ELECTRIC CURRENTS.

CHAPTER XXXVI.

Electric Currents explained—Electric Circuits—Quantity and Intensity Currents—Phenomena of the Return Current—Retardation of the Current illustrated—Estimated Velocity of the Electric Current on Subaqueous Conductors.

ELECTRIC CURRENTS EXPLAINED.

In the consideration of electric currents I shall have especial reference to their application to purposes of practical telegraphing—of the science to the art. It is possible that some of the views entertained by me, and which are founded upon observations during several years of telegraphing, may not be consistent with theoretical laws advanced from time to time by philosophers. In my experience I have found many problems in electrical science unsolved, and which to this day remain hidden mysteries, known to Him alone who rules the storms and directs the movements of worlds.

A current of electricity is the passing of an invisible and an imponderable fluid over certain matter acting as conductor, starting from its generating source, traversing the circuit, and ending at the point of starting.

The source from which the current flows is known as the voltaic battery; one end of which is positive and the other end negative. It is composed of two metals and chemical compounds. The media through which the stream of electricity flows from one end of the battery to the other are called electric conductors, and they are usually of iron or copper metal. The whole chain of metals and chemicals through which the electric current or stream flows is called a circuit. A contact between the parts must be complete or there can be no electricity; because there can be no electricity if the two poles of the voltaic organization are not connected with one continuous and unbroken circuit.

The electric influence is sometimes called a "pulse," a "wave," a "stream," a "current," a "fluid," &c. These terms can mean but one thing, and that is, the presence of electricity.

ELECTRIC CIRCUITS.

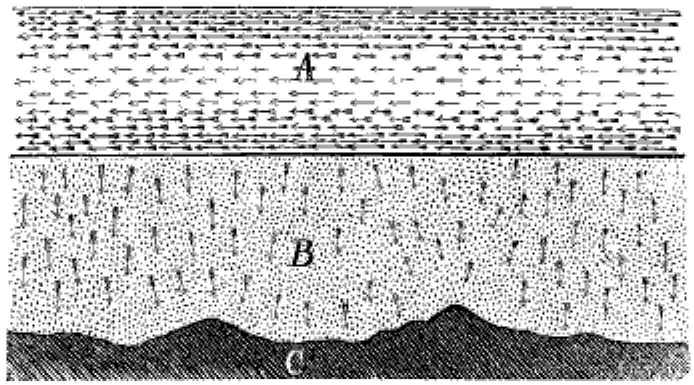
Overground wires, suspended on poles, extend in circuits of indefinite lengths, usually, as a maximum, three hundred miles. The electric circuit will be as a maximum six hundred miles; that is, three hundred miles of wire and three hundred miles of earth. The tendency of the current, when it leaves the positive pole of the battery, is to reach the negative pole as soon as it can. Static or frictional electricity will leap from one conductor to another to reach its opposite; but dynamic electricity, generated by a voltaic series, requires one continuous conductor in order to have life or existence.

In the use of the term or technicality, "dynamic," I mean electricity that has a continuous movement over the conductor, from one pole of the battery to the other, effecting an uninterrupted neutralization or a continual re-union of the two electricities—the negative and the positive.

If "dynamic electricity" is transmitted over very fine metal wire, and of short length, the metal becomes heated and may melt. If the conductor be water, when the "dynamic current" is transmitted, the water is in part decomposed, and its two constituent gases, the oxygen and hydrogen, are seen to be set free.

On a line of some three hundred miles it is certain that there will be many media through which the fluid can, in part, escape to the earth and return again to its original source. From each of these escaping places on the route, branch off lesser circuits; and in the three hundred miles there may be three hundred places where small portions of the current "leak" from the wire and pass off in small streams to the earth. If these conductors were equal to the wire the whole of the current would pass to the earth and return to its original source, and not traverse the line circuit. These media through which the current passes off from the line wire, are some of the many conductors mentioned elsewhere in this work, and to which may be added fog and heat. Fig. 1 represents a line passing through the air on poles. A is a sectional view of the wire; B is fog or heat, and C is the earth. The voltaic current is represented by the arrows. In working a telegraph line through a heavy fog, much difficulty is experienced, and it frequently becomes necessary to increase the number of the

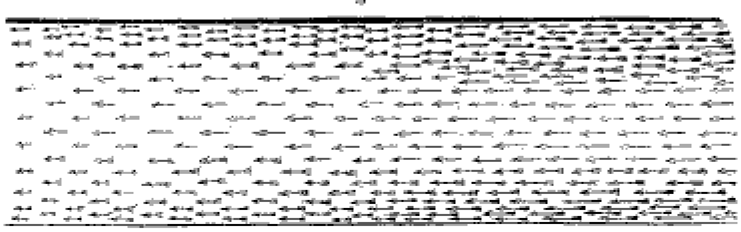
Fig. 1.



cells to obtain intensity of current sufficient to overcome the losses occasioned by the fog. The current escapes through the watery particles in contact and reaches the earth. The figure does not exactly represent the case, but it is sufficiently correct to enable the reader to form an idea as to the "leaking" of the current from the wire through the fog to the earth.

Heat has frequently produced the same result as mentioned above. On some lines in America, during very hot days, in the afternoon, when everything was dry and all surface moisture absorbed by the rays of the sun, I have known it to be impossible to work on a well-insulated line as far as two hundred miles. The result may not have been the heat, but there is no other way to account for it. The metallic circuit was good, because at times when it was dry and cool, or when it rained, and during the morning hours, there was no difficulty in working the line. The dry, hilly regions traversed by the line were free from trees, from grass, and from everything that partook of moisture. If it was not the heat, I know of no means of accounting for the strange phenomena which so often and for so many weeks manifested itself.

Fig. 2.



QUANTITY AND INTENSITY CURRENTS.

I have frequently in this work used the terms *quantity* and *intensity* currents, and I have, on as many occasions as possible, explained the element of each. On a line of three hundred miles a quantity current would be of no value. Connect a line of that length to a large quantity battery, and the wire would be burned long before the intensity nature of the current would reach the farther end. It can be so great that it would partake of the nature of frictional electricity, and pass beyond the management of art. The telegraphic service requires a current of *intensity* and not of *quantity*. The strict technical definitions of these terms have been given by the great philosopher, Prof. Faraday, whose name stands in golden capitals upon many pages of the annals of progressive science. He says:

"The character of the phenomena described in this report induces me to refer to the terms *intensity* and *quantity* as applied to electricity; terms which I have had such frequent occasion to employ. These terms, or equivalents for them, cannot be dispensed with by those who study both the static and the dynamic relations of electricity. Every current, where there is resistance, has the static element and induction involved in it, while every case of insulation has more or less of the dynamic element and conduction; and we have seen that, with the same voltaic source, the same current in the same length of the same wire gives a different result as the intensity is made to vary with variations of the induction around the wire. The idea of intensity, or the power of overcoming resistance, is as necessary to that of electricity, either static or current, as the idea of pressure is to steam in a boiler, or to air passing through apertures or tubes, and we must have language competent to express these conditions and these ideas."

The *quantity* of electricity developed by a given voltaic battery depends practically upon the size of the plates used. The *intensity* is the force with which the quantity is brought to bear upon anything to produce a given result; its *energy* in overcoming obstacles or impediments to the free passage of the electric current. This *intensity* is generally acquired by increasing the number of cells, and it is proportioned to that numerical increase. A *quantity current* can be so great as to be unmanageable for telegraphic service. It becomes as restless as static or lightning electricity, and will leave the wire in part, if near a better conductor. An *intensity current* is necessary for overcoming distance. In reference to this subject, that distinguished philosopher, Dr. Lardner, said, viz.:

"To produce the effects, whatever these may be, by which the telegraphic messages are expressed, it is necessary that the electric current shall have a certain *intensity*. Now, the *intensity of the current* transmitted by a given voltaic battery along a given line of wire will decrease, other things being the same, in the same proportion as the length of the wire increases. Thus, if the wire be continued for ten miles, the current will have twice the *intensity* which it would have if the wire had been extended to a distance of twenty miles.

It is evident, therefore, that the wire may be continued to such a length that the current will no longer have sufficient intensity to produce at the station to which the despatch is transmitted *those effects by which the language of the despatch is signified.*

The *intensity of the current* transmitted by a given voltaic battery upon a wire of given length will be increased in the same proportion as the area of the section of the wire is augmented. Thus, if the diameter of the wire be doubled, the area of its section being increased in a four-fold proportion, the *intensity of the current* transmitted along the wire will be increased in the same ratio.

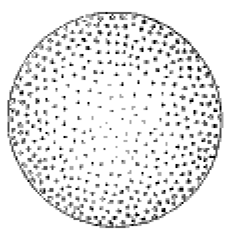
In fine, the *intensity of the current* may also be augmented by increasing the number of pairs of generating plates or cylinders composing the voltaic battery.

Since it has been found most convenient generally to use iron as the material for the conducting wires, it is of no practical importance to take into account the influence which the quality of the metal may produce upon the *intensity of the current.* It may be useful, nevertheless, to state that, other things being the same, the *intensity of the current* will be in proportion to the conducting power of the metal of which the wire is formed, and that copper is the best conductor of the metals.

M. Pouillet found, by well-conducted experiments, that the current supplied by a voltaic battery of ten pairs of plates, transmitted upon a copper wire having a diameter of four one-thousandths of an inch, and a length of six tenths of a mile, was sufficiently intense for all the common telegraphic purposes. Now, if we suppose that the wire, instead of being four one-thousandths of an inch in diameter, has a diameter of a quarter of an inch, its diameter being greater in the ratio of sixty-two and one half to one, its section will be greater in the ratio of nearly four thousand to one, and it will, consequently, carry a current of equal intensity over a length of wire four thousand times greater—that is, over two thousand four hundred miles of wire."

Fig. 2 is intended to represent the intensity current moving in a voltaic conductor. Commencing upon the right and running to the left, the farther from the place of starting the feebler becomes the force. The *intensity* or the energy of the current lessens in its force, as indicated by the lessening of the arrows in the given section of the conductor. In the preparation of the diagram, and the others in this chapter, I have waived the question as to localization of the motion and existence of electricity in the metallic conductor. It is my opinion, however, that the electricity on or near the surface might be properly called "electricity in motion," and that within "electricity at rest." I have no doubt but what the presence of electricity pervades the whole wire, but that the intensity, principally, has its motion at or near the surface. I am led to believe this from the result of some experiments which I have instituted. It is a question of much importance to the telegraphic enterprise, and it is to be hoped that others will give it a careful consideration.

Fig. 3.



In regard to the distribution of electricity on a circular plane, it has been found that the extent or thickness of the electric stratum was almost constant from the centre, to within a very small distance of the circumference, when it increased all on a sudden with great rapidity. The end section of a wire may represent the plane, and the philosophy established would prove that the inner or centre part was but slightly charged with electricity, and that it increased as to volume or amount from the centre to the surface; but that at or near the surface it was very considerably increased. My experiments have confirmed the truth of the foregoing law. It may be possible that the *intensity* of the current moves at or near the surface of the conductor, and that its quantitative element pervades the whole metal.

The foregoing remarks may be applied to all kinds of telegraph conductors, whether in air or in the earth.

PHENOMENA OF THE RETURN CURRENT.

I will, in the next place, notice the difference between practical working of subterranean, submarine and air lines.

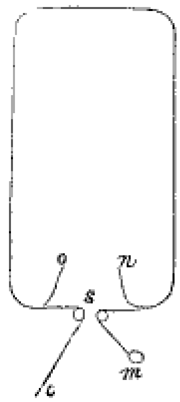
On air lines we have to contend against atmospheric electricity, induced currents and cross currents, or the escape of the electricity by heat, fog, &c. On subterranean and submarine lines a new phenomenon has been manifested, which materially interferes with the successful working of the telegraph. Whether in the earth or in the water, the philosophy is the same, except as the water exists in greater quantities nearer the submarine cable than to the subterranean, the influence is greater on the latter than on the former.

The discovery of this new phenomenon was announced by Professor Faraday in 1854; and notwithstanding electricians have expended much labor and money to discover a remedy for the difficulty, there has been nothing accomplished to ameliorate, in the slightest degree, the effects of the remarkable phenomenon in subaqueous telegraphing, described by Professor Faraday to the Royal Institute of Great Britain. The substance of the report will be found in the following extracts, viz.:

"In consequence of the perfection of the workmanship, a Leyden arrangement is produced upon a large scale; the copper wire becomes charged statically with that electricity which the pole of the battery connected with it can supply; it acts by induction through the gutta-percha (without which induction it could not itself become charged, Exp. Res. 1177), producing the opposite state on the surface of the water touching the gutta-percha, which forms the outer coating of this curious arrangement. The gutta-percha, across which the induction occurs, is only 0.1 of an inch thick, and the extent of the coating is enormous. The surface of the copper wire is nearly eight thousand three hundred square feet, and the surface of the outer coating of water is four times that amount, or thirty-three thousand square feet. Hence the striking character of the results. The intensity of the static charge acquired is only equal to the intensity at the pole of the battery whence it is derived; but its quantity is enormous, because of the immense extent of the Leyden arrangement; and hence, when the wire is separated from the battery and the charge employed, it has all the powers of a considerable voltaic current, and gives results which the best ordinary electric machines and Leyden arrangements cannot as yet approach.

Mr. Clarke arranged a Bain's printing telegraph, with three pens, so that it gave beautiful illustrations and records of facts like those stated; the pens are iron wires, under which a band of paper, imbued with ferro-prussiate of potassa, passes at a regular rate by clock-work; and thus regular lines of prussian blue are produced whenever a current is transmitted, and the time of the current is recorded. In the case to be described the three lines were side by side, and about 0.1 of an inch apart. The pen *m* belonged to a circuit of only a few feet of wire, and a separate battery; it told whenever the contact key was

Fig. 4.



put down by the finger; the pen *n* was at the earth end of the long air wire, and the pen *o* at the earth end of the long subterraneous wire; and, by arrangement, the key could be made to throw the electricity of the chief battery into either of these wires simultaneously with the passage of the short circuit current through pen *m*. When pens *m* and *n* were in action, the *m* record was a regular line of equal thickness, showing by its length the actual time during which the electricity flowed into the wires; and the *n* record was an equally regular line, parallel to and of equal length with the former, but the least degree behind it; thus indicating that the long air wire conveyed its electric current almost instantaneously to the further end. But when pens *m* and *o* were in action, the *o* line did not begin until some time after the *m* line, and it continued after the *m* line had ceased—*i. e.*, after the *o* battery was cut off. Furthermore, it was faint at first, grew up to a maximum of intensity, continued at that as long as battery contact was continued, and then gradually diminished to nothing. Thus the record *o* showed that the wave of power took time in the water wire to reach the further extremity; by its first faintness, it showed that power was consumed in the exertion of lateral static induction along the wire; by the attainment of a maximum and the after equality, it showed when this induction had become proportionate to the intensity of the battery current; by its beginning to diminish, it showed when the battery current was cut off; and its prolongation and gradual diminution, showed the time of the outflow of the static electricity laid up in the wire, and the consequent regular falling of the induction which had been as regularly raised.

When an air wire of equal extent is experimented with, in like manner, no such effects as these are perceived; or if, guided by principle, the arrangements are such as to be searching, they are perceived only in a very slight degree, and disappear in comparison with the former gross results."

MR. BRIGHT'S EXPERIMENTS ON THE VELOCITY OF THE CURRENT.

In reference to this subject, Mr. Edward B. Bright, the very able secretary of the English and Irish Telegraph Company, in association with the late Atlantic telegraph, has written a very clear paper, viz.:

"On extending this system [underground lines] throughout the United Kingdom, where circuits of several hundred miles were brought into operation, it was found upon communicating a current to such wires, that, after the withdrawal of the excitation (whether galvanic or magnetic electricity was employed), an electric recoil immediately took place at the end of the wire to which the current had been previously communicated. This recoil was apparently analogous in all respects to the discharge of electricity from a Leyden jar, except that the current flowing from the wire partook of a quantitative rather than an intense nature; thus, however, finishing the remaining link of comparison, and establishing the identity as regards primary characteristics of all species of electricity.

Although this phenomena, as analyzed by Dr. Faraday, has proved highly gratifying in a philosophical point of view, its existence interfered materially with the working of all the previous existing telegraphic apparatus, not having been at all contemplated or provided for; and, up to this time, I am not aware that, as regards the galvanic system, any adequate remedy has been applied. The nature of the interference will be easily understood, when I mention that, with a letter printing telegraph, the surplus current has the tendency to carry the machinery on further, and to make other letters than those intended. *With the chemical and other recording telegraphs, the surplus flow of electricity will continue nearly a minute, entirely confounding the marks representing one letter with the next.* And, lastly, with Cooke and Wheatstone's and other needle telegraphs, a beat more is made by the back current than intended with every letter formed.

Another remarkable feature to be noticed in connection with the underground system is the small comparative velocity with which the electric impulse is communicated through each conductor in long circuits.

In experiments conducted by my brother and myself upon a circuit of four hundred and eighty miles of the underground wires, a *marked* difference between the communication of the electric impulse, and its arrival at the other end, has been observed; *the interval required for the passage of the sensation amounting to rather more than a third part of a se ond.*

The rate of transmission of the voltaic or magnetic fluids, through such conductors, is therefore only about one thousand miles per second.

Professor Wheatstone's experiments, showing the passage of *frictional electricity* through a short length of wire in a room, to take place at a speed approaching three hundred thousand miles per second, are well known and incontestable.

A subsequent experiment, conducted by Professor Walker, on some of the overground wires comprised in the American system, gives the velocity of the voltaic current, through two-hundred-and-fifty mile circuits, at about sixteen thousand miles per second.

The underground wires, however, as just mentioned, give a far lower result; and hence it appears evident that the velocity of frictional electricity far exceeds the voltaic or magnetic current, owing, doubtless, to the far greater intensity and comparatively small quantitative development of the former.

The retardation experienced in underground wires, as regards the propagation of the electric impulse, is not, however, due to any resistance of the conducting medium; for, as it is found, in the instance of the Leyden jar, that the frictional electricity communicated is temporarily absorbed by the metal in the interior of the jar, so the galvanic or magnetic currents, during their passage through the underground wires, are partly absorbed, until the mass of copper constituting the wire is saturated with electricity; and it would also appear that a definite time is occupied in the absorption of the electricity by the successive portions of the wire, such as is found to occur in charging a Leyden jar; and until this process of impregnation has been completed, the sensation cannot be communicated to the other end of the conductor.

The retardation will, therefore, result, not from resistance, but from the first portion of the charge communicated being absorbed for the time by the conductor through which it passes; for, in addition to the foregoing, copper wire conducts far more freely than the iron wire made use of in the overground wires.

Consequently the speed with which an electric impulse is communicated varies with the energy or intensity of the current employed, and the nature or conditions of the conductor interposed."

In relation to this subject, the following question among others, was propounded to Mr. Charles T. Bright, the engineer of the late Atlantic Telegraph Company, and his answer to the same is herewith given, viz.:

"43. What do you consider return currents? and to what extent do you find the existence of the same on both overground and underground lines? Please state all the points fully.

Answer 43*d*. On overground lines they are very trifling, indeed, compared with underground; the conditions on which the wires are suspended and insulated, passing also through a medium, capable, to a certain extent, of absorbing any electricity developed in surplus, prevents the occurrence of any effects appreciable by ordinary needle telegraphic instruments.

I look upon an underground wire as being exactly similar, on a large scale, to a Leyden jar, and I am borne out in this by the experiments of my brother and myself, and by those instituted by Faraday on the underground wires more recently laid by the Electric Telegraph Company. The magneto-electricity, as well as the voltaic (or chemical) electricity, evinces these phenomena, hitherto supposed to belong to properties appertaining peculiarly to frictional electricity.

The copper may be compared to the inner metallic coatings of a Leyden battery, the gutta-percha to the glass, and the earth and moisture surrounding to the outer covering.

I was much interested, in one of our experiments, to observe that the larger the size of the wire experimented upon, with the same battery power, the greater the amount of return current: a strong support of our opinion, as, had it arisen from an *elastic* return, owing to the wire being unable to receive as much electricity as was forced into it, as some supposed, of course a *smaller* wire (with the same power as that employed with the larger size) should have given out a *greater* amount of return current. If you experimentalize on No. 18 and No. 16, you will see this very clearly."

RETARDATION OF THE CURRENT ILLUSTRATED.

Fig. 5.

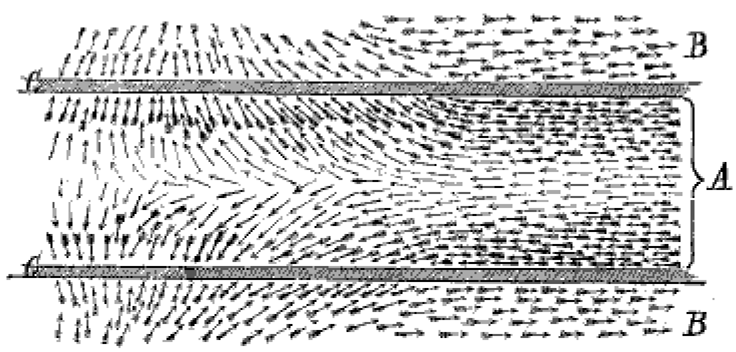


Fig. 5 represents a sectional view of a sub-marine cable: A is the copper conducting wire; C C the gutta-percha covering, serving as an insulation; B B is the water. The arrows represent the voltaic currents starting from A, full of energy. It presses forward in the completion of its circuit until overcome by the influence of the negative electricity of the earth. The wire is, in principle, the same as the inner coating of a Leyden jar, fully charged.

In charging the inner coating, nature furnishes simultaneously an opposite electricity on the exterior covering of the jar. The glass intervenes in the use of the jar, and the gutta-percha intervenes in the case of sub-marine cables. At the end C C, the positive current is seen at rest, brought to the position by the influence of the electricity of the earth, existing in the water. This phenomenon is called the retardation of the current. If at A a negative current be applied, the positive in the cable becomes neutralized. If the battery be disengaged from the cable, and the end of the wire be allowed to hang in the air for an hour, the electricity will be held in the cable in sufficient quantity to discharge a cannon, on renewing the earth circuit. The current thus coming back is called the "return current." The electricity of the earth encircling the cable is negative, when it is charged with a positive current. If the current transmitted through the cable was negative, then the earth electricity would be positive, and the effect would be the same. These imponderable elements seem to exist only in the effort to unite one with the other.

It is this retardation of the electric current that renders the success of ocean telegraphy so exceedingly questionable.

I have, time and again, expressed a want of faith in the practicability of operating long subaqueous conductors for telegraphic purposes, at least, until some new developments in science dispels the difficulties hereinbefore mentioned. The working of the subterranean telegraph lines in England, Denmark, Prussia, Russia, and other states of Europe, and of the various submarine lines, in different parts of the world, prove that long circuits through the water, or through the earth, can not be successfully operated, and that the maximum circuit that can be practically operated for telegraphic purposes, must be less than one thousand miles.

ESTIMATED VELOCITY OF THE CURRENT.

The operating of the line from Sardinia through the Mediterranean Sea to Malta, and thence to Corfu, demonstrates the impracticability of working long submarine telegraphs. The time required for the transmission of the electric current is irregular and unreliable. Such are the facts as known at the present time. The nearest estimate as to the time required for the transmission of the electric current, can be reliably based upon some experiments instituted by the brothers Bright, of England. The following was communicated to me by Mr. Bright:

"Answer 44th. In the course of a long series of experiments carried on last year by my brother and myself, inquiries were instituted with reference to the speed with which the galvanic or magnetic sensation is communicated through underground wires.

The result of the inquiry shows decidedly that the communication of the electric impulse through a length of 500 miles of underground gutta-percha covered copper wire (1-6 gauge) does not exceed 900 to 1,000 miles per second—a speed far below that usually assigned.

Reasoning upon the issue of these experiments, and those previously tried in America, I have no doubt that the speed of any description of electricity varies greatly with the peculiar conditions and nature of the conductor used, and also with the length of the conductor interposed; and that a wire suspended in the open air, especially if insulated only at points of its support, (such as in a pole line) would offer far less resistance (*cæteris paribus*) than a wire underground.

Submarine cables are similar, as regards electrical conditions, to subterranean lines, and the speed with which the electric impulse is communicated would be the same."

On the laying of the Atlantic cable in 1857, Professor Morse communicated the following important fact, viz.: "We got an electric current through until the moment of parting [of the cable], so that the electric connection was perfect; and yet *the further we paid out, the feebler was the current.*"

The highest speed of receiving intelligible and unintelligible signals over the late Atlantic cable, was about one wave, or pulsation, for each $3\frac{1}{2}$ seconds. The value of the wave depends upon their combination in the formation of the alphabet.

WORKING OF THE MEDITERRANEAN TELEGRAPHS.

So true is the philosophy set forth in the preceding, that no practical telegrapher can question it; but, on the contrary, every experiment instituted on submarine or subterranean telegraph lines, adds evidence to its confirmation. Besides the proofs given, reference may be made to the following concise report of Signor Bonelli, the able director general of Sardinian telegraphs, viz.:

"Among the delays observed in the transmission of dispatches which cross Sardinia, I was at first surprised at the long intervals that were noticed between time when the dispatches were presented at Malta, and their reception at the Cagliari station—principally when these dispatches were of considerable length. Unwilling to suspect habitual negligence on the part of the employés at the Cagliari junction, I inquired as to the causes of the delay. I was told that the difficulty was in the method used in this line, in consequence of the well-known inconveniences of submarine cables, which are the greater here, as the lines from Cagliari to Malta, and from Malta to Corfu, are each nearly 600 kilometres (about 375 miles), much longer than any previously existing. I, therefore, deem it useful to exhibit, in some detail, the effects which have been observed, the consequences which result therefrom for the service, and the importance of discovering a remedy.

The submarine cable between Cagliari and Malta is composed of a very fine copper wire, around which are twisted six similar wires of equal fineness, all in free contact with one another, so that if one or more of them should break, the transmission would not be interrupted. The seven wires together form a cord of about two millimetres (1-16 inch) in diameter, covered with a gutta-percha case of two millimetres, and a second envelope of tarred hemp. Eighteen iron wires, two millimetres in diameter, twisted in an extended spiral, enclose the whole, and form the outer covering of the cable, the total diameter of which is thus carried to 14 millimetres (about ½ inch), and weight 547 kilogrammes per kilometre (about 2,000 pounds per mile). The two extremities of the cable, both at Malta and Cagliari, are fastened to two pieces of wire on the land, each 5 kilometres (about 3 miles) long.

After the experiments made in England, and elsewhere, to diminish the difficulties which were foreseen, it was decided to employ for transmission induced electrical currents, with piles of a large surface, and a special apparatus to change the direction of the current alternately.

In spite of all these precautions, the following effects have been experienced:

If the transmission is made too rapidly, the signals are so uncertain as to become unintelligible; it is better, therefore, to be very slow in making them. But several inconveniences result from this. Such a degree of special skill is required in the operator, that among the employés at Malta, for instance, only one was able to transmit the signals satisfactorily. Pauses of nearly a second must be made, so that scarcely 75 signals can be transmitted in a minute—that is to say, but two or three words—while on the land lines the average transmission in the same time is 280 signals, or perhaps ten words.

Besides—principally to avoid the difficulty of a current generated in the opposite direction, called return current—the apparatus is so arranged, that during the transmission from one side, nothing can be received from the other, nor can the current be interrupted. The operator to whom the message is transmitted, cannot, therefore, give notice if a word has escaped him; hence the necessity of suspending the transmission about every ten words, and reversing the apparatus, to ascertain if everything is understood, and if the words must be repeated before going further. This is one cause of an immense loss of time. And if the operator is not able to calculate the interval of the pauses precisely, the confusion of the signals makes frequent repetitions necessary, which almost indefinitely prolongs the duration of a dispatch. Finally, it is impossible to obtain simple points from the instrument, for, in working rapidly, we either get no signal at all, or a line; hence, Morse's alphabet, instead of giving points and lines, is reduced to merely long and short lines. This is enough to show the danger of confusion and mistake.

To give an idea of the delay thus produced, it is only necessary to cite an example: A dispatch, consisting of 58 words, and containing news from India, took more than five hours in passing from Malta to Cagliari.

The causes of this have already been explained by Mr. Faraday, and proceed from the conditions of every cable, which performs the function of a Leyden jar; the copper wire forming the internal armor, the gutta-percha and hemp make the insulation, the iron wire and water serving as the external armor, in communication with the earth. The extreme length of the cable gives it an immense surface, in spite of the fineness of the copper wire, and the interruption of the electric equilibrium which takes place on every passage, or on every discontinuance of the current by the reciprocal influence of the two armors and the insulating substances, occasions the delays as well as the apparent anomalies of which I have spoken in the action of the current on the telegraphic apparatus.

Another phenomenon quite important to notice—for it may perhaps suggest the remedy for the defects inherent in submarine cables—is that the confusion of the signals and the transformation of the points into lines were incomparably more numerous, when the telegraphic apparatus was attached directly to the end of the cable, than since the operation has been performed at stations with the interposition of five kilometres of wire on the land.

If the effects, of which I have stated the simple history, considerably obstruct the service of the Malta and Corfu lines, they also show how far the fears are justified with regard to the mischief they may produce on the far longer Atlantic cable, and the necessity of profiting by the lines already existing for the application of science to the correction of the difficulties.

It is true that Faraday and Whitehouse have made experiments touching the phenomena in question, but these experiments have been made only on cables prepared for immersion and coiled up in storehouses, or on submarine cables by uniting different wires, in order to multiply the length, or by combining them with long extensions of land lines. Now, in each of these cases, the effect took place of an inverse current on the cables or adjacent wires, whence resulted phenomena in the transmission entirely different from those which are manifested with a single current over a single wire of great length. Besides, if we have seen the great effect of the simple connection of five kilometres of land wire on a submarine cable of 600 kilometres, how can we estimate the influence of the land wires of so much greater length employed by the English experiments?

It seems to me that their reasons alone are sufficient to throw great doubt on the certainty of the result obtained by those experiments; but the convincing proof of their insufficiency is derived from a comparison of these results with those presented by the Malta line, although in both cases, the apparatus was the same and similarly arranged. While, in fact, we see an operator of the first order obtain a maximum of 75 signals in a minute, between Cagliari and Malta, on 600 kilometres, in the English experiments of October, 1854, from 210 to 270 signals in a minute (that is 6 or 8 words) were obtained, with currents on a circuit of more than 3,000 kilometres, over the subterranean and submarine wires between London, Dumfries, and Dublin. The rapid increase of difficulties from the Cagliari and Bona line, which is only 260 kilometres, to that of Cagliari and Malta, which is 600, leads to the conclusion that the same difficulties must be much more considerable on a line of 3,000. The reflections which naturally arise from the examination of the facts in the case, show to how great a degree it is necessary to study profoundly these questions of vital importance to the utility of great submarine lines. BONELLI."

The following table contains the proximate velocity of an electric current on subaqueous conductors, based upon reliable experiments, instituted on submarine and subterranean telegraphs.

VELOCITY OF THE ELECTRIC CURRENT ON SUBAQUEOUS CONDUCTORS

No. 16, copper wire. Calculations based upon five pulsations per letter and seven letters per word.

Miles.	Time of Pulsation.		Time per letter.		Time per word.	
	Min.	Sec.	Min.	Sec.	Min.	Sec.
500..............	00	0 $\frac{33}{100}$	00	1 $\frac{66}{100}$	00	11 $\frac{62}{100}$
1000..............	00	1	00	5	00	35
1100..............	00	1 $\frac{24}{100}$	00	6 $\frac{20}{000}$	00	43 $\frac{40}{100}$
1200..............	00	1 $\frac{55}{100}$	00	7 $\frac{75}{100}$	00	54 $\frac{25}{100}$
1300..............	00	1 $\frac{93}{100}$	00	9 $\frac{65}{100}$	1	07 $\frac{55}{100}$
1400..............	00	2 $\frac{42}{100}$	00	12 $\frac{05}{100}$	1	24 $\frac{35}{100}$
1500..............	00	3	00	15	1	45
1600..............	00	3 $\frac{73}{100}$	00	18 $\frac{65}{100}$	2	10 $\frac{55}{100}$
1700..............	00	4 $\frac{65}{100}$	00	23 $\frac{25}{100}$	2	42 $\frac{75}{100}$
1800..............	00	5 $\frac{79}{100}$	00	28 $\frac{95}{100}$	3	22 $\frac{65}{100}$
1900..............	00	7 $\frac{22}{100}$	00	36 $\frac{10}{100}$	4	12 $\frac{70}{100}$
2000..............	00	9	00	45	5	15
2100..............	00	11 $\frac{21}{100}$	00	56 $\frac{05}{100}$	6	52 $\frac{35}{100}$
2200..............	00	13 $\frac{97}{100}$	1	09 $\frac{85}{100}$	8	08 $\frac{95}{100}$
2300..............	00	17 $\frac{40}{100}$	1	27	10	09
2400..............	00	21 $\frac{70}{100}$	1	48 $\frac{50}{100}$	12	39 $\frac{50}{100}$
2500..............	00	27	2	15	15	45