can be introduced instead of one as indicated. From experiments that have been conducted with such bridges as we have described, it has been found that a bridge of 50 ft. span, composed of 27 elements, Fig. 1, 36 elements, Fig. 5, and 664 bolts, weighs about 3.4 tons, and will carry safely a uniformly distributed load of 11 tons, or a waggon weighing 4 or 5 tons may be sent over it with safety. A second bridge, 79 ft. span, of the same type is also extremely light. Composed of 42 elements, Fig. 1, 12 elements Fig. 3, 56 elements, Fig. 5, and 1050 bolts, and weighing about 5.8 tons, its safe working load is 41 lb. per square foot, and it can carry a vehicle of 7 tons.

Bridges up to 82 ft. span, adapted for heavy military service, secondary roads, &c., can be constructed according to the type Fig. 13, and experiments have been conducted with them, showing that with a total weight of structure of 8 tons, a uniformly distributed load of 17 tons can be safely carried. For larger openings and heavier loads, the elements can be doubled as already explained, so as to make double intersection panels, or the width and number of main girders may be increased. Such a bridge 131 ft. span, weighing 495 lb. per foot run will carry a load equally distributed of 165 lb. per square foot, with a strain of less than 6 tons per square inch.

A further development of this system, carried out by Mr. Cottrau, is for the construction of railway bridges, either for contractors, for military purposes, or for temporary work, and by suitably combining the different elements, spans relatively considerable can be very rapidly constructed. Equally the same elements can be used in the construction of piers as shown in Figs. 14 and 15.

In a large majority of cases bridges constructed on this system can be put together, on one bank of the stream they are to cross, and be launched into their ultimate positions, the extreme lightness of the structure rendering this operation comparatively easy, and without any dangerous strain being thrown upon the steel during the operation. And should it be found advisable to balance the bridge during the period of launching this can be easily effected by adding a sufficient number of panels in the ordinary elements.

The great amount of care and ingenuity which so eminent a bridge constructor as Mr. Cottrau has bestowed on the elaboration of this system of portable bridges, will doubtless command for it the attention of contractors, military authorities, and others interested in a practical solution of establishing temporary communication, rapidly and efficiently, especially in countries where the transport of materials is difficult and costly. We shall probably take an opportunity of again referring to this system.—*Engineering.*

THUNDER STORMS.

BY JOHN TROWBRIDGE.

Benjamin Franklin once remarked, in substance, sadly to a friend, "It is now eight years since I showed that mankind could be protected from the danger of lightning by lightning-rods; yet there is hardly a house in Philadelphia provided with them." The heart of the great American philosopher would be greatly warmed if he could perceive the activity of his disciples, who waylay every builder of a house, and awaken fears where all was peace before. There is no question oftener asked of the professor of physics than this: "Shall I put lightning-rods on my house, and, if I erect them, what should be their form and position?" Personally I have given the following abbreviated answers: "If your house is surrounded by tall trees, or if there are higher houses in your immediate neighborhood, I should trust to the trees, or kindly leave the expense of your lightning rods to your neighbor. If your house stands alone, a prominent point in the landscape, on a cliff, or remote from trees, I should be in favor of a properly placed lightning-rod. I should place two or three pointed rods three or four feet above the highest point of the house; allow the metallic rod, which should be at least one-half a square inch in section, to rest, without glass insulators, upon the house; connect all the tin sheathing, the copper gutters, the gas and water pipes with this lightning-rod; and conduct the latter, by the shortest course possible, to *wet earth.*"

These answers seldom conclude the correspondence, however, although one generally prefers to leave to the neighbor the expense of erecting lightning-rods. One brings instances of houses having been struck which are situated lower than one's neighbors, and are surrounded with tall trees which over-topped the houses; and one asks with a shudder, "Can I connect my gas-pipes with a lightning-rod?" Indeed, the writer or would-be authority on lightning rods has not an easy life before him. He must not only satisfy the timid heart of the believer in him, but he must also fight with all his knowledge the brazen limb of ignorance and superstition, who starts with the postulate that no scientific man knows any thing concerning thunder and lightning, and that the true knowledge has been revealed only to himself while working in a cornfield. It is not long since, that an American professor of physics was sued for twenty or thirty thousand dollars damages for maintaining that the members of a lightning rod company which placed lightning-rods like a letter U upon the roofs of houses were practically quacks; the theory of this lightning-rod being, that the lightning, if it struck one point of the U, would be dissipated into the air from the other point. There is a lightning-rod company in Massachusetts at the present time which erects lightning-rods on the theory that lightning always seeks electrical earth-currents; and, if there are earth-currents beneath a house, that house should be protected and the rods led into the path of the earth-current. If, on the other hand, no earth-currents run near the house, such a house is safe, and needs no lightning-rods. The electrician of this firm is self-taught: there are no books on electricity in his library. He discovers the earth-currents by a forked stick. Not deterred by the fact that there is no evidence to prove that a discharge takes place between a charged cloud and a current of electricity in the ground, and, moreover, no evidence to prove that earth-currents move in regular paths through the earth, and, indeed, no *conclusive* evidence of the existence of earth-currents, he persuades even the so-called practical electrician to re-arrange the lightning-rods on his house.

The student of electricity is therefore called upon to assert the grounds of his belief; and he finds it difficult to convince his audience; for they are, in general, not sufficiently conversant with electrical phenomena to appreciate his arguments. The position taken by most professors of physics on the subject of lightning-rods is based upon the experiments of Franklin, in which he showed that pointed metallic rods, so to speak, facilitated electrical discharges; the experiment of Faraday, by which it was shown that a person, and even the most delicate electrical instruments, inside a large metallic cage which was connected with the ground, was unaffected by powerful discharges of electricity between the cage and the prime conductor of an electrical machine; and the statistics collected by the English government, which show, that, since vessels have been provided with lightning rods the number of casualties produced at sea from lightning have been greatly reduced. A building covered by a metallic netting suitably connected with the ground would be well protected from lightning. The nearest approach to this condition of safety would be to connect all the network of metallic conductors about a house with wet ground; and one argument against placing under ground the network of telephone and telegraph wires in cities is, that at present, where they are very numerous, they protect buildings from danger from lightning. This is, of course, not the case where a single telephone or telegraph wire enters a house. The latter should always be well connected with the gas or water pipe. In regard, however, to the belief that tall trees, higher than the houses in their immediate neighborhood, protect the houses, we can point to the well known efficiency of small points in facilitating electrical discharges by slow degrees. Each leaf and twig is such a small point. Moreover, during a rain, the dripping from the leaves reduces the electrical charge on the tree to the same sign and amount as that of the air in the immediate neighborhood, as is shown by the well-known experiment of Sir William Thomson, in which an insulated can, from which a stream of water issues in drops, is connected with an electrometer; and the latter shows that the metallic can has taken the charge of the air in its neighborhood. The drops of water continually reduce the can to the electrical potential of the neighboring air. The tree, therefore, can be looked upon as a more important electrical factor than the few salient lower points of a building.

It is safe to affirm that not one out of a thousand lightning-rods at present upon our buildings are of any use, for the simple reason that they are not led into moist ground, and therefore offer great resistance to the passage of an electrical discharge. Any one can be convinced of this by scraping the lightning-rod at any point, connecting a bright wire at this point, and, having led the other end of the wire to the water-pipe or to a body of water, placing one or two Leclanché cells