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in the Gramme ring, wound on a wooden core instead of an iron core, and drive it within field magnets, excited to the very same intensity as in an ordinary case, that whereas I should get driving it three thousand turns per minute, instead twenty Amperes, the normal current, I get about six Amperes, and in an opposite direction. Do you comprehend the answer to your question? The current is reversed when I use a wooden core. That is precisely the condition involved in the question of Mr. Keith. For here having no iron present, I have simply the return wire at this point.

Now, speaking directly to the point, I have to say, it is in that case the differential effect between one of these and the other, and if the same set of circumstances exists that differential effect may be presumed to be pro rata to the difference of area—take it all the way round. So that whatever may be said it does not depend upon the correctness, or interfere with the correctness of the distribution of the lines of force, not the slightest. But it does completely mislead the student who supposes that he is going to have a current in the same direction; he will have it in the opposite.

MR. KEITH:—Why?

PROF. BRACKETT:—I rather you would not ask me that question.

MR. SPERRY:—I would like to ask you another question as to the ratio of Amperes.

PROF. BRACKETT:—About twenty in one direction; six in the other. That is twenty-six degrees difference. One is in the opposite direction, twenty Amperes, proving the current is in the other direction.

MR. KELLY:—The negative current does not absorb the power.

PROF. BRACKETT:—It is a very curious result, and a striking one.

MR. KEITH:—Mr. Chairman and gentlemen, this to me is a very curious result. The paper is a very interesting one to me, and I am in hopes of being able to carry out this line of experiments on some machines that I have as yet in my head. And I would also remark that his mode of exploring the external magnetic field is a very good one. This afternoon there will be presented a method of exploring the magnetic field by Mr. Mailloux, using an induction coil and a telephone, and drawing his deduction from the tone or the note which is made in the telephone by the various actions which take place in the external field.

Speaking in my official capacity as Secretary, I hope we will have a good attendance when that paper is read.

A paper read before the American Institute of Electrical Engineers, Philadelphia, October, 1884.

EARTH WIRES; OR, THE EARTH AS AN ELECTRIC CIRCUIT COMPLETER.

BY THOS. D. LOCKWOOD, ELECTRICIAN, AM. BELL TEL. CO.

To earth-dwellers, and especially to that portion of the race who are practically interested in the form of molecular motion, which we call Electricity, there is no element or adjunct of electrical science more important in many respects than the terrestrial ball itself, when we consider it in its relationship to the electrical circuit—whether that circuit be inductive or conductive, we are impelled to the opinion that its consequence cannot be too highly estimated.

When used in the arts of electrical communication, it enables us to reduce one-half of the number of line wires, which would otherwise have to be used; and when we consider the immense number of wires that even now fill our streets and line our highways, we cannot fail to reflect upon what might have been, had we been compelled to provide a separate return wire for each telegraphic and telephonic circuit from 1837 until 1884. For not only does the earth assume the functions of a return wire for a multitudinous number of circuits, but when the line wires exceed a few miles in length, the earth return actually completes the circuit in a way which admits of a much smaller expenditure of electrical energy than would be requisite in a line between two points an equal distance apart, connected by a continuous wire circuit; since the resistance of such an earth completed line should not generally exceed more than half of that of a metallic circuit connecting the same two points.

The first instance on record, where the earth or a portion thereof, in the form of water, was used deliberately, as an electrical conductor, to complete an electrical circuit, dates back to July, 1746, when Winkler, of Leipsic, both charged and discharged a battery of three Leyden jars through an insulated wire, thirty-seven and a half yards long, the wire being laid along the bank of the river Pleisse, the waters of which constituted the return part of the circuit. Winkler ascertained by this experiment that the effects of the discharge were not perceptibly different from those observed when a metal discharging rod was used.

About the same time, Le Monnier, of Paris, made similar experiments, and discharged Leyden jars through the water of a tank in the garden of the Tuileries.

We find from Priestley's "History of Electricity," that in England, shortly after the above experiments, Dr. William Watson carried out a number of others in the same line, under the auspices of the Royal Society Committee. On the 14th and 18th of July, 1747, the first experiments were made, a wire being carried over the river Thames on Westminster bridge, the water of the river serving as a return path for the current. On the 24th of the same month, a similar trial was made in a circuit of two miles, at the New River, near London. Two trials were here made; in one of these the electricity successfully traversed a distance of 800 feet overland, and 2,000 feet by water; and in the other, the circuit comprised 2,800 feet of land and 8,000 feet of water. In August of the same year it was discovered by Watson that dry ground conducted the subtle force quite as well as water. Again, on August 14th, 1747, at Shooters' Hill, a circuit was experimented with, consisting of two miles of wire and two miles of dry ground. In all of the above trials the electricity was effectually conducted by the earth acting practically as a return circuit.

Finally, in 1748 and 1749, these results were verified by Franklin and De Luc. We may note here, by the way, that nearly all of the early proposers or devisers of early electric telegraphs, from Le Sage down to Dyer, had intended to employ the earth as a return.

It is also, however, to be remarked that all of the above instances were experiments with high tension electricity; and that thus, if there had been no examples in which voltaic circuits had been completed through the earth, our fathers might have been excused in waiting for Steinheil. But such examples are not wanting, and the conductibility of the earth with respect to chemically generated electricity was also known for a long time anterior to Steinheil.

In February, in 1803, Aldini sent a current from a battery of eighty silver and zinc plates from one side of Calais harbor to the other through a wire supported on masts, the return being

through 200 feet of water. He also repeated the same experiment at Paris and Alford, using the rivers Seine and Marne.

Basse, of Hameln, in the same year made a series of experiments by which he fully established the fact that the earth could be used as a part of a voltaic circuit.

Erman, of Potsdam, somewhat later, verified these results in the waters of the Hamel; and eight years later (1811) Soemmering and Schilling performed almost identical experiments with a view to establish the feasibility of using the earth as part of any electric circuit.

These are the historical circumstances which form a basis for the present system of earth completed circuits; and we may clearly see, that as early as the beginning of this century, the fact that the substance of the earth in the form either of water or dry ground could be used as part of an electric circuit was well established.

In view of these circumstances, it seems very strange that the earth circuit was not used, or even with one exception proposed, for telegraphs, until used by Steinheil in 1838. It is rather difficult to see why a well settled knowledge of the above circumstances which, if acted upon, would at once have halved the number of wires required, was not utilized until so late, even by Schilling and Soemmering, who were two of the earliest telegraphic inventors, and who both, although instrumental in demonstrating the truth by experiment, failed to apply it to their telegraph system.

As we shall presently see by Steinheil's own writings, his idea, to use the earth as a return, was in a measure forced upon him, being an observation made of the result of an experiment tried for quite another purpose.

*Singularly enough, his discovery was foreshadowed in a letter signed "Corpusculum," dated December 8th, 1837, and published in the Mechanic's Magazine. This letter speaks of the numerous designs for telegraphs, which were then being brought forward, and says that he, too, formed one, and prepared a specification for it, five years ago, including a plan of making one wire only serve for the return circuit for all the rest * * * ; "*but even that,*" he goes on to say, "*might I think be dispensed with, where a good discharging train, as gas or water pipes, at each end of the telegraph could be obtained.*"

* Vide Fahie's History of the Early Telegraphs, p. 345. London, 1884.

The *application* of the earth itself, as a return, and a *common* return circuit for telegraph wires, came about in this way:—

Prof. C. A. Steinheil, of Munich, had in the year 1836—1837 constructed a telegraph line, and devised a most ingenious system of operation for the same. In consequence of a suggestion made by Counsellor Gauss (who in conjunction with Prof. Weber was also a telegraphic inventor of no mean order), that the two rails of a railway might be used as conductors for the electric telegraph, Prof. Steinheil, in 1838, tried the experiment on the railroad between Nurnberg and Fuerth. He was, however, unable to insulate the rails properly, and he found that the electricity passed from one rail to the other through the earth. He then used one rail as the return wire, the direct line being an insulated wire, and found it to work perfectly, for the rail itself acted not only as a return, but also as an earth plate.

Subsequently, he discarded the rail, and substituted earth plates at both ends.

It must not for a moment be supposed that the intent of this paper is to belittle the deservedly great fame of Steinheil. If the experiments, which had gone before, affect him in the least, it is but to enhance his perception; since he first had the wit to apply to a practical use what so many had experimented upon and amused themselves with.

I regard his eminently practical application, as being one of the most important ever made, and it certainly gave the art of electric telegraphy an impetus which nothing else could have done; and has contributed immensely to the development and extension of the telegraphs of the world.

This extremely useful suggestion had two great immediate advantages; it halved at once the number of required wires, and since the earth compared with a long line has no appreciable resistance, it doubled the strength of the telegraphic currents; or in other words enabled an halved electromotive force to produce an equal current strength.

The remarks of Professor Steinheil upon this subject are still so pertinent that I make no apology for quoting them here. He writes:

"Quite recently I have made the discovery that the ground may be employed as one-half of the conducting chain forming the circuit with the line wire. As in the case of frictional electricity, water or the ground may with the voltaic current form a

portion of the connecting wire. Owing to the low conducting power of these bodies compared with metals, it is necessary that at the two places where the metal conductor is in connection with the semi-conductor, the former should present very large surfaces of contact. Taking water, for example, which conducts two million times worse than copper, a surface of water proportional to this must be brought in contact with the copper, to enable the voltaic current to meet with equal resistance in equal distances of water and metal; thus, if the section of a copper wire is 0.5 of a square line, it will require a copper plate of sixty-one square feet surface in order to conduct the voltaic current through the ground as the wire in question would conduct it. But as the thickness of metal is quite immaterial in this case, it will always be within our reach to get the requisite surfaces of contact at no great expense."

When Steinheil made his discovery he, as well as other physicists, thought that the earth actually conveyed the electricity from one plate to the other just as a wire does.

This idea was strengthened by experiments subsequently made by Matteucci and Baumgartner, and it is no doubt approximately correct in the case of very short lines.

Later observations do not seem to confirm the correctness of this hypothesis, and it is thought now by the leading minds which have considered the subject, that the earth performs the part in relation to a voltaic circuit with which it is connected, of an extremely large conductor of almost infinitely large mass, capable of absorbing the electricity as fast as it is developed, and thus maintaining the ends of the conducting line at a potential of zero, and permitting the battery (one pole of which, that connected with the line, is a certain degree either of a higher or lower potential than the earth) to work and maintain a flow of electricity until its materials are exhausted.

The evidence is greatly in favor of the latter hypothesis; and I have no hesitation in adopting it in preference to the view which considers the earth as a real return conductor, bringing the current of every source back again to its starting point.

As Electrical Engineers, however, it concerns us more to know that we can in many cases advantageously substitute an earth connection for a return wire, than to speculate upon the why and wherefore of the fact, except in so far as such speculations aid us in determining the best and most efficient methods and conditions of such substitution. Although the resistance of the earth when used as a circuit completer is very rarely of much importance, it still has a certain value, which rapidly decreases as the length of the wire part of the circuit increases, and it is estimated that it becomes too small to be taken into account when the line is over 75 miles long. If therefore we have a long line we need scarcely regard the absolute resistance of the earth, which is in relation to the line wire infinitely small, and we may say that the resistance of the entire circuit is only half of what it would be were the circuit entirely metallic.

But if the line is very short, the resistance of its conductor is correspondingly small, and the resistance of the earth becomes a more important factor in the case, and we cannot therefore regard it as nil, without introducing an error of greater or less degree.

The late Count Du Moncel made observations which tend to show that the resistance of the earth under very favorable conditions is equal to that of a No. 8 line wire of about seven miles in length. When, therefore, the resistance of the line wire is not over ninety or one hundred ohms, it does not seem advantageous if we desire the best electrical results, to use an earth return. By reason, however, of the increased economy in material involved, we would generally use earth terminals for an ordinary circuit as short as half a mile, unless the two ends of the wire, after the stations were all passed, could be brought conveniently near to one another; especially if satisfactory earth connections could be obtained. The last consideration brings us to another point: In addition to the absolute resistance of the earth itself, there is also more or less resistance between the plates and the earth. Here we may very properly recur to Steinheil's view and regard the earth for a time as a return wire, and the earth plate as a joint or connection between the main and return circuit; and in consequence, as a joint between a good conductor and a bad one. This view shows us the necessity of the utmost care in making earth connections, and may be exemplified by assuming that we have to connect a copper wire to an iron wire of the same conductivity, but of course differing widely in size; the iron wire we may assume is No. 8, has a diameter of 165 mils, and a resistance per mile of about 13 ohms per mile. A copper wire of almost an equal degree of conductivity is No. 16, which has a diameter of 65 mils; the diameter of the iron wire is thus about two and a half times that of the copper wire, and its sectional area

is about six and a half times greater. If now we should bring the ends of the two wires squarely against one another, it is clear that more than five-sixths of the area surface of the iron wire would not be touched at all by the copper, and would not therefore aid in making a good point. The conductive lines of the joint are only equal to a smaller section of the iron wire.

Such a joint is of course very defective, but if the copper were enlarged so as to cover the entire end of the iron wire, the whole section of iron is utilized, and the joint is perfect. Applying this idea to the subject in hand, as described by Steinheil; inasmuch as the relative difference between ordinary iron line wire and the earth is at least one million, we find that the iron should at the junction be expanded to at least one million times its original surface, or the joint will be defective, for in practice the terminal connection of a line with the earth is virtually that of a joint. But if the two ground plates are of sufficient size for each of them to bring a surface a million times greater than that of their iron wire section into contact with the earth, the joints as compared with iron are perfect.

Thus we see that if we do not bring a knowledge of applied electricity and its laws to bear, even in the little matter of terminal grounds, we may introduce considerable unwarrantable and unnecessary resistance into an otherwise good line, and we shall then have a line which can never be worked economically.

The ground terminal of a telegraph may well, on account of its importance to the entire circuit, be regarded as the ground in another sense—the ground work or foundation upon which the entire modern telegraph system rests.

The ground or earth wire, of course, is always used to complete a circuit, but under many and varying conditions.

The earth wire may be used as a terminal for a single line, for a few lines, or for many lines.

It may be employed for a regular testing earth at a station, or for a temporary testing earth between stations in times of circuit trouble. We find, moreover, that the earth wire is also essential as an attachment to the lightning arrester or guard with which we protect our delicate instruments from the attacks of electricity in its most impressive form.

Sometimes also it is found necessary to protect the telegraph poles themselves by lightning rods, so that even the lightning rod itself, long regarded as the exclusive property of the charlatan and the electric quack, in its character of a ground wire, demands the consideration of the electric engineer.

Terminal Earth Wires.

In our large cities, good earth can always be obtained upon water or gas pipes, so that the idea of the Mechanic's Magazine writer, already referred to, is realized. Moreover, in many city buildings, at the present time, earth for many purposes can be obtained on almost any metallic surface to be found in the building, notably the pipes of steam heaters or radiators. It is always best to use a water pipe, if obtainable, because piping is often defective in conductivity at the joint, and in the water pipe the liquid itself aids in conducting the electricity. If gas pipes only are to be obtained, an attempt should be made to connect the wire thereto outside of the meter (this especially, if there be but one meter in the building); as otherwise the removal of the meter severs the connection with the earth entirely. If several series of water or gas pipes or both are at hand, I would make assurance doubly sure by connecting the earth wire with all of them.

In any case, the pipe should first at the point of attachment be filed quite clean and bright. A good earth may then be made by first winding a long stretch of copper wire of small size, say No. 16, smoothly and very tightly round the brightened pipe, until about six or eight inches of the pipe is longitudinally covered. This may be tightened up by passing the last few convolutions through one another, and it should be then well soldered to the pipe, leaving a loose end of about eighteen inches. This end should be spliced by a long and neat joint to a No. 6 or 4 main copper wire, which should previously be wound smoothly round the pipe, some eight or ten turns. The spliced ends may now be laid over the convolutions lengthways, and the whole again soldered. The large copper wire leads through the instruments to the line. This forms a good and reliable earth connection. The trouble with terminal wires is that they are frequently too small.

Earth wire clamps to be screwed to a pipe, and which are furnished with a binding screw for the wire are very good, provided they are made with a sufficient amount of longitudinal surface, which may be brought in contact with the brightened pipe, and fitted with a tight screw which will not work loose.

If a large and long clamp cannot be obtained, a number of small ones may be used, and all should have a movable plate of copper or brass between the ends of the clamping screws and the pipe, so that not the screw ends only, but a good surface under them can make the contact with the pipe.

In many places, especially in the country and in newly settled districts, there are still no pipes, and an earth plate has then to be buried.

Bars or wire ropes are by no means as effectual as earth plates.

These plates ought always to be made of copper, or of zinced or tinned iron.

These materials are recommended not on account of any degree of conductivity which they possess, but because their metallic surface is much longer maintained.

Ordinary iron, rusts through much too quick to be any use.

The plates should never be smaller than three feet by four, and they ought to be about one-eighth of an inch thick.

To make a first-class earth, two large insulated copper wires, say No. 6, should be used to connect with the plates, and holes being made through the plates, the ends of the wires may be threaded through; about four holes for each wire will do. The wires should then be soldered to the plate at each hole.

In setting the plate, the hole should be dug until damp earth is reached, and the plate must be set vertically, so that its upper edge does not come above the level of dampness. All strain should be taken from the wires, and above the surface of the ground they may be soldered together, and then to a single iron wire leading to the office and line.

I hold that all points of an earth wire from the instruments to the earth should be well insulated, so that no electrolytic action can arise, due to leakage, at midway points. When the earth wire is to serve as the terminal of many wires, it should be as large as can be conveniently handled. Telephone exchanges of many wires can readily be operated without any main terminal earth wire, as each wire finds earth by way of all the others. Some offices are so worked. We prefer, however, an earth terminal of the highest character, as it is quite conceivable that half of the lines may be in use at one time, in which case the joint resistance of the remainder may be rather high; certainly much higher than the normal joint resistance.

Testing Earth Wires.

These, when at offices, ought to be as perfect as terminal earth wires, especially at terminal or testing stations.

At way, or intermediate stations, this is not so important, as there the earth wire should only be used in the event of circuit trouble. At the terminal station the earth wire may be constructed in the same way as the method described for the terminal. Such a long splice, if a pipe is used, is however, not absolutely so essential. To insure accuracy of testing operations, the resistance of the testing earth wire should be frequently measured.

At a way station, earth can sometimes be temporarily obtained from the rails of the railway, but the earth plate is the only plan I should recommend for a permanency.

Lightning Arrester Earths.

These should be made of the largest copper wire that can be procured and handled, as they sometimes have to convey very heavy discharges. They are to be connected according to the descriptions already given, except that when located in a cable box, they may be attached to the cable armor instead of to a plate. If possible they should invariably terminate at a different plate from that of the terminal wire.

Pole Lightning Rods.

These are for the protection of poles. They may be led from a point about two feet above the pole, down the side thereof, being secured by staple, and terminate in a plate buried in damp earth at the foot of the pole. Unless, however, good earth is made the pole is safer without any wire. When used, they should have branches running out on the cross arms to within half an inch from each insulator.

Any earth wire can readily be measured for resistance in like manner with any other conductor.

No earth wire and plate should measure more than ten ohms.

In conclusion: If earth wires are employed, they should always be of the same metal, as otherwise they will generate currents themselves by virtue of the difference in potential between the two plates, one of them being electro-positive to the other.

I have long been impressed with the pre-eminent importance of this subject, and while I can scarcely hope that I have done it the justice it deserves, I have tried to make it both practical and interesting, and it may perhaps incite others to give us something better worthy of your attention.

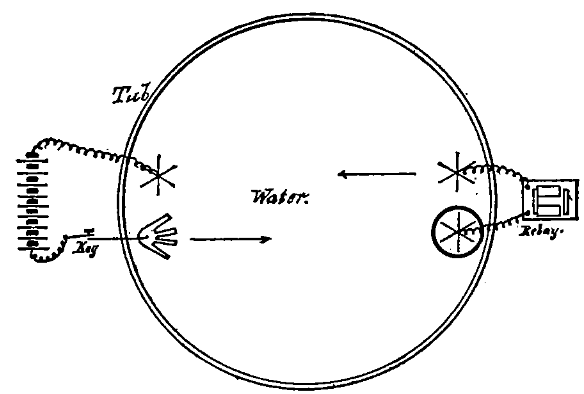
A paper read before the American Institute of Electrical Engineers, at Philadelphia, October, 1884.

TELEGRAPHING WITHOUT WIRES — AN EXPERIMENT.

BY S. J. M. BEAR.

Materials.—A tub of water, ten cells voltaic battery, two copper earth-plates, one zinc earth-plate, and one porous cell, containing a copper plate, immersed in a solution of sulphate of copper, making the fourth ground connection; a relay, or other receiving instrument, of about two hundred ohms resistance, and a transmitting key.

Arrangement of Parts.—All of the battery outside of the tub, with key in circuit, is connected with the water at one part of the tub, and the relay is connected to the water directly opposite. The zinc plate of battery is connected with copper plate in water, and copper plate of battery is in connection with zinc plate in water. These battery terminals in the tub may be quite close together, but must not be in metallic contact with each other. The relay has one terminal in connection with a copper plate in the water, and the other terminal connected with the copper in porous cell in the water; and these two last connections may also be close to each other.



Now, by opening and closing the battery circuit outside the tub, signals may be heard from the relay in response.