPPER = 100).

	Richards and Thomson. Using for Copper the Resistances (1580)	(1562)	*C. F. Scott. Actual Resistance of Copper Employed not Known.*
(1) Soft	65·0	64·2	—
(1) Hard	64·4	63·7	63·1
(2) Soft	62·3	61·6	—
(2) Hard	61·1	60·5	62·2
(3) Hard	55·5	54·9	56·2
(4) Hard	56·0	55·4	58·5
(5) Soft	52·9	52·3	—
(5) Hard	52·5	51·9	55·0

TEMPERATURE COEFFICIENT FOR 1° C.

	C. F. Scott. (Between 15° and 80° C.)	*Richards and Thomson. (Between 0° and 27° C.)*
(1)	·00385	·00392
(2)	·00385	—
(3)	·00360	—
(4)	·00361	—
(5)	·00359	—

In connection with the results of Mr. Scott and ourselves, we may mention for comparison those of Charpentier-Page, who used what he calls *pure* aluminium, which may safely be assumed to be the No. 1 grade of European aluminium, averaging 99 per cent. pure. He finds as follows:

	Specific Resistance. (Calculated to 0° C.)	*Compared with Copper.* (1580) *Per Cent.*	(1562) *Per Cent.*
Soft	2659	59·4	58·8
Hard	2684	58·9	58·2

It should be noticed that these results fall exactly between our Nos. 2 and 3, also just where its composition would most probably lie. The results also agree closely with ours in showing almost exactly 1 per cent. greater conductivity for the annealed than for the hard-drawn wire.

Dewar and Fleming have also recently found as the specific resistance of "Swiss aluminium about 99 per cent. pure" the value 2563 at 0° C., which is 60·9 per cent. of that of copper, according to their own measurements. This also fits in well with our determinations, but the comparison would have been much more satisfactory if the exact composition of their metal had been determined.

C. K. McGee determined, in 1890, the conductivity of aluminium analyzing 98·52 per cent. pure to be 54·8 per cent. that of copper, when unannealed. This metal was nearly identical with our No. 3 in composition, and the results are the same within 1 per cent.

The conclusions we would draw from these experiments and comparisons are that—

The conductivity of hard-drawn commercial aluminium is strongly affected by impurities, being, approximately:

		(*Copper* = *100*)
98·5 per cent. pure aluminium		55·0
99·0 " " " "		59·0
99·5 " " " "		61·0
99·75 " " " "		63·0 – 64·0
100·0 " " " "	probably	66·0 – 67·0

Annealed wire has a conductivity very nearly 1 per cent. greater than the unannealed.

LEHIGH UNIVERSITY, January 19, 1897.