at, and about the point approached: it would there exhibit a *positive* pole; and if the body approached near enough, a discharge from the wire would take place, the force of which would be proportional to the extent of the wire and the electric pressure of the surrounding aerial medium at that time; and as that pressure is continually varying, the charge in the wire will vary also. Therefore the same wire cannot be charged to the same extent at all times, which is a fact well ascertained by several electricians of the highest repute. From the whole of these circumstances, a long insulated wire appears to be well adapted for an important part of an electro-phorascope, which would indicate the changes of electric pressure in the lower strata of the atmosphere, under a cloudless sky; and as such a wire would always represent the electrical state of that stratum of air in which it was suspended, it would also form an important part of an *electro-metaboliascope,* which would indicate those changes from *plus* to *minus*, and *vice versa*, of the air, with respect to the earth, which occasionally take place by the approach, transit, and departure of clouds.

On the Induction from the Discharge of the Battery. *By* M. Ch. Matteucci.*

When I undertook the study of the secondary current developed by induction, by means of a current from the Leyden jar, I took as a measure of the direction and of intensity of this current, the degree and direction of the magnetism which it developes in a steel needle which is contained in a cylindrical spiral *dextrorsum* traversed by this current of induction. M. Henry and M. Marianini, who were occupied at the same time in the study of this phenomenon, have employed the same means; M. Marianini alone made use of temporary magnetism. Without knowing the works of each other, we have published our results, and they are found to agree perfectly. These results may be reduced to the following:—Firstly: If the discharge is feeble, the secondary current is directed in an inverse direction to the current of the jar: in all other cases it has the same direction as the latter. Secondly: If the two currents are removed from each other, we always arrive at a certain distance at which the secondary current is found to be reversed. Thirdly: Any intermediate metallic plates destroy the secondary current by beginning to produce it in an inverse direction, and at the same time the secondary current travelling in the same direction as that of the jar, traverses the plate. M. Reiss has also studied this same subject, making use of a thermoscope to measure the intensity of the secondary current. He obtained some remarkable results, which may in some measure be resolved into those which we obtained. This philosopher accuses

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the process which we employed to determine the direction of the current, of uncertainty, in referring to the beautiful work of M. Savary, which proves how the direction and the degree of magnetization are variable in circumstances which have not yet been subjected to any general law.

Since my first researches I have reflected a good deal on the results of M. Savary; and it will be seen in my memoir, that by employing very feeble discharges and very long circuits, I have endeavoured to place myself in conditions in which the magnetic action of the current no longer presents anomalies. I persist in believing that the indication of magnetism is always correct for measuring the intensity and the direction of the current. I hope that ere long it will not fail to be proved. I believe this process to be more sensitive than all the others which we have employed, and capable of indicating to us, in the duration and force of the current, many variations which escape other methods. I have at all times been desirous of trying if the galvanometer might be employed in these researches; I have taken for this, Gourjon's galvanometer, such as Melloni employed in his researches on heat. I have always employed my two spiral planes, each of which is composed of twenty-three metres of copper wire. These two spirals are brought very near to each other, and are only separated by a plate of very thin glass. It is with this apparatus that I have obtained for the first time very brilliant sparks of induction, by employing one of the smallest Leyden jars that can be made with a smelling bottle. I soon perceived that, in order to have signs from the galvanometer, it would be necessary to employ a battery. The batteries that I have employed consisted of 4, 8, 10, or 12 jars, and had 0 m. c., 3864, 0 m. c., 6828, 0 m. c., 9660, 2 m. c., 152, of coated surface.

Before detailing the results which I obtained, I confess that, particularly with charges of a very slight degree of tension, I have always seen a spark escape in the circuit of the galvanometer. It would have been necessary to employ a galvanometer the wire of which was well covered with varnish, like those of Colladen. I obtained very constant numbers, but I still refrain from giving them as invariable, and as establishing a law numerically expressed. The spark which is given out in the circuit of the galvanometer ought always to destroy a portion of the action of the current, and this portion ought to be variable in each case. With a battery of twelve jars I have obtained the following numbers:—

Tension of the Battery.	Deflection.
10°	4°
20	8
30	12
40	16

The direction of the secondary current is always the same as that of the current of the jar, which goes from the surface which communicates with the conductor of the machine, to the other which communicates with the ground. Moreover, if we charge this battery up to the point where we perceive the noise of the spontaneous discharge, the needle of the galvanometer is pushed on to 90°. I have compared the effects of two batteries of four and of eight bottles, for the same degree of tension, and I obtained for the secondary currents the following numbers :—

Tension.	With 4 bottles.	With 8 bottles.
10°	3°	4°
20	4 ex.	7 ex.
30	6	9
40	8	10
50	10	16

The direction being still the same as in the preceding case. We see clearly that the intensity of the secondary current increases with the tension and with the quantity of electricity which is discharged through the primitive circuit. If we make the distance between the two spirals to vary, the secondary current does not change its direction; it becomes enfeebled with rapidity, and is reduced to zero; but we never obtain an inverse current, as is indicated by the process of magnetizing employed with very feeble discharges. Here are some of the numbers; the charge was from eight jars, and constantly at 40° of tension :—

Distance between the two spirals.	Deflection of the galvanometer.
0m·, 003	17°
0 , 01	9 ex.
0 , 02	8
0 , 06	4
0 , 12	Zero.

In order to establish the law which ought to connect the direction of this secondary current of the Leyden jar with the effects of voltaic induction discovered by Faraday, I have attempted to multiply the number of spirals, in order to oblige the secondary current to become primitive in another circuit. The experiment succeeded very easily. I constructed three pairs of spiral planes of the same copper wire, and of the same length as the two preceding spirals. This is a very remarkable experiment of uniting the functions of these three pairs of spirals in such a manner as to obtain the spark. The disposition of the experiment is very simple: we add to the second spiral—that is to say, to that in which the primary induction takes place—another spiral, and at a certain distance. A fourth spiral is placed like the second and the first, in face of the third. To this fourth spiral we again add a fifth, and in face of this latter we put as for the second and third, a sixth spiral. We dispose the circuit in such a manner that there is an interruption in the circuit of the second and third, another in that of the fourth and fifth, and then a latter one in that of the sixth. It is sufficient if we cause to pass the discharge from a very small jar through the first circuit, to make instantly visible at all points of interruption a spark which seems everywhere to have the same strength and lustre. My first researches have been directed with the end of establishing the direction of the different currents, induced and inducing at the same time. I commenced with two pairs of spirals, and employing two galvanometers in communication with the second and with the fourth spiral. My experiments have been made with the battery of twelve jars, from 10° up to 40° of tension. The pairs of spirals were only separated by a plate of very thin glass. The following table presents the results of my experiments, which I have repeated several times with M. Pacinotti, my colleague, who has considerably aided me in these researches. (Fig. 1). When we employ three pairs of spirals in place of two, the results with the same discharges are produced in the same direction. (Fig. 2). We see very easily that when the induced current becomes an inductor, the current which it develops is always directed as it would be if the induction was produced by a voltaic current which originates it; that is to say, that the direction is the inverse of that of the inducing current. This is precisely the contrary of that which happens to the first current of induction which the discharge produces: the current of induction has the same direction as the inducing current; it acts, consequently, as a voltaic current which intermits.

I wished to study the relations of intensity of these different currents of induction. I always give the numerical results, still being a little diffident of the correctness. At first the needles of the galvanometer lose much of their degree of magnetism by the effect of these currents, and there is always some little spark which explodes. It is for this reason that in all these experiments I have never taken notice of any result without ascertaining whether, in reversing the position of the extremities of the galvanometer, the direction of the deflection was equally reversed. By employing the same galvanometer successively united to the spirals 2, 4, 6, and with the same charge of 10°, I obtained 7° ex., 3°, 1°. These numbers give the intensity for the current of induction of the first, second, and third order.

It was important to study the direction of the current when the spark was given out in the secondary circuit. Having made some trial with the galvanometer, I found that the deviation was hardly sensible in this case, and that even when discharging my jars directly, the deviation was not so great as with my currents of induction. I employed, in place of the galvanometer, a very simple process which was suggested to me by M. Pacinotti. It is that of the hole which the electric spark always makes in paper near to the negative point. The apparatus is very simple, very sensitive, and constant in its results. By interrupting my circuit of the second and third order, I had sparks of induction which yet made a very visible perforation. I took two plates of pewter terminating in a point. I pasted them, one above and the other underneath a morsel of common paper, leaving the two points at two millimetres distance between each other

When the spark was given out a hole was found at the negative extremity. Ordinarily we obtain another sign equally constant. It is that of a black stain near the positive point. In a very great number of experiments that I have made, the phenomenon of the hole at the negative point has always been constant; the other sign very rarely fails. I then disposed several of these pieces of apparatus in my spirals; that is to say, at the second, at the fourth, and at the sixth spiral. We see in every place, with a discharge of 10° of the battery of twelve jars, that the hole is formed, and the direction of the different currents of induction may be seen very readily in the following tables. (Figs. 3 & 4). The law of the direction of the currents of induction produced by the discharge of the battery, and of currents of induction which the induced currents develope, is evident. When the secondary circuit is open, and there is a spark, the secondary current is directed in an inverse direction to the primary current, and this result is verified for the same current of the jar. In fact, the first current of induction has a direction opposite to that which it has when the circuit is closed. The induction is then subject to the same law as voltaic currents at the commencement of their action. We can see what happens when we compare closed circuits with those which are broken. We find everywhere verified that which we saw occur to the first secondary current: if the circuit is closed, the secondary current has the same direction as the current of the jar. I here give several tables which evidently prove it, and the results of which have been many times confirmed. (Figs. 5 and 6). We see, then, that whichever of the secondary currents it is that we take, the current which is developed by induction is always in the same direction as the inducing current, if its circuit is closed, the other being open; or if its circuit be open, the other being closed. If we hold the galvanometer in the open circuit, we obtain very small deflections, and hardly sensible to the instrument I employed. I have always found that when the two ends were very near each other, the needle deviated, giving the same indication as the hole. If we remove the points more remote from each other, the indication of the galvanometer will appear reversed. This is a subject which merits a profound study, and for which I have already disposed apparatus with M. Pacinotti. Perhaps the galvanometer falls short, in this case, by the inductive actions which are always contrary to the current which is commencing, and similar to the current which is ceasing, not being separated. This is a question which we may perhaps resolve when we can obtain signs of induction by a discharge from a battery slowly produced, in such a manner as to see, when in darkness, a continued current of light. Hitherto all the attempts which have been made to accomplish this have been useless. I am persuaded that it is necessary further to insulate the wire of the galvanometer and that of the spirals.

I have only made a small number of experiments on the action of interposed plates between the spirals. At first I said that if we oblige the primitive current of the battery to produce two secondary currents, by placing it in the middle of two spirals, the current of induction which it developes in each of these spirals is always directed as when there is only a single secondary spiral, and the intensity of the current is equal to that which it developes when we suppress one of these secondary spirals. One of these secondary spirals has not any effect on the enfeebling of the secondary current, if its circuit is not closed. On the contrary, if we put in contact with the secondary spiral another spiral closed, in such a manner as to place it between the spiral which is traversed by the discharge from the battery and another precisely similar, the secondary current has the same direction as it would have without this spiral, and its intensity appears augmented.

The action of non-conducting plates interposed is nothing. If we employ metallic plates, the secondary current is considerably enfeebled, but its direction is not changed. It is thus that a plate of zinc of 1½ millimeters of thickness destroys the current of induction from the discharge of eight jars at 40°, and at the distance of 0^m, 01, between the two spirals. A very thin plate of pewter has no influence on this discharge; it requires five, one on the other, to reduce the deviation to 5°, from 9°, when it was without plates. A plate of silver and copper, very thin, hindered the production of the secondary current. It appears, then, that in order to reduce from a given quantity the property which the current possesses of producing induction, it is necessary to interpose a metallic plate whose thickness shall be in inverse ratio to its conductibility.

I was desirous of trying if it was possible to obtain any signs from the galvanometer, by cutting the plate of pewter, and making the two points of the cut disc touch the two wires of the galvanometer. I could obtain nothing with the strongest discharges. This is sufficient to prove the great superiority of the process of magnetism. I prepared a disc of pewter whose diameter was four times greater than that of my spirals. By soldering the wires united with the cylindrical spirals in different parts of this disc, I obtained, with very feeble discharges, a strong magnetization on the steel needles which were introduced into my spirals.

The process of magnetizing merits a more profound study. Hitherto I have not been able to obtain any signs of action in the galvanometer with the discharge from a small bottle which constantly gives a secondary current capable of magnetizing, as a voltaic current would do, directed in a contrary direction to the current from the jar or bottle. This fact is constant.

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10 Fevrier, 1841.

[NOTE.—The tables and figures referred to, are not in the original; and therefore some mistake must have occurred in the printing of it.—EDIT.]