The discontinuity of potential at the surface of glowing carbon.

By Professor J. A. Pollock, A. B. B. Ranclaud, and E. P. Norman.

The Physical Laboratory of the University of Sydney.

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Owing to the projection of ions by hot substances a discontinuity of potential will occur at the surfaces of the electrodes in any circuit in which these latter are formed of heated materials. The value of this potential discontinuity has been calculated by Professor Richardson\(^1\) from considerations connected with the gas theory of metallic conduction, and has been found in the case of carbon by Mr. Duddell,\(^2\) who observed at the surface of the cathode of the ordinary carbon arc a forward electromotive force of 6.1 volts, and a back electromotive force of 16.7 volts at the surface of the anode.

In a circuit with one heated electrode in air at ordinary pressure, the projection of ions from the hot surface necessitates the establishment of a potential difference between the electrodes if the current in the circuit is to be zero. If electrons alone were projected, a layer of gas close to the hot surface would become negative to the solid and the potential difference between the electrodes for zero current might be taken as a measure of the surface discontinuity of potential. When positive ions are emitted as well as electrons, owing to the difference in the distances from the electrode at which the two classes of ions are stopped by collision with the gas molecules, the electric force may

\(^1\) *Phil. Trans., A* 201, p. 497, 1903.  
\(^2\) *Phil. Trans., A.* 203, p. 305, 1904.
change sign in the near neighbourhood of the heated surface. In this case the potential difference between the electrodes for zero current, with appropriate sign, must be less than the value of the surface discontinuity of potential which would be due to the projection, alone, of that class of ions which conditions the sign of the potential difference.

With the apparatus described in a previous paper the potential difference for zero current has been found in the case of glowing carbon at various temperatures. The experiments were a continuation of the work already described, and in the paper just mentioned will be found full details of the method of investigation. The observations, which fulfil the condition that the values should be independent of the distance separating the electrodes, are shown in figure 1. For zero current the hot carbon was positive to the cooler electrode in all cases.

Fig. 1.

Potential differences for zero current.

1 Pollock and Ranclaud, this Journal p. 201.
The heated electrodes were cored carbon rods, 0.5 centimetres in diameter, supplied by Messrs. Siemens Brothers for use with their Lilliput arc lamps, with the exception of the one employed for the observation at 3040° absolute which was a squared rod, 0.5 centimetres on the side, of solid Conradty carbon marke C. As the measure with this material agrees well with the other results, it may be concluded that values of the potential difference for zero current with hot electrodes of different makes of carbon do not seriously differ.

At 3120° absolute, with 50 volts between the electrodes, the ratio of the flow of negative electricity from the hot carbon to the flow of positive, when the sign of the potential difference was reversed, was as 20 to 1.

On the assumption that at high temperatures the potential difference for zero current measures the surface discontinuity of potential, as the number of electrons then projected per second far exceeds that of positive ions, the curve in figure 1 has been continued to the value, 16.7 volts, found by Mr. Duddell, (loc. cit.), for the back electromotive force at the anode of an arc between solid Conradty Noris carbons. This measure has been plotted for the temperature of the crater, 3690° absolute, determined by Messrs. Waidner and Burgess\(^1\) from observations with a Holborn-Kurlbaum optical pyrometer, a similar instrument to that with which we have estimated the other temperatures. Mr. Duddell gives 6.1 volts as the measure of the forward electromotive force at the arc cathode; this value corresponds, on the curve of potential differences for zero current, to a temperature of 3375° absolute, which, if the assumption already stated is legitimate, may be taken as an estimate of the temperature of the cathode of the carbon arc.

\(^1\) *Phys. Rev.*, 19, p. 255, 1904.
With a heated iron wire in the place of the hot carbon of the previous experiments, the potential difference for zero current was 0.85 volts at 1410° absolute and 0.25 volts at 1570°, the hot wire being in both cases, negative to the cooler electrode. The potential difference with a platinum wire, not specially treated, at 1580° absolute was 0.40 volts, the hot wire being again negative. With a Nernst filament, designed for 0.25 ampère at 90 volts and used under those conditions, the potential difference for zero current was 0.25 volts. In this case the filament was positive to the cooler electrode, and with a potential difference between the electrodes of 45 volts, the ratio of the flow of negative electricity from the hot filament to the flow of positive, when the sign of the potential difference was reversed, was as 33 to 1.

Professor Richardson, (loc.cit.), gives, for the number of corpuscles shot off from unit area of a hot conductor per second, the expression \( A \theta^{1/2} e^{-b/\theta} \), in which \( A \) depends on the number of corpuscles per unit volume of the conductor, and \( b \) on the work done by a corpuscle in passing through the surface layer, \( \theta \) being the absolute temperature. The formula, considering \( A \) and \( b \) as constants, very well represents the observations of its author and others on the saturation currents from hot bodies through the range of temperature for which it has been employed; from such observations the values of \( b \) for certain substances have been determined. In the theory by which the expression is deduced, \( b \) is equal to \( \phi/R \), where \( \phi \) is the work done by a corpuscle in passing through the surface layer and \( R \) a gas constant, equal to \( p/N\theta \), \( p \) being the pressure and \( N \) the number of molecules per cubic centimetre. The discontinuity of potential is thus represented by \( bR/e \), where \( e \) is the ionic charge.

The following are the values of the discontinuity of potential as calculated by Professor Richardson:
Temperature absolute. | Discontinuity of potential.
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Sodium ... 490° - 700° ... 2.46 volts.
Platinum ... 1378 -1571 ... 4.1 "
Carbon ... 1520 -1770 ... 6.1 "

These results which are not appreciably altered by recalculation with the new value of the ionic charge determined by Professor Rutherford and Dr. Geiger, seem singularly high. If \( bR/e \) really represents the discontinuity of potential, the fact that the discontinuity varies somewhat rapidly with temperature for higher values shows that \( b \) cannot be considered altogether constant.

In a recent paper Professor Richardson and Mr. Brown originate the theory of a method for finding the kinetic energy of the electrons projected from heated materials, and they have experimentally determined the component, perpendicular to the hot surface, of the velocity with which electrons are projected from glowing platinum, the result for a temperature of 1650° absolute being \( 1.5 \times 10^7 \) centimetres per second. This velocity of projection, in the case of glowing carbon, may, on certain assumptions, be estimated from the results already given in the present paper. As suggested by one of us a point of view is possible from which the work done in connection with the passage of the electrons through the surface layer may be considered as represented by their translational energy when they emerge into the gas. In such a case the surface discontinuity of potential, \( V \), may be expressed by the equation,

\[
V = \frac{1}{2} \frac{m}{e} v^2,
\]

where \( m \) is the mass of the electron, \( e \) the ionic charge, and \( v \) the component, in the direction of the field, of the

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velocity with which the electrons are projected from the hot surface. If this equation holds, on the assumption previously stated, we may deduce from the curve in figure 1, that the velocity with which electrons are projected from glowing carbon varies from $1.5 \times 10^5$ centimetres per second at $3375^\circ$ absolute to $2.5 \times 10^5$ centimetres per second at $3690^\circ$ absolute. In a similar way, from the result previously given, a lower limit to the velocity with which electrons are projected from the Nernst filament may be calculated as $3 \times 10^7$ centimetres per second.

THE SEDIMENTARY ROCKS OF THE LOWER SHOALHAVEN RIVER.

By CHARLES F. LASERON.

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Introduction.—The following paper comprises the main features of geological interest noted in the course of several excursions made to the district within the last four years. As the river for some distance above Nowra is very difficult of access, considerable labour was experienced in exploiting it. But owing to the kindness of one of the local residents, Mr. Robert Condie, who has assisted me on every occasion, I have been able to examine its course nearly to its junction with its tributary, the Kangaroo River. Two camping expeditions were undertaken to this part, the boat with outfit and provisions being hauled up the rapids, which above Burrier are very common. The results of the previous expeditions were briefly reviewed in the Australian

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