April 27, 1871.

General Sir EDWARD SABINE, K.C.B., President, in the Chair.

THE BAKERIAN LECTURE was delivered by CHARLES WILLIAM SIEMENS, F.R.S., D.C.L., "On the Increase of Electrical Resistance in Conductors with rise of Temperature, and its application to the Measure of Ordinary and Furnace Temperatures; also on a simple Method of measuring Electrical Resistances." The following is an Abstract.

The first part of this Paper treats of the question of the ratio of increase of resistance in metallic conductors with increase of temperature.

The investigations of Arndtson, Dr. Werner Siemens, and Dr. Matthiessen are limited to the range of temperatures between the freezing- and boiling-points of water, and do not comprise platinum, which is the most valuable metal for constructing pyrometric instruments.

Several series of observations are given on different metals, including platinum, copper, and iron, ranging from the freezing-point to 350° Cent.; another set of experiments being also given, extending the observations to 1000° Cent. These results are planned on a diagram, showing a ratio of increase which does not agree either with the former assumption of a uniform progression, or with Dr. Matthiessen's formula, except between the narrow limits of his actual observations, but which conforms itself to a parabolic ratio, modified by two other coefficients, representing linear expansion and an ultimate minimum resistance.

In assuming a dynamical law, according to which the electrical resistance of a conductor increases according to the velocity with which the atoms are moved by heat, a parabolic ratio of increase of resistance with increase of temperature follows; and in adding to this the coefficients just mentioned, the resistance r for any temperature is expressed by the general formula

$$r = \alpha T^{\frac{1}{2}} + \beta T + \gamma,$$

which is found to agree very closely both with the experimental data at low temperatures supplied by Dr. Matthiessen, and with the author's experimental results, ranging up to 1000° Cent. He admits, however, that further researches will be necessary to prove the limits of the applicability of the law of increase expressed by this formula to conductors generally, especially when nearing their fusing-point.

In the second part of this Paper it is shown that, in taking advantage of the circumstance that the electrical resistance of a metallic conductor increases with an increase of temperature, an instrument may be devised for measuring with great accuracy the temperature at distant or inaccessible places, including the interior of furnaces, where metallurgical or other smelting-operations are carried on.

In measuring temperatures not exceeding 100° Cent., the instrument is so arranged that two similar coils are connected by a light cable containing three insulated wires. One of these coils, "the thermometer-coil," being carefully protected against moisture, may be lowered into the sea, or buried in the ground, or fixed at any elevated or inaccessible place whose temperature has to be recorded from time to time; while the other, or "comparison-coil," is plunged into a test-bath, whose temperature is raised or lowered by the addition of hot or cold water, or of refrigerated solutions, until an electrical balance is established between the resistances of the two coils, as indicated by a galvanoscope, or by a differential voltameter, described in the third part of the paper, which balance implies an identity of temperature at the two coils. The temperature of the test-solution is thereupon measured by means of a delicate mercury thermometer, which at the same time tells the temperature at the distant place.

By another arrangement the comparison-coil is dispensed with, and the resistance of the thermometer-coil, which is a known quantity at zero temparature, is measured by a differential voltameter, which forms the subject of the third part of the paper; and the temperature corresponding to the indications of the instrument is found in a table, prepared for this purpose, in order to save all calculation.

In measuring furnace temperatures the platinum-wire constituting the pyrometer is wound upon a small cylinder of porcelain contained in a closed tube of iron or platinum, which is exposed to the heat to be measured. If the heat does not exceed a full red heat, or, say, 1000° Cent., the protected wire may be left permanently in the stove or furnace whose temperature has to be recorded from time to time; but in measuring temperatures exceeding 1000° Cent., the tube is only exposed during a measured interval of, say, three minutes, to the heat, which time suffices for the thin protecting casing and the wire immediately exposed to its heated sides to acquire within a determinable limit the temperature to be measured, but is not sufficient to soften the porcelain cylinder upon which the wire is wound. In this way temperatures exceeding the welding-point of iron, and approaching the melting-point of platinum, can be measured by the same instrument by which slight variations at ordinary temperatures are told. A thermometric scale is thus obtained embracing without a break the entire range.

The leading wires between the thermometric coil and the measuring instrument (which may be, under certain circumstances, several miles in length) would exercise a considerable disturbing influence if this were not eliminated by means of the third leading wire before mentioned, which is common to both branches of the measuring instrument.

Another source of error in the electrical pyrometer would arise through the porcelain cylinder upon which the wire is wound becoming conductive at very elevated temperatures; but it is shown that the error arising through this source is not of serious import.

The third part of the paper is descriptive of an instrument for measuring electrical resistance without the aid of a magnetic needle or of resistance scales. It consists of two voltameter tubes fixed upon graduated scales, which are so connected that the current of a battery is divided between them, with one branch including a known and permanent resistance, and the other the unknown resistance to be measured. The resistance and polarization being equal, and the battery being common to both circuits, these unstable elements are eliminated by balancing them from the circulation; and an expression is found for the unknown resistance X in terms of the known resistances C and γ of the voltameter, including the connecting-wires, and of the volumes V and V′ of gases evolved in an arbitrary space of time within the tubes, viz.:—

$$X=\frac{V}{V'}(C+\gamma)-\gamma. \quad \ldots \ldots \quad (1)$$

Changes of atmospheric pressure affect both sides equally, and do not therefore influence the results; but a reading at the atmospheric pressure is obtained at both sides by lowering the little supply-reservoir with dilute acid to the level indicated in the corresponding tube. The upper ends of the voltameter tubes are closed by small weighted levers provided with cushions of India-rubber; but after each observation these levers are raised, and the supply-reservoirs moved so as to cause the escape of the gases until the liquid within the tubes is again brought up to the zero-line of the scale, when the instrument is ready for another observation. A series of measurements are given of resistances varying from 1 to 10,000 units, showing that the results agree within one-half per cent. with the independent measurements obtained of the same resistances by the Wheatstone method.

The advantages claimed for the proposed instrument are, that it is not influenced by magnetic disturbances or the ship's motion if used at sea, that it can be used by persons not familiar with electrical testing, and that it is of very simple construction.

The following communications were read:—

I. "On the Change of Pressure and Volume produced by Chemical Combination." By M. Berthelot. Communicated by Dr. Williamson. Received April 25, 1871.

1. A singular question has arisen in the study of the gaseous combinations, viz. can the pressure be diminished in consequence of a reaction, at the moment it is accomplished, at constant volume, without loss of heat, so that the phenomenon of explosion comes from the excess of atmospheric pressure upon the inner pressure of the system, instead of coming from the inverse excess of the inner pressure? The discussion of this question, however special it appears at first sight, leads to general notions concerning chemical combination.