PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

The Thermal Emissivity of Thin Wires in Air

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IX. *The Thermal Emissivity of Thin Wires in Air.*

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[PLATES 11–15.]

I. *General Character of the Experiments.*

IN 1884 it was observed experimentally that whereas the electric current required to maintain a *thick* wire of given material, under given conditions, at a given temperature, was roughly proportional to the diameter of the wire raised to the power three-halves, the current was more nearly proportional to the first power of the diameter if the wire were *thin.* When this difference in the behaviour of a thick and a thin wire was first noticed it was regarded as quite unexpected. But, as pointed out by one of us in the course of a discussion at a meeting of the Royal Society, the unexpected character of the result was due to people having assumed that the loss of heat from radiation and convection per square centimetre of surface per 1° excess temperature was a constant for a given kind of surface and independent of the size and shape of the cooling body, although as early as 1868 Box had drawn attention to the great difference that existed between the rate of loss of heat from unit area of a horizontal cylinder and per unit area of a sphere. The interchange of heat between unit area of a body and the enclosure might be independent of the shape of the body as far as radiation alone was concerned, but it seemed nearly obvious that the cooling by convection must be materially affected by the shape of the cooling body.

The very valuable investigations that have been made on emissivity by Mr. MACFARLANE, Professor TAIT, Mr. CROOKES, Mr. J. T. BOTTOMLEY, and by Mr. SCHLEIERMACHER, had for their object the determination of the variation of the emissivity with changes of the surface and with change in the density of the gas surrounding the cooling body, but it was not part of these investigations to determine the change in the emissivity that is produced by change in the shape and size of the cooling body. Indeed, so little has been the attention devoted to the very large change that can be brought about in the value of the emissivity by simply changing the dimensions of the cooling body, that in Professor EVERETT'S very valuable book on Units and Physical Constants, the absolute results obtained by Mr. MACFARLANE are given as the "results of experiments on the loss of heat from blackened and polished copper in air at atmosphere pressure," and no reference is made either to the shape or to the size of the cooling body.

[November 19, 1891.—Since this paper was sent in to the Royal Society, a new edition of this book has appeared, and, in consequence of a suggestion made to Professor EVERETT, the word "balls" has been added after the word "copper" in this new edition, as well as the following paragraph:—

"*Influence of Size.*

"According to Professor AYRTON, who quotes a table in 'Box on Heat,' the coefficient of emission increases as the size of the emitting body diminishes, and for a blackened sphere of radius r cm. may be stated as

$$\text{“}\,0{\cdot}0004928 + \frac{0{\cdot}0003609}{r}.$$

"The value in MACFARLANE's experiments was 2."]

The laws which govern the loss of heat from thin cylindrical conductors have not only considerable scientific interest in showing how the shape of a body affects the convection currents, but they are of especial importance to the electrical engineer in connection with glow-lamps, hot-wire-voltmeters, fuses, &c. We, therefore, thought it desirable to ascertain the way in which the law of cooling for thick wires, which involved the diameter raised to the power three-halves, passed into the law for the cooling of thin wires, involving only the first power of the diameter. For this object the investigation described in the present communication was commenced at the beginning of 1888.

A considerable number of preliminary experiments having been conducted for the purpose of arriving at the best conditions to be adopted in the investigation, we finally, in April, 1888, decided to measure the emissivity at different temperatures from nine platinum wires, having respectively the diameters of 1, 2, 3, 4, 6, 8, 10, 12, and 15 mils, or thousandths of an inch. Wires of these sizes having been ordered from Messrs. JOHNSON, MATTHEY, and Co., they were found, when received, to have the following diameters at 15° C.:—

Mils.	Millimetres.
1·2	0·031
2·0	0·051
2·9	0·074
4·0	0·102
6·0	0·152
8·1	0·206
9·3	0·236
11·1	0·282
14·0	0·356

Throughout this paper we have given the diameters of the wires both in mils and in millimetres. It may seem unscientific to mix up dimensions in thousandths of an inch with dimensions in centimetres, but, while it is convenient, for the purposes of comparison, to use one square centimetre as the unit of area in experiments on emissivity, it is also convenient to have some concrete conception of the wires spoken of. Now, fine wires are practically known in this country as wires of 1, $1\frac{1}{2}$, 2 mils, &c., diameter, a wire of 1 mil diameter being, for example, the thinnest that has been practically used in the construction of electrical apparatus. A better idea is, therefore, obtained from stating that the diameters of wires are 1, 2, or 3 mils, than from saying that they are 0·025, 0·051, or 0·074 millim. Attached to several of the curves are the diameters of the wires expressed in millimetres. These numbers are stated to four decimal places, but it would have been better to have given, as in the above Table, only three significant figures, this being the probable limit to the accuracy of the measurement of the diameters.

Suspecting that some of the results of published experiments on the currents required to fuse wires had been much influenced by the cooling action of the blocks to which the ends of the wires were attached, we started by making a calculation on the length necessary to give to our wires so that the loss of heat by conduction should not introduce any important error into the determination of the emissivity. To do this it was necessary to calculate the distribution of temperature along a wire through which a steady current was flowing, and from which heat was lost by radiation, convection, and conduction, and it was further necessary to improve on the calculation one of us had published on this subject in the 'Electrician,' for 1879, by now taking into account the fact that the emissivity, as well as the thermal and electric conducting powers of the wire, were different at different points in consequence of the difference of temperature. Such a calculation has not, as far as we are aware, been hitherto made, it having been assumed in all previous investigations that the effect due to the variation of the thermal and electric conducting power of the material with temperature, as well as the variation of the emissivity per square centimetre with temperature and with the diameter of the wire, could be neglected.

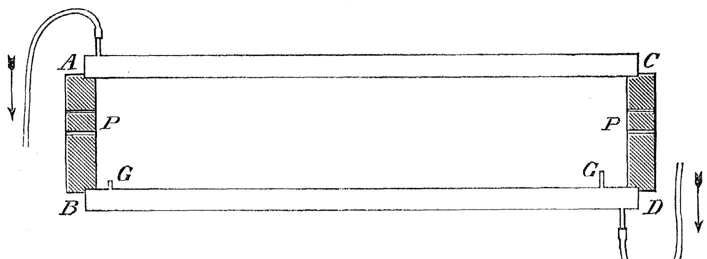
Until we had completed the experiments described in this paper we could of course only employ, in this calculation, values that we had guessed at as something near the truth for the emissivity of platinum wire for different diameters and at different temperatures. Hence, after the completion of the experiments, we took up the mathematical investigation again, substituting for the emissivity such a function of the diameter of the wire and the temperature of the point as we had experimentally found it to be. The investigation by which we finally arrived at the calculated distribution of temperature along the wire is given in § V. of the paper.

The rate at which heat was lost by any one of the wires was measured by the product of the current passing through it into the P. D. (potential difference) maintained between its ends, while the ratio of the P. D. to the current gave the resistance of the wire, and therefore its temperature. As the variation of resistance with temperature of different specimens of platinum is known to differ, it was not considered sufficiently accurate to deduce the temperature of the wire experimented on by using some supposed temperature coefficient for platinum; consequently the variation of resistance, with temperature of each piece of platinum wire employed, was experimentally determined up to 300° C. The investigation, therefore, divided itself into two distinct parts, viz. :—

A, the measurement of the power required to be given to platinum wires of various diameters, so as to maintain them at various temperatures above that of the enclosure.

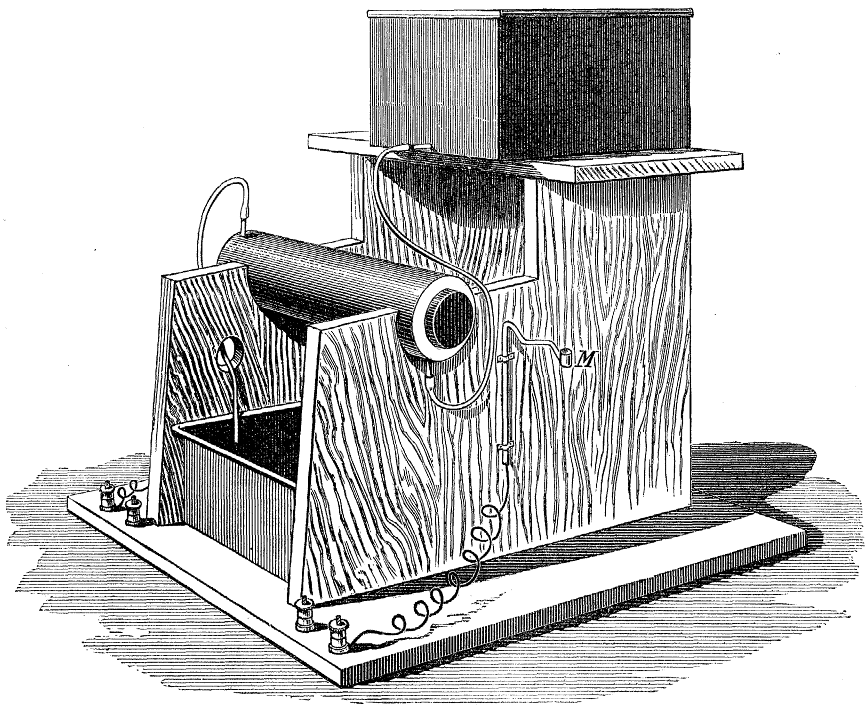
B, the determination of the law connecting the resistance with the temperature for each piece of wire employed in A.

Fig. 1.



And the second investigation also consisted of two parts, since a very considerable time had to be finally spent in determining the errors of the thermometers that had been employed in measuring the variation of the resistance of the wires with temperature.

Fig. 2.



For carrying out the first part of the investigation, each wire was placed horizontally along the axis of a water-jacketed cylinder shown in section *A, B, C, D* (fig. 1), 32·5 centims. long, 5·08 centims. internal, and 7·62 centims. external diameter, the interior surface of the cylinder being coated with dull lamp black. A stream of water of constant temperature entering by the pipe at *D*, and leaving by the pipe

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at A, flowed through the water jacket and prevented the surface of the cylinder from becoming warmed by radiation and convection from the hot wire under experiment. Fig. 2 shows the water-jacketed cylinder in position.

For inserting the wire to be tested into the enclosure-cylinder, it was attached at its two ends to a lamp-blacked brass carrier E, F (fig. 3), which could be slid, between guiding pins G, G (fig. 1), along the bottom of the inner cylinder into a definite position. The two ends of the wire were soldered to the tips α, α (fig. 3), of two wires $\alpha\beta$, $\alpha\beta$, 1 millim. in diameter, which were made of platinum-silver so as to

Fig. 3.

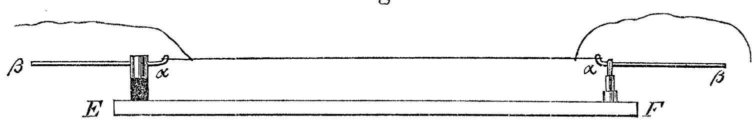
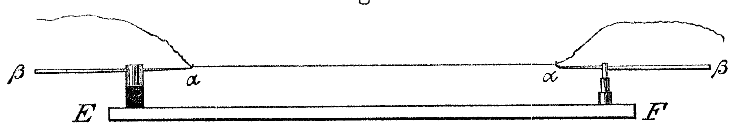


Fig. 4.



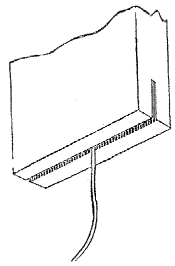
have but a small heat conductivity. Two short pieces of platinum wire, 0·025 millim. in diameter, to be used as terminals for the voltmeter, were soldered with the slightest touch of solder to two points about 6 millims. distant from the ends α, α, of the wire under test, it having been determined that at this distance from the terminals α, α, the temperature would not be much lower than the average temperature of the wire. In the case of the two finest wires tested, having diameters of 0·025 and 0·051 millim. respectively, it was not found necessary to adopt this arrangement, and the ends of the wires were themselves used as the voltmeter terminals, as seen in fig. 4; the platinum-silver wires, $\alpha\beta$, $\alpha\beta$, were, however, filed down quite thin to prevent the fine wire being cooled by heat being conducted away from its ends. The shaded portion of figs. 3 and 4 represents an ebonite cap used to insulate one end of the wire α, α, from the brass carrier E, F.

To prevent draughts entering the enclosure-cylinder, each of its ends was closed with an ebonite plug, P, P (fig. 1) through two holes in which passed the platinum-silver wires, $\alpha\beta$, $\alpha\beta$, used as the terminals for the main current, and the fine platinum wire used for measuring the P. D. Connection was made between these latter and the wires which led to the voltmeter itself by their dipping into two mercury cups M, M (fig. 2), carried from the stand of the apparatus, and which were turned into position close to the holes in the ebonite plugs, after the latter had been inserted into position.

For the experiments on the variation of resistance of the wires with temperature which were conducted during May, June, and July, 1888, the two ends of each wire were fastened to two thick rectangular copper bars, about 7 millims. thick by 20 millims. wide. The fastening was effected by making a fine saw cut about 6 millims.

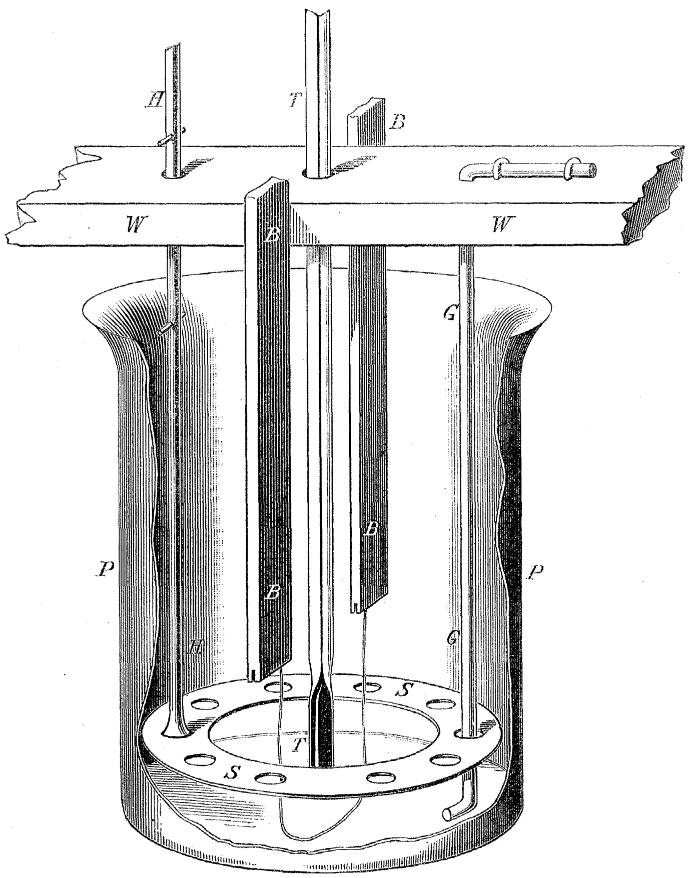
deep in the end of the bar (fig. 5) inserting the end of the wire to be tested into the cut and gently hammering the copper so as to grip the wire. The copper was then heated in a blowpipe, and solder having a higher melting point than 350° C., run in so as to fill up all interstices.

Fig. 5.



These copper bars, *B*, *B* (fig. 6), dipped into oil contained in an iron pot *P P* wrapped round with asbestos cloth to prevent loss of heat, and were supported from a

Fig. 6.



wooden cross-piece *W W*, which carried the thermometer *T T*, the guide *G G* for the stirrer *S S*, and itself guided the handle *H H* of the stirrer, the up and down motion of which was limited by two pins.

Four thermometers of different ranges were used in these tests, and each of them

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was subsequently compared with a Kew standard thermometer. Considerable difficulty was introduced into the carrying out of these comparisons from the fact that it is, or, at any rate, was not three years ago, possible to obtain a standard thermometer from the Kew Observatory to read, say, from 200° to 300° C., with a short wide chamber at the base in which the mercury expanded below 200° C. All that could be obtained was a long thermometer which had been carefully tested between 0° C. and 100° C., and the remainder of whose tube had been simply calibrated for uniformity of bore. The consequence was that when we desired to compare one of our thermometers reading say, from 200° C. to 300° C., with the Kew standard thermometer, their bulbs were very far apart when they were both immersed in oil so that the top of the mercury column of each was just at the top of the oil; secondly, whereas we had kept each of our thermometers with its bulb close to the wire whose resistance was being tested, and, therefore, at a fixed distance below the surface of the oil while it was being used, the Kew standard thermometer had to be continually lowered further and further into the oil as the temperature rose in order that correct readings could be obtained.

By adopting, however, the following device, a satisfactory, although very laborious, comparison between the four thermometers and the Kew standard thermometer was finally carried out in the autumn of 1889, by three of the students of the Central Institution, Messrs. MÜLLER, STEPHENS, and WIGHTMAN. The thermometer to be tested was placed in a deep oil bath in exactly the same position, relatively to the surface of the oil, as that in which it had previously been used. To obtain uniformity of temperature throughout the oil bath, the oil was kept constantly agitated by means of a stirrer driven by an electromotor, and further, the heat was applied not merely at the bottom of the bath but along the whole of its long vertical sides, which were covered with several layers of asbestos cloth to prevent the flames warming one part of the surface more than another. The bulb of the thermometer was surrounded by a bobbin of wire, the resistance of which was very carefully measured for many readings of the thermometer. Then the Kew standard thermometer was inserted in place of the thermometer to be tested, but now, as the temperature rose the coil and the standard thermometer were depressed together so as to keep the coil always surrounding the bulb of the thermometer, and so that the level of the mercury in the thermometer tube was always only just above the level of the oil. The temperatures were then read off on the standard thermometer which caused the coil of wire to have exactly the same resistances as before, and which were, therefore, the true temperatures corresponding with the readings of the thermometer to be tested. In consequence of the unwieldy length of a Kew standard thermometer reading to 300° C., it was necessary to use an oil bath 80 centims. deep for this experiment.

Much thought and labour was given to the piece of apparatus, and many devices were introduced into it which it is not necessary to describe here, first because after we had completed this part of the investigation we learnt that much more suitable standard thermometers might have been obtained from abroad than could be purchased from the Kew Observatory; secondly, because if one were making such an investigation again, one would use as standards of comparison the coils of accurately known resistances at high temperatures which can now be purchased, but which we were advised three years ago had not then the necessary degree of accuracy.

II. *Variation of Resistance of Platinum Wires with Temperature.*

We will now return to the main part of the investigation B, and it is to be understood that all temperatures mentioned are the *true* temperatures as corrected by using the results obtained from the comparison of the thermometers with the standard thermometer.

The first point was to determine the variation of resistance with temperature of the copper bars *BB*, *BB* (fig. 6), and the thick copper wires that went to the Wheatstone's bridge. The total resistance of the bars and wires at 0° C. was 0·0050 ohm, and, as the wires were protected by an asbestos screen from the action of the heat, the total variation in the resistance of the copper bars and wires combined was very small, being only 0·0003 ohm between 0° C. and 325° C. This variation was, therefore, almost negligible compared with the variation of the resistance of even the thickest platinum wire experimented on, for which the following are the results.

TABLE I.—Piece of the Platinum Wire that had been used in the Experiments on Emissivity.

May 10th, 1888. Diameter 14 mils, or 0·356 millim. Length unknown, but about 23 centims.

Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.
° C.		° C.		° C.	
17·5	0·262	72·7	0·310	148·3	0·374
17·9	0·262	81·8	0·318	154·4	0·382
23·9	0·268	93·3	0·328	170·5	0·392
37·5	0·280	105·3	0·338	182·0	0·402
46·8	0·288	122·0	0·352	194·2	0·412
61·1	0·300	135·1	0·362		

Although the exact length of the above wire was unknown, the results are not the less useful for giving the law of variation of resistance with temperature, for, as pointed out in § III., "Results of Emissivity Experiments," the observations contained in Tables I. to V. were employed to give the ratios of the resistances of any one of the wires at any two temperatures, and not the specific resistance at any one temperature. Hence it was unnecessary to know the lengths of the wires used in the experiments, the results of which we recorded in Tables I. to V., and the lengths where mentioned are only approximate in some cases.

The next piece of wire used was of the same diameter, and was also a bit of the actual wire that had been used in the emissivity experiments. The length of this piece was, however, accurately known.

TABLE II.—Piece of Platinum Wire that had been used in the Experiments on Emissivity.

May 14th and 15th, 1888. Diameter 14 mils, or 0·356 millim. Length 22·76 centims. Curve No. 1, fig. 7 (Plate 11.)

Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.
° C.		° C.		° C.	
15·8	0·262	145·1	0·372	242·6	0·452
16·1	0·262	145·1	0·372	255·2	0·462
52·3	0·294	157·3	0·382	256·9	0·462
55·0	0·296	168·8	0·392	270·1	0·472
63·1	0·303	171·6	0·394	271·1	0·472
74·5	0·313	180·4	0·402	277·8	0·477
85·8	0·323	193·1	0·412	278·8	0·478
97·5	0·333	206·1	0·422	284·6	0·482
	0·343	207·3	0·422	291·0	0·487
	0·343	218·6	0·432	298·5	0·492
121·4	0·352	230·3	0·442	306·1	0·497
132·9	0·362	231·9	0·442		

The equation connecting the resistance and the temperature of the preceding specimens was determined in two distinct ways. First, a curve (No. 1, fig. 7) was drawn connecting all the values of temperature and resistance obtained on May 14th and 15th, then three points on this curve were selected, viz., those corresponding with

Temperature.	Resistance.
15°·0 C.	0·262
153°·3 C.	0·380
300°·0 C.	0·493

From these, on the assumption that r, the resistance at temperature $t°$ C., could be expressed in terms of r_0, the resistance at the temperature 0° C. by the equation

$$r = r_0 (1 + \alpha t + \beta t^2)$$

the values of r_0, α, and β were calculated. The values thus obtained were

$$\left.\begin{aligned} r_0 &= 0{\cdot}2487 \text{ ohm} \\ \alpha &= 0{\cdot}00358 \text{ ,,} \\ \beta &= -0{\cdot}000000101 \text{ ,,} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (1).$$

Next, with the object of ascertaining the magnitude of the error that would be introduced into the values of r_0, α, and β by a small error having been made in reading the temperature, the preceding calculation was repeated on the assumption that the second temperature instead of being 153°·3 C. was 155° C. The values then obtained were

$$\left.\begin{aligned} r_0 &= 0\cdot2488 \text{ ohm} \\ \alpha &= 0\cdot00354 \text{ ,,} \\ \beta &= -\,0\cdot000000896 \text{ ,,} \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (2).$$

Thirdly, the method of least squares was applied to all the observations made on May 10th, and given in Table I. In this way there were obtained the values

$$\left.\begin{aligned} r_0 &= 0\cdot246987 \text{ ohm} \\ \alpha &= 0\cdot003560 \text{ ,,} \\ \beta &= -\,0\cdot000000645 \text{ ,,} \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (3).$$

Lastly, the method of least squares was applied to all the observations made on May 14th and 15th, and given in Table II., the values thus obtained being

$$\left.\begin{aligned} r_0 &= 0\cdot247338 \text{ ohm} \\ \alpha &= 0\cdot003650 \text{ ,,} \\ \beta &= -\,0\cdot0000001091 \text{ ,,} \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (4).$$

To compare the values of r_0, α, and β obtained from the curve recording the observations of May 14th and 15th with the values obtained by applying the method of least squares to the same observations, we may examine the value of the difference between r_{100}, the resistance of the wire at 100° C., and r_0, the resistance at 0° C.; using the values of r_0, α, and β given in (1), we find

$$r_{100} - r_0 = 0\cdot0862,$$

whereas, using the values of r_0, α, and β given in (4) we have

$$r_{100} - r_0 = 0\cdot086325.$$

Again the mean coefficient of increase of resistance per 1° C., between 15° C. and 85° C. when obtained from the curve alone, is 0·00350, whereas the mean coefficient per 1° C., between 0° C. and 100° C., using the means of the values of r_0, α, and β given in (1), (3), and (4), is 0·00348.

We may, therefore, conclude that it is not necessary to use the lengthy method of least squares to obtain the values of r_0, α, and β, and that the values obtained by using three points on a curve which graphically records the results of the experiments on temperature and resistance are accurate enough for practical purposes. The three-point method was, therefore, alone adopted for the remaining wires. Indeed, for the purpose of determining the temperatures of the wires in the emissivity experiments which corresponded with the various observed resistances, it was found most easy and most accurate to simply read off the temperature at once from the curves which recorded the results of the experiments made on the variation of the resistance with temperature for the particular wires. Specimens of such curves are seen in curves 1, 2, 3, 4, 5, 6, figs. 7 and 8. (Plates 11 and 12.)

We were, however, led to study the various formulæ that had been published by different investigators on the connection between the resistance and temperature of different metals, and this led us to carry out a considerable amount of calculation which brought to light some interesting results. Since these results, however, are not specially connected with this present investigation on emissivity, we purpose presenting them in a separate communication later on.

TABLE III.—Piece of the Platinum Wire that had been used for the Experiments on Emissivity.

June 11th and 12th, 1888. Diameter, 11·1 mils, or 0·282 millim. Length, 14·02 centims. Curve No. 2, fig. 7 (Plate 11).

Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.
° C.		° C.		° C.	
15·3	0·2953	102·2	0·365	214·0	0·455
15·6	0·2959		0·375	225·6	0·465
16·3	0·2962		0·375	226·8	0·465
31·8	0·3096	141·5	0·395	226·8	0·465
39·1	0·3150	164·9	0·415	238·8	0·475
39·1	0·3150	176·2	0·425	239·2	0·475
51·6	0·325	176·9	0·425	239·2	0·475
64·9	0·335	188·8	0·435	251·8	0·485
75·8	0·345	200·4	0·445	252·7	0·485
77·3	0·345	200·8	0·445	264·3	0·495
87·8	0·355	201·8	0·445	276·8	0·505
89·4	0·355	212·8	0·455		
99·8	0·365	213·3	0·455		

The following results (Table IV.) were not obtained with a piece of wire that had been actually employed in the emissivity experiments, but with a piece of wire cut off the same reel from which was taken the wire used in the emissivity experiments. Before, however, making the measurements given in Table IV., the piece of wire used was heated by a strong current, so as to be brightly luminous for 40 minutes, in order to bring it to the same state as that of the piece that had been used in the emissivity experiments.

TABLE IV.

July 16th, 1888. Diameter, 11·1 mils, or 0·282 millim. Length unknown.
Curve No. 3, fig. 7 (Plate 11).

Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.
° C.		° C.		° C.	
15·9	0·4496		0·577	222·1	0·711
40·9	0·483	141·9	0·609	238·2	0·731
59·9	0·507	150·3	0·620	255·2	0·752
68·2	0·518	162·6	0·635	272·0	0·771
79·1	0·532	175·4	0·650	291·4	0·792
89·2	0·545	187·6	0·665		0·809
100·5	0·560	200·7	0·6801	292·5	0·792
	0·569	209·6	0·695	273·1	0·771

The curves recording the results given in Tables III. and IV. are shown in Curves 2 and 3, fig. 7.

TABLE V.—Piece of Platinum Wire that had been used in Experiments on Emissivity.

July 27th, 1888. Diameter, 9·3 mils, or 0·236 millim. Length, 20·19 centims.

Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.
° C.		° C.		° C.	
19·2	0·6844	150·8	0·905	276·5	1·104
48·5	0·736	175·0	0·945	293·3	1·130
79·2	0·789	207·2	0·996	304·0	1·145
97·4	0·820	232·4	1·035	July	30th.
113·0	0·847	256·9	1·065	17·3	0·678

JULY 20th, 1888. Diameter, 8·1 mils, or 0·206 millim. Length unknown.

Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.
° C.		C.		° C.	
18·1	0·6191	112·5	0·805	301·0	1·138
43·7	0·670	205·6	0·971	295·8	1·130
62·8	0·707	232·9	1·020	265·9	1·079
78·1	0·737	262·9	1·075	254·8	1·059
94·8	0·770	284·3	1·110		
104·7	0·790	295·2	1·128		

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JULY 26th, 1888. Piece of the preceding wire. Length, 18·54 centims.

Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.
° C.		° C.		° C.	
19·0	0·6184	106·3	0·790	216·9	0·990
42·4	0·665	114·0	0·805	233·3	1·020
58·9	0·697	149·2	0·865	251·9	1·055
69·1	0·717	160·0	0·885	274·7	1·095
79·2	0·737	170·7	0·905	284·1	1·110
89·4	0·757	187·0	0·935		
96·1	0·770	206·5	0·971		

JULY 12th, 1888. Diameter, 6 mils, or 0·152 millim. Length, 17·07 centims. Fig. 14.

Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.
° C.		° C.		° C.	
14·8	1·047	131·1	1·445	266·7	1·885
32·7	1·110	153·7	1·520	273·2	1·905
45·0	1·153	160·1	1·541	280·0	1·925
53·85	1·183	176·8	1·595	289·0	1·950
61·8	1·210	183·2	1·616	294·8	1·967
73·0	1·248	195·2	1·657	302·0	1·988
81·0	1·276	202·5	1·680	306·0	2·000
93·3	1·318	213·7	1·715	309·0	2·010
102·8	1·352	224·7	1·750	311·0	2·015
110·2	1·377	231·3	1·772	305·0	1·995
112·5	1·385	240·0	1·800		
114·0	1·390	250·5	1·835	149·2	1·0475
126·7	1·426	257·0	1·855		

JULY, 19th, 1888. Diameter, 4 mils, or 0·102 millim. Length, 15·37 centims. Curve 4, fig. 8 (Plate 11).

Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.
° C.		° C.		° C.	
17·3	4·127	113	4·645	233·5	5·245
42·4	4·265	147·7	4·815	253·4	5·345
76·0	4·445	163·5	4·895	273·8	5·445
94·5	4·545	183·1	4·995	280·3	5·475
103·6	4·595	207·8	5·115		

The smallness of the variation of resistance of the last wire with temperature shows that it is not a pure platinum wire, and that it possibly contains a trace of silver or iridium.

JULY 5th, 1888. Diameter, 2·9 mils, or 0·074 millim. Length, 18·08 centims. Curve 5, fig. 8 (Plate 12).

Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.
° C.		° C.		° C.	
17	4·630	181·5	7·115	282·3	8·535
35·1	4·915	194·0	7·295		
49·8	5·145	202·3	7·415	15·8	4·611
59·6	5·295	211·7	7·545	69·2	5·445
69·5	5·445	215·9	7·605	105·3	5·995
79·1	5·595	224·2	7·725		
89·0	5·745	232·5	7·845	9·3	4·515
88·2	5·735	239·3	7·945	8·1	4·495
98·7	5·895	249·8	8·095	5·1	4·445
105·2	5·995	257·1	8·195	0·0	4·365
111·7	6·095	261·1	8·255	− 0·8	4·355
125·9	6·305	264·5	8·305	− 5·2	4·285
132·1	6·395	268·9	8·365	− 7·8	4·275
154·0	6·715	273·0	8·415	−11·0	4·225
159·8	6·805	274·9	8·445	−11·75	4·215
166·1	6·895	277·7	8·475	−12·5	4·205
173·3	6·995	279·0	8·495		
180·0	7·095	280·5	8·515		

The last set of results was obtained by placing the wire in alcohol and surrounding it with a freezing mixture.

JULY 3rd, 1888. Diameter, 2 mils, or 0·051 millim. Length about 10·31 centims. Curve No. 6, fig. 8 (Plate 12).

Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.
° C.		° C.		° C.	
16·4	5·375	94·0	6·795	160·1	7·945
66·1	6·295	99·6	6·895	168·7	8·095
71·7	6·395	105·4	6·995	175·1	8·195
77·2	6·495	107·8	7·045	184·1	8·345
82·3	6·595	111·0	7·095	192·5	8·495
88·4	6·695	155·3	7·865	203·3	8·645

JULY 11th, 1888. Diameter, 1·2 mil, or 0·031 millim. Length about 12·17 centims.

Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.	Temperature.	Resistance, in ohms.
° C.		° C.		° C.	
15·15	15·169	85·7	18·52	157·3	21·81
37·6	16·25	96·2	19·01	163·7	22·09
53·2	16·99	102·5	19·31	174·9	22 59
66·1	17·59	109·0	19·62		
74·6	17·99	129·9	20·56		

III. *Results of Emissivity Experiments.*

To determine the temperature of any one of the wires used in the emissivity experiments from its observed resistance, we might proceed as follows: calculate the specific resistance and then determine from the preceding curves, 1, 2, 3, &c. (figs. 7 and 8), the temperature at which a piece of the same wire had the same specific resistance. To do this it would be, of course, necessary to know the lengths of the two pieces of the same wire used in the two sets of experiments.

Now, whereas in each of the emissivity experiments a straight piece of wire of about 28 centims. was employed, the length of which could be measured with considerable accuracy, it was only possible to use shorter pieces for the experiments on the variation of resistance with temperature, for the latter pieces were parts of the wires that had actually been used in the emissivity experiments, and detaching a piece of wire from the apparatus seen in figs. 1 to 4, and attaching it to the clamp shown in figs. 5 and 6, necessarily shortened its length.

Since, therefore, there was this greater difficulty in measuring the exact lengths of the wires used in the experiments recorded in Tables I. to V., curves 1, 2, 3, &c., figs. 7 and 8, it was decided to regard these experiments as giving the relative resistances of each particular wire at different temperatures, but not the specific resistance at any particular temperature.

In order then to use these curves of relative resistance with temperature 1, 2, 3, &c., for the purpose of determining the temperature of the wires in the emissivity experiments, we must know the resistance of each of the latter wires at some one temperature. This might have been ascertained by means of the Wheatstone's bridge, but, as a relative resistance rather than absolute resistance was required, the following method was employed instead, since it avoided the possible introduction of an error that might have arisen from some want of agreement in the unit of resistance of the Wheatstone's bridge and the units of current and P. D. The ratio of P. D. to current, or the resistance of the wire, having been measured for a number of currents, a curve was plotted connecting the resistance of the wire for various currents flowing through it, and by continuing this curve until it cut the axis along which resistance was measured we obtained the limiting value of the ratio P. D. to current for current nought, that is, the resistance of the wire when at the temperature of the enclosure. Fig. 9 (Plate 13) shows the curve thus obtained for the thickest wire, viz., that of 14 mils, and similar curves were drawn for all the other wires for the purpose of ascertaining their respective resistances when at the temperature of the enclosure.

Let l and d be the length and diameter of the wire in centimetres, t_0 be the temperatures of the water jacket surrounding the enclosure cylinder $ABCD$ (figs. 1 and 2); t be the temperature of the wire when A amperes are passing through it, and when V volts is the P. D. between the ends of the wire, e be the emissivity, that is the number of calories (gramme C.) lost per second per square centimetre of surface per 1° C. excess temperature, then

$$e = \frac{0 \cdot 239 \text{ AV}}{\pi \, . \, l \, . \, d \, (t - t_0)},$$

l and d are not, however, absolute constants for a given wire, since as the wire gets hotter and hotter its length and diameter become larger and larger. If γ be the coefficient of linear increase of platinum per 1° C., which, according to KOHLRAUSCH, is 0·000009, then allowing for the lengthening and thickening of the wire as it increases in temperature, we have, if l and d be the values at 15° C.—

$$e = \frac{(1 + 15\gamma)^2}{(1 + \gamma t)^2} \cdot \frac{0 \cdot 239 \text{ AV}}{\pi \, . \, l \, . \, d \, (t - t_0)}$$

$$= \frac{0 \cdot 076094}{l \, . \, d} \cdot \frac{\text{AV}}{(1 + \gamma t)^2 \, (t - t_0)} .$$

Now $(1 + \gamma t)^2 (t - t_0)$ may be regarded as equal to $(t - t_0) + \Delta (t - t_0)$ where $\Delta (t - t_0)$ is a correction that must be added to the observed excess temperature $(t - t_0)$, the amount of this correction depending on the value of t. The values of $(1 + \gamma t)^2 \; (t - t_0)$ and the amounts of the correction for different values of t are given in the following Table VI., and are shown plotted in fig. 10 (Plate 13). The corrections are but small, but they have nevertheless been taken into account in determining the values of the emissivity given in the following Tables VII., VIII., and IX.

TABLE VI.

Temperature t.	$(1 + \gamma t)^2 \, (t - t_0)$.	$\Delta \, (t - t_0)$.
° C.		
15	0·500065	0·00014
30	15·5084	0·008
50	35·532	0·032
70	55·57	0·07
85	70·61	0·11
100	85·65	0·15
120	105·73	0·23
140	125·82	0·32
160	145·92	0·42
180	166·04	0·54
200	186·17	0·67
240	226·48	0·98
280	266·84	1·34
300	287·04	1·54

Table VII.

Diameter, 14 mils, or 0·356 millim. Length, 28·09 centims. Water-jacket, 14°·5 C. May 3rd, 1888. Fig. 11. (Plate 14.)

Current, in amperes.	P.D., in volts.	Resistance, in ohms.	Equivalent temperature of wire.	Emissivity.
			° C.	
0·05	0·01584	0·3168		
0·075	0·02395	0·3195		
0·10	0·03198	0·3198		
0·15	0·04853	0·3235		
0·20	0·06386	0·3193		
0·25	0·07900	0·3160		
0·30	0·09464	0·3155		
0·40	0·1268	0·3170		
0·50	0·1602	0·3204	17·4	·002104
0·60	0·1939	0·3232	19·7	·001705
0·80	0·2627	0·3284	24·6	·001585
1·00	0·3349	0·3349	30·0	·001645
1·20	0·4091	0·3409	35·7	·001764
1·50	0·5334	0·3556	50·4	·001698
1·80	0·6667	0·3700	64·5	·001825
2·10	0·8261	0·3934	87·0	·001820
2·40	1·004	0·4182	111·0	·001899
2·70	1·201	0·4449	137·4	·002005
3·00	1·439	0·4796	172·5	·002074
3·40	1·815	0·5338	226·6	·002207
3·80	2·291	0·6029	304·0	·002278

The first eight observations in the above Table were made to enable the early part of the curve in fig. 9 to be plotted, so as to find the resistance of the wire that corresponded with current nought; and this the curve shows to be 0·318 ohm. The wire, then, at the temperature of the water-jacket, viz., 14°·5 C., has this resistance, 0·318 ohm.

TABLE VIII.

Diameter, 11·1 mils, or 0·282 millim. Length, 28·35 centims. Water-jacket, 15° C
May 2nd, 1888. Fig. 11.

Current, in amperes.	P.D., in volts.	Resistance, in ohms.	Equivalent temperature of wire.	Emissivity.
			° C.	
0·05	0·02817	0·5634		
0·075	0·04241	0·5655		
0·10	0·05655	0·5655		
0·15	0·08532	0·5688		
0·20	0·1133	0·5665		
0·25	0·1415	0·5660		
0·30	0·1694	0·5647		
0·40	0·2260	0·5650		
0·50	0·2867	0·5734		
0·60	0·3479	0·5798	25·6	·002054
0·80	0·4782	0·5978	37·3	·001705
1·00	0·6148	0·6148	48·7	·001787
1·20	0·7583	0·6319	60·0	·001965
1·50	1·007	0·6713	84·9	·002081
1·80	1·307	0·7261	121·1	·002123
2·10	1·667	0·7938	166·0	·002211
2·40	2·088	0·8700	215·4	·002379
2·70	2·587	0·9581	273·7	·002563

As in the case of Table VII., the first nine observations in Table VIII. were made only for the purpose of enabling the early part of the curve in fig. 9 to be drawn. In the following Table IX., which gives the results for the remaining wires, the first eight or nine observations that were made in each case are omitted, since, although these observations were of value in enabling the early part of the curve, such as is shown in fig. 9, to be drawn for each wire, the difference between the temperature of the wire and of the water-jacket was too small to enable the corresponding emissivities to be accurately calculated.

TABLE IX.

Diameter, 9·3 mils, or 0·236 millim. Length, 27·86 centims. Water-jacket, 15°·9 C.
April 28th, 1888. Fig. 11.

Current, in amperes.	P.D., in volts.	Resistance, in ohms.	Equivalent temperature of wire.	Emissivity.
			° C.	
0·60	0·5193	0·866	40·9	·001441
0·80	0·7078	0·885	49·9	·001926
1·00	0·9206	0·921	66·9	·002087
1·20	1·1554	0·963	86·1	·002281
1·40	1·423	1·016	113·6	·002353
1·70	1·895	1·115	164·8	·002495
2·00	2·484	1·242	232·4	·002642
2·30	3·186	1·385	310·0	·002865

TABLE IX.—continued.

Diameter, 8·1 mils, or 0·206 millim. Length, 27·86 centims. Water-jacket, 12°·3 C. April 26th, 1888. Fig. 11.

Current, in amperes.	P.D., in volts.	Resistance, in ohms.	Equivalent temperature of wire.	Emissivity.
			° C.	
0·50	0·5200	1·040	24·8	·002761
0·60	0·6366	1·061	31·2	·002682
0·70	0·7589	1·084	38·6	·002681
0·80	0·8922	1·115	48·0	·002654
0·90	1·0336	1·148	58·0	·002696
1·00	1·1855	1·186	69·5	·002747
1·20	1·5423	1·285	101·3	·002755
1·40	1·971	1·408	141·8	·002822
1·60	2·478	1·549	188·7	·002974
1·80	3·093	1·718	242·0	·003206
2·00	3·792	1·896	309·0	·003375

Diameter, 6 mils, or 0·152 millim. Length, 27·46 centims. Water-jacket, 12° C. April 24th, 1888. Fig. 11.

Current, in amperes.	P.D., in volts.	Resistance, in ohms.	Equivalent temperature of wire.	Emissivity.
			° C.	
0·075	0·1283	1·711	15·2	·000547
0·10	0·1716	1·716	16·4	·000709
0·15	0·2600	1·734	19·3	·000972
0·20	0·3488	1·744	20·8	·001442
0·25	0·4390	1·756	23·0	·001814
0·30	0·5334	1·778	26·6	·001993
0·40	0·7238	1·810	32·6	·002556
0·50	0·9414	1·883	45·9	·002525
0·60	1·179	1·965	60·2	·002663
0·70	1·449	2·069	78·2	·002781
0·80	1·744	2·180	97·8	·002954
0·90	2·093	2·326	125·4	·003013
1·00	2·466	2·466	150·8	·003222
1·20	3·398	2·832	219·5	·003560
1·40	4·620	3·300	314·0	·003873

TABLE IX.—continued.

Diameter, 4 mils, or 0·102 millim. Length, 27·69 centims. Water-jacket 13° C.
April 14th, 1888. Fig. 12. (Plate 14.)

Current, in amperes.	P.D., in volts.	Resistance, in ohms.	Equivalent temperature of wire.	Emissivity.
			° C.	
0·04102	0·30934	7·540	17·9	·000701
0·06154	0·46555	7·565	20·4	·001047
0·08205	0·61868	7·540	17·9	·002803
0·10256	0·77591	7·565	20·4	·002909
0·12307	0·93418	7·590	23·0	·003110
0·14358	1·0894	7·587	22·4	·004502
0·17435	1·3319	7·639	27·8	·004245
0·20512	1·5600	7·605	24·4	·007593
0·24614	1·8951	7·699	33·8	·006067
0·28717	2·2301	7·766	40·9	·006210
0·32819	2·5877	7·884	52·4	·005831
0·36922	2·9464	7·980	61·9	·006006
0·41024	3·3246	8·104	74·6	·005980
0·46152	3·8179	8·272	91·9	·006034
0·5128	4·347	8·477	113·3	·006000
0·5641	4·892	8·655	132·0	·006258
0·6154	5·498	8·935	162·6	·006010
0·6666	6·141	9·211	193·0	·006132
0·7179	6·809	9·483	222·7	·006282
0·8205	8·340	10·164	298·9	·006441

We have already drawn attention to the fact that the above wire, of 4 mils or 0·102 millim. in diameter, has a much smaller variation of resistance with temperature than the other wires, and therefore that it is probable that this wire has some iridium or silver in its composition. From the preceding table we see that the variation of emissivity with temperature is also much smaller with this wire than with the others.

TABLE IX.—continued.

Diameter, 2·9 mils, or 0·074 millim. Length, 28·85 centims. Water-jacket, 15°·6 C. May 4th, 1888. Fig. 12.

Current, in amperes.	P.D., in volts.	Resistance, in ohms.	Equivalent temperature of wire.	Emissivity.
			° C.	
0·020	0·1614	8·070	19·1	·000330
0·030	0·2426	8·087	19·7	·000635
0·040	0·3268	8·170	22·8	·000650
0·050	0·4120	8·241	25·3	·000760
0·075	0·6266	8·266	26·2	·001587
0·100	0·8471	8·471	33·5	·001694
0·150	1·312	8·748	44·1	·002472
0·200	1·817	9·083	56·5	·003181
0·250	2·369	9·476	72·0	·003753
0·300	2·989	9·965	89·5	·004339
0·350	3·699	10·569	112·5	·004774
0·400	4·574	11·435	146·2	·005001
0·450	5·587	12·415	185·4	·005283
0·500	6·817	13·634	234·2	·005559
0·550	8·271	15·038	293·5	·005829

Diameter, 2 mils, or 0·051 millim. Length, 24·46 centims. Water-jacket, 13° C. April 4th, 1888. Fig. 12.

Current, in amperes.	P.D., in volts.	Resistance, in ohms.	Equivalent temperature of wire.	Emissivity.
			° C.	
0·06155	0·7904	12·842	19·0	·004965
0·08206	1·0690	13·026	23·6	·005068
0·10258	1·3619	13·277	29·4	·005217
0·13335	1·8296	13·710	39·4	·005660
0·16413	2·3281	14·185	50·2	·006291
0·19490	2·8615	14·682	61·7	·006999
0·22568	3·4639	15·349	77·2	·007445
0·25645	4·1443	16·160	96·3	·007804
0·29748	5·1115	17·183	121·1	·008598
0·33851	6·532	19·296	173·4	·008416
0·38980	8·351	21·424	227·0	·009268
0·44109	10·834	24·561	306·0	·009934

TABLE IX.—continued.

Diameter, 1·2 mil, or 0·031 millim. Length, 25·10 centims. Water-jacket, 10°·5 C
April 13th, 1888. Fig. 12.

Current, in amperes.	P.D., in volts.	Resistance, in ohms.	Equivalent temperature of wire.	Emissivity.
			° C.	
0·01026	0·31863	31·062	13·0	·001301
0·02052	0·64035	31·212	14·54	·003236
0·03077	0·96618	31·396	16·5	·004930
0·04103	1·3054	31·814	20·8	·005173
0·06155	2·0177	32·782	30·4	·006208
0·08206	2·7598	33·630	39·3	·007823
0·10285	3·5564	34·669	49·5	·009306
0·12310	4·4660	36·281	66·1	·009819
0·14361	5·4784	38·148	85·0	·010492
0·16413	6·6502	40·518	109·3	·010968
0·18464	7·9247	42·919	135·4	·011627
0·20516	9·4305	45·967	168·0	·012182
0·23593	12·0567	51·102	224·5	·013168
0·26671	15·1916	56·960	291·2	·014284

Using the values of temperature and emissivity given in the preceding Tables VII., VIII., and IX., the curves shown in fig. 11 have been drawn for the five thicker wires, viz., those having diameters of 14 mils, or 0·356 millim.; 11·1 mils, or 0·282 millim.; 9·3 mils, or 0·236 millim.; 8·1 mils, or 0·206 millim.; and 6 mils, or 0·152 millim., respectively; and the curves shown in fig. 12 have been similarly drawn for the four finer wires, viz., those having diameters of 4 mils, or 0·102 millim.; 2·9 mils, or 0·074 millim.; 2 mils, or 0·051 millim.; and 1·2 mil, or 0·031 millim., respectively.

The curves for the four finest wires on fig. 12 and for two of the thicker wires on fig. 11, appear to be fairly regular throughout their whole length, while the curves for the 14, the 11·1, and the 8·1 mils wires appear doubtful for temperatures below 60° C.

On examining the curves we see that:—

1. For any given temperature the emissivity is the higher the finer the wire.

2. For each wire the emissivity increases with the temperature, and the rate of increase is the greater the finer the wire. For the finest wire the rate of increase of emissivity with temperature is very striking.

3. Hence the effect of surface on the total loss of heat (by radiation and convection) per second per square centim. per 1° C. excess temperature increases as the temperature rises.

The wire of 4 mils diameter appears to be an exception to these rules; but we have already seen reasons for believing that this wire was not drawn from pure platinum like the rest, but possibly from platinum-iridium or platinum-silver.

On comparing the loss of heat from the wire of 1·2 mil diameter when at 300° C. with that from the wire of 6 mils diameter when at 15° C., both being in an enclosure at 10° C., we see that the former loses per square centimetre per second, not

$$\frac{300 - 10}{15 - 10} \text{ or } 58 \text{ times}$$

as much heat as the latter (which it would do if the emissivity were the same) but instead,

$$60 \times 58 \text{ or } 3480 \text{ times}$$

as much heat; arising from the fact that the emissivity, that is, the number of calories (gramme C.°) lost per second per square centim. of surface per 1° C. excess temperature of the 1·2 mil wire at 300° C., is 60 times as great as that of the 6 mils wire at 15°, the latter varying very rapidly with the temperature near 15° C.

From the curves on figs. 11 and 12 the following table has been drawn up giving the emissivities of the various wires at eight useful even temperatures.

TABLE X.—Emissivities at—

Diameter of wire in		40° C.	60° C.	80° C.	100° C.	150° C.	200° C.	250° C.	300° C.
Mils.	Millims.								
1·2	0·031	0·00823	0·00956	0·01030	0·01085	0·01187	0·01278	0·01362	0·01440
2·0	0·051	0·00595	0·00686	0·00750	0·00790	0·00860	0·00907	0·00948	0·00985
2·9	0·074	0·00219	0·00334	0·00409	0·00455	0·00509	0·00538	0·00563	0·00584
6·0	0·152	0·00246	0·00266	0·00280	0·00293	0·00321	0·00346	0·00367	0·00384
8·1	0·206	..	..	..	0·00280	0·00294	0·00308	0·00322	0·00335
9·3	0·236	..	..	..	0·00230	0·00245	0·00259	0·00272	0·00284
11·1	0·282	..	..	..	0·00205	0·00222	0·00236	0·00249	0·00261
14·0	0·356	..	..	..	0·00189	0·00203	0·00214	0·00222	0·00229

The next step taken was to express mathematically the law connecting the emissivity of a wire with its diameter for a fixed temperature, and this was done for three fixed temperatures, viz., 100° C., 200° C., and 300° C. Using the values of the emissivity contained in the three columns headed with these temperatures in Table X. we obtained :—

$$\text{For } 100° \text{ C., } e = 0·001036 + 0·012078\, d^{-1} \quad . \quad . \quad . \quad . \quad . \quad . \quad (5),$$

$$\text{,,} \quad 200° \text{ C., } e = 0·001111 + 0·014303\, d^{-1} \quad . \quad . \quad . \quad . \quad . \quad . \quad (6),$$

$$\text{,,} \quad 300° \text{ C., } e = 0·001135 + 0·016084\, d^{-1} \quad . \quad . \quad . \quad . \quad . \quad . \quad (7),$$

where d is the diameter of the wire in mils or thousandths of an inch.

The following Tables, XI., XII., and XIII., give the actual emissivities, the emissitives calculated by means of the three preceding formulæ respectively, the differences, and the percentage differences.

TABLE XI.—Wire at 100° C.

Diameter of wire. (mils.)	Diameter of wire. (millims.)	Actual emissivity.	Calculated emissivity.	Difference.	Percentage difference.
1·2	0·031	0·01085	0·01104	+ 0·00019	+ 1·8
2·0	0·051	0·00790	0·00707	− 0·00083	− 11·7
2·9	0·074	0·00455	0·00520	+ 0·00065	+ 12·5
6·0	0·152	0·00293	0·00305	+ 0·00012	+ 3·9
8·1	0·206	0·00280	0·00253	− 0·00027	− 10·9
9·3	0·236	0·00230	0·00233	+ 0·00003	+ 1·6
11·1	0·282	0·00205	0·00212	+ 0·00007	+ 3·3
14·0	0·356	0·00189	0·00190	+ 0·00001	+ 0·5

TABLE XII.—Wire at 200° C.

Diameter of wire. (mils.)	Diameter of wire. (millims.)	Actual emissivity.	Calculated emissivity.	Difference.	Percentage difference.
1·2	0·031	0·01278	0·01303	+ 0·00025	+ 1·9
2·0	0·051	0·00907	0·00826	− 0·00081	− 9·8
2·9	0·074	0·00538	0·00604	+ 0·00066	+ 11·0
6·0	0·152	0·00346	0·00349	+ 0·00003	+ 1·0
8·1	0·206	0·00308	0·00288	− 0·00020	− 6·9
9·3	0·236	0·00259	0·00265	+ 0·00006	+ 2·4
11·1	0·282	0·00236	0·00240	− 0·00004	− 1·5
14·0	0·356	0·00214	0·00213	− 0·00001	+ 0·4

TABLE XIII.—Wire at 300° C.

Diameter of wire. (mils.)	Diameter of wire. (millims.)	Actual emissivity.	Calculated emissivity.	Difference.	Percentage difference.
1·2	0·031	0·01440	0·01454	+ 0·00014	+ 1·0
2·0	0·051	0·00985	0·00918	− 0·00067	− 7·3
2·9	0·074	0·00584	0·00668	+ 0·00084	+ 12·6
6·0	0·152	0·00384	0·00382	− 0·00002	− 0·5
8·1	0·206	0·00335	0·00312	− 0·00023	− 7·4
9·3	0·236	0·00284	0·00286	+ 0·00002	+ 0·7
11·1	0·282	0·00261	0·00258	− 0·00003	− 1·2
14·0	0·352	0·00229	0·00228	− 0·00001	− 0·4

The values of the emissivity given in the last table are plotted in the curve shown in fig. 13 (Plate 15).

The statement not unfrequently made that the current required to maintain a wire of a given material at a given temperature above that of the surrounding envelope is proportional to the diameter of the wire raised to the power three halves, is equivalent to stating that the emissivity is independent of the diameter. Now if we may assume that the three formulæ (5), (6), (7) given above for e may be used not merely for the platinum wires when fine, but also as giving at any rate a rough approximation of the value of e when the wire is as much as 4 or 5 millims. thick, we may conclude that for a temperature of 100° C. the value of d in the formula

$$e = 0{\cdot}001036 + 0{\cdot}012078\, d^{-1}$$

must be something of the order 220 mils, or 5·6 millims., so that the neglect of the second term may not make an error in e of more than 5 per cent., and something of the order 1·15 inch, or 29·3 millims., if the error is not to exceed 1 per cent.; that for a temperature of 200° C., the value of d in the formula

$$e = 0{\cdot}001111 + 0{\cdot}014303\, d^{-1}$$

must be something of the order 244 mils, or 6·2 millims., so that the neglect of the second term may not make an error in e of more than 5 per cent., and something of the order 1·28 inch, or 32·5 millims., if the error is not to exceed 1 per cent.; and that for a temperature of 300° C., the value of d in the formula

$$e = 0{\cdot}001135 + 0{\cdot}016084\, d^{-1}$$

must be something of the order 267 mils, or 6·8 millims., so that the neglect of the second term may not make an error in e of more than 5 per cent, and something of the order 1·39 inch, or 35·3 millims., if the error is not to exceed 1 per cent.

Generally, then, although it may be possible to obtain only very rough approximations of the values of the emissivities of thick wires by using the three formulæ that we have deduced from the experiments on thin wires, still it follows that to assume that the emissivity is a constant for wires whose diameters vary from a small value up to 1 inch is to make a large error in the case of the greater number of the wires, and an error of hundreds per cent. in the case of some of them.

The formulæ (5), (6), (7) given above have been calculated from the results of experiments made on wires varying from 1·2 to 14 mils, and the method of calculation employed makes the percentage difference between the observed and calculated emissivity very small at each end of the range as well as in the middle. We may, therefore, use the formula to obtain some idea of what the emissivity is likely to be for a wire somewhat smaller than that used in the experiments, say, of 0·75 mil in diameter. Using formula (7) to obtain the emissivity at 300° C., we find it to be 0·02258. We can now make an approximate estimate of the current density, or amperes per square centimetre, it would be necessary to employ with a platinum wire of 0·75 mil in order to keep it at a temperature of 300° C., when the enclosure was, say, at 15° C.

From the tables that we have given of the resistance of platinum wire at different temperatures, we see that the resistance of 17 centims. of wire 0·152 millim. in diameter is about 2 ohms at 300° C. Hence the resistance of 17 centims. of wire 0·75 mil., or 0·0191 millim. in diameter, will be about

$$2\left(\frac{0{\cdot}152}{0{\cdot}0191}\right)^2, \text{ or } 128{\cdot}0 \text{ ohms.}$$

If, therefore, x be the required current density, the rate of production of heat in calories (gramme-centigrade) per second will be

$$\left\{x \times \pi \times \left(\frac{0{\cdot}00191}{2}\right)^2\right\}^2 \times 128{\cdot}0 \times 0{\cdot}239,$$

which must equal the number of calories lost per second, viz.,

$$17 \times \pi \times 0{\cdot}00191 \times 0{\cdot}02258 \times 285, \text{ or } 0{\cdot}6546,$$

therefore, $x = 51330$ amperes per square centimetre. If the wire, instead of being platinum, had been made of copper, and if the emissivity for a copper wire, 0·75 mil in diameter, were the same as that of a platinum wire of the same diameter, the current density that would be required to keep the copper wire at a temperature of 300° C., when the enclosure was at 15° C., would be about

$$51330\sqrt{5{\cdot}7},$$

that is, 122,600 amperes per square centimetre, or 790,500 amperes per square inch.

[It may be useful to give the general formula which we have arrived at for calculating the current A amperes, required to be sent through any long thin platinum wire d mils in diameter to maintain it at a temperature of 300° C. when the enclosure (having about the dimensions shown in fig. 1) is maintained at a temperature of 15° C.

From the various measurements given in the paper it follows that the resistance per cubic mil of platinum at 300° C. is about 0·0086 ohm. Hence, equating the rate of production and loss of heat per mil length of the wire, we have

$$\frac{A^2 \times 0{\cdot}0086 \times 4 \times 0{\cdot}24}{\pi d^2} = \frac{\pi d \times 285}{(393{\cdot}7)^2}(0{\cdot}001135 + 0{\cdot}016084\, d^{-1}),$$

therefore,

$$A = 1{\cdot}483\sqrt{(0{\cdot}001135\, d^3 + 0{\cdot}016084\, d^2)} \text{ about.}$$

Also, if the wire having the conditions described above be l inches long, the watts that must be expended on it equal approximately $(0{\cdot}3869 + 0{\cdot}02732\, d)\, l$.

IV. *Comparison of the Results with those obtained by MM.* DULONG *and* PETIT.

All the emissivity curves in figs. 11 and 12 (Plate 14) have the same general shape, being concave to the axis of temperature, and it is interesting to see how far this general shape agrees with the results obtained in the classical researches of MM. DULONG and PETIT for the loss of heat from thermometer bulbs in air.

The formulæ they developed for the loss of heat by radiation and convection in air lead to the following expression for the emissivity :—

$$e = \frac{1}{t}\{\mathrm{H}a^{\theta}(a^{t} - 1) + \mathrm{K}p^{0\cdot45}t^{1\cdot2333}\},$$

where θ is the temperature of the enclosure, t the excess temperature of the cooling body, a a constant having the value 1·0077 if the temperature be measured in degrees Centigrade, p the pressure of the gas, H a constant depending on the nature of the surface of the cooling body and of the enclosure, and K a constant depending mainly on the nature of the gas surrounding the cooling body and but very slightly on the nature of the surface of the cooling body.

Substituting the value of a and expanding in powers of t we have

$$\begin{aligned} e = {} & 0\cdot0076705 \times 1\cdot0077^{\theta}.\mathrm{H}.\{1 + 0\cdot00383526\,t + 0\cdot000009806\,t^2 \\ & + 0\cdot0000000188\,t^3 + 0\cdot0000000000029\,t^4 + \ldots\} \\ & + \mathrm{K}.p^{0\cdot45}.t^{0\cdot233}. \end{aligned}$$

If y be used to stand for the expression in the brackets and y' for $t^{0\cdot233}$, calculation shows that y and y' have the following values for the different values of t :—

Values of		
t.	y.	y'.
0	1	0
10	1·03935	1·7100
100	1·50067	2·9242
200	2·31430	3·4367
300	3·56405	3·7772

And using for H and K the values found by Mr. HOPKINS for polished limestone cooling in air at 760 millims. pressure, contained in an enclosure at 0° C., the expression given above for e becomes

$$e = \lambda (0{\cdot}069\, y + 0{\cdot}038\, y'),$$

hence, substituting the values given in the last table for y and y', we have

Values of	
t.	e/λ.
0	0·069
10	0·137
100	0·222
200	0·291
300	0·389

Consequently, if the law connecting the loss of heat from thermometer bulbs in air with the difference of temperature between the bulb and the enclosure is of the same nature as that connecting the loss of heat from very fine horizontal wires in air with the difference of temperature, we should expect to find that the curve connecting the values of e/λ and t in the last table would, when plotted, be everywhere *concave* to the axis of t. But this is not the case, for we find on plotting this curve that while it resembles our curves in being concave to the axis of t, for values of t less than about 200° C. it changes its curvature at about this point and becomes distinctly convex.

It is, of course, to be remembered the maximum value of t in the experiments of MM. DULONG and PETIT was 240° C., while in some of ours t exceeded 300° C. We are, however, inclined to attribute the inability of the formulæ of MM. DULONG and PETIT to give even the general shape of the curves which we have obtained to the fact that the convection which occurs with thermometer bulbs hardly suggests the very great convective cooling that experiments show to occur with very fine wires at high temperatures.—May 31, 1892.]

V. *Calculation of the Distribution of Temperature along a Platinum Wire Heated by an Electric Current.*

Let d be the diameter of the wire in centimetres.

t „ temperature in degrees centigrade at any point of the wire distant x centimetres from the nearer of the two supports to which the ends of the wire are attached.

t_0 „ temperature of the supports.

$f(t)$ „ electrical resistance, in ohms, of a cubic centimetre of the wire at a temperature t.

$\phi(t)$ „ thermal resistance of a cubic centimetre of the wire at a temperature t.

$\psi(t)$ be the emissivity at a temperature t for a wire of diameter d.
K ,, number of calories corresponding with one watt-second.
A ,, current in amperes flowing through the wire;

then following the method of reasoning employed with such problems, we have

$$\frac{\pi d^2}{4}\frac{d}{dx}\left(\frac{\frac{dt}{dx}}{\phi(t)}\right)+\frac{4}{\pi d^2}\mathrm{KA}^2 f(t)=\pi d(t-t_0)\psi(t) \quad . \quad . \quad . \quad . \quad . \quad . \quad (8).$$

$\phi(t)$ is in reality the reciprocal of the amount of heat in calories that would flow per second across one cubic centimetre of the material for 1° C. difference of temperature between the opposite faces and for a mean temperature of the material of t°.

$\psi(t)$ is the number of calories lost per second on account of radiation and convection for 1° C. excess temperature from a square centimetre of the platinum wire of diameter d and at a temperature t.

In the preceding equation d is strictly the diameter of each part of the wire at the particular temperature it is at. As, however, an increase of the temperature from 0° C. up to 300° C. only increases the linear dimensions of platinum by about 0·26 per cent., d may be taken as the diameter of the wire at 15° C.

$f(t)$ and $\psi(t)$ are known from the various curves connecting resistance with temperature and emissivity with temperature for each of the various wires experimented on. The variation of the thermal resistance of platinum with temperature has not, as far as we can learn, been experimentally examined, nor does it appear to be even known whether the thermal resistance of platinum increases with temperature, as does the thermal resistance of iron, or diminishes with the rise of temperature, as does the thermal resistance of copper and German silver. Under these circumstances we decided to assume that the thermal resistance of platinum was a constant, and had the value it is known to possess at ordinary temperatures, and to see what sort of result a mathematical assumption based on this result would lead to.

As a matter of fact, even the thermal conductivity of platinum at ordinary temperatures is not stated explicitly in books, but it can be easily arrived at indirectly. For we find that WIEDEMANN and FRANZ determined that

$$\frac{\text{Thermal conductivity of platinum}}{\text{Thermal conductivity of copper}}=\frac{8\cdot 2}{77\cdot 2},$$

and in the article "Heat" in the 'Encyclopædia Britannica,' the value of the thermal conductivity of copper, 0·96 as determined by ÅNGSTRÖM, is stated to be trustworthy. From these numbers we deduce that the thermal resistance of platinum, at ordinary temperatures, is 9·858, which is the value we have taken for $\phi(t)$.

Equation (8) can then be written in the form

$$\frac{d^2t}{dx^2} = \mathrm{P}\,(t - t_0)\,\psi\,(t) - \mathrm{Q}f\,(t) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

where

$$\mathrm{P} = \frac{4 \times 9\cdot858}{d},$$

and

$$\mathrm{Q} = \frac{4\mathrm{KA}^2}{\pi d^2} \cdot \frac{4 \times 9\cdot858}{\pi d^2},$$

P and Q are therefore constants for a particular wire with a particular current flowing through it.

We next tried to expand $\psi(t)$ and $f(t)$ as functions of t from the curves which we had experimentally obtained connecting emissivity with temperature and resistance with temperature, but we found that it was not possible to express these functions of t in any such simple shape as would allow the integration of equation (9) to be effected analytically, and a result obtained suitable to be used for easily determining the value of t for any value of x. We, therefore, consulted Professor HENRICI regarding the integration of equation (9) in a practical form, and we have to express our thanks to him for the warm interest that he has taken in this mathematical problem, and for the many suggestions that he has kindly made, and which have enabled us to arrive at the following solution. We have also to thank one of our assistants, Mr. WALKER, for carrying out the graphical and numerical calculations contained in this section of the paper.

It is clear that the law of distribution of temperature along the wire will depend on the diameter of the wire among other things, also on the current passing through it, the variation of temperature with length of wire being the more rapid the thicker the wire and the greater the current passing through it. We therefore selected for consideration a wire of mean diameter, namely, that of 6 mils or 0·152 millim., and we took the case when 1·4 ampere was passing through it, which is the greatest current that was passed through this wire in the emissivity experiments.

Having selected this wire and current, the next step consisted in calculating $\mathrm{P}\,(t - t_0)\,\psi\,(t)$ and $\mathrm{Q}f\,(t)$ for different values of t. t_0 is 12° C., P is 2587·4, and the value of $\psi\,(t)$ may be obtained from the emissivity curve for the 6 mils or 0·152 millim. wire given in fig. 11. Instead of calculating $f\,(t)$ the resistance per cubic centimetre of the material for different values of (t) it is more convenient to write

$$\mathrm{Q}f(t) \text{ as } \frac{\mathrm{KA}^2}{l} \cdot \frac{4 \times 9\cdot858}{\pi d^2}\,\mathrm{F}\,(t),$$

where l is the length, 17·07 centims., of this 6-mil wire that was used in the experiments from the results of which the curve in fig. 14 (Plate 15) has been drawn, and

F (t) is the resistance in ohms of this 17·07 centims. of this 6-mil wire at any particular temperature, t. Now, when A equals 1·4 ampere, and d equals 0·152 millim., and l is 17·07 centims.,

$$\frac{\mathrm{KA}^2}{l} \cdot \frac{4 \times 9{\cdot}858}{\pi\, d^2} = 1491{\cdot}7\ ;$$

therefore, the equation (9) becomes

$$\frac{d^2t}{dx^2} = 2587{\cdot}4\,(t - 12)\,\psi\,(t) - 1491{\cdot}7\ \mathrm{F}\,(t) \quad . \quad . \quad . \quad . \quad . \quad . \quad (10).$$

To obtain a curve representing the first term on the right-hand side of this equation, the curve for $\psi\,(t)$, given for the 6-mil wire in fig. 11, was altered by simple geometrical construction so as to give a curve for $t \times \psi\,(t)$. The ordinates of this curve were then altered, graphically, so as to give to a convenient scale a curve for $2587{\cdot}4\ t\,.\,\psi\,(t)$, and, lastly, the ordinates of this curve were reduced, graphically, in the proportion of $t-12$ to t.

To obtain the curve representing the second term on the right-hand side of equation (10), the ordinates of the curve on fig. 14 were multiplied by 1491·7, and then the curve was re-drawn to the same scale as the curve representing $2587{\cdot}4\,(t - 12)\,\psi\,(t)$. The ordinates of the two curves were then subtracted from one another, and a curve, having for its ordinates the difference of the ordinates of the last two curves, was drawn, which gives the values of d^2t/dx^2 for any value of t. This curve is seen in fig. 15 (Plate 15), it is parabolic in shape, cuts the axis along which temperature is reckoned at t equals 315° C., and has its vertex approximately in the line along which d^2t/dx^2 is reckoned.

A similar investigation was made for the same wire for a current of 0·6 ampere, and it was found that the curve for d^2t/dx^2 in this case cut the axis of temperature at 60°·3 C.

The fact that d^2t/dx^2 is nought at a particular temperature tells us, of course, mathematically nothing about the actual value of dt/dx, but from our general knowledge of temperature curves, we know that when a current is passing through a fine wire, as in our experiments, the temperature will rise rapidly along the wire in the neighbourhood of the supports, then rise more slowly, and at no great distance from the supports the temperature curve will become nearly flat, and will be absolutely flat over the middle portion of the wire.

We are, therefore, justified in assuming that d^2t/dx^2 and dt/dx are nought at about the same point of the wire.

On examining the numbers in Table V., which refer to the 6-mil wire, it will be noticed that the mean temperatures of the wire for currents of 1·4 and 0·6 ampere respectively, were 314° C. and 60°·2 C., which are almost exactly the temperatures

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for which d^2t/dx^2 are nought for these two currents in question. It is certainly surprising that a calculation based on the assumption that the thermal resistance of platinum is the same at all temperatures between 0° C. and 300° C. as it is at ordinary temperatures, should have led to the result that, both for a current of 1·4 ampere and a current of 0·6 ampere passing through this 6-mil wire, d^2t/dx^2 should be nought, that is, the temperature curve should be flat at almost exactly the mean temperature that the wire had in each case. It would, therefore, appear that the assumption regarding the thermal resistance of platinum having a constant value 9·858 at different temperatures has not introduced any serious error.

If we assume that the vertex of the parabolic curve for d^2t/dx^2 is in the line along which d^2x/dt^2 is reckoned, which is very nearly the case, then

$$\frac{d^2t}{dx^2} = t^2 \cdot \frac{a}{\mathrm{T}} - a \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11).$$

where a is minus the value of d^2t/dx^2 when x equals nought, and T is the value of t when d^2t/dx^2 equals nought.

At the point of the wire where the temperature is the highest the temperature curve will be flat, that is, dt/dx will be nought, and at the end of the wire where it is attached to the support the temperature will have some definitive value, T_0, in other words when

$$t = \mathrm{T}, \quad \frac{dt}{dx} = 0,$$

and when

$$x = 0, \quad t = \mathrm{T}_0.$$

With these two conditions only and without any reference to the length of the wire, it is possible to integrate the equation (11), and the result we arrive at is

$$x = \pm \sqrt{\frac{\mathrm{T}}{2a}} \cdot \log \frac{\sqrt{(t + 2\mathrm{T})} - \sqrt{3\mathrm{T}}}{\sqrt{(t + 2\mathrm{T})} + \sqrt{3\mathrm{T}}} \cdot \frac{\sqrt{(\mathrm{T}_0 + 2\mathrm{T})} + \sqrt{3\mathrm{T}}}{\sqrt{(\mathrm{T}_0 + 2\mathrm{T})} - \sqrt{3\mathrm{T}}} \quad . \quad . \quad (12).$$

An examination of this equation shows that in order that t may equal T, x must equal infinity, and, therefore, in obtaining this integral we have tacitly assumed that the maximum temperature of the wire is only obtained at an infinite distance from its end. But while great simplicity is obtained by this hypothesis, no more error is introduced by its employment than is met with by the use of the ordinary equation for the conduction of heat, and which leads to the result that two bodies initially at a different temperature take an infinite time to arrive at thermal equilibrium, even when connected together by a good conductor of heat.

On examining the curve for d^2t/dx^2 on fig. 15, which as already stated has been calculated for the 6-mil wire for the maximum current used, viz., 1·4 ampere, we find that

$$a = 1592,$$
$$T = 315^\circ \text{ C.}$$

The temperature of the enclosure in the emissivity experiments with this wire was 12° C., and as the temperature T_0 of the point of the wire where it was joined to the support would be somewhat higher than this, we may take T_0 as about 15° C. It is to be noticed that the higher this temperature actually was the more uniform must have been the temperature of the whole wire and the more accurate will be our experiments on emissivity.

Substituting these values for a, T and T_0 in equation (12), we have

$$x = \pm\, 3148 \log \left(- 10{\cdot}58 \frac{\sqrt{(t + 630)} - \sqrt{945}}{\sqrt{(t + 630)} + \sqrt{945}} \right),$$

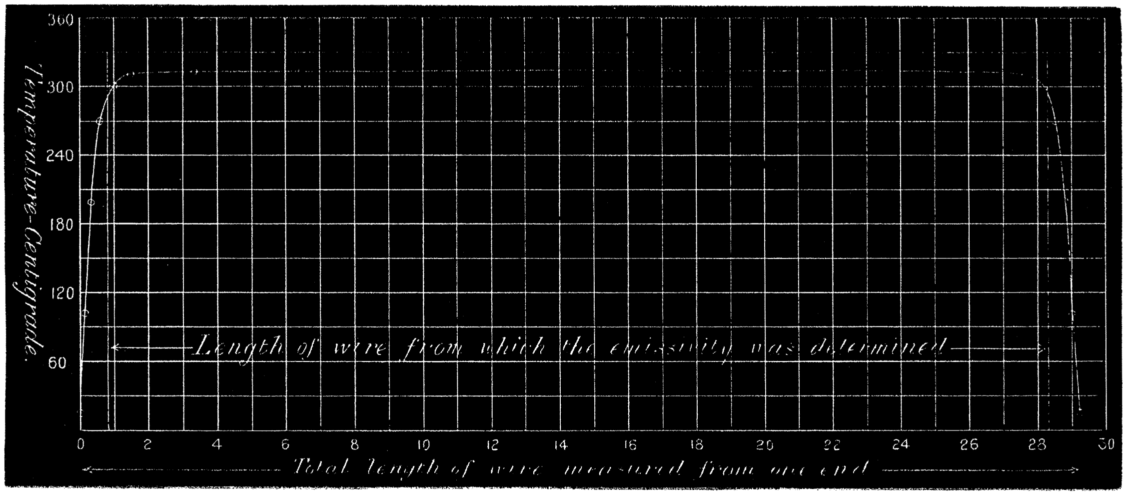
and the following are the values of t obtained for the corresponding values of x :—

Temperature, in degrees Centigrade.	Distance in centimetres from the end of the wire.
15	0
100	0·123
200	0·339
270	0·646
300	0·980
312	1·498
314	3·296

The actual length of this 6-mil wire between the points of support was 29·18 centims., and the maximum temperature was 315° C. Therefore, as the calculated temperature is 300° C. at a distance of 0·98 centim. from the support, it follows that in 3·3 per cent. of the wire, reckoning from the support, the temperature rises to about 95 per cent. of the value it has at the middle of the wire; while at a distance of 1·498 centim. from the support, that is, in about 5 per cent. of the whole length, the temperature has reached about 99 per cent. of its value at the middle.

The calculated distribution of temperature along this 6-mil wire, when traversed by the largest current employed with this wire, is shown in fig. 16. The distance between the voltmeter wires was 27·46 centims., as indicated in the figure; and it is with the distribution of temperature over this portion of the wire only that we have to deal in the emissivity experiments. Of this length, about 25·70 centims. is seen to be at a temperature a little over 314° C.; while 1·76 centim. has a mean temperature of about 308° C. The error, therefore, which we have made in assuming that the whole length of 27·46 was at 314° C. was not serious.

Fig. 16.



And, *à fortiori,* the lengths which were employed with all the finer wires in the emissivity experiments and the position of the voltmeter wires, were such that the temperature was practically constant over all the length of the wire used in the emissivity calculations.

In the case of the wires thicker than 6 mils, the error arising from the conduction was necessarily greater; and the calculations that we have made on the distribution of temperature along the 6-mil wire have led us to the conclusion that, if we were going to repeat the experiments, we should, in the case of the thickest wires employed, attach the voltmeter wires at about 2 centims. from the supports. We do not, however, think that any serious error has been introduced by attaching them at only about 7 millims., except, perhaps, in the case of the largest currents with the largest wires.

When plotting the curve for d^2t/dx^2 given in fig. 15, it was noticed that this curve, where it cuts the axis along which d^2t/dx^2 is reckoned, was not strictly parabolic. Professor Henrici suggested that an idea might be obtained of the error ntroduced, by assuming the lower portion of this curve to be parabolic, if a tangent were drawn to the true curve for d^2t/dx^2 at about t equals 315° C., and if calculations were made on the assumption that this tangent line were itself the curve for d^2t/dx^2.

Doing this, we obtain the following equation by integration for the temperature curve

$$x = \sqrt{\frac{T}{b}} \log \frac{t - T}{T - T_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

where T, as before, is 315° C., and where b is minus the value of the ordinate of this tangent when t equals nought. When measured, b is found to be 2388.

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Solving equation (13) for various values of t, we find

Temperature, in degrees Centigrade.	Distance, in centimetres, from the end of the wire.
15	0
100	0·123
200	0·339
270	0·649
320	0·980
312	1·498
314	3·296

If now a distribution of temperature curve be drawn, similar to that seen in fig. 15, but using these values of t and x instead of those found from equation (9), it is found that the two curves showing the distribution of temperature along the wire are not very different. We may therefore conclude that the exact shape of the curve for d^2t/dx^2 for small values of t, has but little effect on the resultant distribution of temperature curve, and therefore that no important error is made by assuming, as we have done, that the true curve for d^2t/dx^2 is a parabola, with its vertex on the line along which d^2t/dx^2 is reckoned in fig. 15.

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Ayrton & Kilgour.

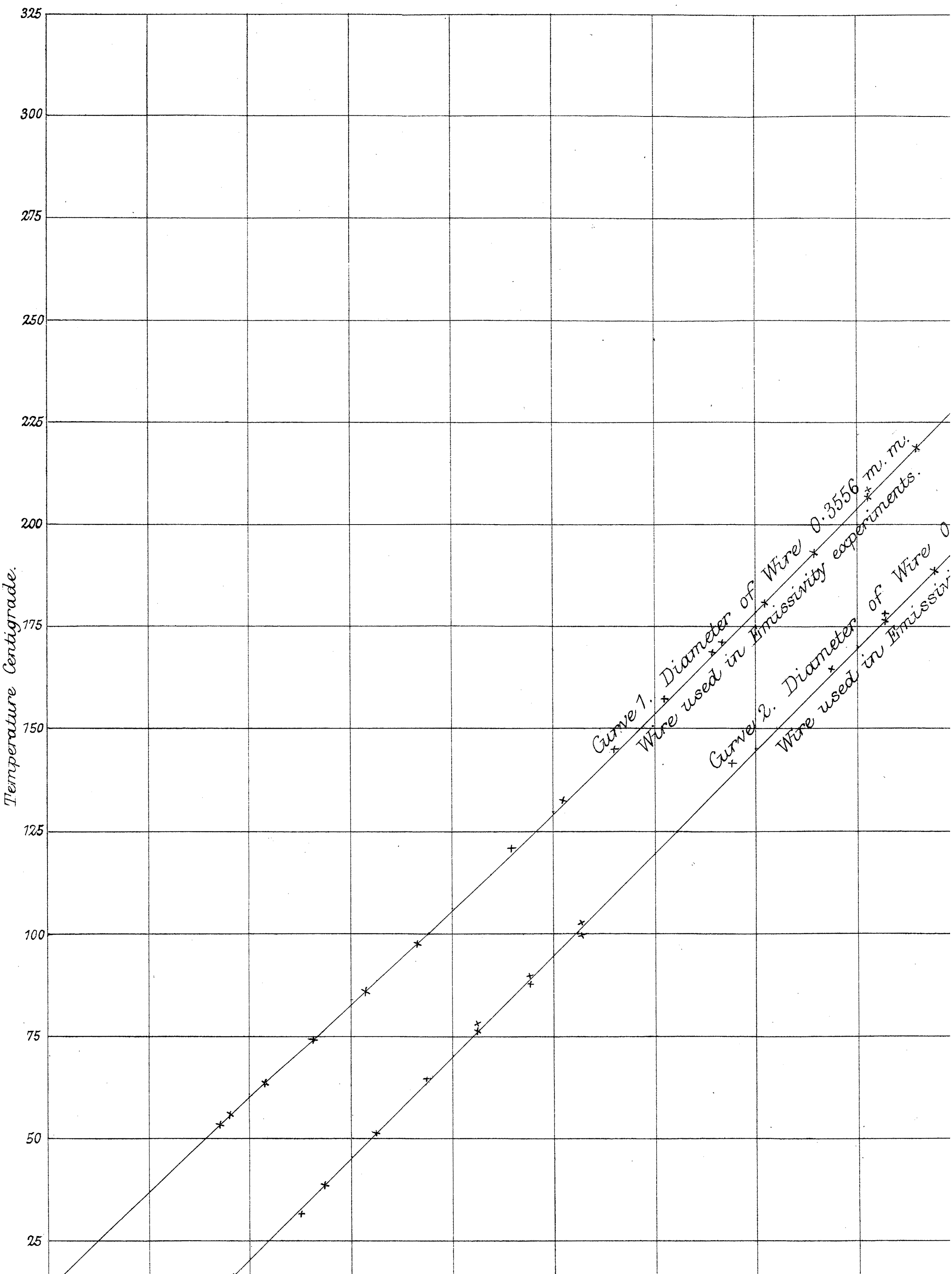

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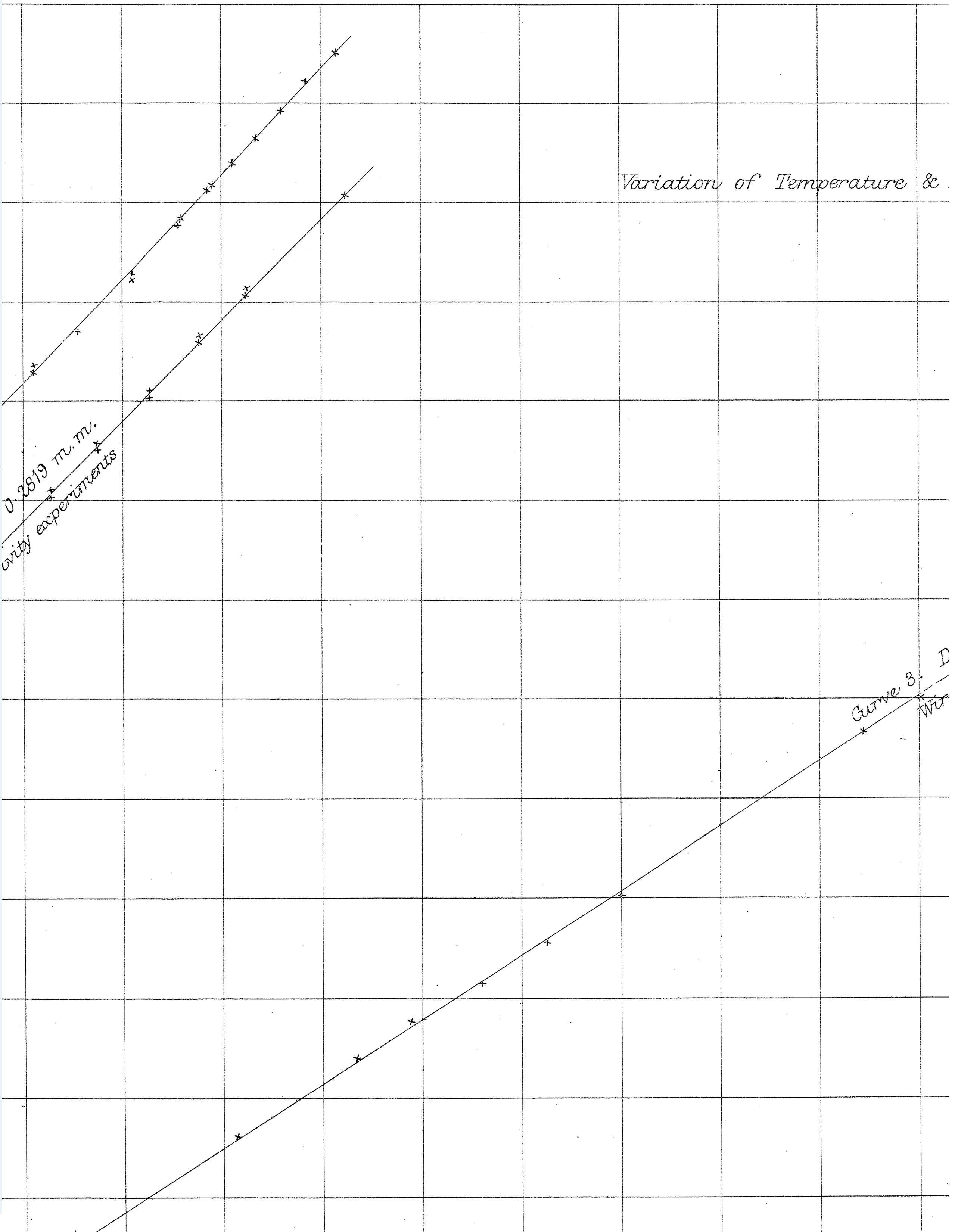
Fig. 7.



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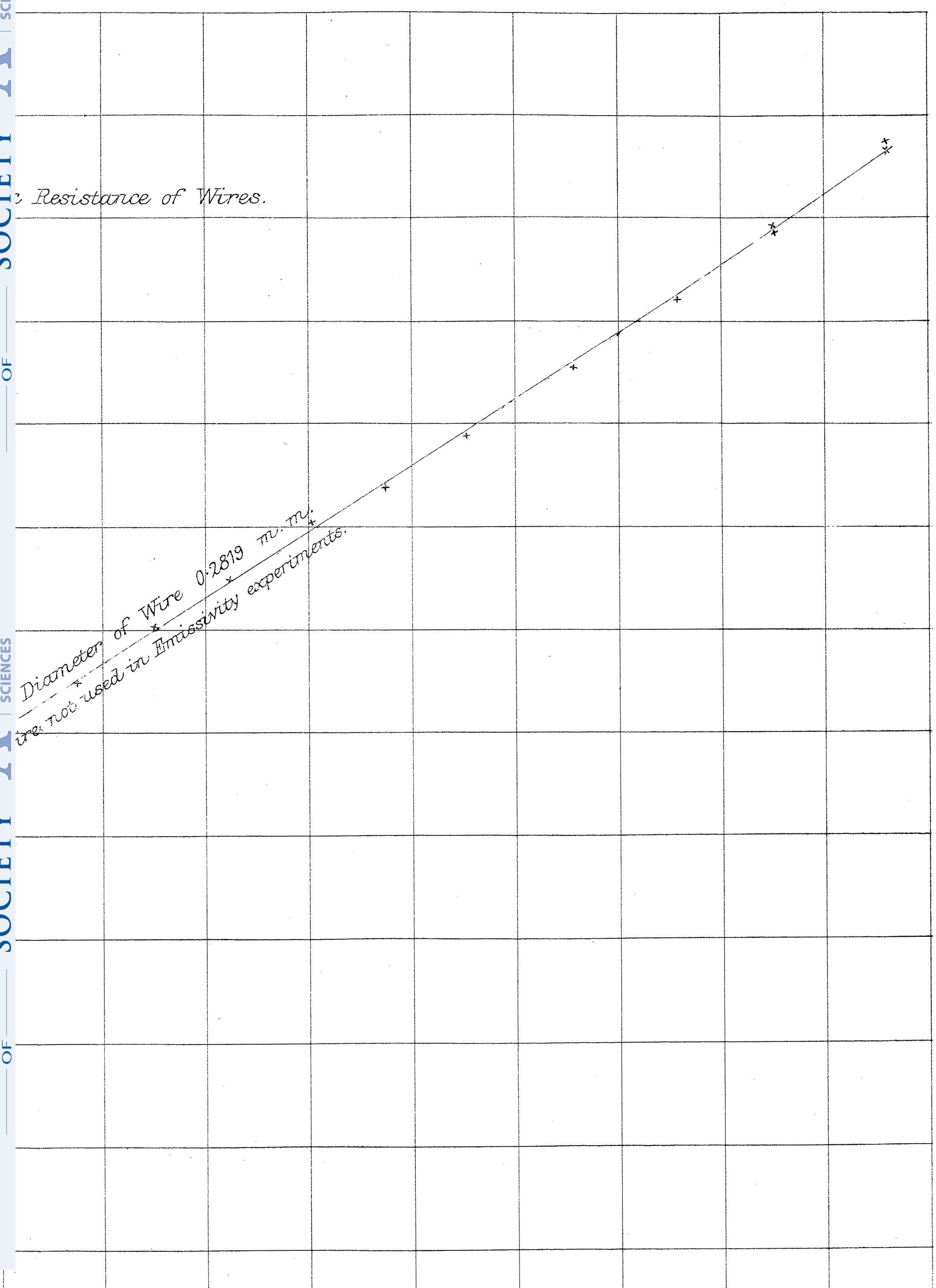
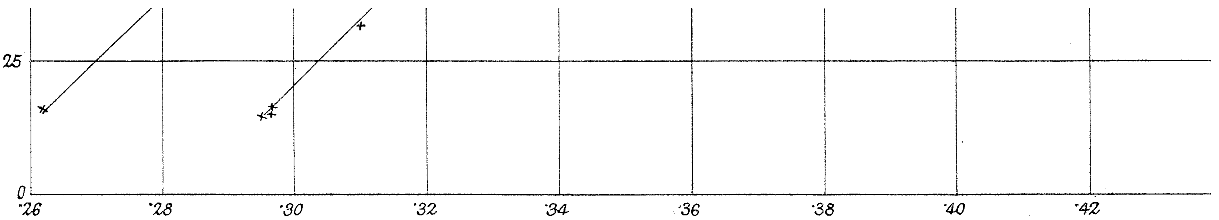

Resistance of Wires.
Diameter of Wire 0·2819 m.m.
not used in Emissivity experiments.



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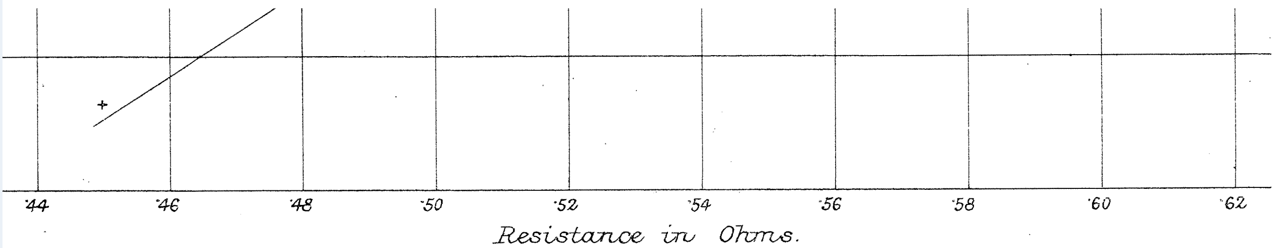
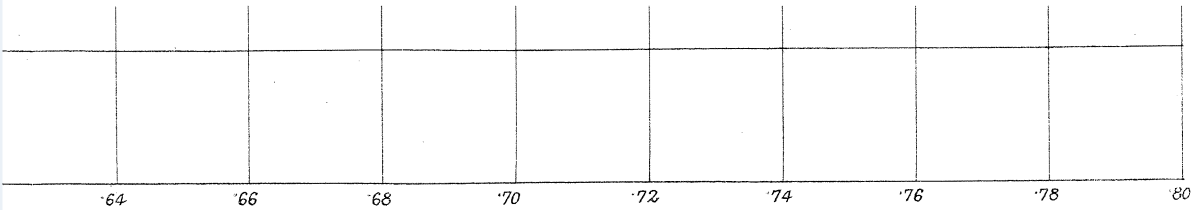


MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES
PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A

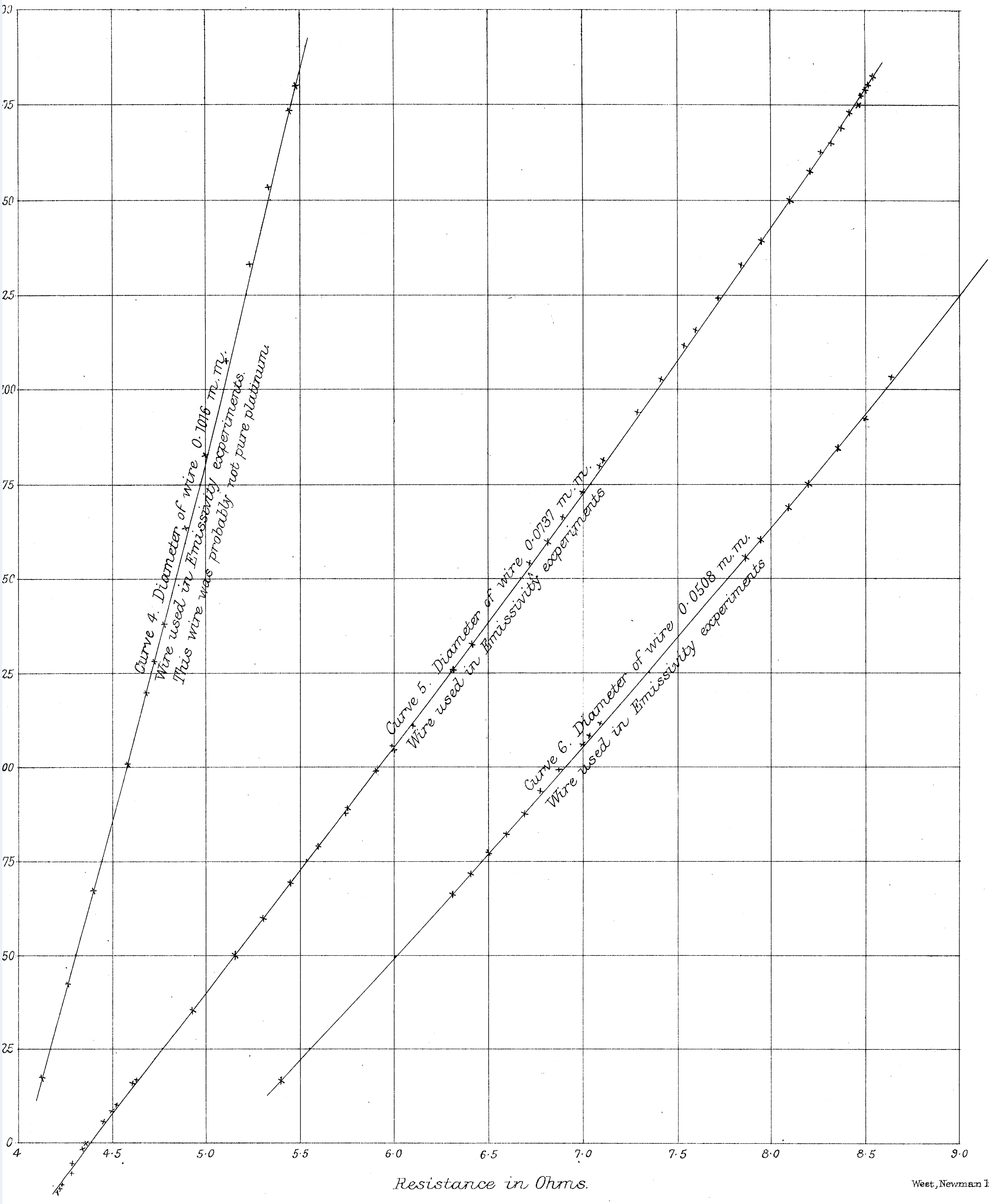


West, Newman lith.

MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES
THE ROYAL SOCIETY A
PHILOSOPHICAL TRANSACTIONS OF

Fig. 8.

Variation of Temperature & Resistance of Wires.



West, Newman lith.

Fig. 9.

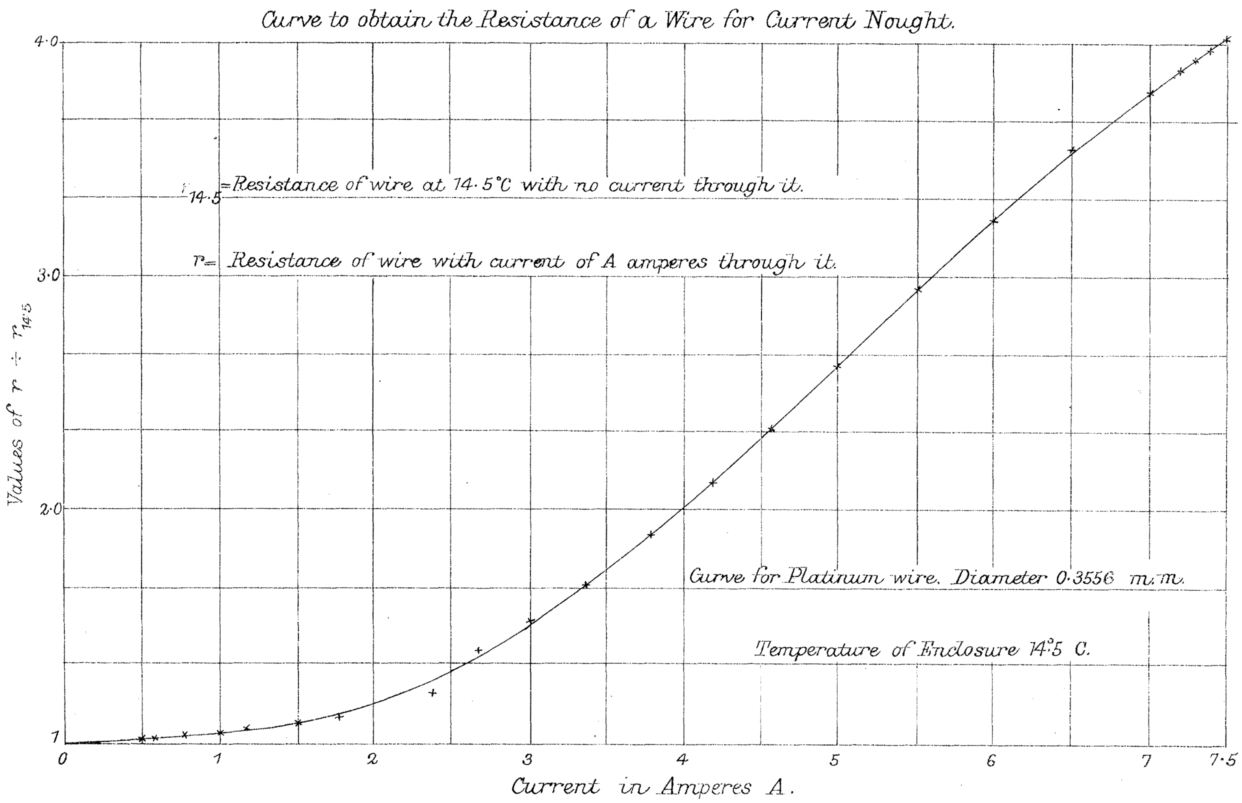

Curve to obtain the Resistance of a Wire for Current Nought.
$r_{14\cdot5}$ = Resistance of wire at 14·5°C with no current through it.
r = Resistance of wire with current of A amperes through it.
Curve for Platinum wire. Diameter 0·3556 m.m.
Temperature of Enclosure 14°5 C.
Values of $r \div r_{14\cdot5}$
Current in Amperes A.
4·0
3·0
2·0
1
0
1
2
3
4
5
6
7
7·5

Fig. 10.

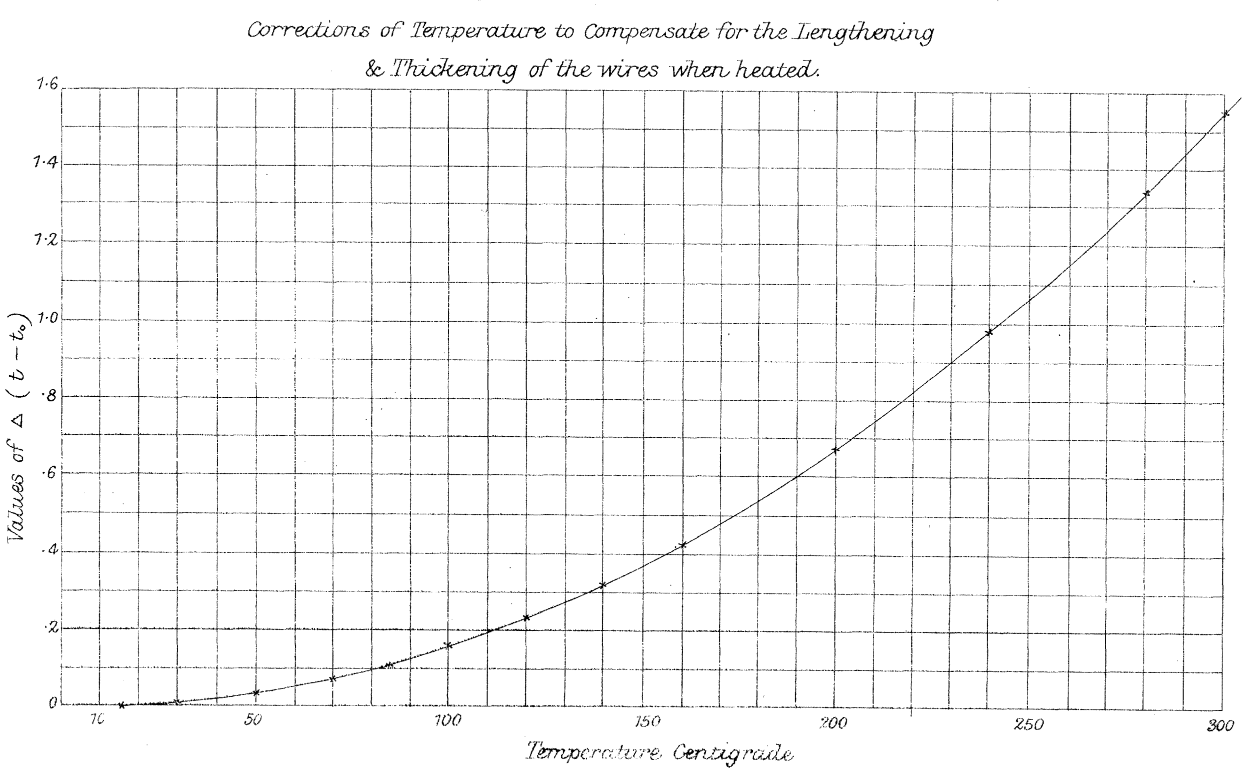

Corrections of Temperature to Compensate for the Lengthening & Thickening of the wires when heated.
Values of Δ (t − t₀)
Temperature Centigrade
1·6
1·4
1·2
1·0
·8
·6
·4
·2
0
10
50
100
150
200
250
300

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Fig. 11.

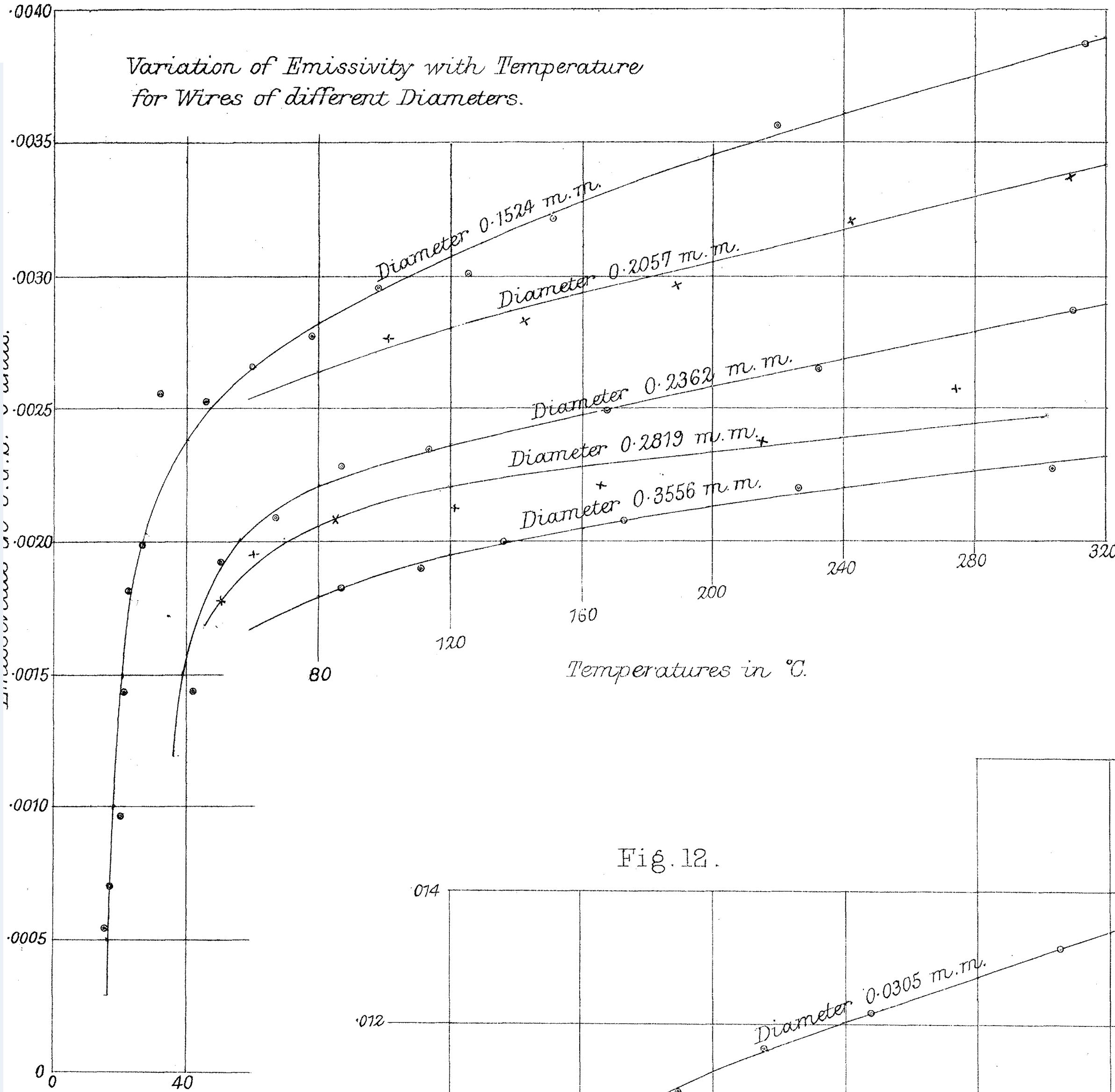
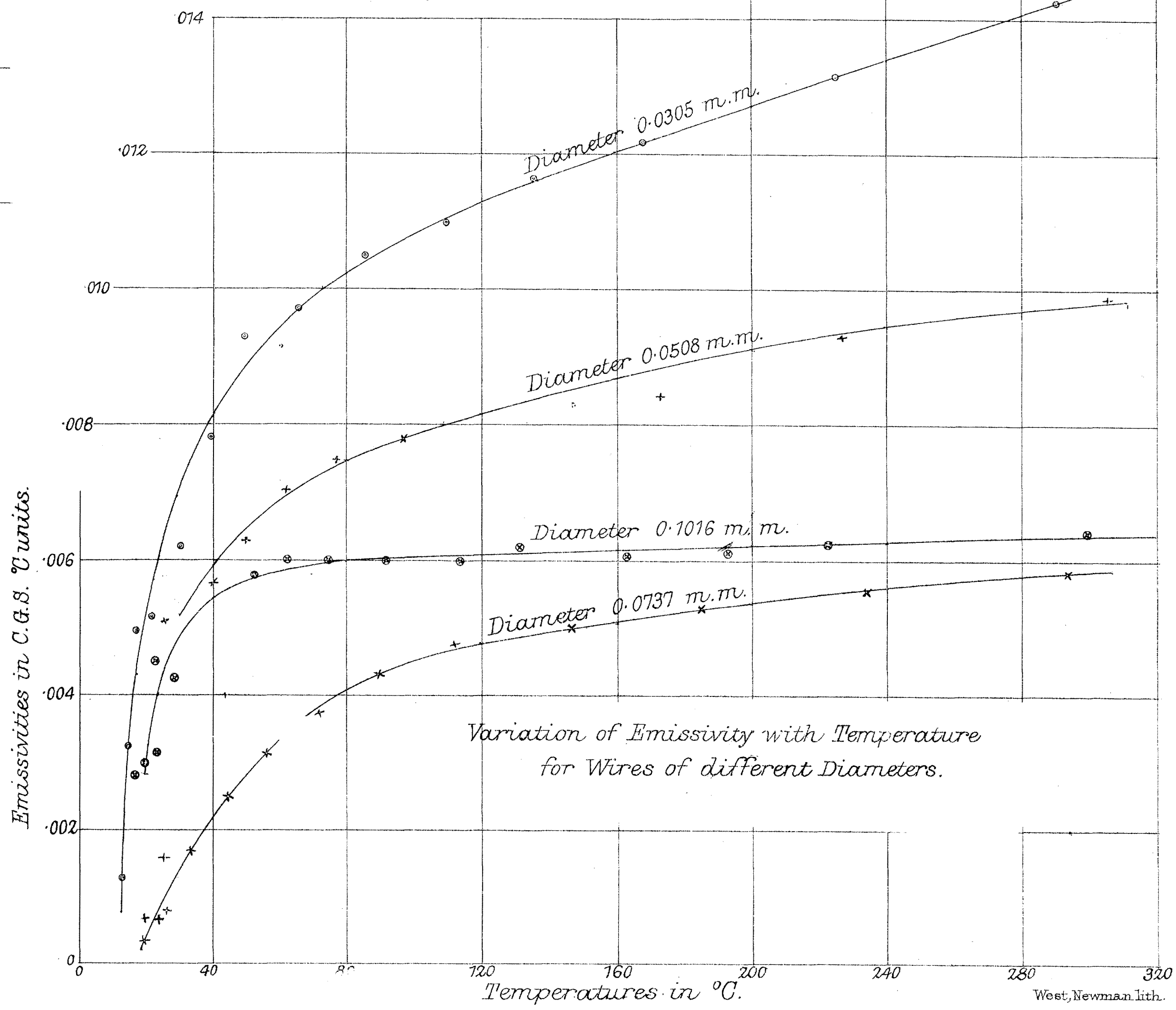


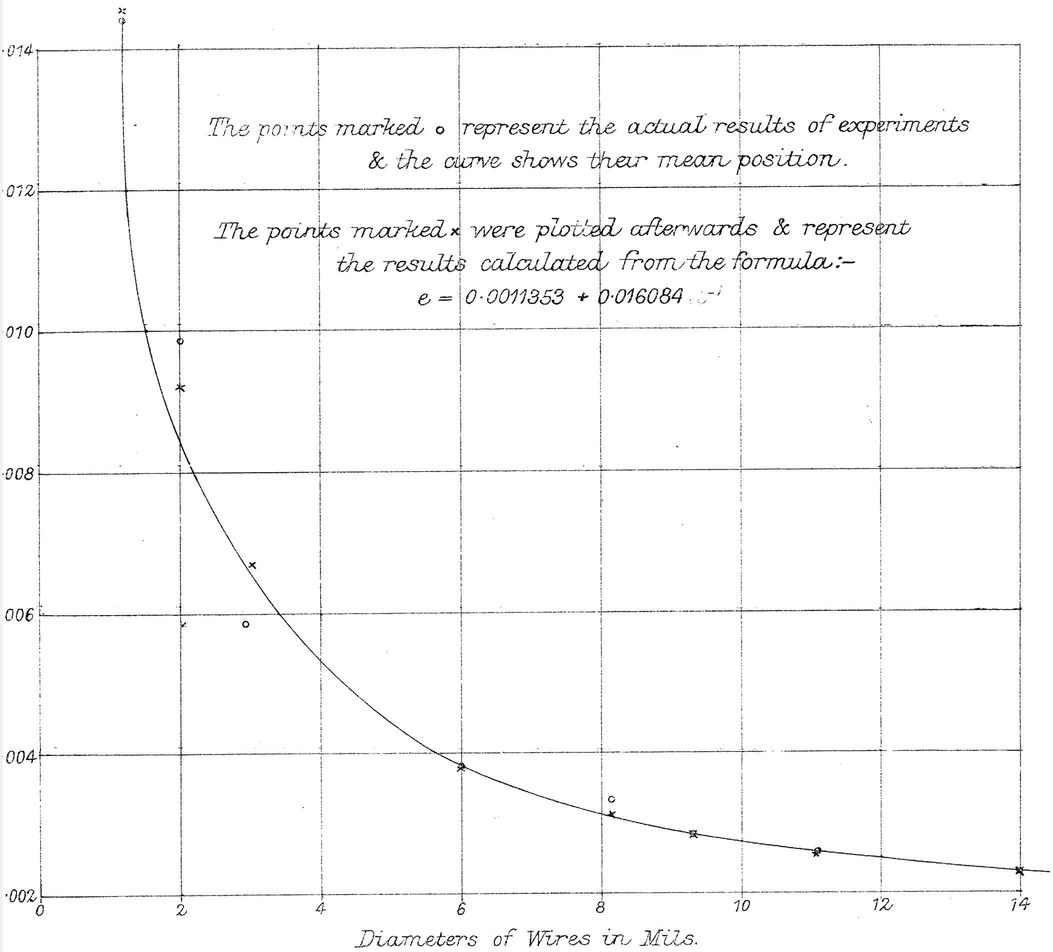
Fig. 12.

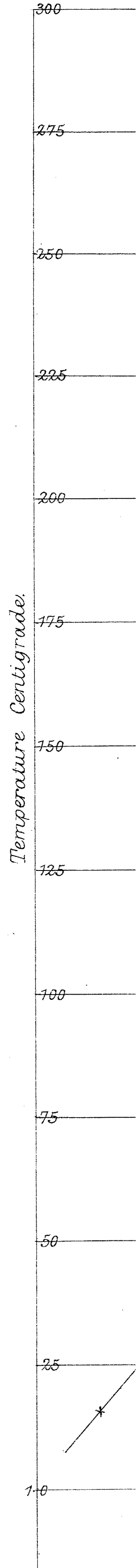


West, Newman lith.

Fig. 13.

Variation of Emissivity with Diameter at 300° C.





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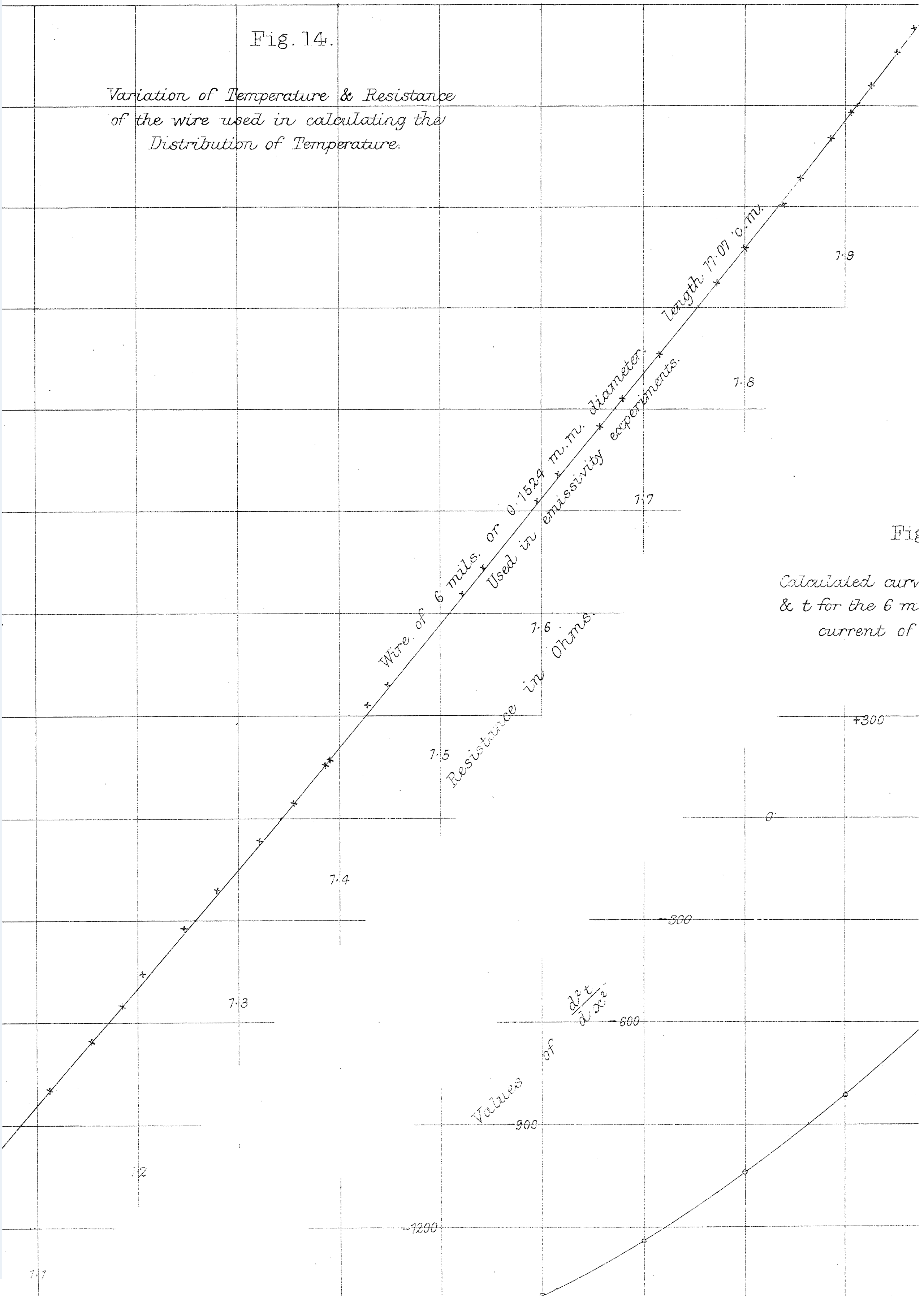

Fig. 14.

Variation of Temperature & Resistance of the wire used in calculating the Distribution of Temperature.

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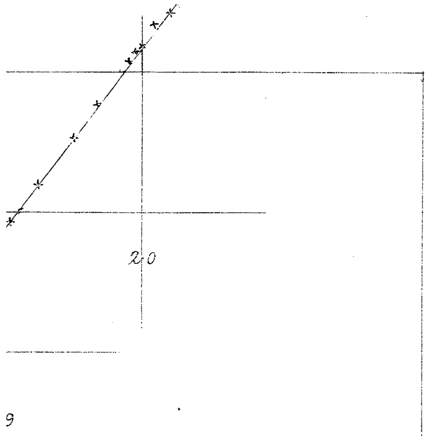
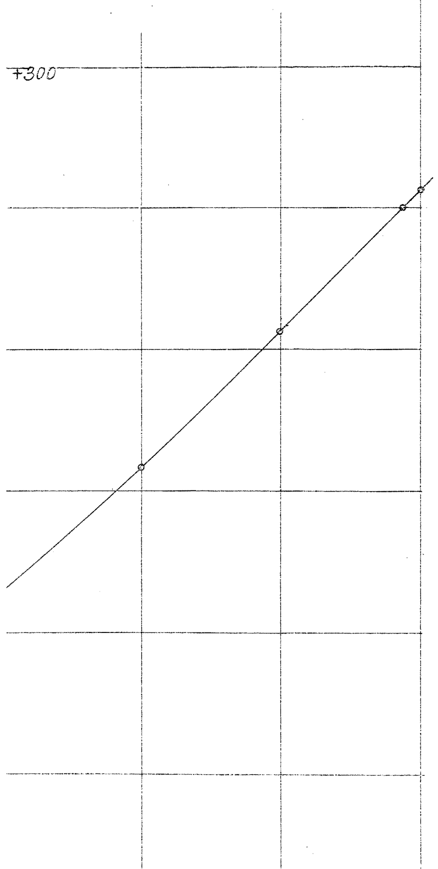


Fig. 15.

...ed curve connecting $\frac{d^2t}{dx^2}$
the 6 mil. wire with a
...rent of 1·4 amperes.



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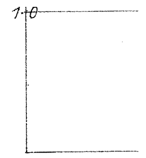

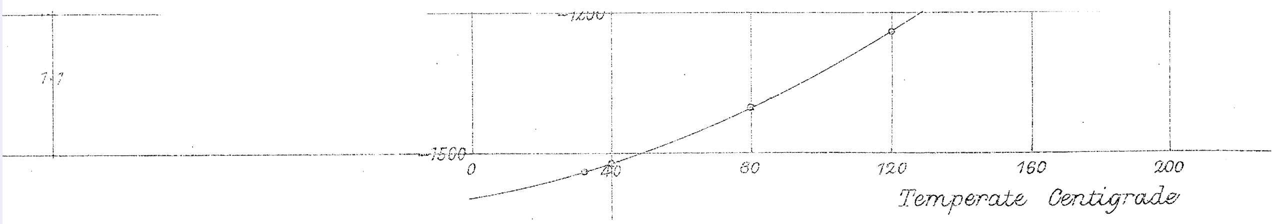

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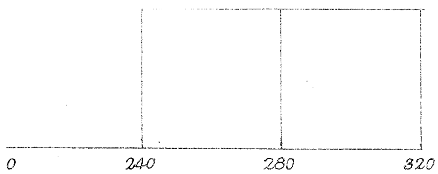

West, Newman lith.

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Fig. 7.

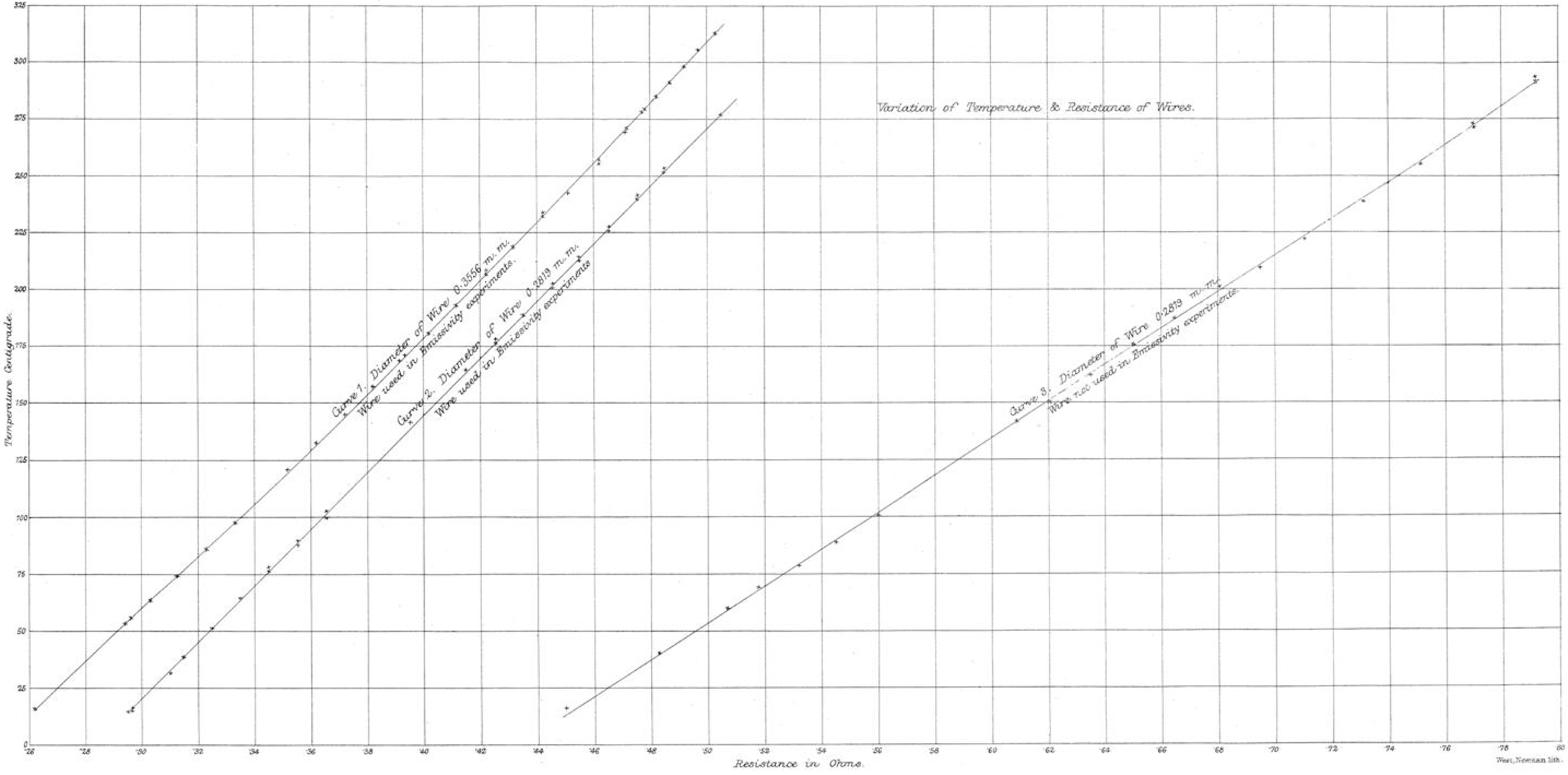
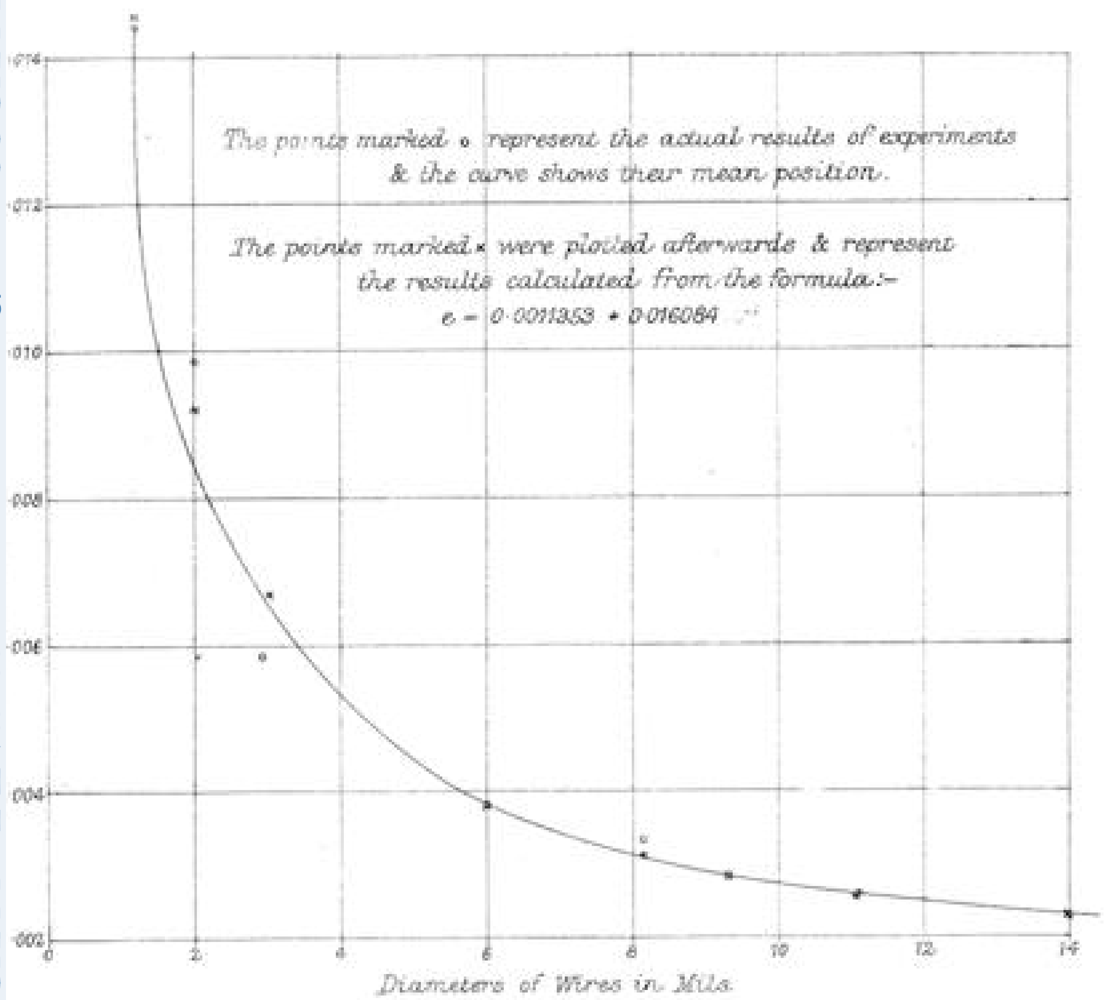
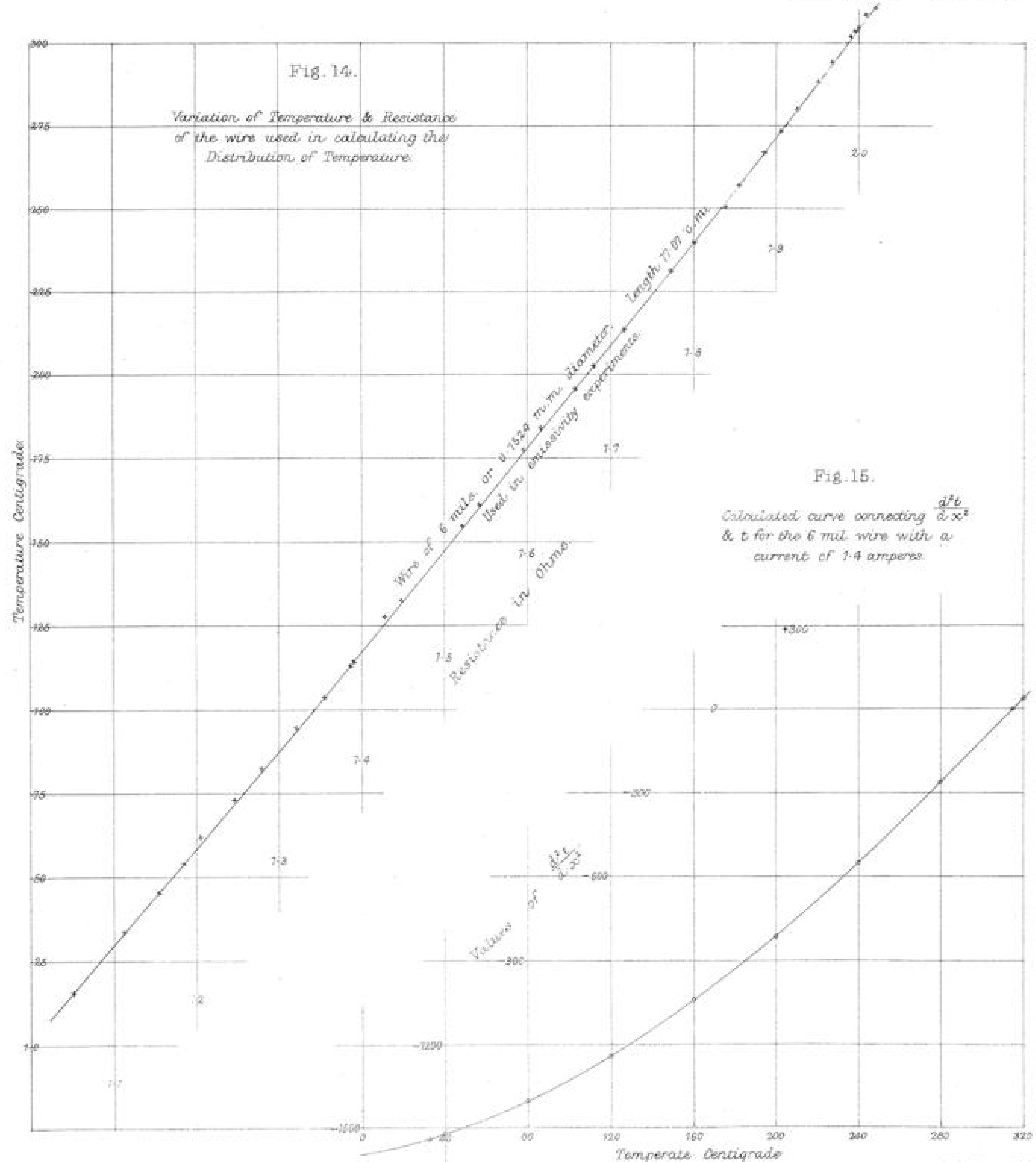

Variation of Temperature & Resistance of Wires.
Curve 1. Diameter of Wire 0·3556 m.m.
Wire used in Emissivity experiments.
Curve 2. Diameter of Wire 0·2819 m.m.
Wire used in Emissivity experiments
Curve 3. Diameter of Wire 0·2819 m.m.
Wire not used in Emissivity experiments.
Temperature Centigrade
Resistance in Ohms.
325
300
275
250
225
200
175
150
125
100
75
50
25
0
·26
·28
·30
·32
·34
·36
·38
·40
·42
·44
·46
·48
·50
·52
·54
·56
·58
·60
·62
·64
·66
·68
·70
·72
·74
·76
·78
·80
West, Newman lith.

Fig. 13.

Variation of Emissivity with Diameter at 300° C.





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