PROCEEDINGS

OF THE

GEOLOGICAL & POLYTECHNIC SOCIETY

Of the West-Riding of Yorkshire,

AT THE THIRTY-FIFTH MEETING, HELD IN THE TOWN HALL, PONTEFRACT, ON THURSDAY, SEPTEMBER 23RD, 1847.

The Right Hon. EARL FITZWILLIAM, F.R.S., the President of the Society, took the Chair, and called upon W. SYKES WARD, Esq. to read the first Paper.

ON A NEW GALVANOMETER, AND ON SOME OF THE PHENOMENA OF VOLTAIC CURRENTS. BY WILLIAM SYKES WARD, ESQ., LEEDS.

In voltaic electricity, apparatus which should accurately indicate the dynamic effect of a current has long been a desideratum. The instruments hitherto used are objectionable for some one of the following reasons:—being either very delicate and expensive in their construction, requiring tedious manipulation, or giving results which at best are only approximative, or which require considerable powers of calculation to reduce their indications to a real value. I believe that the little instrument I have the pleasure of introducing is not liable to any of these objections, that it will assist the mathematician in obtaining the data he may require, and enable the experimentalist easily to record the power which he employs. Prior to describing my galvanometer, it may not be uninteresting to you, particularly to those who are not much versed in voltaic science, to describe the instruments and processes by which voltaic currents have hitherto been estimated.

I make use of the term "current" to express the effect which is communicated by conductors, through which electricity is supposed to pass. There is no science in which greater difficulty has been found in using appropriate and unexceptionable names and terms than in electricity. The terms which have been used in most sciences have been such as expressed, or were supposed to be in accordance with, the then theories and ideas. Such theories have since, in many cases, been found incorrect; and the terms have consequently proved not only inapplicable, but detrimental, from their conveying false ideas, which, when once acquired, are with difficulty eradicated or corrected. The best terms in all sciences would be those which should not express any definite meaning at all. But it would be most difficult to fix such terms in the mind. It is, therefore, best to use expressions which have a general meaning, but which do not convey ideas appertaining to any particular theory. The term voltaic current has been generally adopted, and is one of the most unexceptionable; but even in using this term I must beg to be understood not to mean that any fluid, thing, or matter passes, but merely that a cause or force producing an effect is transmitted; and that I do not express any opinion that we have yet any real knowledge of the nature of electricity, though I may on some future occasion have the pleasure of laying before you some speculations or proposed theory on the subject.

The following methods have been used for estimating the force of voltaic currents:—

By observing the length of platina wire, of a given thickness, heated to redness by the current. In this method it is difficult to observe the exact length and degree of ignition, and the method is quite inapplicable if both the quantity and intensity be not considerable.

By passing the current through a Breguet's metallic thermometer. This method is much used by some electricians, but, besides requiring an expensive and delicate apparatus, the results of both this and the foregoing methods are affected by the temperature and currents of the air.

By the voltameter; that is, by the measured quantity of gas evolved per minute from the decomposition of water. This method requires a somewhat tedious observation, and is only applicable to the measurement of currents of considerable energy.

By the magnetic needle galvanometer; which, perhaps, I may be permitted to describe somewhat in detail. When a voltaic current is passed through a conducting wire, and a delicately-suspended magnetic needle is brought near it, the needle will exhibit a tendency to place itself at right angles to the wire. If the current be supposed to proceed from east to west, and the needle to be placed above the wire, the end of the needle, commonly called the north pole, will point to the north. From this fact Dr. Faraday, being anxious to avoid the false nomenclature of positive pole and negative pole, has named the terminals of voltaic circuits anode and catode,—that is, the way up and the way down; and in relation to the idea of electric currents passing in the apparent direction of the sun round the earth, and causing the phenomena of terrestrial magnetism.

The needle does not, however, place itself at right angles to the conductor in obedience to repulsion, as appears at first sight to be the case, but really from an inclination to revolve round the conducting wire. This was pointed out by Dr. Faraday amongst his earliest discoveries.

It was soon discovered that if the conducting wire were bent, so as to pass both above and below the needle, the effect thereon was nearly doubled; and that when many folds of wire were coiled in like manner, the effect was increased by each coil. This is the ordinary form of galvanometer.

If two needles be connected one above the other, so that one be within the coil and the other above, the ends being reversed, the effect is increased; as both the needles are affected by the current, and the directive influence of terrestrial magnetism is neutralised. From the latter circumstance this arrangement is termed the astatic galvanometer. The astatic galvanometer may be constructed so that the needles move on a horizontal, instead of a vertical, axis, as in the form adopted by Messrs. Cooke and Wheatstone in the electric telegraph now in general use.

These galvanometers are usually furnished with graduated indices, marked with degrees of a circle, and in many cases are extremely useful for the measurement of weak or moderate currents; but are liable to the material objection that the deflections produced are not in the ratio of the degrees indicated, but in a complicated ratio of tangents of the angles indicated, and of the distance of the needle from the coil further complicated, as the coil does not represent a mathematical line, and by the magnetism of the needle not being strictly permanent.

The torsion galvanometer is an *astatic needle, suspended* by fine fibres of silk. This may be made exquisitely sensible, and its indications, as dependent upon the torsion of the fibres, are very consistent; but it is, unfortunately, not easily applicable when energetic currents are to be measured, and it is an expensive instrument, and liable to be deranged.

Electro-magnets have been used to estimate energetic currents, by observing the weight which the keeper will sustain; and electro-magnetic machines have also been employed. These are not very easily applicable, as very slight variations of the distance to which the keeper is allowed to approach makes a material difference; and even the polish of the surfaces, if in contact, produces a disturbing effect.

A very good instrument has been formed by floating a small bar magnet perpendicularly in water, like a hydrometer, and placing a coil of wire around it; or by suspending a bar magnet from one of the arms of a balance, and in like manner placing a coil of wire around it. These instruments possess many of the advantages of the new instrument I produce to you, but are much more expensive and difficult to manage.

Being engaged in a series of experiments relative to the conduction of voltaic electricity, and requiring a galvanometer in addition to the instruments I possessed, and not being able to obtain any instruments suitable for my purpose from the makers of philosophical apparatus in the county, I was led to make the galvanometer before us. The construction being new to me, and, as I conceive, combining simplicity of construction with several other advantages, I shall have much pleasure if it be found useful to those engaged in electrical investigations. My instrument consists of about thirty feet of copper wire wrapped with cotton, coiled upon itself, and cemented with shell lac at the end and side, so as to retain its form, having the ends of the wire bent so as to form points at which the coil is suspended in a vertical position. The points of the wire dip into two small cups, drilled into the end of two thick brass wires, which serve as supports for the coil; a little mercury being put into the cups. Two arms of wire are attached to the coil, on the ends of which a small scale to contain weights is suspended, thus forming a kind of balance, which, when nicely adjusted, is sensible to about the tenth part of a grain. A common permanent horse-shoe magnet is placed within the coil. Connexions are made between the electrodes and the supports of the coil by binding screws, or otherwise, as most convenient.

Various coils of wire may be used, according to the quantity of the currents to be measured. With a coil of very fine wire the instrument is moderately sensible, and is applicable when the currents are too powerful to be estimated by the torsion galvanometer.

I believe the instrument possesses the following advantages:

That the indications are by weight, being a direct ratio to the forces of the currents.

That various coils of known lengths and thicknesses of wire can be used, and can be readily changed.

That by using short and thick wires it may be employed for very powerful currents, with little danger of disturbing the polarity of the magnet.

That the magnet being fixed, the indications are not disturbed by the attraction of iron apparatus or of the conducting wires.

That the apparatus is easily constructed, and does not require delicate workmanship.

It will also be readily seen that the apparatus may be employed for ascertaining the relative strength of horse-shoe magnets.

After finding that the instrument worked very satisfactorily in all other respects, I endeavoured to ascertain whether the weights counterbalanced might be regarded as strictly expressing the force or dynamic effect of the voltaic current. For this purpose I had recourse to the method pointed out by Professor Wheatstone, in his admirable essay, printed in the Transactions of the Royal Society for 1843, paragraph 18, page 326.

Feeling some little doubt, however, as to the correctness of Ohm's theory, and of Professor Wheatstone's application thereof, on the ground that it appears to me that the resistance of a conductor is not, in all cases, in the direct ratio of its length, I thought it preferable to make use of another method of experimentally adjusting the apparatus, making use of Professor Wheatstone's differential resistance measurer, by which I adjusted wires attached to the galvanometer, so as to have the means of dividing a current, so that exactly half any given current could be passed through the galvanometer coil. By this means I have proved that the indications of my galvanometer are in the exact ratio of the currents passing through it, at all events within the limits of the powers of the batteries which I have tried it with. Thus, if a current through the battery be found to balance 110 grains in the scale, the current from the same battery being divided between the galvanometer coil and the diverting coil, will, within the limits of error arising from the three measurements of wire, be found to lift 55 grains.

Before entering on the consideration of the phenomena of voltaic currents in relation to conduction, I feel it incumbent upon me to draw your attention to the theory of Ohm, which has been universally admired by those who have studied it, and which has become the foundation of the modern applications of mathematics to voltaic electricity. I regret that I cannot at present go very fully into this, as it would occupy too much time, that I have not had access to the original paper, and that I have some doubts as to the strict accuracy of some of the deductions therefrom, which I have not yet had time fully to confirm. I, however, hope shortly to do this with the assistance of the new galvanometer.

The main features of Ohm's theory are simply expressed in the following formula, $F = \frac{E}{R}$, in which F denotes the force of the current, E the electro-motive forces, and R the resistances. These are thus defined by Professor Wheatstone:—

"By electro-motive force is meant the cause which in a closed circuit originates an electric current, or in an unclosed one gives rise to an electroscopic tension. By resistance is signified the obstacle opposed to the passage of the electric current by the bodies through which it has to pass; it is the inverse of what is usually called their conducting power.

"When the activity of any portion of the circuit is increased or diminished, either by a change in the electro-motive force, or in the resistance of that portion, the *activity of all the other parts of the circuit increases or* decreases in a corresponding degree, so that the same quantity of electricity always passes in the same instant of time through every transverse section of the circuit.

"The force of the current is directly proportional to the sum of the electro-motive forces which are active in the circuit, and inversely proportional to the total resistance of all its parts; or, in other words, the force of the current is equal to the sum of the electro-motive forces divided by the sum of the resistances."

This may be rendered more familiar by experiment. If we take a plate of amalgamated zinc and a plate of platinized silver immersed in diluted sulphuric acid, forming the arrangement invented by Mr. Smee, and known by his name, and connect the plates, decomposition of the water takes place, the zinc being oxidated at the expense of the oxygen of the water, and the corresponding quantity of hydrogen being evolved at the platinized surface. By this the electro-motive force E is developed. I will not now discuss the chemical and contact theories of electricity, but merely state the undisputed fact, that the chemical decomposition and electro-motive force are correllative, not only in being simultaneously developed, but also in quantity. Now the force F, developed in every part of the circuit, may be strictly expressed by E, the electro-motive force of the elements, that is, the water decomposed and the formation of sulphate of zinc dissolved, (the electro-motive force from the latter is generally supposed to be extremely small,) divided by the resistance to conduction of the fluid, (in technical language, the electrolyte,) and also of the plates themselves, and the conducting wire connecting them. I have selected this form of battery as visibly manifesting these effects, for, on connecting the plates by a short wire, the force F is considerable, and is manifested by the energy of the evolution of gas; but if I introduce a greater resistance into the circuit, the evolution of gas will be much diminished: by introducing the galvanometer into the circuit we obtain an estimate of the force in grain weights supported. If we add a still greater length of wire, for instance, adding a coil of 70 feet, we shall find the evolution of gas again diminished, and in like manner the force as manifested by the diminution of weight supported.

So far the theory is beautiful and unexceptionable; but in further applications of the theory as stated by Professor Wheatstone, "the resistance of the connecting wire of the circuit is directly proportional to its length, and to its specific resistance, and inversely proportional to its section."

Some experiments were made by Mr. Barlow many years ago, but which were imperfect, both from the construction of the batteries employed, and from not taking into account the resistances of the battery itself, (Ohm's theory being then little known.) From these experiments it appeared that the resistance was directly proportional to the square root of the length of the wire, and inversely proportional to the quantity of metal contained in the wire.

Some experiments confirm these views, particularly when the resistances of the battery are not estimated. The results of my own experiments, which are not yet so complete as I desire, lead me to suppose that the same law of conduction does not hold in regard to currents of considerable quantity, as in regard to currents of considerable intensity and slight quantity.

Such experiments demonstrate the utility of employing an instrument the indications of which are in strict relation to the forces of the current; if the ordinary galvanometer had been employed, it would have been much more difficult to ascertain whether the instrument or the theory was at fault.

Having received some intimation or suggestion, I think from a paragraph in a newspaper, that two voltaic currents might be passed through the same conductor, it appeared to me that if it were proved that two currents could pass through the same wire in opposite directions, and without interfering with each other, such fact might lead to important inferences in the theory of electricity, and that, at all events, the result of experiments on this subject might be of some importance in ascertaining the conducting power of the various bodies. Having at hand several coils of wire 200 or 300 yards in length, and also electro-magnets, I passed a voltaic current from a series of very small plates through about 300 yards of thin wire, and also through the coil of wire of an electro-magnet, consisting of about 30 yards of much thicker wire. A moderately delicate galvanometer was connected with the small wire, and formed part of the circuit; and a pint cell, according to Daniel's arrangement, was connected with the coil of the magnet, and I did not find that the deflections of the galvanometer were sensibly affected by the more powerful current passed through the coil of the magnet; and it appeared that two currents might be passed in the same, or in opposite directions, through the same conductor, without interfering with each other. I then varied the experiments, passing currents from two small voltaic pairs through considerable lengths of wire, sometimes in the same, and at others in the contrary, direction, a galvanometer being introduced between the long wire and the pair, which may be designated No. 1. I found that although the galvanometer was deflected by the current from No. 1, yet the current from No. 2 in one direction increased the deflection, in the other diminishing it.

Being desirous of knowing whether such experiments were at all new, I mentioned some of the results to my friend, Martyn J. Roberts, and was by him referred to the notice of a communication by Mr. Gassiot, published in the Transactions of the London Electrical Society. Mr. Roberts also mentioned that he had, some years ago, tried experiments of a similar nature, and that he was of opinion that two currents could not be passed in opposite directions through the same wire by any arrangement which was free from suspicion of fallacy, arising from the action of one series of elements on the other.

Finding the inferences drawn by Mr. Gassiot and the opinion of Mr. Roberts at variance, but not being acquainted with the precise manner in which the experiments of either were conducted, I made a considerable number of experiments, making use of coils of copper wire of 100 feet in length, and of the thickness known as No. 20 of the Birmingham wire gauge, or .035 inch.

Mr. Ward then detailed numerous experiments, the results of which were exhibited on diagrams, and stated that he had arrived at the following conclusions:—

That currents cannot pass along a conductor in opposite directions; that the appearance of their doing so is due to the transmission of the current from one pair or series of elements to the other; but that, on the other hand, the conducting power of wires is diminished to the amount of current passing through them.

At the conclusion of the paper, a brief but interesting discussion took place, arising out of some suggestions by Mr. Morton. The first of these suggestions was very important in its bearing upon the preservation of human life, namely,—Whether it was not desirable that men conversant with the science of galvanism, (instancing Mr. Ward in particular,) should direct their attention to experiments to ascertain whether it would be possible to produce light without flame, for use in coal mines. Another suggestion had for its object the consideration of the propriety of experiments directed especially to ascertain whether it would be practicable and economical to apply galvanism to motive forces and the raising of weights.

The Noble Chairman remarked that the importance of the former suggestion had been painfully impressed upon the people of this part of England within the last few months.

Mr. Ward said his attention had been already in some measure directed to the application of magnetism to the purposes in question, and if it would be of any advantage to the society, he should be glad to pursue his investigations further. The result of his experiments hitherto led him to fear that, even if the instruments were perfect, voltaic currents would be an expensive means of obtaining mechanical power. With regard to lighting coal mines by light without flame, he stated that a patent had some time since been taken out with that view, but he expressed his opinion that galvanism would be an inconvenient means of effecting that object, it being necessarily attended with a cumbersome apparatus.

With regard to the application of galvanism to the electric telegraph, (which formed the subject of another suggestion from Mr. Morton)—

Mr. Ward said that he should be glad, on a future occasion, to bring forward some of his own experiments, which he could not do until he had specified a patent.

The Noble Chairman now called for the next Paper

ON THE POLICY OF PROMOTING AND ENCOURAGING THE GROWTH OF FLAX IN GREAT BRITAIN AND IRELAND; AND AN INQUIRY WHETHER FLAX CAN BE PRODUCED (lb FOR lb) AS CHEAPLY AS THE COST OF IMPORTED COTTON. BY HENRY BRIGGS, ESQ., OF OVERTON, NEAR WAKEFIELD.

It is maintained by many individuals that there is no such thing as positive evil in existence; that the indulging in a contrary opinion would, in fact, be a reflection upon the wisdom and beneficence of the Divine Being; and that those events which we call evils are, in reality, only blessings in disguise, or, as the poet expresses the sentiment,—

> "All nature is but art, unknown to thee;
> All chance, direction, which thou canst not see;
> All discord, harmony, not understood;
> All partial evil, universal good."

It may, probably, be rather a difficult task fully and cordially on all occasions to subscribe to these doctrines; yet still, it must be acknowledged by all thinking men, that few events occur, however afflictive to individuals they may be, without their being the means of accomplishing some good end. And we may fully agree with the expression of the poet, in the last line of the quotation, if we qualify his meaning by presuming that he intends to convey the idea that partial evil *results* in universal good.

That our common country has, within the last twelve months, experienced a grievous visitation in the failure of the potato crop, which produced a partial famine, with its attendant evils, particularly in Ireland, cannot be gainsaid;