definitely extended by the mixture of air and coal-dust produced by the disturbance which it initiates.

The dangers due to the presence of coal-dust in dry mines can be very easily avoided by sprinkling water plentifully on the principal roadways along which the air currents pass, in going to, and coming from, the working places. For example, Llwynypia Colliery, which was formerly one of the driest and most dusty of the mines in the South Wales basin, is now kept constantly damp or wet in this way with a daily expenditure of about 1,800 gallons of water. The amount of air passing through it at present is over 80,000 cubic feet per minute, and its out-put of coal is, on the average, about 800 tons per day.

III. "The Contact Theory of Voltaic Action." No. III. By Professors W. E. Ayrton and John Perry. Communicated by Dr. C. W. Siemens, F.R.S. Received February 19, 1879.

(Abstract.)

The authors commence by referring to the experiments that had been made prior to 1876, on the difference of potentials of a solid in contact with a liquid, and of two liquids in contact with one another, and they point out that:—

1. The earlier experiments were not carried out with apparatus susceptible of giving accurate results.

2. Owing to the incompleteness of the apparatus assumptions had to be made not justified by the experiments.

3. *No direct* experiments had been performed to determine the difference of potential of two liquids in contact, with the exception of a few by Kohlrausch, using a method which appeared to the authors quite inadmissible as regards accuracy of result.

In consequence of this great vagueness existed as to whether the contact difference of potentials between two substances, when one or both were liquids, was a constant depending only on the substances and the temperature, or whether it was a variable dependent upon what other substance was in contact with either. Some authorities regarded it as a variable. Gerland considered he had proved it to be a constant, but first, the agreement of the value of the electromotive force of each of his cells with the algebraical sum of the separate differences of potential at the various surfaces of separation, and which was the test of the accuracy of his theory, was so striking, and so much greater than polarisation, &c., usually allows one to obtain in experiments of such delicacy, that one could not help feeling doubtful regarding his

conclusions; secondly, his apparatus did not allow of his experimenting with two liquids in contact, consequently he could not legitimately draw any conclusion in this latter case. And although Kohlrausch had made some few experiments on the difference of potentials of liquids in contact, still since he employed moist blotting paper surfaces instead of the surfaces of the liquids themselves, the authors considered for that reason alone, if for no other, that his results did not carry the conviction the distinguished position of the experimenter might have led them to anticipate.

They therefore designed a method and an apparatus for carrying it out, by means of which they could measure the difference of potentials in volts at each separate contact of dissimilar substances in the ordinary galvanic cells, from which they could ascertain whether the algebraical sum of all the contact differences of potential was, or was not, equal to the electromotive force of the particular cell in question. From the results they obtained, and which are given in Papers Nos. I and II, "Proc. Roy. Soc.," No. 186, 1878, they concluded within the limits of their experiments that if $\overline{AB}$, $\overline{BC}$, $\overline{CD}$, &c., were the contact differences of potential measured separately of the substances A in contact with B, B in contact with C, &c., then, any one or more of the substances being solid or *liquid*, if any number A, B, C - - - - - K were joined together, and the electromotive force of the combination $\overline{AK}$, measured, the following equation was found true:—

$$\overline{AK}=\overline{AB}+\overline{BC}+\overline{CD}+ \text{ - - - - - } +\overline{JK},$$

which proved that each surface of separation produced its effect independently of any other.

Their method by which any single contact difference of potentials was measured was as follows:—Let 3 and 4 be two insulated gilt brass plates connected with the electrodes of a delicate quadrant electrometer. Let 1 under 3, and 2 under 4 be the surfaces whose contact difference of potential is to be measured; 3 and 4 are first connected together and then insulated, but remain connected with their respective electrometer quadrants. Now 1 and 2 are made to change places with one another, 1 being now under 4 and 2 under 3, then the deflection of the electrometer needle will give a measure of the difference of potentials between 1 and 2; and in the present paper it is proved that in order that the observed difference of potentials in the electrometer quadrants shall be proportional to the contact difference of potentials desired to be measured, either there must be perfect symmetry in the induction apparatus before and after reversal of 1 and 2, a condition very difficult to be obtained, or else the plates 3 and 4 must, in addition to being connected together, be also put to earth, or reduced to zero potential, before each reversal, and also the mean potential of the substance under test

must be kept as low as possible, conditions that were always carefully observed in the experiments.

The apparatus employed by the authors in the present investigation is then explained in detail, and it is shown how, by improving on their earlier form, they have removed a difficulty which formerly existed, and which prevented their previously experimenting on pairs of substances having very different weights, such as a vessel of mercury and a sheet of metal. The method of making the permanent and temporary adjustments, the tests for leakage, the experimental mode adopted of compensating the error arising from defects in parallelism of the apparatus affecting the results obtained from two rigid surfaces (as that of copper and zinc) differently from the result found with one or with two liquid surfaces under test are then described, as well as the details of a complete experiment and the precautions adopted to obtain clean metallic surfaces.

The authors explain that the results they have obtained in this investigation have divided themselves into three groups :—

1st. The contact difference of potentials of metals and liquids at the same temperature.

2nd. The contact difference of potentials of metals and liquids when one of the substances is at a different temperature from the other in contact with it, for example, mercury at 20° C. in contact with mercury at 40° C.

3rd. The contact difference of potentials of carbon and platinum with water, and with weak and with strong sulphuric acid;

but that they give only the results under head No. 1 in the present communication, reserving those they have obtained under heads Nos. 2 and 3 for a future occasion.

Then follow arranged in the order in which they were obtained from January to May, 1878, some 150 results of experiments (each number being on the average the mean of eight observations), representing the contact differences of potential of nine solids and twenty-one liquids. They explain that the numbers given are those to which alone they attach importance; but that in consequence of much time having in such delicate experiments to be spent in obtaining measurements, which are often found out to be wrong, a considerable number of results have been rejected, and are not mentioned in the paper, and that this, therefore, explains why in some cases one measurement only is apparently the result of a whole day's work. These remarks especially apply to the authors' attempts to measure the contact difference of potentials between a liquid and a paste, for example, mercury and mercurous sulphate paste; great difficulty being introduced by the extremely thin layer of water on the surface of the paste acting inductively instead of the paste itself. They mention that this difficulty is a very good example of the inaccuracies that

must have been introduced by former experimenters using a moist blotting-paper surface instead of the surface of the liquid itself.

A large number of discordant results were obtained in March, 1878, and their explanation led to the interesting result that the apparent contact difference of potentials between a metal and mercury, as measured inductively, varied much with small additions of temperature. The accidental difference of temperature in the different experiments arose from the mercury having been redistilled in the laboratory between every two experiments to remove all possible traces of impurities, and probably in some cases it had not become perfectly cold before a new experiment was made. The investigation of this apparent change of contact difference of potentials with temperature led to a consideration of the contact difference of temperature of mercury with air, since, of course, in all these inductive experiments two air contacts are included in the result. The results thus obtained will form part of the substance of the next paper.

Next follow a number of checks of the accuracy of the results based on the well known law that in any compound metallic circuit at uniform temperature there is no electromotive force. This is followed by some considerations regarding the measurement of the difference of potentials between substances and the air in contact with them, and of measurements of the Peltier effect.

It has usually been thought that the differences of potential of liquids in contact with one another were so small as to be almost inappreciable in comparison with the differences of potential of metals in contact; but the authors have ascertained, among other results, that strong sulphuric acid in contact with distilled water, solutions of alum, copper sulphate, and zinc sulphate has a measured difference of potentials of 1·3 to 1·7 volts, an electromotive force more than twice as high as that of zinc and copper in contact. And hence the importance of an apparatus that can directly measure the difference of potentials of two liquids.

March 20, 1879.

THE PRESIDENT in the Chair.

The Presents received were laid on the table and thanks ordered for them.

The following Papers were read :—