without doing any harm than to run the risk of having it once struck while without any means of conduction of the current to the earth except through the poorly conducting portions of the building, which are almost sure to suffer injury or destruction.

I do not think that lightning rods are of much utility in the case of buildings which have metal pipes running from the ground up to the highest story and through the roof, especially if these pipes should extend to a considerable height above the building, or above the highest part of the building. In case the building has a metal roof, with pipes running from the ground to the roof, there is little liability of damage being done below the roof, but any chimney which projects above the roof might be struck and shattered. In such cases a connection from the pipe or metal of the roof to a short rod running up the chimney and extending above it a short distance would be advisable. Lightning rods are but little use for buildings adjoining tall chimneys or church spires themselves provided with good lightning conductors. The actual area which is protected by a church spire provided with a lightning conductor has never been satisfactorily determined, but it is probably at least equal to that of a circle whose radius is eqnal to the height of the spire or chimney above the top of the building to be protected.

All that I have said in relation to the effectiveness of the lightning rod, implies, of course, that it be properly put up—that is, pnt up with a knowledge of the conditions of the service which is to be had from it—and that it be thoroughly connected with the ground at its lower end. Merely running the end of the rod into the ground a short distance, as sometimes done, is by no means sufficient. A connection of the system to gas or water pipes generally furnishes a good ground. The running of the lower end of the rod, made of some metal which cannot be easily corroded, either into a pit or well filled, with broken coke or tin scrap, will make a good ground, provided the well is deep enough to be always in a moist state. A still better way is to fork the end of the rod into several branches, which run away from the building and pass downward into several small pits or wells,with the conducting material, such as coke, iron borings, tin scrap, or the like, placed in them.

The most perfect lightning protection is obtained when the building is virtually in a metallic cage, the parts of which in connection with the earth are very thoroughly grounded or connected with the moist stratum. Such thoroughness as this is, however, not necessary. With even a large building the carrying of a conductor down each corner and grounding it as above mentioned would be sufficient. Of course the rod should have sufficient metal in it not to be injured by the heaviest possible discharge which would be liable to pass over it. It should, in other words, be built with a factor of safety, so as to be able to carry to the ground all the current which could ever reach it from the clouds. I think it is pretty generally conceded that ½-inch iron rod has never been known to be injured by the passage of a lightning discharge through it, and that such rod conducts the discharge freely enough for the purpose. Experience, of course, is to be the teacher in this case. A lightning rod made of galvanized iron pipe, say 1-inch pipe, used with the screw joints well secured and painted so as not to rust at the joints, would be about as good a conductor as could be desired. A flat strip of copper securely tacked to the building and running down its corners, the dimensions of the copper being, say, $\frac{1}{16}$ inch thick by 1½ inches wide, would also answer, and is in many respects a good form of conductor. If the metal aluminum becomes cheap enough I think an iron bar covered with this metal would be an excellent conductor on account of the small liability of the aluminum to rust.

Concerning the action of a lightning rod in saving a building from harm, this can be briefly stated to be the mere interposing of some good conductor in the path of the lightning discharge, so that the charge can be carried to earth, or the electric strain relieved, without the necessity for following poorer conductors, which, if traversed, would be torn to pieces or destroyed. More scientifically, it may be stated to be the provision of a path or centre of action for the discharge in the vicinity of the building of such a character that the discharge selects it in preference to forming a centre of discharge or path for itself through the building, which may be made of materials not able to carry the discharge without destruction. The concentration of the energy of a discharge on ordinary building material, such as wood, stones, brick or plaster, gives rise to destruction from the mere fact that these substances are not capable of conveying the energy without being highly heated. If wood be suddenly heated the watery vapor in it forms a gas and explodes it. The destructive effects, then, of the electrical discharge are due to expansion of gases, or the production of vapors within the material damaged.

Lightning rods need not be insulated from the building. It matters very little whether they are or are not insulated, as the ordinary provisions for insulation, so far as a lightning discharge is concerned, are practically *nil*. The insulation given to a lightning rod is frequently that which is not good enough for a telegraph line where the pressure of the current on the line may not exceed in all 200 volts, while in the lightning discharge the pressure may be many millions of volts. Where there are large masses of metal in a building it would do no harm as a rule to connect these masses to the ground as well as to the lightning rod ; and it may be said also that where a building is filled with masses of metal or machinery, damage from lightning could be largely obviated by connecting the various masses of the metal one to the other and to the ground. It is not, however, essential that they be actually connected to the ground ; for if a mass of metal in the building is but slightly separated from the ground wire by what is known as a discharge space, it will be quite sufficient to allow lightning to pass. A slight opening between two parts of a conductor constitutes a discharge space. Such discharge spaces and protective arrangements are used commonly on telegraph and telephone lines, in which the lines, although they are not connected to earth at each instrument, may be so near the earth by the provision of a discharge space between the line and earth that they are practically connected.

The effectiveness of lightning rods depends, I think, not alone upon their cross sections nor alone upon their surface. It is as much a mechanical as an electrical question. There needs to be a sufficient cross section of metal not to be melted by any discharge, and it is best that the metal be made in the form of a pipe or flat strip, since the tendency of the lightning discharge is to follow the surface portion of the conductor. This is due to the fact that it is an extremely quick discharge and may take upon itself an oscillating character. This means that each spark which connects earth and cloud is not a stream of something running in one direction, but merely a core or axis for a set of disturbances or reliefs of pressure which may act alternately in opposite directions during the short intervals through which the flash lasts. The oscillating action may be illustrated by fastening the end of a thin steel rod and bending it by carrying the free end to one side. This, if let go, will be followed by a series of oscillations made very quickly, but which are akin to oscillations of a pendulum. The relief of electrical pressure is in lightning so sudden as to result in the action of relief going too far, after which a relief in the opposite direction ensues, back and forth, until all of the energy of the discharge has been used up in the form of light and heat.

This must not be confounded with the action which often occurs during thunderstorms, when two, three or more separate discharges are visible separately to the eye, and follow down the same path or the track which has been opened by the first discharge. This is a phenomenon common enough and easily observed, but it has no relation to the oscillations of a single lightning discharge. These oscillations, if they exist at all, are in periods inconceivably small, and therefore are not to be discovered by the unassisted eye. Neither do I wish to be understood as subscribing to the opinion that all lightning discharges are oscillating in character. I am convinced from my own observation that very many lightning discharges, particularly those which pass over great lengths of clouds, are more apt to be discharges of some duration. Observation over a long period of years has led me to think that it may be possible that the discharges in some instances have a measurable rate of progress from cloud to cloud, and perhaps to earth. The photographic plate, which is being more and more applied to the study of lightning discharges, will some day resolve this doubt.