On the Price of the Factor of Safety in the Materials for Lightning-rods

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1887 Proc. Phys. Soc. London 9 122

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Mr. H. F. Newall asserts*, however, that he has shown that the reglow is "not due to differences in conductivity in iron at different temperatures," and that "there is a rise of temperature not only at the surface . . . but also throughout the mass." Mr. Newall has not yet brought before us any experimental evidence in proof of these assertions; but he has promised to do so.

Mr. Newall seems to agree with the author that the process going on during recalescence "partakes of the nature of an explosion, in that once started it continues throughout the mass of the iron," but he regards the rise of temperature as being caused by internal *chemical* action. The author looks forward with much interest to the publication of Mr. Newall's results.

XVII. *On the Price of the Factor of Safety in the Materials for Lightning-rods.* By PROFESSOR SILVANUS P. THOMPSON, D.Sc.†

It is possible to determine in an absolute manner what metal is best for securing safety by a system of lightning-conductors, for a given prime cost. In the calculations that follow it is assumed that the duration of the lightning-discharge is so brief that there is no time for appreciable radiation or convection of heat from the surface of the conductor, or for conduction into other bodies; and that the conductor is devoid of self-induction.

Safety is dependent, other things being equal, upon the difficulty of fusion of the conductor. The difficulty of fusion of the conductor varies directly as the fusing-point of the material (or, more strictly, as the difference between this temperature and that of the surrounding air, assumed here to be 15° C.), and inversely as the temperature-rise occasioned in it by the discharge of electricity, the amount of which is supposed to be given. The temperature-rise varies inversely as the specific thermal capacity of the material, and directly as the heat developed in it. The heat caused by a given discharge of electricity varies directly as the total electric resistance of the

* Phil. Mag. vol. xxiv. No. 150, p. 436 (1887).

† Read January 28, 1888.

conductor. The total electric resistance of the conductor varies directly as the specific electric resistance per unit cube of volume of the material of the conductor, also directly as its length, and inversely as its area of cross section (supposed uniform throughout). The area of section varies directly as the volume and inversely as the length (supposed given). The volume varies inversely as the density of the material and directly as its mass. The mass of the conductor varies directly as the total cost, and inversely as the cost per unit of mass.

Hence, writing f for the temperature of fusion above that of the surrounding air (assumed at 15° C.), s for the specific thermal capacity, ρ for the specific electric resistance, l for the given length, d for the density, k for the cost, in pence, per pound of the material of the conductor, it at once follows that

$$\text{Safety varies as total cost} \times \frac{f \times s}{\rho \times d \times l^2 \times k}.$$

Hence, as the total cost and the length are supposed to be given, we have

$$\text{Factor of safety for equal total cost} = \frac{f \times s}{\rho \times d \times k}.$$

The only metals about which it is necessary to inquire are copper, silver, iron, lead, platinum, and tin. In the following table the values of f are deduced from the figures of Violle and of Rudberg. The values of k are deduced from the market-prices in London on December 7, 1887: viz. copper, £75 per ton; silver, 4s. per troy ounce; iron (rod) £5 10s. per ton; lead, £16 10s. per ton; platinum, 32s. per troy ounce; tin, £170 per ton. The figures given in column 6 for the factor of safety for equal cost are calculated by the foregoing formula multiplied by 10^4 . The figures in the seventh column, giving the total cost of equal safety, so far as prime cost of material is concerned, are of course inversely proportional to the figures in column 6.

	f .	s .	ρ .	d .	k .	Factor of safety.	Total cost for equal safety.
Copper ...	1039	0.0949	1615	8.94	8.045	9.488	£100
Silver	939	0.0570	1609	10.51	699.84	0.045	£18,770
Iron	1585	0.1138	9827	7.79	0.589	39.97	£21 9s.
Lead	307	0.0314	19847	11.35	1.769	0.242	£3508
Platinum..	1760	0.0325	9158	21.36	5598.7	0.00052	£1,621,600
Tin	213.5	0.0548	13360	7.29	18.22	0.6593	£1287

The prime cost of copper is known to be greater than that of iron for equal conductivity; and reckoning on this basis, irrespective of difficulty of fusion, it is stated in the Report of the Lightning-rod Conference to be 50 per cent. dearer. If that were all, then doubtless the small saving in using iron would be more than counterbalanced by the attendant disadvantages of deterioration by rust, and the like. But when the higher fusion-point, the greater capacity for heat, and the lesser density of iron are taken into account, the superiority of iron, for equal total prime cost, becomes so marked as to once more raise the question whether it may not be expedient to return to the original practice of Franklin, and use lightning-rods of iron instead of those of copper.

London, December 12, 1887.

XVIII. *An Experimental Study on the Influence of Magnetism and Temperature on the Electrical Resistance of Bismuth and its Alloys with Lead and Tin.* By EDMOND VON AUBEL, of Liège, Member of the Physical Society of London.*

PRELIMINARY COMMUNICATION.

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MANY physicists have been at work upon the influence of

* Read January 28, 1888.