SCIENCE

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SOME POSSIBLE MODIFICATIONS IN THE METHODS OF PROTECTING BUILDINGS FROM LIGHTNING. — DISCUSSION.[1]

[Continued from p. 255.]

MR. EDWARD P. THOMPSON: — I have listened with a great deal of interest to the matter presented in the paper just read. The alleged facts seem to agree with our ideas of electricity of low potential. Electricity occurs in thunder-storms, and the best thing to do is to get rid of it. One way is by conducting it away sufficiently rapidly by means of a conductor of very large surface capacity, as the conductivity of a metal as to static electricity depends upon the surface and not upon the sectional area. This principle is applied in the ordinary lightning-rod. As I understand the speaker, he proposes to provide a system whereby the electrical energy is not conducted away, but converted into heat. In view of the conduction principle having so often proved a failure, and the conversion principle having succeeded every time, according to the researches of the speaker, and since his theory agrees with well-known electrical principles, I think Mr. Hodges has presented matter well worthy of the consideration of the institute, and I, for one, can find no objection to his system as to correctness of principle. As to practical equipment, some incombustible non-conductor, such as asbestos, should be placed between the thin metallic strip and the structure to be protected, or else the melted metal may set fire to the building.

Dr. William E. Geyer: — It seems to me that the occurrence quoted here from Franklin tends to show that the ordinary theory of the lightning-rod is essentially true. The bell-wire, so far as it went in the occurrence here described, was a lightning-rod, and protected the building so far as that lightning-rod went. It was not heavy enough to carry the current, and it was for that reason dissipated, so that the dissipation was simply an accident. The mere dissipation, however, did not save that part of the building where the wire stopped and there was no good conductor: the building was without any lightning-rod, and was more damaged than where it had even a small rod.

Mr. Townsend Wolcott: — Professor Lodge's theory of the Leyden-jar discharge is that it is oscillatory under ordinary conditions, that is, where the coatings are connected with a good conductor. Now, if they are connected with a bad conductor, such as a wet string, Professor Lodge says that the discharge may be only in one direction, that is, the energy is all dissipated in a single discharge; whereas, if the conductor is good, there is little energy dissipated in getting from one coating to another. So far, Mr. Hodges' theory would seem to agree with Professor Lodge's, that if you can use up the energy of the electricity in destroying the conductor you will get rid of it more quickly than you would in any other way, and the lightning will have less effect outside of that. But there are some other points. Mr. Hodges says we do not attempt to make a good connection at the top with the dielectric. I do not exactly understand that. We do attempt to give it good connection with a conductor. If a cloud is charged, that is a charged conductor, and so long as the current is to come down to the earth, we try to get as good connection with it as we can, by putting points on the lightning-rod, for instance. A better way to do that would be to have a flame or something of that sort. As an experiment in drawing electricity from the air, a flame is better than a point. But, of course, it would not work in a thunder-storm.

As to the point which Dr. Geyer just mentioned, that Mr. Hodges' experiments support the ordinary theory of the lightning-rod, I think his reasoning does, to some extent, too, in regard to getting rid of the energy on the central core. Take the ordinary lightning-rod. The way it is intended to work is rather to prevent a disruptive discharge than it is to take care of one that has already occurred. We desire to equalize the difference of potential by drawing off the charge from the cloud before it gets to a dangerous limit. If we can do that, we do not have any disruptive discharge at all. It is just like a brush discharge, such as you get from a conductor with points on an electric machine. I think the fact is not questioned that lightning sometimes is discharged in that way, but not always. There is the trouble. I do not think that any one system of lightning-rods has proved successful. Sometimes a lightning-rod will take care of several discharges in a single storm, and that seems to be something which Mr. Hodges' lightning-rod would not do; because, after it had been dissipated by one discharge, I do not think, even if it could be put up in a few moments, that anybody would care to be monkeying around a conductor when there was lightning. Mr. Hodges, having asked us to clear our minds of the idea of conducting electricity, seems to go further than most of the modern theorists on electricity. I think Mr. Hodges, even if he does not use the idea of electricity, will admit that we want to make a metallic way entirely down to the earth. The case is somewhat analogous to the Leyden jar; that is, two conductors separated by a dielectric. Now, we want to bridge over the whole space of the dielectric, whether you use the idea of conductivity or not. So I don't think it makes much difference whether you use his dissipatable lightning-rod or a stout one.

Mr. Hodges: — I would like to bring the discussion back once more. In order to make the paper of some length, I gave some theory; but the fact as I have found it is this: I know how the books state that the ship "Jupiter" was saved from destruction in spite of her lightning-rod going to pieces. But take the fact without going to the books at all. What do the records show? I want to get a case where the conductor has gone to pieces, and where the ship has not been saved. I have not found such a case. Suppose the conductor is dissipated between two points [illustrating]. I found this to be true in every single case of a church-tower being struck where the wire runs from the bells to the clock. The wire goes, and the church-tower is saved between those two planes. Now, that is a matter of record. The ship "Jupiter" had a chain conductor, and it was dissipated; and the

[1] A paper, by N. D. C. Hodges, read at the fifty-sixth meeting of the American Institute of Electrical Engineers, New York, April 21.

books say that the ship was saved in spite of the conductor being dissipated. But that is a man's opinion. What I want to urge on the institute is simply this: that in every single case when a conductor goes to pieces every thing else is saved. Why and wherefore, I do not care. I gave some theoretical reasoning which seems to me more or less correct, but it is unimportant. I want to bring the discussion back to simply this matter of fact: Can you cite a case where the conductor has gone to pieces, and there has been any destruction to the building between practically two horizontal planes passing through the upper and lower ends of that dissipated conductor? You will find that there is damage above and damage below, very likely. But as I went on through the "Philosophical Transactions" I found one case there of a thunder-storm passing over a village (it was a century ago, or more), and the people were dependent on the church-clock for the time. In the morning they did not hear the clock strike. They went up in the church-tower to see what the matter was, and found the windows smashed just above the bell; found the wires running from the bell to the clock were gone, and that was all the damage done. To show how small a conductor, when dissipated, will save a house, I will cite the case of a palace in France in the early part of the century. The interior was heavily gilded. The people were sitting around on gilded sofas resting against the walls, — resting against thin gilded strips. A Fellow of the Royal Society visited the palace the day after it was struck by lightning, and looked over the ground. No one was killed. No damage was done to that palace as far as the gilding extended; that is, in the gilded rooms no damage was done except that the gilding disappeared: it was dissipated. When they got to the lower portions of the palace, where there was no gilding, things were smashed. But, as I say, I started out in this thing with an hypothesis which was to a certain extent wrong. I looked into the records to see what was recorded, not as a matter of opinion, but to find out what actually happened. And what actually happened was, so far as I was able to judge, that there was no case where a dissipated conductor failed to protect a building under these limitations which I state. Of course, above or below, damage did occur.

A Member: — From a practical standpoint, would you kindly tell us where you put that conductor on a house, and would you put more than one strip on a building?

Mr. Hodges: — Along the ridge-pole, down the eaves, down to the ground. I should avoid, at the lower end, making connection with any large masses of metal. The number of strips placed on a building would depend on the size.

I got a patent on this thing last year. I told a friend of mine that I was interested in the protection of buildings from lightning, and, a patent not being issued, I could not tell him much about it. The next day he met me and said, "Did you read in the *Post* the account of the lightning-storm in Jersey yesterday?" I said, "No." He said, "There was one case where a house was struck by lightning in Jersey and the rod was smashed, but the house was uninjured." I noted it down as another case. A man who was in my employ some years ago came to my office. I described this thing to him, and he said, "I have been there." He said when he was a boy he had a telegraph line running from his house to a neighbor's house. It was made of piano wire, and the lightning struck the roof somewhere there [illustrating], then followed along the metallic gutter to a point here. This piano wire ran down to the ground, and ran over here to the neighbor's house. At this point a little damage was done to it. The discharge followed along the conductor without doing any material damage, and there was no other damage to the house except that the wire was gone.

Mr. Wolcott: — Although I do not question that conductors work that way, we also find that they work the other way, according to the old theory, in very many instances. It certainly is a matter of record that conductors have sometimes carried off several discharges in the same thunderstorm, which a dissipatable conductor could not do unless you were able to put up a second one in the place immediately after the dissipation of the first.

A Member: — The Washington Monument is a pretty good lightning arrester. I was shown, a few weeks ago, by Professor Owens, where lightning had struck and knocked out big chunks of stone from the monument. He seemed to think that lightning followed the path of least electrical resistance, so he put up an additional wire and connected that with the new iron work of the monument, and he says he has not had any trouble since then with stones being knocked out.

Mr. E. P. Thompson: — I have not heard of any experiments being performed upon Mr. Hodges' proposed system. It may seem, perhaps, impossible to perform experiments with lightning in a laboratory, because of the inconvenience of waiting for a thunder-storm; but it can be done with the induction system, and possibly, therefore, some way may be thought of for testing Mr. Hodges' invention. About three years ago I tried some experiments in connection with a client, a well-known lightning-rod manufacturer, Capt. Hubbell, who has equipped government magazines. His new system was tried with considerable elaborateness in the Equitable Building during its repair, for the consideration of the Standard Oil Company, who met with great losses of oil-tanks, caused by lightning. An immense Leyden battery was charged with an electrical friction machine, and artificial lightning was thus generated. Small oil-tanks containing alcohol — more easily lighted by the spark than petroleum — were equipped, and by discharging the battery it was easily determined how many times out of a hundred the Captain's system was successful. Some experiment with Mr. Hodges' system would soon settle the question of effectiveness.

Mr. Charles Steinmetz: — To one point more I wish to draw attention. By using such an interrupted conductor of small cross-section, that is of comparatively high resistance, you are liable to change the whole nature of the lightning discharge. You change it from an oscillating discharge to a steady and continuous rush of current, from which you must expect quite different effects.

When, for instance, you discharge a condenser by a conductor of very low resistance, you get an oscillating discharge of an extraordinary high frequency. If you increase the resistance of the conductor, the number of oscillations of the discharge decreases, it runs down quicker, until at last you reach a value of resistance where only one wave of discharge current appears, that is, the discharge of the condenser becomes steady. Now, if we can make a lightning discharge steady, instead of oscillating, then we have first to expect that the electricity traverses the lightning-rod only once, slowly increasing in current strength and then decreasing again by going down to the ground; while in an oscillating discharge the current will rush to and fro through the conductor until its energy is consumed by the resistance of the lightning-rod, or by electro-magnetic radiation and re-radiation from the induced currents produced by the oscillating discharge in neighboring conductors.

This, perhaps, may account for some of those phenomena mentioned to-night: that, when the lightning-rod is dissipated, that is when its resistance was very high in comparison with the quantity of electricity rushing through, there was a steady discharge and no harm was done; while, when it is an oscillating discharge, the slightest irregularity will cause the discharge to "jump the track," that is, to leave the lightning-rod, which is obstructed by the counter electro-motive force of self-induction, and to spark over to metal masses of larger condenser capacity: for what I consider as the most dangerous part of lightning discharges is not the enormous voltage of the discharge, nor the strong current rushing through the lightning-rod, but the electromagnetic field of force, which alternates with enormous frequency and reaches far out into space from the real path or centre of disruptive discharge, and thereby must cause inductive effects everywhere, which, as before said, cause not only the main discharge to spark over, but produce true secondary or induced lightning discharges. Hence I must be very much in favor of every arrangement which is able to change the oscillating discharge into a steady rush of current.

The resistance of the lightning-rod I consider as of subordinate importance only, except so far as carrying capacity is concerned: for of what use is a resistance as low as a few ohms, when the self-induction of the lightning-rod causes a spurious resistance of perhaps hundreds of thousands of ohms?

Mr. Hodges: — I would bring this discussion back once more to this matter of fact that I am interested in. The theory I do not care so much about. It may be interesting as mental gymnastics. I came here feeling quite sure that somebody would stand up and say, "I know a church or a house in this town or that town where the conductor was dissipated and yet damage was done on the same level." I have not found a case.

Dr. Geyer: — In a disruptive discharge, the length of the lightning-rod, it seems to me, is a very small part of the total path. I should imagine that any resistance the conductor would have would be such a small part of the total that it would not have much effect on the character of the discharge.

Mr. Steinmetz: — I believe I have been misunderstood in what I meant by the influence of the resistance upon the nature of the discharge. Indeed, the whole resistance of the lightning-circuit is so large that under any circumstances the resistance of the lightning-rod is imperceptibly small. But, as explained in my former remark, it is not the resistance proper, but the consumption of energy by the resistance, which causes the amplitude of the oscillating discharge to decrease slower or quicker until, for a very rapid consumption of energy by resistance, only one wave appears that is a steady or continuous current. This phenomenon is similar to a pendulum oscillating in a liquid: the greater the frictional resistance of the liquid, the quicker the amplitude of the pendulum motion decreases, until, at last, in a very tough liquid, the pendulum comes to rest without any oscillation at all — periodically. In such a way the resistance of the conductor, by consuming the energy of the electric discharge, could change the discharge from an oscillating to a continuous one, although the whole "resistance" has still about the same value, "infinite," if we were allowed to speak with the usual meaning of "resistance" of disruptive discharges, which we are not.

Mr. Birdsall: — I think Mr. Hodges has given us the most original idea on this lightning-rod question that has been put forward for some time. I also think that Mr. Steinmetz has hit the nail on the head in his explanation of it. It only shows us again what we do not know about the various phases of alternating currents. His theory also gives me a little uneasiness, because I have advised a number of friends who have built houses in the country to put in a metal lath, as I thought that, having plenty of metal around, if the house happened to be struck, it would go to the ground through this metal lath. Now, if any of those houses are struck, and that metal lath turns into gas, I think I shall emigrate.

Mr. Hodges: — That metal lath reminds me, — I wrote to Edward Atkinson about this. You know he is president of about the only insurance company in the country that cares about stopping fires; that is, reducing the amount of damage done. He wrote back that they had experience with lightning-rods, and that their experience was such that they had abolished them on all factories that were insured by the Manufacturers' Mutual Fire Insurance Company. Now, in the mills there is a considerable surface of metal; and they find, as is natural, that the discharge spreads itself probably over the surface of this metal. At any rate, the potential was so reduced as to very materially mitigate the effects. As Mr. Atkinson puts it, it spreads out over the surface of the machinery, so that no great damage is done. But they have taken off their old rods.

Mr. Wolcott: — There is one question I would like to ask in regard to that drawing on the board. If you do not say that no damage was done to the end of the building, in spite of the fact that the conductor was dissipated, why don't you have to say that no damage was done along the eaves, in spite of the fact that the conductor was not dissipated?

Mr. Hodges: — That is a fair question. A dissipated conductor may run horizontally any reasonable distance, and then run down; and when it goes to pieces the thing is saved. But when the conductor is not dissipated, there are any number of cases where the building is not saved.

Mr. Wolcott: — I can understand it, that a dissipating conductor would very often save the building, but, according to the accounts that have been cited, it does not seem to make any difference how little there is of that metal. There must be some limit. When it gets down where a little bit of gold-leaf is going to save a building, it looks rather improbable. If a little bit of metal being dissipated would save a building from a lightning discharge, then an ordinary lightning discharge would not be sufficient to dissipate some of these larger conductors which are dissipated.

Mr. Hodges: — I do not pretend to understand any thing about it. I have theorized upon it, but that is not important. It is only the fact, and the fact stands there until somebody gets up and shows a specific case where it does not work.

Mr. Birdsall: — I do not think that Mr. Wolcott can hold that argument, because he has not any data on the comparative energies of these various discharges of which we have record. We have a record of the damage done in the dissipation of the conductor, but we have no record of the foot-pounds of energy in the discharge.

Now, the discharge that burnt up the gold-leaf on the wall might have been a great deal smaller than some of the discharges which burned up the larger conductors. Then another point has been raised about the replacing of the conductor immediately after it was dissipated. This will never be necessary, it seems to me, for it is a recorded or alleged fact that lightning never strikes twice in the same place. They say that in naval combats the safest place to put your head is through the hole that the cannon-ball has just come through; and if it did strike more than once the rods could be arranged on the principle of the multiple fuse, and a new one plugged in as fast as they dissipated.

Mr. Wolcott: — Mr. Birdsall has been facetious on this point, and I will try to be so, too. I have heard it stated that one reason why lightning does not strike in the same place twice is that the place is generally gone when the lightning has struck once. I certainly have read of several cases where the conductor has conducted several discharges to earth in the same storm. Now, with regard to gold-leaf discharge. That this charge was smaller, of course, may be true. But the fact that the discharge in each of these cases is just about suited to the size of the conductors would seem to show that there was some coincidence about the matter. If a dissipated conductor always stops the damage, or very nearly always, there is something more than coincidence about it. It seems to me that such an instance as that could not be more than a mere coincidence — that a discharge which was capable of doing considerable damage to the building where the conductor was not dissipated, should be all used up by dissipating a very small amount of metal, is not probable.

The President: — I will call the attention of the Institute to the fact that our usual time of adjournment has very long passed.

Mr. Hodges: — Ships have been struck a number of times in the same storm. If you can cite specific cases against me, all right. I have found, so far as I know, that a dissipatable conductor protects. Why, is another question that does not concern us. Why that gold-leaf protected we do not care. It did protect. There is no arguing against its being reasonable, that will set aside the fact. I thought over the matter, and have some theoretical considerations to show why it does protect, but those are not essential.

This is all I want to give at the present time. But I believe there is one other way of furnishing protection against lightning which has been ignored for a number of years. The facts have been staring us in the face. I think about the same time that Harris introduced his system of lightning-rods there was a modification made in the rigging of ships which has tended to mitigate the disastrous effects of lightning. The facts were well known long before Harris came into existence; but they were so thoroughly out of tune with all the science of that day that they were simply ignored; so that, in fact, in the report of the lightning-rod conference, there is only the title of one paper bearing on the subject. To find that paper I hunted through the Astor Library, and put one of their expert searchers to work there; and it was evidently considered of so little importance, that it had not been copied in any periodical. By going back further and further in the "Philosophical Transactions," I found the same facts reported of a most positive character, and I think they have a bearing on this apparent immunity of ships when they are supplied with good conductors. I am inclined to think that it is not the Harris conductor that has been doing good service entirely, but it is something else. But all that I would have said this evening, if it had not been necessary to present a paper of some length, was that a dissipatable conductor protects.

Mr. James Hamblet: — I understand the gentleman to say that a dissipatable conductor protects. I have in mind a very large building situated at the top of a hill, in a very exposed position. That building is constructed with a metal roof, entirely over the building, but having no lightning-rods. It has large iron pipes, six inches in diameter, to conduct water through the building down to the ground. That building has never been injured by lightning at all, but frequently trees around it on the hill have been destroyed by lightning. The lightning conductors of the building, which are these same iron pipes I have mentioned, have not been dissipated.

THE BROOKLYN INSTITUTE BIOLOGICAL LABORATORY.

THE location of this biological laboratory, at the head of Cold Spring harbor, Long Island, is one of the most favorable on the coast. The country around affords excellent hunting ground for every form of animal and vegetable life common to the climate. Just above the laboratory is a series of three fresh-water ponds, each fertile in its own peculiar forms of fresh-water life, and through which flows the water of Cold Spring Creek. Just below the laboratory is the harbor of Cold Spring, divided by a sandy neck into an inner and an outer basin. The inner basin is particularly rich in marine life, and the channel between the inner and outer basins has a varied and vigorous growth of algæ, mollusks, and echinoderms. The outer basin has rocky projections, shallow flats, banks and eel grass, sheltered pools, oyster-beds, and other conditions favorable for collection and study. The outer basin opens into Long Island Sound, whose coast is varied in character for twenty miles in either direction.

The main laboratory occupies the first floor of the New York State Fish Commission building, and is a room thirty-six feet wide and sixty-five feet long, provided with ample light from every side. It is furnished with laboratory tables, aquaria, hatching-troughs, glassware, and all the apparatus and appliances required for general biological work. Into the laboratory is conveyed a bountiful supply of the water of the Cold Springs for use in the aquaria and troughs. This water is as pure as a crystal, has the same low temperature throughout the year, and is the water used so successfully by the New York State Fish Commission in hatching and growing salmon, trout, and other food fishes. The laboratory is also supplied with an abundance of salt water, which is pumped up from the harbor into a brick reservoir, from which it runs to the laboratory.

The station is provided with three small row-boats and a naphtha launch, together with nets, trawls, and dredges, for use in collecting and dredging. Near the main laboratory is a photographic room, with a dark room and work room adjoining. Each student is provided with dissecting instruments, chemicals, and glassware, to be used in the dissection, preparation, and study of tissues. Microscopes will be provided for those students who cannot provide themselves with instruments.

The following general course is open to each student, and is under the direction of Professor Conn. It will consist primarily of laboratory study of specimens illustrating the types of animal life. The practical work will be accompanied by lectures giving an outline of systematic zoölogy, for the purpose of showing the relations of the forms studied to other animals. The lectures will also touch upon various matters of general biological interest. The types studied in course will be as follows: *Protozoa*, — study of microscopic forms, including directions in the use of the microscope; 1. *Cœlenterata*, — hydroids, including the study of jelly fishes and the development of hydroids; 2. *Echinodermata*, — the star-fish; 3. *Bryozoa*, — study of an adult Bryozoan; 4. *Mollusca*, — the clam, the snail, development of the oyster or some other type; 5. *Crustacea*, — the crab, with a study of its development; 6. *Insecta*, — the grasshopper; 7. *Vertebrata*, — dissection of the fish, dissection of the frog.

Accompanying this course of laboratory work and lectures will be given instruction in methods of mounting objects and in the preparation of microscopic sections. Opportunity will also be given for collecting and surface skimming.

A special feature of the laboratory this season will be an extended course in the methods of bacteriological research. The