The Electrical Resistance of a Conductor the Measure of the Current passing

This content has been downloaded from IOPscience. Please scroll down to see the full text.

1903 Proc. Phys. Soc. London 19 658

(<http://iopscience.iop.org/1478-7814/19/1/353>)

View [the table of contents for this issue](#), or go to the [journal homepage](#) for more

Download details:

IP Address: 155.69.4.4

This content was downloaded on 03/10/2015 at 22:54

Please note that [terms and conditions apply](#).

ago he suggested experiments similar to those described by Dr. Watson for measuring inertia bars, and although preliminary observations were made they were not carried far.

Dr. WATSON said he knew of no other substance but quartz which was suitable for the experiments he had performed. He had not found any variation of period due to magnetic permeability. With regard to Dr. Glazebrook's remarks, he said the measurement of the diameter of the bars was easy but that the determination of the length was much more difficult.

LIII. *The Electrical Resistance of a Conductor the Measure of the Current passing.* By W. A. PRICE, *Fellow Phys. Soc.**

1. CHANGE in the length of a platinum wire is a convenient measure of the current, but the ordinary hot-wire instrument is not sufficiently precise for some purposes. The experiments in this paper were made by Mr. C. H. Wright, in Crompton & Co.'s works at Chelmsford, to ascertain whether the resistance of a conductor would be a better measure of the current than its length where considerable accuracy is required, the practical object in view being the calibration of alternating-current instruments. It was hoped to retain the advantage possessed by the dynamometer of calibration by direct currents, and thus of direct reference to the Clark cell and standard resistance; to get the precision of other resistance measurements; and to avoid the use of apparatus which is easily put out of adjustment.

2. To try whether the resistance of a conductor carrying alternating current could be easily measured, the connexions were arranged as in fig. 1. The mean fall of potential over R carrying a current from the alternating supply A was compared with that over S, a standard; a small direct current being passed through the system from the accumulator H. The potential-differences of R and S were compared on the potentiometer. B, K were regulating resistances, and highly inductive coils at M, N the primaries of

* Read May 12, 1905.

small high-voltage transformers reduced the alternating currents in circuits where only direct-current effects were required. If the alternating current in R be I , and the direct current i , the heat developed $\propto I^2 + i^2$; so that if I be large compared with i , say 100 times as great, the heating

Fig. 1.

effect of i is negligible. The experiments of fig. 1, in which I was several hundred milliamperes, and i was 1 milliampere, were designed to show whether the resistance of R carrying alternating current could be measured by a superimposed direct current so small that it would not affect the heat developed. It was found that using the Chelmsford town-supply for the alternating source observations could be made without any difficulty, the widening of the galvanometer-line by the alternating current producing no appreciable inconvenience in reading. With the workshop supply readings were impossible, as the line was given a violent jerk every time a motor was started or stopped.

3. It was assumed that the temperature of R , a thin conductor, will be the same for a direct current as for an alternating current of the same root mean square; so that if R

can be constructed to measure direct currents, it can be calibrated with those, and used to measure alternating currents. All the subsequent experiments were accordingly made to ascertain the conditions for its use with direct currents.

4. Silver was chosen for trial. Being a pure metal, its resistance changes rapidly with temperature, and its molecular condition is unlikely to change with repeated heating and cooling as might be the case with an alloy. Being a good conductor, it is heated rapidly by a low potential-difference. It was available as foil .5 mil thick, in which form it has a large radiating surface for a small heat capacity. In the end we found this foil gave irregular results, probably from being too fragile, and platinum-foil of 1 mil in thickness was used instead. A few preliminary experiments showed the results to be exceedingly sensitive to draughts; and a great many different arrangements were tried to protect conductors from irregular cooling by currents of air. Conductors of thin foil were enclosed in large vessels and in small, packed in mica slips and in slag-wool. The containing vessels were protected in various ways, or immersed in water or paraffin-oil. The nett results were clear. If any considerable free body of air is near to the conductor, currents of air and irregular cooling are produced when the conductor is heated, and no consistent measurements are obtained. If, on the other hand, the containing vessel or any solid packing is near to the conductor, its heat capacity affects the temperature, which only slowly reaches a permanent value. These results indicate that the conductor must be contained in a relatively large vessel, exhausted of air, and suggest that an incandescent lamp may be suitable for small currents and large pressures, and a slip of metal foil for large currents and small potential-differences.

5. Experiments on the above lines were started on—

A. Carbon-filament incandescent lamps.

B. A platinum ligament in a metal box, exhausted by a Fleuss pump.

C. A platinum ligament sealed into an exhausted glass bulb.

All these experiments were directed to the establishment of a relation between the resistance of the conductor and the direct current passing. The connexions are shown in fig. 2,

where R is the conductor under test, shown, *e. g.*, as an incandescent lamp, S is a standard resistance of known value, B is a regulating resistance, E a storage-cell, and C a standard cell. The potential-differences of R , S , and the E.M.F. of C were compared on the potentiometer P for a series of different currents obtained by regulating B ; and from the three readings the current through and the resistance of R are calculated. In each case there are four leads to the resistance, two carrying the current, and two which carry no current connected to the potential points, and the resistance measured is in every

Fig. 2.

case that between the potential points. The potentiometer lends itself admirably to experiments of this class, since all the data are obtained from adjustments on one calibrated wire, while the whole of the conductor whose resistance is measured may be inside the exhausted vessel, so that the leading-in wires are not involved. With a bridge the current could not be measured with the resistance, while the resistance of leading-in wires would have to be taken into account.

6. The resistance of a 50 volt, 8 c.p. Stearn lamp was measured with a small testing-current immersed in a paraffin-bath warmed up to 56°C . to obtain an idea of the change of resistance with temperature. The mean change over a range of 40°C . was -0.0224 per cent. per degree. In the resistance was included in this case that of the leading-in wires; and it may be mentioned as a curiosity that a particular 4-volt

lamp tested at the same time showed a very nearly constant resistance over the same range, the increase of the platinum and the decrease of the carbon resistance just balancing one another. The combination of a carbon lamp and a metallic conductor might be useful for some purposes as having a small or negligible temperature-coefficient.

7. To determine the effect of external temperature a 50-volt 8 c.p. lamp was tested in a paraffin-bath, with the following results:—

Current in milliamperes.	Resistance in ohms.	
	Bath at 7° C.	Bath at 50° C.
10	160	159
30	150.35	149.97
50	142.84	142.6
70	137.14	136.83
89.98	131.96	131.82

As would be expected, the effect of the external temperature diminishes as the current employed increases. A current of 110–120 milliamperes just made the above lamp incandescent, the above measurements being taken with the filament black. Observations on the lamp in air, quite unprotected, gave closely similar and consistent results, showing that air-draughts outside an exhausted bulb are of no appreciable importance.

8. To ascertain how far the resistance of the lamp is affected by use, the following results were obtained, on a lamp when new, and after it had been run for 6 hours and 17 hours respectively at its full voltage of 50 volts.

Current in milliamperes	Resistance in ohms.		
	New in air at 11° C. 6 hrs. run, air 15° C. 17 hrs. run, air 15° C.		
10	163	164.7	164.25
30	153.6	155.5	155
50	146.2	147.7	146.45
70	140.2	141.4	140.5
90	135.2		135.26

These experiments seem to indicate that these lamps might serve very usefully for measuring alternating currents from 50 up to a few hundred milliamperes, or even a thousand, but would not be instruments of much precision. The reason for the discrepancies was not then apparent.

9. Curves of three lamps of the same manufacture, taken to see how far they followed the same form, are given in

Fig. 3.

fig. 3, which indicates that possibly one formula connecting current and resistance might be employed for all lamps of one method of manufacture.

10. A platinum-foil ligament in a circular box, exhausted by a Fleuss pump, was then tried. The form of the ligament

and the arrangement of the box are shown in fig. 4. The joints between the rubber packing and the box, and also

Fig 4.

Enlarged Plan of Platinum Strip .001 inch thick.

between the brass wires and the ebonite cap, were sealed with stiff machine-oil before exhausting. Before this box was used a smaller and thicker one had been tried, of 2 inches diameter, which was found to give an appreciable lag, owing to the containing box being too near the ligament. In this the resistance of the filament continued to rise for 20 minutes under a steady current, and had not then attained its maximum. With the vessel of fig. 4 no change in the resistance was observed after the current had been applied for the shortest time necessary to obtain the first set of readings, which was about $\frac{3}{4}$ minute, so that there was no appreciable lag.

11. The results of experiments on the effect of outside air temperature on the conductor of fig. 4 are given in fig. 5. The results were not very consistent, only a mercurial thermometer being used, and the exact position of the curve is a

little uncertain; but its character is well defined. In the diagram the abscissæ are the percentage corrections to be applied to the resistance for each degree by which the air temperature differs from 15° . The resistance thus corrected is the value for an air temperature of 15° .

Fig. 5.

12. The results of experiments on the degree of exhaustion of the vessel are given in the diagram of fig. 6. It will be noticed how rapidly the resistance for a given current, 1.2 amperes, air temperature 15° C., increases with the exhaustion when the latter is fairly perfect. This might form the basis of a useful gauge for high vacua. In the next set of experiments the vacuum was actually gauged in this way, the pumping being started before each set of readings and continued until the resistance of the strip for a given current, 1 ampere, corrected for the air temperature from the figures of fig. 5, took the same value as before. The curve at normal atmospheric pressures is too steep to be of any use as a barometer.

13. On the diagram of fig. 7 are plotted a number of observations made on four different occasions of the resistance of the platinum strip of fig. 4; the vessel being exhausted to about .2 inch mercury, the exhaustion being fixed by the resistance at 1 ampere.

Fig. G.

Fig. 7.

14. Experiments were then carried out on a platinum-foil ligament sealed into an exhausted glass vessel shown in fig. 8.

Fig. 8.

As before, two of the connexions sealed through the glass carry the current, and two are potential-leads and carry no current. The degree of exhaustion of the vessel was not known; but it was a high vacuum from a good mercury-pump, and much better than that obtained in the vessel of fig. 4 from a mechanical hand-pump.

Fig. 9.

15. Fig. 9 gives the results of experiments on the effect of the air temperature on the resistance of the strip, the abscissæ being as in fig. 5 percentage corrections to reduce to an air

temperature of 15°C . Two points are noticeable in this diagram. The effect of the air temperature becomes negligible for much lower current-densities in the highly exhausted glass vessel than in the imperfectly exhausted brass one. The second point is that the extension of the curve to the x axis appears to indicate a temperature-coefficient of resistance for the metal of which the slip was composed, which was believed to be pure platinum, of about $\cdot 375$, which is higher than the accepted figure; so that the exact position of this curve, though it was very carefully taken, could not be relied on without confirmation.

16. The figures of the following table are different sets of measurements of the resistance of the slip of fig. 8, at various currents and after different treatment.

Current in milliamperes.	Resistance in ohms.			
	A.	B.	C.	D.
$\cdot 3$	$\cdot 32$	$\cdot 319$	$\cdot 318$	$\cdot 3155$
$\cdot 35$	$\cdot 368$	$\cdot 368$	$\cdot 363$	$\cdot 361$
$\cdot 4$	$\cdot 421$	$\cdot 420$	$\cdot 416$	$\cdot 413$
$\cdot 45$	$\cdot 479$	$\cdot 479$	$\cdot 474$	$\cdot 471$
$\cdot 5$	$\cdot 531$	$\cdot 534$	$\cdot 5295$	$\cdot 529$

The figures A were taken as the bulb was received from the maker; B were taken ten days afterwards, a good many experiments with currents not exceeding $\cdot 5$ ampere, alternating and direct, having been made in that time; C were taken shortly after B, the slip having been heated previously for one hour to a bright red by a current of $\cdot 9$ ampere; D were taken after a further heating for $\frac{3}{4}$ hour of the same current, $\cdot 9$ ampere. The resistance of the slip when cold was unchanged throughout. It had been raised to a bright-red heat before originally sealing into the glass bulb. It seems clear that the explanation of the changes between A, B, C, D must be looked for in the small quantities of gas occluded by the platinum before sealing in, and given off when subsequently heated *in vacuo*; and this effect may also explain the changes in the resistance of a carbon filament noticed in § 8 above.

If a conductor of this kind is to be used as a gauge for the measurement of current, either, as Prof. Callendar has suggested to me, the exhaustion of the vessel must be poor, so that the absorption or occlusion of gas by the platinum does not make any appreciable change in the amount in the vessel, giving the case of the results of § 13; or else the exhaustion and sealing must be performed when the platinum is at a bright-red heat, so that no occluded gases are left. Either course seems to promise a satisfactory result.

DISCUSSION.

Prof. AYRTON pointed out that at any rate for small alternating currents a suitably wound instrument of the Kelvin-balance type was quite sufficiently accurate.

Mr. CAMPBELL asked was any compensation introduced for the temperature of the walls of the enclosure, or was the temperature merely read and a correction made for it?

The AUTHOR, in his reply, said that in all cases corrections were applied for the external temperature.

LIV. *A Simple Method of Determining the Radiation Constant: suitable for a Laboratory Experiment.* By A. D. DENNING, M.Sc., Ph.D., Demonstrator in Physics in the University of Birmingham*.

THE following experiment was suggested to me by Prof. Poynting, F.R.S., as a laboratory experiment, and as it is by no means difficult to carry out and appears to give good results, it may be useful to give an account of it.

The principle of the method followed may be thus briefly described:—A hemispherical radiator, blackened inside, was quickly placed over a flat silver disk of known dimensions and which formed one of the junctions of a constantan-silver thermoelectric couple. From observations, at definite intervals of time, of the deflexions of the moving coil of a low-resistance d'Arsonval galvanometer included in the circuit,

* Read May 12, 1905.