LIGHTNING AND LIGHTNING-RODS.

As we stood before the rich carvings, the bas-relief, and mediæval tracery of an old cathedral in a European city, our eyes wandered upward, beyond the gargoyles, beyond the fretwork, and finally rested, before endeavoring to penetrate the mysteries of a rich cloud-form, upon a little, pointed iron rod. Within the walls of the cathedral, during the grand anthems, our eyes rested upon a chandelier which hung from a great height by a slender rod. It swung with a slow, scarcely perceptible motion, as it did in the time of Galileo. One could see that it moved, by fixing the eye upon a stained-glass image of a saint behind one of its pendants. At regular intervals this passed with a certain measure of impudence over one eye of the grim saint, and then returned from its excursion. "Science, at least, is true," we said to our companion with a sigh of relief as we emerged from the ancient pile. "Yes, but science too has its superstitions," he remarked, pointing upward to the lightning-rod.

Notwithstanding the respect that every native American feels for the name of Benjamin Franklin, there is, we are sorry to say, a wide-spread distrust of lightning-rods; we heard of a man lately who, after having put them upon his buildings, was asked why he did not gild the ends of the rods; he replied that he did not wish to offer any additional inducements. The writer has received letters from remote sections containing honest acknowledgments of a fear of thunder and a respect for lightning, together with plans of houses and barns which bristled all over with lightning-rods; and inquiring as to the probable safety of the inmates. Men often protect their buildings out of a respect to insurance companies, and shudder every time a storm-cloud breaks over their heads.

The ordinary thunder-storm needs no description. Its lightning can be divided into three classes. The first embraces those discharges which consist of long, straight or zigzag lines of brilliant white light. This phenomenon can be imitated by a Holtz electrical machine provided with powerful condensers. Upon exciting the machine a brilliant spark passes from one of its knobs to the other, which is connected with the ground. In its general character the spark closely resembles the crinkled lightning which is embraced under the first class. The same phenomenon can be produced by exciting a powerful induction-coil, in the circuit of which large Leyden jars are interposed. Upon bringing the terminals of the coil near to each other we have the zigzag line of light and the crackle which characterize lightning of the first class. The second class comprises those flashes which are ordinarily termed sheet-lightning. They light up the overshadowed bosoms of cumuli, showing their pearly folds and chaste recesses. They flash generally from the edges of clouds, not in a line, but with a diffuse glare which is often of a gorgeous hue. Our imitations of this kind of lightning are often hypothetical. If a large exhausted receiver contains the two terminals of an induction-coil, separated from each other by a convenient interval, and the induction-coil is excited, the rarefied space will be filled with a roseate flush of light which strongly reminds us of a certain phase of sheet-lightning. The experiment may be repeated with a tube which is partially filled with a salt of calcium. The beautiful light which manifests itself recalls many memories of actual lightning. The third class of lightning includes those masses of light which Arago classifies under the head of globular lightning. The appearance is like that of a ball of fire, or a meteor.

It is easy to convince ourselves by experiment that lightning chooses the shortest path. If we take a glass plate provided with strips of tin-foil separated from each other by intervals of glass, forming two rows, one of which is longer than the other, and after carefully drying it to dispel any moisture which may cling to it, coat it with a fine film of lycopodium powder, which is composed of the spores of a species of moss, and send a discharge through the tinfoil, the dust is scattered along the shortest line between the strips of tin-foil, forming a curious striated discharge. A bit of cotton saturated with ether and placed near the line of discharge, only a little out of the actual path, remains unignited. Placed in the path of the spark it is instantly ignited.

On several occasions the length of forked-lightning has been measured by noting the probable value of the angle which it subtended. Many discharges were thus found to exceed a mile in length. By exciting a Holtz machine to its full capacity, a brilliant spark nearly a foot in length passes through the air between the conductors of the machine. Imagine a similar spark, or bolt, a mile long, with an enormously greater diameter, and you can form some conception of the terrible character of a powerful lightning discharge. The duration of the forked and sheet lightning is, to all intents and purposes, instantaneous. The swiftest express train, illuminated by a flash of lightning, seems to be silently standing on the track. A cannon-ball would appear to be held aloft in mid-air for about one eighth of a second. The wind-tossed trees would seem to be silently bent over before the coming storm, as if transfixed in a mood of resignation. A circular disk of large size, painted with broad bands of color which run from the centre to the circumference in sectors, appears of a uniform gray tint when rapidly turned. When it is placed so that it can be illumined by the discharges of an electrical machine it seems to stand still, and all its colors are visible. The character of the lightning-flash has been made the subject of an extended study by Professor Rood, of Columbia College, who concludes that "the nature of the lightning discharge is more complicated than has generally been supposed; it is usually, if not always, multiple in character, and the duration of the isolated constituents varies very much, ranging from intervals of time shorter than $\frac{1}{1000}$ of a second up to others at least as great as $\frac{1}{20}$ of a second." Professor Rood also favors the hypothesis that zigzag, heat, and sheet lightning are identical, being due to the same cause, but apparently differing because seen under different circumstances.

The spectroscope has been directed to the light of the different discharges of atmospheric electricity, and the result has been the determination of certain bright lines in the spectrum which belong to oxygen, hydrogen, and nitrogen. Vogel identified a number of lines in flashes of lightning which are observed in the electric spark of the common atmosphere. It was found that sometimes the spectra consisted of bright lines on a dark ground, while at other times the bright lines were traced on a less bright continuous spectrum. Sometimes a bright continuous spectrum destitute of lines was obtained. Wullner has shown that instantaneous sparks in rarefied air give a spectrum consisting of lines, while the prolonged constituent of the spark of an induction-coil often produces a banded spectrum. Spectrum analysis merely shows a close relationship between the lightning discharges and those of the electrical machine. By its analysis of lightning it throws some light upon vexed questions as to the complex distribution of layers of rarefied and non-rarefied air in the atmosphere. It endeavors to show a relationship between the shifting gleams of the northern lights and electrical discharges through rarefied media, but the relationship is yet hypothetical. There is great difficulty in observing the spectrum of lightning. After waiting in suspense for a time, one sees a number of bright lines flash out in the field of the spectroscope; they vanish before their position can be observed, and we are in doubt whether our senses have not multiplied their actual number.

Although we can closely imitate certain forms of lightning, we cannot do the same with respect to its accompaniment, thunder. There are many theories to account for the latter, but none of them are perfectly satisfactory. Is the crackle which accompanies the electrical discharges from a machine analogous or identical with the thunder-clap? It seems highly improbable. If a large battery of Leyden jars, affording a very great surface upon which the electrical charge can accumulate, is connected with a Holtz machine, and after many turns of the electrical machine we discharge the jars, one hears a report almost as loud as that of a pistol. Some of us have heard thunder-claps which closely resembled the noise of this discharge. "It is supposed that the explosion opens for itself a passage through the air like a projectile, and that the air rushes into the vacuum thus produced, causing a loud vibration." The passage of a shot through the air, however, is not accompanied by a similar noise. When lightning strikes near us we hear a sharp crackle and then a rising and falling sound of thunder. On the other hand, a discharge at a distance is almost inaudible at first; the thunder augments in intensity, and finally rolls over us, making the objects upon our tables vibrate, and then sullenly dies away. Some have endeavored to account for thunder by supposing that the vibrations producing the sound arise from different centres, which are formed by the forked nature of the discharge, and that these waves of sound reinforce each other or interfere with each other, thus producing variations in the sound which we term thunder. The echoes produced by the various depressions and elevations of the earth's surface also, doubtless, contribute to the peculiarities of peals of thunder. The atmosphere itself may reflect the sound-waves, producing aerial echoes, so to speak. Some explain thunder by supposing that a decomposition and recomposition of the constituents of the charge takes place in different media. There are no observations which lead us to believe that thunder has ever been heard more than fourteen miles from the point of discharge.

Thunder-clouds are ordinary clouds charged with a large amount of electricity. As they float over the surface of the earth, they attract electricity of the opposite nature to that with which they are already charged, and they repel electricity of the same nature. This inductive action is manifested upon all objects on the earth's surface, but to a different degree with each object. For instance, a tree standing in sandy soil will be much less influenced than one whose roots extend down through moist earth and afford a connection with subterranean water-sheets. We generally think of the earth as a common reservoir of electricity. Thus in experiments with the electrical machine we connect one of its conductors with the ground whenever we wish to isolate the electricity of an opposite nature upon the other conductor. With even the most powerful electrical machine we find no practical differences in the power which different poorly conducting bodies possess to lead electricity to the ground. The phenomena of induction on the terminations of poorly conducting bodies connected with the earth show no marked differences in intensity. In the electricity of the clouds, however, we have an immeasurably greater electric state than we can obtain by artificial means. We must disregard the layer of rock and of dry, sandy soil, and look for great inductive effect only in good conductors, such as large bodies of water, or in projecting parts of the earth's surface which are in immediate connection with subterranean moisture. We can therefore regard the charged clouds and the earth, with the layer of air between, as a Leyden jar. The earth's surface forms one coating, the clouds the other; and instead of glass we have the air as a dielectric between. The discharge of lightning is produced by the tension of the electricity in the clouds becoming so great as to enable a disruptive discharge to take place through the intervening layer of air. The same phenomenon takes place often in our Leyden jars. When the charge upon the tin-foil becomes too great, it often shatters the glass in passing from one coating to the other. In ordinary language we speak of the charge upon the interior of the jar uniting with the opposite charge on the outside coating. This inductive action of electricity is a very curious one, and is apt to be confusing to those who have not become familiar with the subject. The presence of a positive electrical charge upon a ball suspended from the ceiling of a room is sufficient to attract to the nearest surface of all bodies in its neighborhood a negative charge, and to repel to the surface most removed a positive charge. Any change in the amount of the charge upon the ball is followed by fluctuations in the induced charges upon neighboring bodies. Its most delicate pulsation, so to speak, is accompanied by a responsive throb in every object about it. This inductive action can be shown in various ways. Sir William Thomson's water-dropper forms a remarkably sensitive arrangement. This is a tin vessel which is mounted on a glass support, and carefully insulated from the ground. It is provided with a long, horizontal glass tube, which is drawn out to a fine point at its extremity. The vessel is filled with water, which can issue in a fine stream from the end of the glass tube, and break into fine drops a short distance below the orifice. These drops fall upon an insulated metallic plate, which is connected with a very delicate instrument for detecting electrical changes, — also invented by Sir William Thomson, — which is called an electrometer. The movement of a bright spot of light over a distant scale shows the nature of an electrical disturbance. If it moves to the right it will denote that positive electricity has been induced, and if it moves to the left, negative. If one now approaches the falling stream of water, and the metallic plate upon which it strikes, with an insulated plate containing a charge of electricity, the spot of light will move quickly to the right or left. Every time that a spark passes between the conductors of a neighboring electrical machine, a pulsation in the metallic plate upon which the stream of water falls is shown by a quick movement of the spot of light. In a thunder-storm the same phenomena can be observed. I have often stood watching this spot of light on a sultry day in June. Sometimes it does not move from its position of rest for hours. Then it will vibrate as if the support of the instrument had been jarred. After such movements one hears a low, sullen rumbling of thunder, and on looking into the west one perceives a thunder-cloud rolling up. The movements of the spot of light were caused by the inductive effect of the discharges of lightning yet many miles away. We resume our position, and watch the indication on the wall with greater attention. Every few moments the spot of light jumps responsive to a distant discharge of lightning, just as it does every time that a spark passes between the conductors of a neighboring electrical machine. Some time after such pulsations we hear the thunder. Presently the room grows darker. The trees outside wave tumultuously from side to side. Heavy drops of rain strike the tinned roof, and a gray sheet of rain shuts out the landscape. Vivid flashes of lightning dart hither and thither, and the spot of light moves responsively to them. We can thus realize the inductive nature of the electricity of thunder-clouds. When they pass over the landscape they induce an electrical charge on all projecting points. Mr. Marvine, who is connected with government geological surveys, told the writer of a remarkable electrical disturbance which he witnessed in Colorado. The jagged peaks among which his party was at work, with levels and theodolites, were repeatedly struck by lightning, and each time the discharge occurred, painful shocks were felt even at some distance from the points of rock which were apparently struck. The observers were conscious of being highly electrified. Whenever they touched their instruments they experienced painful sensations. Their work was seriously interfered with. Often they were obliged to retreat to some covert and leave their instruments until a more favorable opportunity occurred. There were certain areas where thunder-storms seemed to be the normal phenomena. They were rarely absent. Every prominence and *aiguille* of rock seemed to be in a state of discharge, and when, by reason of some great local accumulation, a lightning-flash occurred, the phenomenon of the return or back-stroke was the unfailing accompaniment; and a rapid alternation of charge and discharge ensued, in order to establish electrical equilibrium. This was an example of induction on a grand scale. When such mountain-peaks are covered with ice and snow, as among the Alps, the electricity induced by the clouds beneath the poorly conducting layer of snow tends to accumulate on projecting points of rock. On Alpine summits, in thick snow-storms, the adventurous climber sees discharges of lightning around him, and sometimes witnesses the shattering of some isolated aiguille. The following extract is from an article by M. Charles Martins, in the Revue des Deux Mondes, March 15, 1865, entitled Ascensions on Mont Blanc: —

"At half-past six we arrived on the Grand Plateau; the tent was standing, the instruments were intact, but we had hardly examined them before the snow began to fall as upon our first ascent. The wind freshened from the southwest. The thunder rumbled, and a violent storm burst upon the Grand Plateau. We constructed, in haste, a lightning-rod out of an Alpenstock, to which we fixed a metallic chain. The stick was erected near the tent, and the chain buried in the snow. The precaution was not useless, for the sound of the thunder almost immediately followed the lightning-flash. From the very short interval which separated them, we judged that the lightning struck some neighboring summit about a kilometre distant. To our great astonishment the thunder did not roll, but resembled the sharp crackle of the detonation of a fire-arm."

Before an electrical discharge, a dissipation of the charge accumulated on two neighboring points takes place. The most striking manifestation of this is in the brush-discharge. Those who are near an electrical machine in a dark room can see this beautiful phenomenon. Interweaving rays of pale light terminate a straight line of a delicate pink or rose color, accompanied with a hissing noise. By placing inside a receiver a ball which is connected with one of the conductors of an electrical machine, we can rarefy the air about this ball; and on bringing the other conductor of the machine to the neighborhood of the outside of the receiver, one will notice that the receiver is filled with a roseate flush of light. This silent discharge always accompanies great accumulations of electricity. Indeed, it is possible, by surrounding the conductors of electrical machines with points, to dissipate the charge upon them, so that a greatly lessened discharge takes place between the knobs of the machine. This glow has scarcely any heating effect. If some gunpowder is interposed in the receiver, so that it may be enveloped by the glow, it is not ignited. The silent discharge is seen about conductors over which intense streams of electricity are passing. From the facts collected by Sir William Snow Harris in regard to the manner in which ships have been struck by lightning, "it is found that the electrical state of the air is frequently such as to convey the idea of the ship being wrapped in a blaze of electrical fire; and that the discharge is often attended by a whizzing noise." In Rogier's Journal, a flash of lightning is said to have struck the conductor of a powder-magazine in Silesia. "It appeared to envelop the whole building in electrical fire."

The return stroke is a mystery to people in general. After the clouds have discharged themselves, a discharge takes place from the earth to the clouds. This is an effect of induction. By the first discharge the electrical state of the clouds becomes lower than that of the earth, and there is then a discharge from the earth to the clouds to reëstablish equilibrium. It is not difficult to show this phenomenon by an experiment. We can take two large balls, one of which is kept highly electrified positively, and the other is highly charged negatively. When they are but little removed from each other a spark passes between them;

after the passage of the spark of course it is necessary to reëlectrify the balls. If we now quickly discharge one of the balls, a discharge at once follows from the other ball to the one just exhausted of its charge. Thus it is seen that electricity passes from points of high tension or intense electrical accumulation to points of lower. The return charge is generally feebler than the direct one. Men and animals are often, however, killed by it. It is said that they exhibit no signs of burns or contusions, or of the punctures which the direct stroke generally leaves on some part of the body. Here let me observe that death from lightning must be painless. The nerves of the human body do not convey a sensation of pain instantly to the nerve-centres. There is an appreciable interval before we are cognizant of what has happened. The time of an electric flash is a small fraction of this interval. While the velocity of a nervous sensation of pain is less than a hundred feet a second, that of electricity, varying under different circumstances, is many thousand times greater. We are killed before we know it. Yet there is probably a greater dread of death from this cause than from almost any other.

Prodigious effects of lightning have been recorded. In 1769 it struck a powder-magazine in Brescia: two hundred thousand pounds of powder were exploded. One third of the houses of the city were thrown down, and three thousand men lost their lives. A similar accident occurred four months since in Turkey, which was also accompanied by great loss of life. Many ships have been destroyed by lightning, and some which have never been heard of after sailing may have been set on fire by this agency. "In July, 1848, a fine vessel was struck by lightning off Boulogne, and consumed within sight of the coast. In 1843, a large transport, the Marian, conveying a part of H. M. 49th Regiment, was struck by lightning off the Cape of Good Hope, five men killed, and the vessel nearly wrecked. Another ship, the Defiance, laden with rockets, shells, artillery, and other military stores, was fearfully struck by lightning at Nankin, in August, 1842, and narrowly escaped being blown up. The cases of the packet ship New York, nearly annihilated by lightning in April, 1827; of the Toronto, another liner, in 1843; of the Underwood, in 1840; of the Madras, also in 1840, in which case part of the side was knocked out; together with a multiplicity of others, present fearful examples of the terrible effects of lightning in our merchant navy, but from which ships of the royal navy are now secure." (Sir William Snow Harris, on Protection of Ships from Lightning.)

Lightning, although occurring seldom, is at no time more dangerous than in the winter. Arago, from carefully sifted data obtained from latitudes to the north of the equator, found that ships were more frequently struck in winter than in summer. His list ran as follows: January, 5; February, 4; March, 1; April, 5; May, 0; June, 0; July, 2; August, 1; September, 2; October, 2; November, 4; December, 4. It appears, therefore, that thunder-storms at sea in winter are far more dangerous than in summer. Although thunder-storms are the most frequent in the tropics, still there are warm countries in which they are rare occurrences, as for instance in Egypt, and in portions of Peru. It is said that the inhabitants of Lima rarely hear thunder. The frequency of thunder-storms diminishes as we near the poles. Scoresby, in his Arctic Expeditions, speaks of noticing but two thunder-storms. In our temperate latitude thunder-storms are of frequent occurrence. It is comparatively common to hear of houses being struck by lightning, but the proportion of deaths to the number of houses struck is exceedingly small. The damage that can ensue from strokes of lightning is, however, very great, and the question of the best method of protecting life and property from their effects is an important one.

The experience of the tower of St. Mark's in Venice is an instructive one in the history of lightning-rods. This tower is more than three hundred and sixty feet high. It has been struck many times. Once, in 1338, it was much shattered. In 1417 it was burnt to the ground. This also happened in 1489. It had been constructed of wood; and after these repeated destructions it was rebuilt in stone. It was struck in 1548, 1565, and 1653. "In 1745 the whole tower was rent in thirty-seven places and almost destroyed. The expense of repairing it amounted to eight thousand ducats. In 1761 and 1762 it was again severely injured; but since the erection of a lightning-rod, in 1766, it does not seem to have suffered from any of the effects of lightning." The log-books of sea-captains afford the best statistics of the effects of lightning conductors. Sir William Snow Harris published in 1850 some remarkable instances of the preservation of certain ships of the royal navy from lightning. This tract was designed to show the advantage of providing ships with a conductor invented by the author. His conductor consisted of a double set of copper plates, which ran down the side of the masts and were so arranged that the movement of the yards or the tackle of the ship could not, in any event, misplace the conductor or destroy its continuity. On reaching the bottom of the mast it was connected with the metallic sheathing of the vessel. This conductor differed from the slight affairs formerly in use, by its stability and superior conducting power. The light rods formerly in use had never been properly insulated, and were liable to be displaced at any moment by the swinging of a yard-arm, or other appendage of the mast. In his preliminary remarks Sir William states that between the years 1810 and 1815, no less than thirty-five sail of the line and thirty-five frigates, together with other vessels, are known to have been disabled by lightning. He computes that the loss to the country, when the navy was on a war footing, had not been less than from seven thousand to ten thousand pounds per annum; and in times of peace from two thousand to five thousand pounds. He claims that since the adoption of his lightning conductors, serious damage by lightning to the English navy is quite unknown; and strengthens this statement by extracts from the ship logs of over thirty men-of-war that had been struck by lightning, the destructive effects of which had been obviated by his conductors. The value of Sir William Snow Harris's method of protecting ships or buildings lies in providing a conductor of large section, which is carefully connected with the principal masses of metal about the ship, and then with the water.

We have no trustworthy statistics respecting the value of lightning-rods for the protection of buildings. The methods in use are very various. Some buildings bristle with iron points, and others rely upon a single rod. The fact that the conductor should terminate in moist ground is pretty generally known, but it is often practically disregarded. Let us examine these points in detail. In the first place, let us decide what size our lightning conductors should be of. It is a common impression that we are dealing with that kind of electrical charge which resides upon the surface of bodies, and therefore that a conductor which exposes the most surface will convey a lightning discharge with the most safety; hence that it would be better to use a flat or twisted conductor than a rounded or square one with the same amount of metal; for we should evidently obtain in the flat or twisted conductor greater surface than in the round or square conductor of the same metallic mass. It is true that a portion of the electrical discharge passes over the surface of the conductor; but the area of the section of the lightning-rod is an important element in conveying away the discharge. If one should connect the two conductors of an electrical machine by a fine iron wire, it would be found impossible to melt it, however fast the disk of the machine is turned. The same wire interposed between the poles of five voltaic cells, which depend upon chemical action for the production of electrical currents, is quickly burned. Here we are dealing with electrical quantity. However near we bring the poles of a battery of five cells, no spark will leap across the interval between them. If we experiment in the same manner with the poles of fifty cells, we can obtain no spark until the poles are actually in contact. With the electrical machine, however, although we cannot melt the iron wire, we can obtain the most vivid sparks even when the knobs of the conductors are separated by a distance of eight inches. With the electrical machine we obtain electricity of high tension, but of very little quantity. The bolts of lightning are identical with the sparks which pass between the knobs of this machine. Can we not, therefore, disregard the heating effects of a lightning discharge? Will not an ordinary iron wire conduct the lightning to the ground, just as the iron wire recombines the charges which accumulate upon the knobs of this electrical machine? An experiment can be made which will settle this question. If we charge a large battery of Leyden jars with an electrical machine, and after a few moments discharge the jars through a fine iron wire, the wire is severed by the heat. Here we have evidently electric quantity as well as electric tension; and we have reproduced on a small scale the action of lightning, an ordinary flash of which can melt or volatilize more than three hundred feet of ordinary bell-wire. We read in a report to the United States Naval Department, that in 1827 a surveyor's chain one hundred and thirty-one and three tenths of a foot long, made of iron wire twenty-four hundredths of an inch in diameter, which served as the lightning conductor of the packet-ship New York, was melted by a stroke of lightning and scattered in incandescent fragments. The area of the lightning-rod evidently is a matter of much importance, for if it can be fused by a lightning discharge the bolt will then jump to the nearest good conductor in the building, and spread destruction in its path. A lightning-rod of this character can well justify the fears of those who claim that lightning-rods attract danger.

What should then be the size of our lightning-rods in order that they may not be melted? A commission appointed by the French government to consider this subject concludes that square iron rods fifty-nine hundredths of an inch square, and several hundred feet in length, are perfectly competent to convey lightning discharges of the usual nature to the ground; and that copper conductors of the same section are still better than iron, on account of the superior conducting power of copper. A copper rod through which is discharged a large battery of Leyden jars, which are charged to their utmost capacity, can be held in the hand while the discharge leaps to it and then passes through it to the ground. The body in this case is a poor conductor compared with the rod, and remains unaffected, like the building which is thoroughly protected by a lightning-rod. Having decided upon the size of our rod, questions arise as to its insulation. To speak in general terms the better the insulation the better the protection. Glass insulators of any form are sufficient. Even the wood of the house itself is sometimes used; but this insulation cannot be depended on. The point most often overlooked is a proper connection with the various bell-ropes and metallic pipes which run through our buildings, and with other metallic masses. The lightning-flash descending the lightning-rod often chooses to leap to some neighboring metallic pipe or wire, through intervening partitions of wood or stone, before it seeks the ground. The effects of this peculiarity can often be noticed by a careful observer of telegraph poles. We remember last summer, in riding on a stage-coach through Maine, to have noticed four telegraph poles, in a distance of as many miles, which bore evident marks of having been struck by lightning. In some instances they were scorched; in others, large slivers of the wood projected in a bristling manner from yawning cracks which showed where the lightning had been. Why did not the lightning run along the iron wires, which are far better conductors, apparently, than the wooden posts, and descend into the ground at some telegraph station where the main wire of the line was connected with the ground? Because the passage from the telegraph wire to the ground, which is, in general, a good conductor, is electrically shortest through the wooden posts. When we say electrically shortest, we infer that certain conditions of moisture, together with the section of conductor, make a poor conductor really a good conductor for electricity of high tension as well as high quantity. It is instructive to notice also, in passing, that in most cases when lightning seeks the ground through a poor conductor, it shatters it without setting it on fire. On the 5th of November, 1755, lightning struck a powder-magazine in the neighborhood of Rouen, and shattered two powder-kegs without setting the powder on fire. If we cause the spark from an electrical machine to pass through a heap of gunpowder, the powder-grains are instantly scattered about, but are not ignited. The spark must be retarded by passing through a comparatively poor conductor, like a wet string, before it can inflame the powder.

Supposing that our lightning conductor is of sufficient section, and is connected with all outlying metallic masses of large extent, how many projecting rods should we have, and how high should they rise above the highest point of the building? It is recommended by the French commission which we have already quoted, and also by a commission appointed by the United States government to inquire into the protection of powder-magazines, "that the height of the point of a lightning-rod above the highest point of a building to be protected should be from nine and eight tenths feet to sixteen and four tenths, according to circumstances, and that it is almost always better to increase the number of the rods, keeping within these limits, and to join them all together by a common conductor, than to increase the height of any one point." On the other hand, it is claimed by some that a high pole overtopping the highest points of a crowded area of houses, and provided with a massive conducting rod of metal, will protect a large number of buildings in its neighborhood. When we consider the probable distance from which a stroke of lightning comes, we are converted to this opinion for a moment. The height of thunder-clouds is variously estimated. Three hundred feet would probably be a low estimate for the lowest limit of thunder-clouds over comparatively level tracts of country not far removed from the level of the sea. The discharge of lightning must therefore be at least over a hundred feet long. Possessing enormous tension and very great quantity, it will disregard the small, insufficient lightning-rods, the mass of which is insignificant in comparison with that of the building itself, and seek the higher and better conductor. Considerations of economy and convenience, however, have great weight in favor of the present method of distributing lightning conductors over each building, with proper considerations in reference to insulation and the connection of all metallic masses into one conducting system.

In reference to the best connection of lightning-rods with the ground, the opinion is unanimous that the termination should be in moist ground, or with a system of water-pipes. It is necessary to reach what is called the subterranean sheet of water, that is, the supplier of the various water-courses, wells, and springs; in short, the vast area of good conducting earth, beneath sandy and rocky tracts, which are poor conductors.

We have not, indeed, secured absolute safety from the ravages of lightning, even by our most improved systems of lightning-rods; but no one who has considered the character of lightning discharges can doubt the efficiency of properly-constructed lightning conductors. In 1838, the East India Company, believing that buildings which were provided with lightning-rods were more frequently struck than those which were without them, removed them from their powder-magazines. It is related that shortly after this action, one of their magazines was struck and destroyed. The statistics which we have upon the efficiency of lightning-rods are meagre; but there is no doubt that a building can be protected from the ravages of lightning.

John Trowbridge.