## LIGHTNING AND LIGHTNING CONDUCTORS.

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The common conception of lightning may almost be described as a belief that there is a something packed away in the clouds, which at some uncertain moment falls from them as a "thunder bolt," or rushes out upon the earth as a discharge of "electric fluid," with destructive effects, resembling in some degree those of the bursting of a reservoir of water. The conductor is regarded as having some attraction for the "bolt," and also as a pipe to receive and carry off the fluid. These ideas also as a pipe to receive and carry off the fluid. These ideas are not only erroneous scientifically, but they are the source of many practical mistakes in the setting up of conductors which sometimes lead to fatal results.

Those who know comething of electricity are of course aware that lightning is strictly analogous to the artificial electric ( discharge; but the common erioneous views of this latter, based on the fluid theories of electricity, lead to notions not unlike those just described.

The di-charge does not merely issue from the clouds and rush to the earth, but the latter fulfils a function just as important as that of the clouds, the latter are indeed "prime conductors" of Nature's great electrical machine, but the force is distributed over a vast " inductive circuit," of which the air and the earth form as much a part as the clouds themselves, and the discharge is a redistribution of force all over this inductive circuit, not across the air simply.

The thunder cloud is in fact to all intents a condenser plate upon which terminates the polarised chain of a circuit, and there are two varieties of thunder-storm, which depend upon the nature of the opposite condensing plate. This may be another cloud above, or at a distance from the first ; then the discharges occur only between the clouds themselves, and the only effect on the earth is of an inductive nature, and is usually slight; this is the case with what is called sheet lightning, in which the clouds are vividly illuminated, but there is no line of light visible. In the other class the surface of the earth forms the second condenser-plate, the air and all bodies be-tween the clouds and the earth are "pola-ised," and assume a condition analogous to that produced in the neighbourhood of an electric machine at work. Discharge at last occurs in one or more lines in which the resistance happens to be least, when the tension has risen to a degree greater when the resistance of the circuit con sustain. Very slight circumstances determine the direction of this discharge : an animal standing on the ground, a tree, the presence of extra moisture, or a metallic vein, or a range of piping in the ground may suffice. This is very evident in the case of ships at sea: they will not only draw a flish of lightning, but will frequently cause a change in the direction of the wind itself, by the electrical attraction they set up.

I have frequently seen this occur. On one occasion a very heavy squall-cloud rose on the weather bow of a ship I was in, within the Tropics, when I was in charge of the vessel, it crossed our course and went away to leeward, we running up nearcr and nearer to its path : the cloud then stopped, rapidly returned toward us, against the wind we had, and as it reached above us, a violent change of wind occurred, the cloud threw out its charge, struck our fore and main top-gallant masts and killed two men.

To this same order belong a variety of natural phenomena, such as what sailors call St. Elmo's Fire, when the points of masts and yards are tipped with lambent flames, which resemble the common brush discharge of our machines. A third variety, called Ball Lightning, is very uncom non, and its electrical nature is not at present explainable; if, indeed, it is directly electric in its nature at all. In this a large ball of fire is seen to roll along the earth, doing great mischief on its path. and apparently having some connection with or relation to the revolving winds called tornadoes or whirlwinds, models of which may frequently be observed in our streets when the dust is not properly laid by watering, and of which the waterspout is another variety.

In the true thunderstorm the cloud consists of a series of layers or zones opposite by electrified with a similarly arranged but opposite series on the earth beneath, the air between completing an electric circuit. Such a circuit is often

one extremity a corresponding one in the reverse direction (sometimes called the back stroke) occurs at the other extrem-ity, perhaps twenty miles away. The clouds themselves may be only 100ft. away, or two or thr e miles. Flashes of such length have indeed been measured by the angle occupied by the line of light and the period between the flash and the sourd of the thunder, which tog ther furnish the means of calculating the length of the visible flash. Several attempts have also been made to measure the time occupied by a discharge. Moving objects, when thotographed by its light, appear as distinct as if stationary, but by means of revolving mirrors it has been accertained that the actual duration of a flash is some-thing less than 1-500th of a second, its apparent duration is an effect of our own eyes, due to what is called persistence of vision, owing to which we cannot lose au impression once pro-duced in much less than a sixth of a second, on which principle are based so many optical toys.

It is frequently stated that the hodies of those killed by lightning are marked with impressions of neighbouring objects. It is hard to say what amount of truth there is in this, and how much natural exaggeration ; credit is most often given to a neighbouring tree as the image copied, and it would seem not unlikely that such marks are caused by an action like that of the brush discharge, causing a series of striggling lines, which the imagination of excited observers converts into a tree. It is of more moment to those who are alarmed at the flashes of lightning to understand that when a flash is seen all danger from it is passed, a person struck never sees the flash, and it would appear that this death is the most instantaneous and painless which can be conceived.

The foregoing considerations as to the nature of the discharge will enable us to see what are the true principles of conductors to avoid its effects. They are not inten led to attract or convey a d scharge from the clouds. Their object is to supersede the condition of polarisation and tension in the space to be protected. They do this in a twofold manner  $\cdot -1$ They practically raise the earth's surface to such a curved height as corresponds to the electric relations of the conductor and the air; not in an exact invariable form, as some suppose the protected area to assume; but still, roughly in a cone from the apex of the conductor, and of a radius perhaps equal to the height of the point, but this applies only to the rod its lf, when buildings are in the included cone no law can be given, as the conductivity is affected by their materials and contents Whatever the space protected may be, within it the condu tor lowers or nullifies the condition of tension, transferring it to the space outside the cone, &c. They react also upon the exterior space in the direction of a reversed cone, by the discharging properties of points when forming part of a polarised area On points, the lines of polarisation converge, and so affect the circuit that it will not rise to its extreme tonsion ; the action is precisely that of a point connected to the rubber of a machine, and held (even much beyond the sparking distance), towards the prime conductor; in these conditions no charge can be given ; a brush discharge is kept up and a current passes instead. The lightning conductor performs the same duties soon as the charged cloud approaches, and would begin to set up an "inductive circuit" under tension in the air to the earth beneath it, a current begins to flow quietly in the conductor, the tension above it is rapidly lowered, and may not be able to accumulate sufficiently for a violent discharge, i.e., a lightning flash, at all; but if it does, the discharge will occur through the space between the cloud and the outer area of the conductor's cone; and the conductor takes it up in the form of a momentary increase of current. In considering these principles it must be remembered that lightning is not a mere thread of flame, or confined to the visible line; a large space all round the line takes part in the discharge, and gives up the force previously accumulated in it as tension.

These principles settle for us all questions as to conductors. They should connect to earth every portion of a building, and as that is possible only with metal buildings, they should connect every salient point and as much of the surface as possible, so as to extend around the building the area of low tension, or artificial "earth" surface opposed to the cloud. Chimneys require especial attention, because they are tubes lined with cond cting material, containing warmer air, and if with fires, then extending a comparatively good conducting column of warm air towards the cloud and so inviting a discharge ; hence extended over many miles, so that when a discharge occurs at is that lightning almost always enters a house by the chim-