IX. *An account of Experiments made with the view of ascertaining the possibility of obtaining a Spark* before *the Circuit of the Voltaic Battery is completed. By* John P. Gassiot, *Esq. Communicated by* P. M. Roget, *M.D. Sec. R.S. &c.*

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1. In presenting an account of the following experiments to the notice of the Royal Society, I am fully aware that the results are somewhat at variance with those obtained by philosophers whose names are so eminent in science, that it may appear presumptuous in me even to offer an opinion as to the correctness of their statements. The discrepancy may very possibly arise from error on my part; but as the experiments relate to facts and not opinions, I can only state that I present a faithful record of those performed by myself with the assistance of two or three private friends, and that this record is extracted from my note-book, wherein the experiments were entered from day to day as they were performed.

2. Until some recent experiments of Dr. Jacobi* no one appears to have disputed the correctness of Dr. Faraday's original experiment of a spark appearing *before contact*, or before the circuit of a voltaic battery was completed, when consisting of a single pair of plates.

3. That a spark does appear when the contact is made *on completing* the circuit of the voltaic battery, is well known to all who have experimented with that apparatus. Dr. Faraday has shown that this spark can be produced even with a single pair of plates†; and although, in the preface affixed to the octavo edition of his Researches, this philosopher considers, from the results obtained by Dr. Jacobi, he was in error as to the spark taking place before contact, yet, with the precaution which he has described, the spark will invariably appear whenever the circuit is completed.

4. Sir Humphry Davy, in his Elements of Chemistry‡, says a bright spark was produced of $\frac{1}{30}$th or $\frac{1}{40}$th of an inch in the open air, and in vacuo nearly half an inch, by using 2000 of Dr. Wollaston's plates.

5. Mr. Children informed us, that with 1250 pairs the spark was capable of passing through a distance of $\frac{1}{50}$th of an inch§.

6. Dr. Henry, in his Elements of Chemistry, expressly states that the galvanic fluid passes through air and certain *non-conductors* in the form of sparks.

7. In the edition of Turner's Chemistry, now in the progress of publication, it is stated‖ that, on approximating the wires of an active circle, a brilliant spark passed between them just *before* contact, as well as in the act of breaking contact.

* Philosophical Magazine, December, 1838, p. 401.

† Philosophical Transactions, 1834, § 957.

‡ Page 152.

§ Philosophical Transactions, 1809.

‖ Page 153.

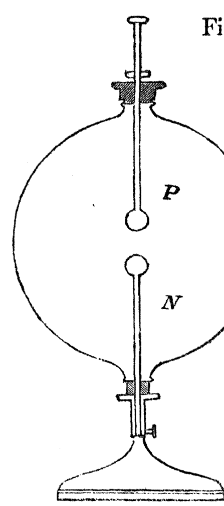
8. Professor DANIELL, in describing some very curious and important experiments made with his constant battery when excited with strong acid solutions*, says, "That "a discharge may take place from the copper of one cell to the copper of the next, "when the regular circle is interrupted between the two, I had many opportunities of "observing with the powerful currents with which I had been experimenting; *for I "have frequently seen it pass in the form of a spark* when the cells had been too much "approximated in the air." And in his Introduction to the Study of Chemical Philosophy, § 725, this gentleman also informs us, that, when the energy of the battery has been elevated by the repeated impulses of a series, it will project through an interval of air in the form of the most dazzling fire.

9. With this array of authority before me, I certainly entered into the investigation with some diffidence: but the inquiry was important. Dr. JACOBI's experiments, to which I have already alluded, proved that with twelve platinum and zinc plates, excited with a solution of eight parts sulphuric acid to 100 parts of water, the spark could not pass through $\frac{1}{20,000}$th of an inch; and the question was now, whether using a more powerful apparatus this alleged spark was obtainable or not. Fortunately the researches of Professor DANIELL have, in the constant battery†, placed an apparatus in the hands of the experimentalist which enables him to examine his results with that care and attention so indispensable in all philosophical pursuits, but which were quite incompatible with the acid batteries used in the time of DAVY.

10. My first experiments were made with 160, and subsequently with 320 series of the constant battery, each series consisting of the usual elements of zinc and copper, each pair being placed in a half-pint porcelain jar, the exciting liquids, solutions of muriate of soda and sulphate of copper, separated from each other by brown paper. The effects from this battery were of the most brilliant description; but as they have been described elsewhere‡, it is only necessary for me to state that this arrangement was used in the following experiments.

11. Fig. 1. represents a glass globe which was attached to a good air-pump, the upper wire sliding through collars of leather air-tight, P and N representing the positive and negative electrodes of the battery (10.) The small balls attached to the two wires were then approximated, as near as the eye could determine, without being in actual contact; but no sparks could be observed even when the globe was exhausted by means of the air-pump.

Fig. 1.



12. In order to avoid as much as was in my power any error in the approximation of the electrodes, I had an instrument prepared which, in order to understand correctly the next series of experiments, it is necessary I should describe.

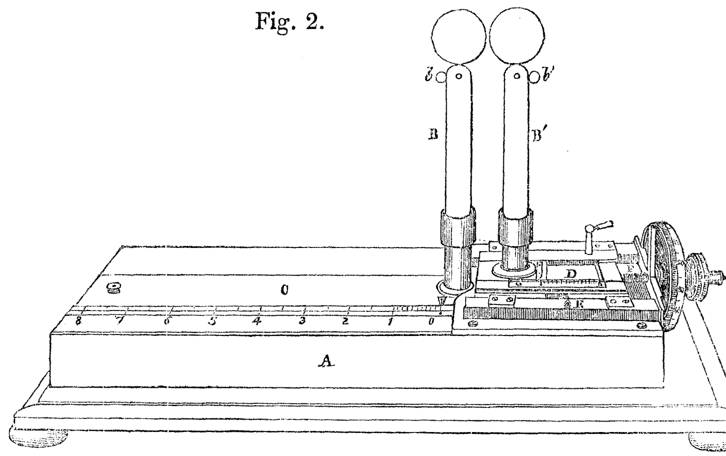
* Philosophical Transactions, 1837, p. 121.

† Ibid. 1836.

‡ Transactions of the Electrical Society.

Fig. 2. A represents the wooden base of the instrument: B B′ are two glass pillars about three inches high, on which are fixed two brass balls with binding screws attached, *b b′*, and by which discs or points of platinum, or small pieces of charcoal, may be attached: C is a wooden slide with an ivory scale divided into tenths of an inch, and by which the pillar B can be moved; D a metal slide (to which the pillar B′ is attached) with

Fig. 2.



an index and scale to tenths of an inch; and E a scale attached to the base of the instrument, graduated to $\frac{1}{50}$th of an inch: the metallic slide D is moved by a *micrometer screw*, F, to the circumference of which is attached a scale divided into 100 equal parts. One complete revolution of the screw F acts on the metallic slide D, and consequently on pillar B′, to the extent of $\frac{1}{50}$th of an inch; and as the circumference of the scale attached to the screw is divided into 100 equal parts, every division will indicate an action on the pillar B′ to the extent of $\frac{1}{5000}$th of an inch. For the purpose of reference, I will designate this instrument as the *Micrometer Electrometer*.

13. It will be seen by the preceding description of the instrument, that I was now enabled to measure a distance of $\frac{1}{5000}$th of an inch, with what correctness the following experiment will show. A magneto-electric machine (made to avoid the use of mercury, by having a metallic break attached to the armature, on which contact is broken, and where of course the usual spark appears as the armature is rotated,) was placed on the table; wires were then attached to the pillars B B′ by the binding screws *b b′* of the micrometer electrometer (12.), and these wires being also attached to the magneto-electric machine in such a manner as to form part of the circuit, on rotating the armature, a brilliant spark was invariably obtained on the *break* whenever the points or balls of the micrometer electrometer (12.) were in contact, but when separated to the $\frac{1}{5000}$th of an inch, as denoted by one division of the scale, the spark immediately disappeared; showing that when the circuit was divided by this minute space, a space not appreciable to the eye even when assisted with a powerful lens, the spark could not be obtained. By this experiment, I not only ascertained that the magnetic spark could not pass through the space of $\frac{1}{5000}$th of an inch, but, what was more important to me for the object I had in view, I proved the correct action of

my instrument; and I now purport describing the different arrangements of the voltaic battery with which I used it.

14. I have had in constant action for upwards of twelve months a voltaic battery consisting of the usual elements, zinc and copper, each pair being placed in a separate circular glass vessel containing about a quart of rain water. The entire battery is composed of 150 series or pairs. A minute but brilliant spark is perceivable on *completing* the circuit with charcoal terminals: it will charge a Leyden jar sufficiently to deflect the leaves of a gold-leaf electroscope, and a Leyden battery of twelve one-gallon jars sufficiently to fuse the ends of a fine steel wire or point of a penknife; but although the greatest care was taken in adjusting the micrometer electrometer (12.), not the slightest appearance of a spark could be perceived through the minute space of $\frac{1}{5000}$th of an inch.

15. Recollecting that Professor DANIELL had a water battery of an extended series, I applied to that gentleman for permission to use it, which he kindly granted me. This battery, which Mr. DANIELL has described in his Introduction to the Study of Chemical Philosophy, § 743, consists of a series of 1024 pairs; attractions as well as repulsions, when the electrodes terminate in strips of gold leaf, are plainly perceptible; a minute but distinct spark is seen on completing the circuit; but with the *battery alone the spark could not be obtained* through the space of $\frac{1}{5000}$th of an inch.

16. The property of the voltaic battery, particularly when extended to such a series as that of Mr. DANIELL'S (15.), to charge a Leyden battery is well known; and I accordingly found, when a battery of nine jars was introduced in the circuit, I obtained distinct sparks to a distance varying from $\frac{1}{5000}$th to $\frac{6}{5000}$ths of an inch. When the space was reduced to $\frac{1}{5000}$th or $\frac{2}{5000}$ths of an inch, the sparks appeared in quick succession, the intervals between the sparks varying from two seconds to twelve seconds; but when the space was increased to $\frac{4}{5000}$ths, it required at least two minutes before there was sufficient accumulation or power to force a passage for the spark through such a space.

17. Having been, by the invitation of Professor DANIELL, witness on the 16th of February 1839 of the powerful effects obtained by a series of seventy of the large constant battery, I was induced to prepare 100 of precisely the same dimensions. On the first day I excited that battery (14th of July), and when I was favoured with the company of Dr. FARADAY, I also excited 100 of the smaller cells already described (10.); *but neither with these two powerful batteries combined,* or separate, could any appearance of a spark be observed until contact was made and the circuit completed.

18. Dr. FARADAY placed a silk handkerchief between the electrodes of the 100 large cells, and although the terminal balls or ends of the connecting wires were pressed together and then separated, and this repeated several times, no effect could be obtained through this minute space; or, in other words, one thickness of a silk handkerchief interposed between the electrodes of such a powerful battery was sufficient to prevent any perceptible action.

19. Those who had the pleasure of witnessing the experiments of Professor Daniell, at King's College, when a series of only seventy pairs of his constant battery was used, will no doubt recollect the brilliant effects produced with this powerful apparatus, and may form some idea of those obtained by using nearly one third increase of power. Titanium, which had been previously given to me by Dr. Faraday, was fused into a solid mass, and is now in that gentleman's possession; platinum was volatilized; and the flame from charcoal as well as from metallic electrodes was so intense as to render it indispensable that the eyes of those present should be protected by thick screens of black crape. On another evening sixteen feet four inches of platinum wire No. 20 iron gauge, was ignited to a red heat; and even this length might have apparently been extended had I had a greater quantity of that wire; but with such a powerful apparatus no effect could be obtained even through one thickness of a silk handkerchief.

20. It will be seen by the preceding experiments that I was unsuccessful in my attempts to obtain a direct spark, or what is usually denominated the striking distance, by the direct or *unassisted* action of any of the powerful batteries hitherto described in this paper; but that when a Leyden battery of nine jars was introduced in the circuit of the 1024 series (15. 16.), the spark passed through the space of $\frac{6}{5000}$ths of an inch.

It is necessary to explain, that, since making the experiments I am about to describe, my attention has been pointed to similar results obtained by Dr. Faraday in his Ninth Series*; and had I been aware of them I should certainly have saved myself much useless time and expense. The results are however in every way confirmatory of the experiment of this philosopher†; but from the powerful apparatus I used the results obtained were proportionately more decided.

21. In the course of my previous experiments I had often introduced coils of copper ribbon and of copper wire in the circuit of the voltaic battery, without being enabled to obtain any indication of a spark before contact, although the brilliancy of the spark is thereby so much increased when the contact is broken. From the effects obtained by the water battery (15. 16.) of 1024 series, when the Leyden battery was introduced in the circuit, I was induced to try what effects could be obtained by what is generally called the secondary coil, or the action of an induced current. It is not, however, my intention to enter into the particulars of the numerous experiments made by myself, in conjunction with those private friends who kindly assisted me in this inquiry, but I will at once briefly explain the apparatus I ultimately used, and from which the most satisfactory results were obtained.

22. Twelve hundred and twenty-five iron wires, No. 20 gauge, each wire about twenty-one inches long, being previously well coated with resin, were bent into the usual horse-shoe form. 115 feet of No. 12 copper wire, well covered with cotton, and divided into three separate lengths, were then wound round the iron wires; bind-

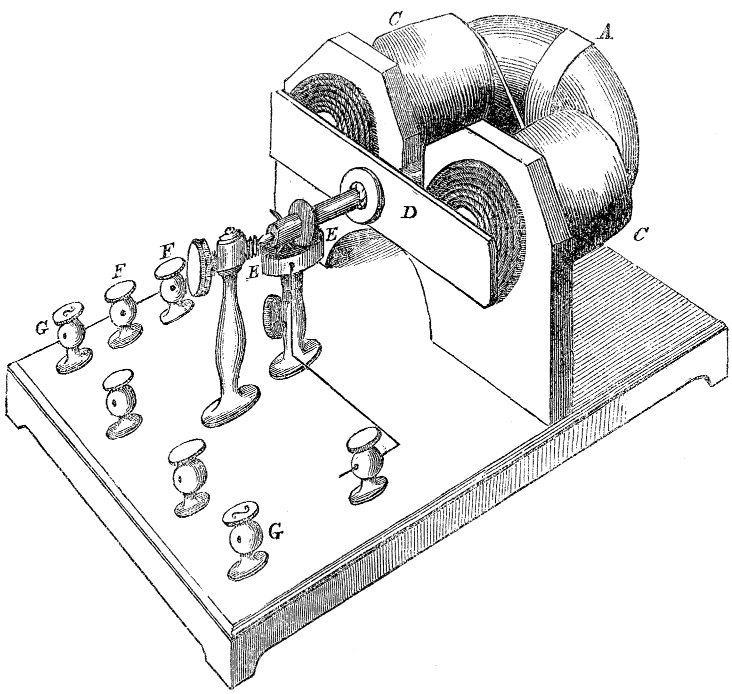
* Philosophical Transactions, 1834.

† Ninth Series. § 1090.

ing screws were attached for the purpose of making connexions with the voltaic battery, the whole forming an electro-magnet of considerable power. Over this thick wire 2268 feet of No. 30 copper wire, also well covered with cotton, were wound round, the ends being attached to separate binding screws, and forming a secondary coil. A bar of soft iron was placed so as to rotate within about $\frac{1}{50}$th of an inch from the ends of the iron wires, which ends were previously ground quite smooth, so as to expose an even surface; and connexions were made from the primary wire by means of two cups of mercury, so that the contact with the voltaic battery should be made and broken at every revolution of the iron bar.

The apparatus when in action is represented by fig. 3, and may be described as follows. A represents the iron wires forming the electro-magnet when the voltaic

Fig. 3.



current is passed through the primary coil; C, C the secondary coil; D the bar of soft iron; E, E cups of mercury connected with the primary coil; F, F binding screws to connect the primary coil with the voltaic battery; G, G binding screws attached to the ends of the secondary wire. Slips of copper are attached to the bar D, so that when the bar rotates the connexion of the mercury cups, E, E, with the primary coil, and consequently with the voltaic battery, is made and broken at every revolution. The weight of the iron wires is about 8 lbs., the primary coil about $4\frac{1}{2}$ lbs., and of the secondary wire about 1 lb. The entire apparatus is mounted on a strong wooden base.

23. On making connexion with the primary wire, by the binding screws F, F, to a series of twenty of the constant battery large cells (17.), the bundle of iron wires

becomes intensely magnetic, and the bar D rotates with great rapidity. Copper wires attached to the secondary coil by the screws G, G, are connected with the pillars of the micrometer electrometer (12.); and when the platinum points or plates of this instrument are approximated to $\frac{1}{100}$th of an inch, *a minute but brilliant spark appears* at every revolution of the bar.

24. When the pillars of the micrometer electrometer (12.) were separated three or four inches, the spark could be taken by the knuckle, or by a metallic ball, from either of the balls attached to the pillars, which then became the terminations of the secondary coil; and a Leyden jar was charged sufficient to deflect the leaves of a gold-leaf electroscope.

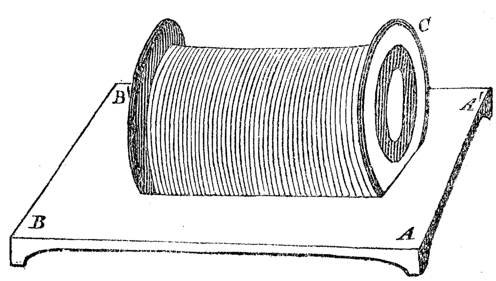
25. On introducing an extremely delicate Harris's thermo-electrometer in the current of the secondary wire, the liquid rose 3°.

26. A voltameter filled with water slightly acidulated with sulphuric acid, was introduced in the secondary circuit, and the gases were evolved in minute bubbles as the bar rotated; and when charcoal points were attached to the terminations of the secondary coil, and these were approximated by means of the micrometer electrometer (12.) to within $\frac{1}{500}$th of an inch, the sparks appeared in such quick succession while the armature rotated, as to have the appearance of a continued but glimmering flame.

27. Thin paper introduced between the platinum or charcoal terminals, was perforated at every revolution of the bar, *but no increase of distance in the spark could be obtained through the vacuum obtained by means of a good air-pump.*

28. In the preceding experiments I had obtained most of the usual results, which are generally denominated intensity effects: the spark (23.); charge of a Leyden jar (24.); heating power (25.); chemical action (26.). In respect to the shock, it was most intense. One revolution of the bar, when the hands were in contact with the terminations of the secondary wire, created a most painful sensation. On two occasions I inadvertently touched both wires, the armature making three or four revolutions; the pain was so intense that I suffered from the effects for a considerable time afterwards; but as this effect, as is well known to all who have experimented with the secondary coil, is so much increased by the introduction of iron wires in the helix, I repeated the experiments under rather different circumstances, viz. by avoiding the use of this metal.

Fig. 4.



29. For this purpose the apparatus (22.) was removed, and a helix composed of 150 feet of No. 18 copper wire, covered with cotton, formed the primary, and 2100 feet of No. 26, similarly insulated, formed the secondary, the whole wound round a hollow cylinder of wood. Fig. 4. represents the form of the coil; C the coil, the shaded part representing the primary, and the

outer circle, the secondary wires; at A, A′ are binding screws, by which the connexions may be made with the primary wire to the battery (17.), and at B, B′ similar screws attached to the terminations of the secondary.

30. The primary coil (29.) being introduced in the circuit of a battery of twenty of the large cells (17.), and connexion made from the secondary coil to the pillars of the micrometer electrometer (12.), whenever the connexion with the primary wire was *broken*, a spark passed through a space of $\frac{2}{5000}$ths of an inch; but no effect could be observed on the liquid in HARRIS's thermo-electrometer (25.), until a bundle of iron wires was introduced in the centre of the helix, when the liquid rose 3°.

31. When two galvanometers are introduced, one in the circuit of the primary and the other in that of the secondary wire, the deflections of the needles will indicate currents in opposite directions. This action was noticed by Dr. FARADAY in some of his earliest Researches*. In the course of these experiments I however repeatedly observed that no effect could be obtained on an exceedingly delicate galvanometer introduced in the *circuit* of the secondary wire, *unless it was completed by actual contact*. I introduced two galvanometers, one A, in the circuit of the primary, and the other B, in that of the secondary; when the ends of the latter were approximated to within $\frac{1}{5000}$th of an inch, the spark appeared whenever the contact with the primary was broken, but without producing the slightest action on the galvanometer B, the needle A of course being acted on in obedience to the direction of the current.

32. Although I had succeeded in obtaining a distinct spark through an appreciable and *measured* space (16. 23. 24. 26. 30. 31.), still the effects could only be assumed as due to some secondary cause; for while with 100 series of Professor DANIELL's powerful constant battery the spark could not pass through a space occupied by a single thickness of a silk handkerchief, yet with the apparatus (22.), a single pair, as I afterwards found, was sufficient to produce the spark.

33. In the next series of experiments, I used an apparatus of a very different description to those I have described, one which, although well known to every electrician, has been very little used in this country; I allude to the pile of ZAMBONI. The one I have consists of a 10,000 series of laminated zinc, paper, and oxide of manganese, each disc being about one inch in diameter: this pile was divided into ten separate piles of 1000 series each.

34. With this apparatus, using the micrometer electrometer, I obtained distinct sparks through a space of $\frac{1}{25}$th of an inch, when the two *balls* were used, one being connected by wires to each end of the pile; and when *points* were fixed to the pillars the sparks passed through $\frac{1}{10}$th of an inch. At $\frac{1}{50}$th the stream of sparks was so powerful as to produce that peculiar phosphorescent odour which is always perceptible in the action of the electric machine, or in the gases evolved from the decomposition of water by the voltaic battery.

35. A HARRIS's unit jar was introduced in the circuit, a wire from one end of the

* Philosophical Transactions, 1831.

pile being attached to the outer, and one from the other to the inner coating. On the two small balls which are fixed to this really beautiful and simple instrument being approximated to about $\frac{1}{50}$th of an inch, the jar was charged and discharged every three seconds, and this action continued for several minutes without the slightest variation.

36. I have since repeated the experiment with one pile or 1000 series: a spark passed between the *plate* and *point* of the micrometer electrometer through a space of $\frac{12}{5000}$ths of an inch, but I could not obtain any effect, even with the entire series, on HARRIS's thermo-electrometer, or with a delicate galvanometer, or any evidence of chemical action*.

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37. Subsequently to the completion of the experiments detailed in this paper, my attention was drawn to a paper in the American Philosophical Transactions, entitled Contributions to Electricity and Magnetism, by Dr. HENRY of Philadelphia, Third Series. I have not had the opportunity of seeing the previous series, but find that the present investigations of this celebrated experimentalist have been directed to the discovery of inductive actions in common electricity analogous to those of galvanic, and I was in great hopes that Dr. HENRY had examined the action of the spark; his views, however, appear to me to have been directed to other objects.

In the twenty-ninth paragraph he alludes to the spark appearing when the ends of the second coil were rubbed together; in the thirty-first, that by uniting a number of coils the brilliancy of the spark was much reduced; and in the ninety-sixth, to the fact of the induced current in an adjoining conductor being more powerful than in the first, and that to render the spark visible, the electricity must be projected through a small distance of air: the following experiment was suggested by those of Dr. HENRY.

38. Five cells of Professor DANIELL's constant battery were charged and connected with the electro-magnetic machine (22.); the primary coil of the apparatus (29.) was connected with the secondary wire of the machine (22.), and the micrometer electrometer (12.) to the secondary wire or coil of the apparatus (29.); the armature of the machine rotated, but no spark appeared even through $\frac{1}{5000}$th of an inch, although slight shocks could be perceived; but when the *secondary* coils of both instruments (22. 29.) were connected together, a minute but brilliant spark passed at the break of the primary wire of the apparatus (29.) through $\frac{1}{5000}$th of an inch.

It is not my intention to intrude any theoretical opinions of my own, but I will

* I have since repeated the experiments as to the evidence of chemical action with great care, and after many trials have at length been enabled to obtain chemical decomposition of a solution of iodide of potassium in the following manner. I fastened about two inches of platinum wire to each end of the pile of 10,000 series; the two points were approximated parallel to each other, about a quarter of an inch apart; a piece of bibulous paper, saturated with a solution of iodide of potassium, placed on a slip of glass, was then brought into contact with the ends of the wires, and the iodine invariably appeared on that attached to the end of the pile terminating with the oxide of manganese.—*Nov.* 19*th*, 1839.

content myself by briefly referring to those which are now generally received as axioms in electrical science.

The effects that are obtained from different sources of electricity, as well as those obtained from different forms and dimensions of the voltaic battery, have been conveniently generalized under the terms QUANTITY and INTENSITY. Let us now examine the results obtained by the experiments detailed in this paper; a series of one hundred of Professor DANIELL's constant battery, excited with strong acid solutions, will scarcely affect the leaves of a delicate gold-leaf electroscope, yet a single excitation by a silk handkerchief on the glass globe by which they are surrounded, will rend the leaves of such an instrument to shreds; and we find that the space occupied by a single fold of a silk handkerchief, or even a piece of tissue paper, is sufficient to insulate a power, which after the circuit has been once completed will ignite upwards of sixteen feet of thick platinum wire and fuse titanium into a solid mass, effects never, I believe, before obtained by the voltaic battery.

A one thousand series of ZAMBONI's piles is sufficient to elicit a distinct spark to the measured space of $\frac{12}{5000}$ths of an inch; yet these different results are at once assumed as being due to what is usually denominated quantity and intensity.

It has been often urged that any objection which may have arisen as to the identity of electricity and galvanism, was at once removed by the fact of a spark of the latter being capable of passing through space, or what is usually denominated the striking distance; and it argues little for the correctness of our experimental investigations, that such an important fact, (although perhaps until it is more satisfactorily proved it can scarcely be assumed as a fact,) one apparently so easy of confirmation, should rest on one or two doubtful and isolated experiments. Although I must consider that Professor DANIELL laboured under some error when he describes the discharge passing in the form of a spark (8.) when the cells were approximated, yet I cannot but feel that it will be with the aid, and through the principles of this philosopher's scientific apparatus, which he has so appropriately denominated the constant battery, that the true principles of voltaic action will be correctly ascertained. There is already one fact which was obtained with the 160 pairs (10.) which cannot, I believe, be satisfactorily accounted for by any of the existing theories. I allude to the remarkable heating of the positive electrode two inches *beyond* the part where the circuit was completed*.

Before I conclude, I should wish it to be distinctly understood that I offer no opinion as to the possibility of obtaining the striking distance or spark before contact; I merely present an account of those experiments which have been made by me to obtain it. That according to the present theoretical views of the action of the voltaic battery, with the apparatus I used, it ought to have taken place, I think most persons will acknowledge; and also, that if by still more powerful apparatus it cannot be produced, the theory must in some way or other be incorrect.

* Transactions of the Electrical Society, Part I. p. 65.