N. TESLA.

LIGHTNING PROTECTOR.

APPLICATION FILED MAY 6, 1916.

1,266,175. Patented May 14, 1918.

Fig. 1.

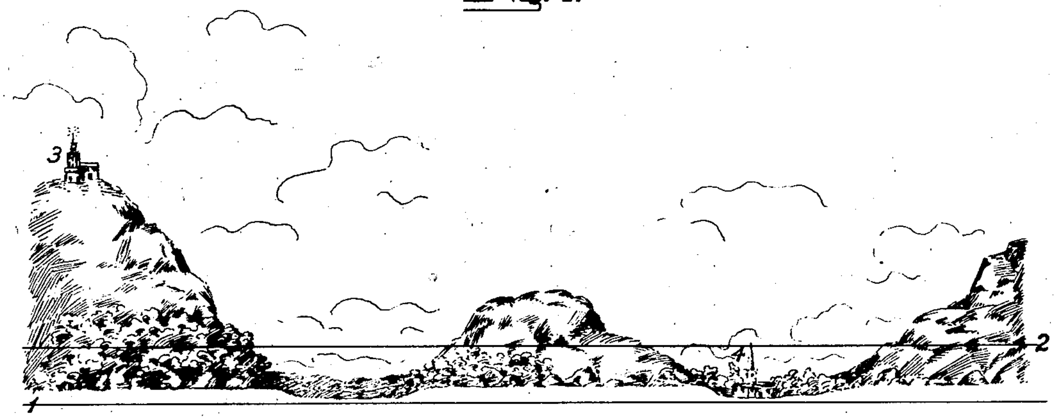


Fig. 3.

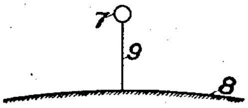


Fig. 2.

Fig. 4.

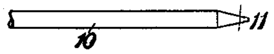


Fig. 5.

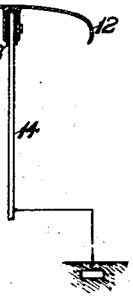


Fig. 6.

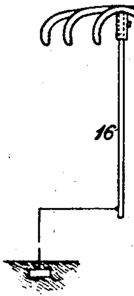


Fig. 7.

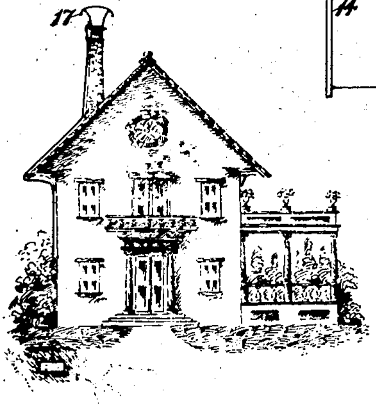
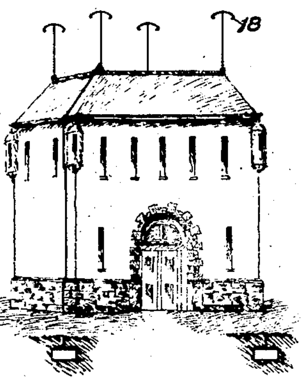


Fig. 8.



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NIKOLA TESLA, OF NEW YORK, N. Y.

LIGHTNING-PROTECTOR.

1,266,175. Specification of Letters Patent. Patented May 14, 1918.

Application filed May 6, 1916. Serial No. 95,830.

To all whom it may concern:

Be it known that I, Nikola Tesla, a citizen of the United States, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Lightning-Protectors, of which the following is a full, clear, and exact description.

The object of the present invention is to provide lightning protectors of a novel and improved design strictly in conformity with the true character of the phenomena, more efficient in action, and far more dependable in safe-guarding life and property, than those heretofore employed.

To an understanding of the nature of my invention and its basic distinction from the lightning rods of common use, it is necessary briefly to explain the principles upon which my protector is designed as contrasted with those underlying the now-prevailing type of lightning rod.

Since the introduction of the lightning rod by Benjamin Franklin in the latter part of the eighteenth century, its adoption as a means of protection against destructive atmospheric discharges has been practically universal. Its efficacy, to a certain degree, has been unquestionably established through statistical records but there is generally prevalent, nevertheless, a singular theoretical fallacy as to its operation, and its construction is radically defective in one feature, namely its typical pointed terminal. In my lightning protector I avoid points, and use an entirely different type of terminal.

According to the prevailing opinion, the virtue of the Franklin type of lightning rod is largely based on the property of points or sharp edges to give off electricity into the air. As shown by Coulomb, the quantity of electricity per unit area, designated by him "electrical density" increases as the radius of curvature of the surface is reduced. Subsequently it was proved, by mathematical analysis, that the accumulated charge created an outward normal force equal to 2π times the square of the density, and experiment has demonstrated that when the latter exceeds approximately 20 C. G. S. units, a streamer or corona is formed. From these observations and deductions it is obvious that such may happen at a comparatively low pressure if the conductor is of extremely small radius, or pointed, and it is pursuant to a misapplication of these, and other, truths that the commercial lightning rod of today is made very slender and pointed. My invention, on the contrary, while taking cognizance of these truths, correctly applies them in the provision of a lightning protector that distinctively affords an elevated terminal having its outer conducting boundaries arranged on surfaces of large radii of curvature on two dimensions. The principles which underlie my invention and correct application of which dictate the form and manner of installation of my protector, I will now explain in contrast with the conventional pointed lightning rod.

In permitting leakage into the air, the needle-shaped lightning-rod is popularly believed to perform two functions: one to drain the ground of its negative electricity, the other to neutralize the positive of the clouds. To some degree it does both. But a systematic study of electrical disturbances in the earth has made it palpably evident that the action of Franklin's conductor, as commonly interpreted, is chiefly illusionary. Actual measurement proves the quantity of electricity escaping even from many points, to be entirely insignificant when compared with that induced within a considerable terrestrial area, and of no moment whatever in the process of dissipation. But it is true that the negatively charged air in the vicinity of the rod, rendered conductive through the influence of the same, facilitates the passage of the bolt. Therefore it increases the probability of a lighting discharge in its vicinity. The fundamental facts underlying this type of lightning-rod are: First, it attracts lightning, so that it will be struck oftener than would be the building if it were not present; second, it renders harmless most, but not all, of the discharges which it receives; third, by rendering the air conductive, and for other reasons, it is sometimes the cause of damage to neighboring objects; and fourth, on the whole, its power of preventing injury predominates, more or less, over the hazards it invites.

My protector, by contrast, is founded on principles diametrically opposite. Its terminal has a large surface. It secures a very low density and preserves the insulating qualities of the ambient medium, thereby minimizing leakage, and in thus acting as a quasi-repellant to increase enormously the safety factor.

For the best and most economical installation of protective devices according to my invention, those factors and phenomena that dictate size, number of protectors and physical qualities of the apparatus must be grasped by the installing engineer, and preliminarily, for full understanding of the principles of my invention, these should be briefly explained.

Economical installation, of course, demands that the protective capability of any given equipment be not needlessly greater than is required to meet the maximum expectancies under the conditions surrounding the particular building to be protected, and these depend, partially, as I shall show, upon the character of the landscape proximate to the building site.

In the drawings, Figures 1 to 4 inclusive, are diagrams requisite to illustration of the facts and conditions relevant to the determination of specific installations of my invention, and Figs. 5 to 8 illustrate construction and application of the protectors. Specifically:

Fig. 1 is a landscape suited for purpose of explanation; Figs. 2, 3 and 4 are theoretical diagrams; Figs. 5 and 6 illustrate forms of improved protectors; and Figs. 7 and 8 show buildings equipped with the same.

In Fig. 1, 1 represents Lord Kelvin's "reduced" area of the region, which is virtually part of the extended unruffled ocean-surface. (See "*Papers on Electrostatics and Magnetism*" by Sir William Thomson). Under ordinary weather conditions, when the sky is clear, the total amount of electricity distributed over the land is nearly the same as that which would be contained within its horizontal projection. But in times of storm, owing to the inductive action of the clouds, an immense charge may be accumulated in the locality, the density being greatest at the most elevated portions of the ground. Assuming this, under the conditions existing at any moment, let another spherical surface 2, concentric with the earth, be drawn—which may be called "electrical niveau"—such that the quantities stored over and under it are equal. In other words, their algebraic sum, taken relatively to the imaginary surface, in the positive and negative sense, is *nil*. Objects above the "niveau" are exposed to ever so much more risk than those below. Thus, a building at 3, on a site of excessive density, is apt to be hit sooner or later, while one in a depression 4, where the charge per unit area is very small, is almost entirely safe. It follows that the one building 3 requires more extensive equipment than does the other. In both instances, however, the probability of being struck is decreased by the presence of my protector, whereas it would be increased by the presence of the Franklin rod, for reasons that I will now explain.

An understanding of but part of the truths relative to electrical discharges, and their misapplication due to the want of fuller appreciation has doubtless been responsible for the Franklin lightning rod taking its conventional pointed form, but theoretical considerations, and the important discoveries that have been made in the course of investigations with a wireless transmitter of great activity by which arcs of a volume and tension comparable to those occurring in nature were obtained ("Problems of Increasing Human Energy" *Century Magazine* June 1900 and Patents 645,576, 649,621, 787,412 and 1,119,732) at once establish the fallacy of the hitherto prevailing notion on which the Franklin type of rod is based, show the distinctive novelty of my lightning protector, and guide the constructor in the use of my invention.

In Fig. 2, 5 is a small sphere in contact with a large one, 6, partly shown. It can be proved by the theory of electric images that when the two bodies are charged the mean density on the small one will be only

$$\frac{\pi^2}{6} = 1.64493$$

times greater than that on the other. (See "*Electricity and Magnetism*" by Clerk Maxwell). In Fig. 3, the two spheres 7 and 8 are placed some distance apart and connected through a thin wire 9. This system having been excited as before, the density on the small sphere is likely to be many times that on the large one. Since both are at the same potential it follows directly that the densities on them will be inversely as their radii of curvature. If the density of 7 be designated as d and the radius r, then the charge $q=4\pi r^2 d$, the potential $p=4\pi rd$ and the outward force, normal to the surface, $f=2\pi d^2$. As before stated, when d surpasses 20 C. G. S. units, the force f becomes sufficiently intense to break down the dielectric and a streamer or corona appears. In this case $p=80\pi r$. Hence, with a sphere of one centimeter radius disruption would take place at a potential $p=80\pi=251.328$ E. S. units, or 75,398.4 volts. In reality, the discharge occurs at a lower pressure as a consequence of uneven distribution on the small sphere, the density being greatest on the side turned away from the large one. In this respect the behavior of a pointed conductor is just the reverse. Theoretically, it might erroneously be inferred from the preceding, that sharp projections would permit electricity to escape at the lowest potentials, but this does not follow. The reason will be clear from an inspection of Fig.

4, in which such a needle-shaped conductor 10, is illustrated, a minute portion of its tapering end being marked 11. Were this portion removed from the large part 10 and electrically connected with the same through an infinitely thin wire, the charge would be given off readily. But the presence of 10 has the effect of reducing the capacity of 11, so that a much higher pressure is required to raise the density to the critical value. The larger the body, the more pronounced is this influence, which is also dependent on configuration, and is maximum for a sphere. When the same is of considerable size it takes a much greater electromotive force than under ordinary circumstances to produce streamers from the point. To explain this apparent anomaly attention is called to Fig. 3. If the radii of the two spheres, 7 and 8, be designated r and R respectively, their charges q and Q and the distance between their centers D, the potential at 7, due to Q is $\frac{Q}{D}$. But 7, owing to the metallic connection 9, is at the potential

$$\frac{Q}{R}=\frac{q}{r}.$$

When D is comparable to R, the medium surrounding the small sphere will ordinarily be at a potential not much different from that of the latter and millions of volts may have to be applied before streamers issue, even from sharp protruding edges. It is important to bear this in mind, for the earth is but a vast conducting globe. It follows that a pointed lightning-rod must be run far above ground in order to operate at all, and from the foregoing it will be apparent that the pointing of the end, for supposed emissive effect, is in part neutralized by the increasing size below the extreme end, and the larger the rod, for reduction of electrode resistance, the more pronounced is this counter-influence. For these reasons it is important to bear in mind that sufficient thickness of the rod for very low electrode-resistance is rather incompatible with the high emissive capability sought in the needle-like Franklin-rod, but, as hereinafter set forth, it is wholly desirable in the use of my invention, wherein the terminal construction is intended for suppression of charge-emission rather than to foster it.

The notion that Franklin's device would be effective in dissipating terrestrial charges may be traced to early experiments with static frictional machines, when a needle was found capable of quickly draining an insulated electrified body. But the inapplicability of this fact to the conditions of lightning protection will be evident from examination of the simple theoretical principles involved, which at the same time substantiate the desirability of establishing protection by avoiding such drainage. The density at the pointed end *f* should be inversely as the radius of curvature of the surface, but such a condition is unrealizable. Suppose Fig. 4 to represent a conductor of radius 100 times that of the needle; then, although its surface per unit length is greater in the same radio, the capacity is only double. Thus, while twice the quantity of electricity is stored, the density on the rod is but one-fiftieth of that on the needle, from which it follows that the latter is far more efficient. But the emissive power of any such conductor is circumscribed. Imagine that the "pointed" (in reality blunt or rounded) end be continuously reduced in size so as to approximate the ideal more and more. During the process of reduction, the density will be increasing as the radius of curvature gets smaller, but in a proportion distinctly less than linear; on the other hand, the area of the extreme end, that is, the section through which the charge passes out into the air, will be diminishing as the square of the radius. This relation alone imposes a definite limit to the performance of a pointed conductor, and it should be noticed that the electrode-resistance would be augmented at the same time. Furthermore, the efficacy of the rod is much impaired through potential due to the charge of the ground, as has been indicated with reference to Fig. 3. Practical estimates of the electrical quantities concerned in natural disturbances show, moreover, how absolutely impossible are the functions attributed to the pointed lightning conductor. A single cloud may contain 2×10^{12} C. G. S. units, or more, inducing in the earth an equivalent amount, which a number of lightning rods could not neutralize in many years. Particularly to instance conditions that may have to be met, reference is made to the *Electrical World* of March 5, 1904, wherein it appears that upon one occasion approximately 12,000 strokes occurred within two hours within a radius of less than 50 kilometers from the place of observation.

But although the pointed lightning-rod is quite ineffective in the one respect noted, it has the property of attracting lightning to a high degree, firstly on account of its shape and secondly because it ionizes and renders conductive the surrounding air. This has been unquestionably established in long continued tests with the wireless transmitter above-mentioned, and in this feature lies the chief disadvantage of the Franklin type of apparatus.

All of the foregoing serves to show that since it is utterly impracticable to effect an equalization of charges emissively through pointed lightning-rods under the conditions presented by the vast forces of nature great improvement lies in the attainment of a minimized probability of lightning stroke to the area to be protected coupled with adequate conductivity to render harmless those strokes that may, notwithstanding, occur.

Furthermore, a correct application of the truths that have thus been explained with reference to the familiar pointed type of lightning-rod not only substantiates the theoretical propriety of the form in which I develop my improved lightning protector, but will lead the installing engineer properly to take cognizance of those conditions due to location of the building, with respect to surrounding earth formations and other buildings, probabilities of maximum potential-differences and charge-densities to be expected under the prevailing atmospheric conditions of the site, and desirable electrode resistance and capacities of the protectors installed.

The improved protector, as above stated, behaves in a manner just opposite to the Franklin type and is incomparably safer for this reason. The result is secured by the use of a terminal or conducting surface of large radius of curvature and sufficient area to make the density very small and thereby prevent the leakage of the charge and the ionization of the air. The device may be greatly varied in size and shape but it is essential that all its outer conducting elements should be disposed along an ideal enveloping surface of large radius and that they should have a considerable total area.

In Fig. 5, Fig. 6, Fig. 7 and Fig. 8, different kinds of such terminals and arrangements of same are illustrated. In Fig. 5, 12 is a cast or spun metal shell of ellipsoidal outlines, having on its under side a sleeve with a bushing 13 of porcelain or other insulating material, adapted to be slipped tightly on a rod 14, which may be an ordinary lightning conductor. Fig. 6 shows a terminal 15 made up of rounded or flat metal bars radiating from a central hub, which is supported directly on a similar rod and in electrical contact with the same. The special object of this type is to reduce the wind resistance, but it is essential that the bars have a sufficient area to insure small density, and also that they are close enough to make the aggregate capacity nearly equal to that of a continuous shell of the same outside dimensions. In Fig. 7 a cupola-shaped and earthed roof is carried by a chimney, serving in this way the twofold practical purpose of hood and protector. Any kind of metal may be used in its construction but it is indispensable that its outer surface should be free of sharp edges and projections from which streamers might emanate. In like manner mufflers, funnels and vents may be transformed into effective lightning protectors if equipped with suitable devices or designed in conformity with this invention. Still another modification is illustrated in Fig. 8 in which, instead of one, four grounded bars are provided with as many spun shells or attachments 18, with the obvious object of reducing the risk.

From the foregoing it will be clear that in all cases the terminal prevents leakage of electricity and attendant ionization of the air. It is immaterial to this end whether it is insulated or not. Should it be struck the current will pass readily to the ground either directly or, as in Fig. 5, through a small air-gap between 12 and 14. But such an accident is rendered extremely improbable owing to the fact that there are everywhere points and projections on which the terrestrial charge attains a high density and where the air is ionized. Thus the action of the improved protector is equivalent to a repellant force. This being so, it is not necessary to support it at a great height, but the ground connection should be made with the usual care and the conductor leading to it must be of as small a self-induction and resistance as practicable.

I claim as my invention:

1. A lightning protector consisting of an elevated terminal, having its outer conducting boundaries arranged on surfaces of large radii of curvature in both dimensions, and a grounded conductor of small self-induction, as set forth.

2. A lightning protector composed of a metallic shell of large radius of curvature, and a grounded conductor of small self-induction, as described.

3. Apparatus for protection against atmospheric discharges comprising an earth connection of small resistance, a conductor of small self-induction and a terminal carried by the same and having a large radius of curvature in two dimensions as, and for the purpose set forth.

4. In apparatus for protection against atmospheric discharges an insulated metallic shell of large radius of curvature supported by a grounded conductor and separated from the same through a small air-gap as, and for the purpose described.

5. A lightning protector comprising, in combination, an elevated terminal of large area and radius of curvature in two dimensions, and a grounded conductor of small self-induction, as set forth.

6. In apparatus for protection against lightning discharges, the combination of an elevated metallic roof of large area and radius of curvature in two dimensions, and a grounded conductor of small self-induction and resistance, as described.

7. As an article of manufacture a metallic shell of large radius of curvature provided with a sleeve adapted for attachment

to a lightning rod as, and for the purpose set forth.

8. A lightning protector comprising an ellipsoidal metallic shell and a grounded conductor of small self-induction, as set forth.

9. In apparatus for protection against atmospheric discharges a cupola-shaped metallic terminal of smooth outer surface, in combination with a grounded conductor of small self-induction and resistance, as described.

In testimony whereof I affix my signature.

NIKOLA TESLA.