

(1) Number of pages 42
 (2) Date of repair 30-5-86
 (3) Initials of the Referencer low

TAMIL NADU ARCHIVES

GOVERNMENT OF TAMIL NADU

P. W. D. DEPARTMENT

G.O. No.	1, 454 W	Press.
B.P. No.		Mis.
Dated 21 - 3 - 1878 197		

Not to be folded or roughly handled

V.S.M.

GOVERNMENT OF MADRAS.
PUBLIC WORKS DEPARTMENT.

21st March 1878. No. 1,454 W.

Buildings and Roads.
Civil Works.

Read the following papers:—

No. 311. From the Assistant Secretary to the Government of India, Public Works Department, (Civil Works—Miscellaneous,) to the Secretary to the Government of Madras, Public Works Department, General Branch, dated Fort William, 19th December 1877, Circular No. 74, Public Works.

In continuation of Circular No. 66 P.W. of the 7th ultimo, the undersigned is directed to forward for information copy of "instructions" issued by the British War Department regarding the application of lightning conductors for the protection of powder magazines and other buildings.

(Signed) G. T. SKIPWITH, Captain, R.E.,
Asst. Secy. to the Govt. of India.

No. 311-A. From the same Officer, dated Fort William, 13th March 1878, No. 92 M.

In reply to the request made in your letter No. 1,076 of the 1st current, asking to be supplied with 50 additional copies of the "instructions" issued by the British War Department regarding lightning conductors for protection of powder magazines, &c., forwarded with Public Works Department Circular No. 74, 19th December 1877, I am directed to say that there are no more spare copies available in this office.

No. 312. ORDER THEREON, 21st March 1878, No. 1,454 W.

COMMUNICATED to District Engineers for information and to the Military Department.

(True Extract.)

(Signed) E. A. FOORD, Colonel, R.E.,
Secretary to Government, P.W.D.

(True Copy.)

Colonel,
Under Secy. to Govt., P.W.D.

To District Engineers,
To the Consulting Architect,
" Consulting Engineer for Railways, } with copies of instructions.
" Military Department.

Exd. B. C. Shanker.

Spare Copies

Cont. of 11878; *Public Works.*
PUBLIC WORKS.

ENGINEERS

Enclosure to P. W. D. Circular No. 74 Public Works.

[Issued with Army Circulars, dated 1st May, 1875.]

INSTRUCTIONS AS TO THE APPLICATION

OF

LIGHTNING CONDUCTORS

FOR THE

PROTECTION OF POWDER MAGAZINES
AND OTHER BUILDINGS.

Gen. No. 5.
236.

1. The principles on which buildings should be protected against lightning are set forth in Appendices A and B, which papers were drawn up by the late Sir William Snow Harris, F.R.S. These principles are still generally held to be sound, and should be carefully considered with reference to any system of lightning conductors. In consequence, however, of the progress of electrical science, some modifications are necessary in the application of these principles.

2. In considering the application of conductors for the protection of buildings, it should be understood that the terminating plane of the action of lightning is sometimes beneath the surface of the ground; where, from the presence of moisture, the earth forms a good medium for the diffusion of electricity.

3. Light, dry soil, such as shingle and sand, or even ordinary vegetable soils when in a dry condition, may, for the present purpose, be regarded in most cases as non-conducting matter resting upon the electric surface of the earth.

4. Lightning conductors should therefore invariably be continued through these intervening substances into soil which is permanently damp.

5. Underground magazines are usually in dry soil, or soil rendered dry by careful drainage.

6. When large quantities of explosives are stored in underground magazines, such as the main magazine of a fort, they should be fitted with lightning conductors on the same principles as ordinary magazines above ground. The same rule holds good as regards underground magazines situated on prominent points, the top of a hill for example, under which circumstances like precautions should be taken.

7. Small expense magazines under ground need not, as a rule, be provided with lightning conductors.

8. Casemated batteries of modern construction, in which the magazines are distributed throughout the basement story, must be provided with lightning conductors.

9. The arrangements will vary with the plan and extent of the work; but it will generally be convenient to have one or two horizontal conductors on the parapet or terreplein, extending from end to end of the battery, attached to vertical conductors connected with the earth. The flagstaff should have a conductor, terminating in the truck, or a point above the truck, and in large works, several points, projecting 5 feet above the top of the building, must be provided. Iron verandahs and iron railings form good conductors when they are properly connected with the earth.

10. An iron building is, of itself, a good conductor, but when it is covered with non-conducting substances, such as asphalt and concrete, it is necessary to provide rods or points projecting above the asphalt, and in all cases there must be a proper connection with the earth. Iron shields in casemated works must be placed in connection with the conductors: this may be effected through the iron racers in their rear, or by means of horizontal bands, extending from one shield to another, externally.

11. Copper is recommended by the late Sir William Snow Harris as the best material for lightning conductors. It possesses great conductivity, is not liable to corrosion, and is very durable.

12. Where, however, conductors are exposed to mechanical injury or are liable to be stolen, and where attendant circumstances are not such as to promote corrosion, iron may be employed, using proportionately larger dimensions to provide for its smaller conductivity, which is only about $\frac{1}{3}$ th that of copper.

13. Copper lightning conductors should be of the following dimensions: rods $\frac{1}{2}$ inch in diameter, tubes $\frac{3}{4}$ inch in diameter and $\frac{1}{4}$ inch thick, or bands 1 $\frac{1}{2}$ inches wide and $\frac{1}{4}$ inch thick.

14. Iron lightning conductors should be either solid rods 1 inch in diameter, or bands 2 inches wide and $\frac{1}{4}$ inch thick.

15. In deciding upon the metal to be employed in any system of lightning conductors, the relative qualities of the two metals, copper and iron, must be weighed in connection with the circumstances of each particular case. Copper possesses higher conductivity, and is less liable to injury from corrosion, but it is very much more expensive, more liable to mechanical injury, and more likely to be stolen. Its fusing temperature (1994° Fahrenheit) is much lower than that of iron.

16. The fusing temperature of iron is 2786° Fahrenheit. In this respect it has a marked advantage over copper, but it readily becomes rusty, and when rusted its electrical resistance is immensely increased. Roughly speaking, an equal amount of conducting

power may be obtained in iron and copper for the same cost, the number of conductors purchasable for the same price in the former being far in excess of those in the latter metal, and in suitable positions the more numerous conductors would, no doubt, provide perfectly efficient protection.

17. In applying lightning conductors, the expansion and contraction of the metal must be provided for, especially at points where two lengths of metal are joined together.

18. This may be done by introducing suitable bends, at intervals, in long lines of horizontal conductor.

19. In vertical lines, and in some cases in horizontal lines, the effect of expansion and contraction may be sufficiently provided against by giving freedom to slip through the bearing collars.

20. Soldered or welded joints are not absolutely necessary, but they should be employed where practicable.

21. The joints hitherto used in the Royal Engineer Department, under the recommendation of the late Sir William Snow Harris, shown in Plates IIa., IIb., IIIa. and IIIb., attached hereto, should be adopted for copper conductors where soldered joints cannot be employed.

22. Soldered or welded joints should be employed in all positions where the brush or discharge, which might occur with unsoldered joints, would be liable to ignite dust or any inflammable substance.

23. Iron rods may be welded or connected by joints, similar to those recommended for copper conductors, or by screw junctions such as are used in forming the connections of gas-pipes, the end of the rod inserted into the socket being equal in length at least to its diameter, but no white lead, which is a bad conductor of electricity, should be made use of in the joints. (See Plate IVa., IVb. and IVc., attached hereto.)

24. Flat iron bands, where welding is not considered advisable, may be connected by rivets or screws working in slots to allow for expansion and contraction; each of the surfaces in contact should be of at least six times the sectional area of the band.

25. Copper bands should be connected by rivets or screws working in slots, and with similar precautions as to the area of the surfaces in contact. Joints between different metals may be soldered, screwed, or riveted, the extent of the surfaces in contact being regulated by the dimensions of the metal possessing the least conducting power. In all cases of contact between two metals, precautions should be taken to prevent access of moisture, which would induce local galvanic action with its attendant metallic decomposition.

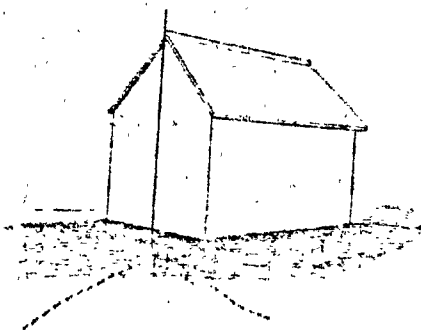
26. It is not possible to assign the precise limits of the protecting power of conductors. The French philosophers formerly considered that they afforded protection over a circle whose radius was equal to twice their height; but in England, the limit is usually considered the radius of their height from the ground. This may be sufficiently correct for all practical purposes; but such a radius of protection cannot always be relied upon.

27. Conductors of themselves have no attraction for lightning, which seeks them only on account of the facility they afford for the combination of the opposed states of the electricity of the clouds and of the earth beneath them, separated by the atmosphere which is a bad conductor. A lightning conductor, buildings, trees, or any object on the surface of the earth, is only to be regarded as diminishing the resistance due to the air. When an electrified cloud is passing over the earth and its potential is just counteracted by the resistance of the air, a body, however small, which reduces this resistance, will cause a discharge. Even a change in the nature of the soil over which the cloud is passing may have this effect, and it is very frequently produced by a fall of rain.

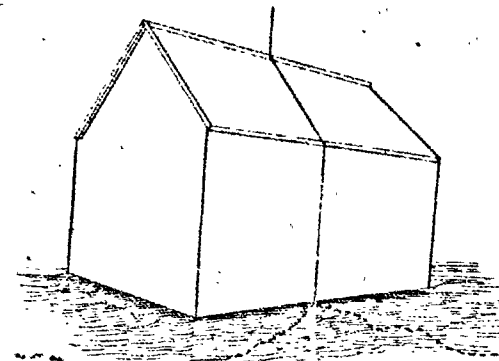
28. From this we may conclude that the angle of a building which a thundercloud approaches, may receive the discharge, while another but more distant angle is provided with a conductor; and that for important buildings containing explosive materials, every prominent elevated part ought to be provided with a lightning conductor.

29. For a building of uniform height, a solid rod, pointed and rising not less than five feet above it, should be provided at each end, and at intervals of about 15 yards along its length. When the rod is of iron, its point should be gilt.

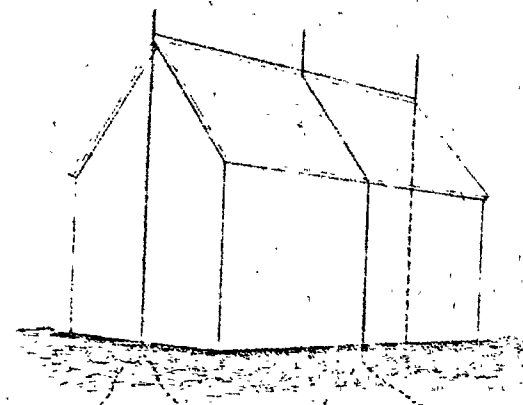
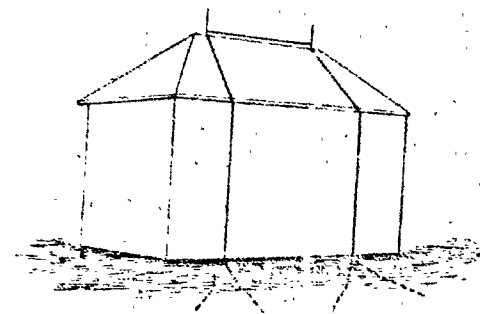
30. Small simple buildings, not exceeding 20 feet in length, may be protected by one vertical conductor at the end, the point rising not less than five feet above the ridge of the roof; a horizontal conductor should be provided on the ridge.



31. A building from 20 feet to 40 feet long should be protected by one vertical conductor in the centre of its length, with a horizontal conductor on the ridge.



32. A building exceeding 40 feet in length should have two, and if exceeding 100 feet in length, three conductors.



33. Larger and more complicated buildings should be protected upon similar principles, as shown in Plate I., attached hereto.

34. A fork, or brush of three or four points instead of one, has been recommended for the top of a lightning conductor; the practical value of this arrangement is not apparent unless the points are widely separated; but for a single rod on a prominent point, this construction may be adopted. All parts of buildings which are of marked elevation and prominence should be fitted with a lightning conductor.

35. Where several lightning conductors are used in a single building, they should be connected horizontally. Such connection may be conveniently effected along the ridge or eaves. When the ridge covering or eaves gutters are of metal, they should invariably be connected with the system. All metal surfaces, whether lead, copper, or iron, in ridges, roofs, gutters, or coverings to doors or windows, shall be connected with the conducting system.

36. The relative conductivity of the ordinary metals used in building, is given by the late Sir William Snow Harris, as follows:—

Lead.	Tin.	Iron.	Zinc.	Copper.
1	2	2½	4	12

Lead, on account of its low conducting power, cannot be altogether depended on, and this must be carefully considered in connecting the lead, used in a building, to the system.

37. Long lengths of horizontal conductor, without sufficient intermediate earth connections, must be avoided. Should there be any failure of continuity in such a conductor without intermediate earth connections, the current might leave the conductor and pass to earth by the most favourable course, and this would be attended with danger. Sharp angles in conductors are objectionable.

38. Good earth connections are most important. Any fault in the earth connection itself manifestly impairs efficiency, and a very bad earth connection is a source of absolute danger. Lightning conductors should, where practicable, be led into springs or wells of water, or into ground which is permanently wet. The sea or any large body of water, except a watertight tank, forms an excellent earth connection. Shingle, dry sand, or ordinary vegetable mould in a dry condition, are not efficient connections, and lightning conductors should invariably be led through these into ground that is permanently damp. Several earth connections should always be provided in all large systems of lightning conductors, so that, should one be defective, the discharge may be effected through the others.

39. Conductors should be led into moist ground, by means of a trench or trenches extending to a depth of at least 18 inches below the surface, and in which a length of not less than 30 feet of metal should be in actual contact with moist earth.

40. Where practicable, it is desirable to lead a flow of water, from the down pipes from the roof, over the ground in the vicinity of the lightning conductors and earth connections.

41. Where a lightning conductor terminates in rocky, or more or less dry soil, special precautions are necessary: it should be led into a trench, so disposed as to obtain all the moisture possible from the ground. These trenches should extend from its foot to distances of from 10 to 40 yards, according to the amount of moisture.

42. The connections in the trenches may be of railway or other old iron formed into a continuous metallic surface, the trenches being filled up with cinders or coal ashes, and the water from the down pipes being led over them as already recommended. Water-pipes form excellent earth connections, but gas-pipes should never be used for this purpose, instances having occurred where a heavy lightning discharge has damaged the gas-pipes and lit the gas.*

43. Lightning conductors should be frequently inspected, to ascertain that they are in perfect condition and properly connected with the earth. Particular attention should be paid to the joints, especially when they connect different metals.

44. The state of the conductors should be noticed in the Inspectional Reports, in which the efficiency or otherwise of all joints and earth connections, and the extent of oxidation of iron conductors should be distinctly specified. It must be borne in mind that in the case of an iron rod or band, the metallic portion only can be looked upon as efficient, oxide of iron being a very inferior conductor.

45. In order to obviate the ill effects of rust, iron employed in the construction of lightning conductors should be galvanized.

46. When galvanized iron is used, particular care should be taken to see that the coating of zinc covers the conductor thickly and effectively; damp would produce galvanic action, and the zinc in the vicinity of the smallest exposed iron surface would be quickly decomposed.

47. Should it be necessary to bring the zinc coating in contact with other metals, and especially with copper, every precaution should be adopted to exclude moisture, for the above reason.

WAR OFFICE,

6th April, 1875.

FRED. E. CHAPMAN,

Inspector-General of Fortifications.

* A remarkable accident of this nature occurred at Halifax, Nova Scotia, in the Summer of 1871, during a heavy thunderstorm, the electric discharge, in traversing the gas-pipes of the old Provincial Buildings, fused a portion which was composed of white metal composition, near the metre in the basement, and lit the gas, by which the buildings were nearly set on fire.

The popular objections to Lightning Conductors on the ground that they invite Lightning to the building, that we do not know the quantity of electricity in the clouds, and that hence they may cause destruction, are now quite untenable, and have only arisen out of a want of knowledge of the nature of electrical action. What should we think of a person objecting to the use of gutters and rain-pipes for a house, on the ground of their attracting or inviting a flow of water upon the building; and since we do not know the amount of rain in the clouds, it is possible that the building may be thereby inundated, yet such is virtually the argument against Lightning Conductors.*

11. It follows from the foregoing principles, that a magazine constructed entirely of iron or other metal, would be infinitely more safe on lightning atoms than if built with masonry in the usual way: and the rest for magazines, with capacious metallic Conductors to the earth, would be unobjectionable, and a source of security.

Metallic spitters and ridges having continuous metallic connection with the earth are also unobjectionable.

A good method of Conductors for magazines built of masonry, would be such as already described (7), regard being had to the position of the building, its extent, and most prominent points, also to the nature, state, and condition of the soil, whether it be moist or dry, alluvial, calcareous, or of hard rock; we must also consider the extent, disposition, and peculiar position of the metallic bodies entering into the general structure of the building, whether the roof be flat, or pointed, or angular in various parts.

The pointed projecting extremities of the Conductors, one or more in the case may be, will be commonly sufficient; but, in buildings having tall chimneys or other elevated prominent points, at a distance from the Main Conductor, it will be requisite to ground such chimneys or other parts by a pointed rod, led along the side of the metal of the roof, or directly connected with the Main Conductors, by metallic connections.

[illegible]

12. Pointed terminations of the Conductors in the air are so far important that they tend to break the force of a discharge of Lightning when it falls on them. In fact, before the great shock actually takes place, under the form of a dense explosion, a very large amount of the discharge, which otherwise would be concentrated, runs off, as it were, through the pointed Conductor; but they have no other influence.*

With respect to these pointed terminations, no great care need be taken about them, except that they should consist of solid copper rod of about three-quarters of an inch in diameter and about a foot in length, and be united by brazing to the conducting tube, elevated at such convenient height above the walls of the building as the nature of the case may suggest.

As a support to the Conductor, when raised above the wall, we may employ a small staff or spar of wood fixed to the masonry.

It has been occasionally the practice to gild the points of Lightning Conductors, or make them of platinum, or otherwise bestow an extraordinary amount of care on perfecting the point, all of which is not only unnecessary but in some instances detrimental to the action of the Conductor; if, for example, the Conductor be constructed of copper (a metal of high conducting power), then it would be manifestly prejudicial to terminate it in a platinum point, platinum being a metal not having one-half the conducting power of copper.

Much has been said relative to the oxidation of the surface of the metal, but this is of very little moment to the line of conduction, and, in the case of copper, it is trifling. Under any circumstances the metallic oxide is better than the bad or non-conducting air, which is always in contact with the surface of the metal; besides, we observe that in many cases the wires of the Electrical Telegraph transmit currents of electricity with perfect freedom, even when enclosed in gutta-percha or other non-conducting matter.

With respect then to the point—it will be sufficient if the terminating solid rod be roughly pointed; almost any termination of the Conductor, even if a ball, a foot in diameter, would be virtually a point when opposed to a thousand acres of charged clouds.

13. Copper linings to the doors and window-shutters of magazines are not objectionable, if requisite, as a precaution against fire; but they are useless as a means of keeping out lightning; on the other hand, it is not easy to conceive a case in which the explosion of the gunpowder is to be apprehended from the action of Lightning on the doors or windows; supposing, however, such metallic linings desirable as a precaution against common cases of fire, then the masses of metal should, according to the principles already laid down (7) have metallic communication with the general system of conduction in the building and the Main Conductor.

* A pointed Conductor has been supposed to protect by attraction over a circular area, equal to twice the radius of its elevation, which is a pure piece of hypothesis contradicted by experience, *e. g.*, ships have been struck and damaged by Lightning on the foremast, a pointed Conductor being upon the mainmast.

The popular objections to Lightning Conductors on the ground that they invite Lightning to the building, that we do not know the quantity of electricity in the clouds, and that hence they may cause destruction, are now quite untenable, and have only arisen out of a want of knowledge of the nature of electrical action. What should we think of a person objecting to the use of gutters and rain-pipes for a house, on the ground of their attracting or inviting a flow of water upon the building; and since we do not know the amount of rain in the clouds, it is possible that the building may be thereby inundated, yet such is virtually the argument against Lightning Conductors.*

11. It follows from the foregoing principles, that a magazine constructed entirely of iron or other metal, would be infinitely more safe in lightning storms than if built with masonry in the usual way; and the fact that iron magazines, with capacious metallic Conductors to the earth, would be undisturbable, and a source of security.

Metallic gutters and ridges having continuous metallic connection with the earth are also undisturbable.

A good method of Conductors for magazines built of masonry, would be such as already described (7), regard being had to the position of the building, its extent, and most prominent points, also to the nature, state, and condition of the soil, whether it be sand or clay, alluvial, calcareous or of hard rock; we must also consider the extent, disposition, and peculiar position of the metallic bodies entering into the general structure of the building, whether the roof be flat, or pointed, or angular in various parts.

The pointed projecting extremities of the Conductors, one or more as the case may be, will be commonly sufficient; but, in buildings having tall chimneys or other elevated prominent points, as a precaution from the Main Conductor, it will be requisite to lead such chimneys or other parts by a pointed rod, led along from the metal of the roof, or directly connected with the Main Conductors, by metallic connections.

It has been recommended to place Lightning Conductors some feet distant from the buildings, or otherwise separate them from the walls by glass or resin; all this is clearly opposed to the principle upon which the Conductors are applied; we should not place a rod in 10 feet distant from a house if we wish to carry off run from the roof. A lamentable result of the practice of placing Lightning Conductors distant from a building recently occurred at Exmouth Lodge, in Jamaica, the residence of J. Kenne, Esq. A lightning rod, of small dimensions of iron, had been set up within 10 feet of the south-east angle of the building, as practiced frequently in cases of Gunpowder Magazines, on the supposition that the Rod would attract the Lightning, and secure the building. So far from this, the building itself was struck in a heavy thunder-storm, 25th July 1867. The south-east angle first was shattered in pieces; the escape of the family appears to have been miraculous; whilst the Lightning Rod, 10 feet distant, remained untouched. If this building had been a deposit of Gunpowder, it would certainly have blown up.

To detach or insulate the Conductors is to run away from our own principle, which is, that the Conductor is the channel of communication with the ground, in which the electrical discharge will move in preference to any other course. To detach or insulate the Conductor, is to provide for a contingency at once subversive of our principle. It is possible to conceive that an agency which can rent large rocks and tract break down perhaps a mile of dense air, and lay the mast of a ship weighing 10 tons in ruins, is to be arrested in its course by a ring of glass or pitch, an inch thick or less, supposing its course were from any cause determined in that direction?

12. Pointed terminations of the Conductors in the air are so far important that they tend to break the force of a discharge of Lightning when it falls on them. In fact, before the great shock actually takes place, under the form of a dense explosion, a very large amount of the discharge, which otherwise would be concentrated, runs off, as it were, through the pointed Conductor; but they have no other influence.*

With respect to these pointed terminations, no great care need be taken about them, except that they should consist of solid copper rod of about three-quarters of an inch in diameter and about a foot in length, and be united by brazing to the conducting tube, elevated at such convenient height above the walls of the building as the nature of the case may suggest.

As a support to the Conductor, when raised above the wall, we may employ a small staff or spar of wood fixed to the masonry.

It has been occasionally the practice to gild the points of Lightning Conductors, or make them of platinum, or otherwise bestow an extraordinary amount of care on perfecting the point, all of which is not only unnecessary but in some instances detrimental to the action of the Conductor; if, for example, the Conductor be constructed of copper (a metal of high conducting power), then it would be manifestly prejudicial to terminate it in a platinum point, platinum being a metal not having one-half the conducting power of copper.

Much has been said relative to the oxidation of the surface of the metal, but this is of very little moment to the line of conduction, and, in the case of copper, it is trifling. Under any circumstances the metallic oxide is better than the bad or non-conducting air, which is always in contact with the surface of the metal; besides, we observe that in many cases the wires of the Electrical Telegraph transmit currents of electricity with perfect freedom, even when enclosed in gutta-percha or other non-conducting matter.

With respect then to the point—it will be sufficient if the terminating solid rod be roughly pointed; almost any termination of the Conductor, even if a ball, a foot in diameter, would be virtually a point when opposed to a thousand acres of charged clouds.

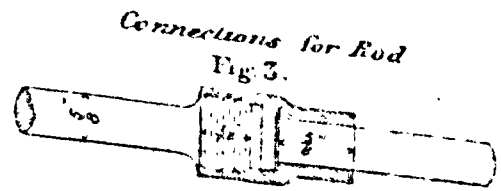
13. Copper linings to the doors and window-shutters of magazines are not objectionable, if requisite, as a precaution against fire; but they are useless as a means of keeping out lightning; on the other hand, it is not easy to conceive a case in which the explosion of the gunpowder is to be apprehended from the action of Lightning on the doors or windows; supposing, however, such metallic linings desirable as a precaution against common cases of fire, then the masses of metal should, according to the principles already laid down (7) have metallic communication with the general system of conduction in the building and the Main Conductor.

* A pointed Conductor has been supposed to protect by attraction over a circular area, equal to twice the radius of its elevation, which is a pure piece of hypothesis contradicted by experience, e. g., ships have been struck and damaged by Lightning on the foremast, a pointed Conductor being upon the mainmast.

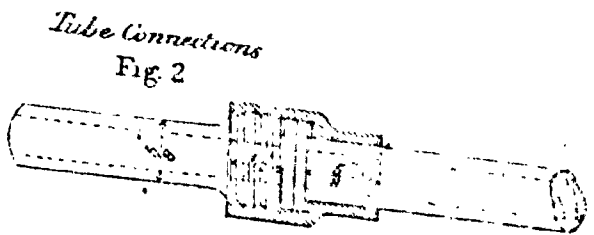
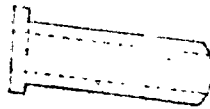
LIGHTNING CONDUCTORS CONNECTIONS FOR COPPER CONDUCTORS Scale: Half Size



Corner Connections
Fig 1.



Connections for Rod
Fig 3.



Tube Connections
Fig 2

N.B. Soldered Joints are always to be preferred where practicable.

APPENDIX B.

SUPPLEMENTARY PAPER.

Lightning Conductors for Magazines and other Buildings.

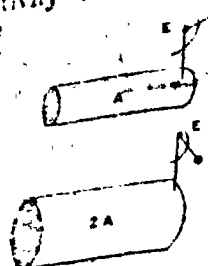
1. Whether a hollow or solid Conductor be the more desirable, the quantity of metal being the same?

This question has been usually considered in relation to the heating effects of an electrical discharge upon comparatively small Conductors, in which the resistance to the discharge is considerable. In this case a given quantity of electricity melts the same quantity of metal, under whatever form it be placed, whether as a solid or a hollow cylinder for example; at least such is to be inferred from the experiments hitherto continued. See a paper by Mr. Snow Harris, *Phil. Trans.* for 1812, on Conductors of Electricity, &c., last four paragraphs. In this case it is immaterial whether the Conductor be solid or hollow, provided the mass be the same.

Another and very important view, however, is to be taken of this question, as being applicable to a case in which the mass of metal is considerable, and the heating effect so small as to admit of being neglected; in this case the resistance of the mass, as a conductor, is not considerable; such a case as this brings us to the consideration of certain statical laws of Electrified Conductors; since for an enormous portion of time, during which a shock of Lightning traverses a Lightning Conductor, we may consider the Conductor as being more or less charged with electricity, tending to pass in a given direction, — viz. the direction of the Conductor.

Now it is proved, that in a case of this kind, the greater the extent of surface over which the Electricity can expand, the less the intensity or activity in any one point; in fact the intensity approaches the second power or square of the surface inversely, so that a given quantity of Electricity, disposed on twice the extent of surface, has only one-fourth the activity or intensity, whilst twice the quantity on the same surface has four times the activity considered in any one point. Take, for example, two Conductors, A and $2A$, whose surfaces are 1 and 2, or $2A$ double the surface of A ; let the charges be the same if you wish.

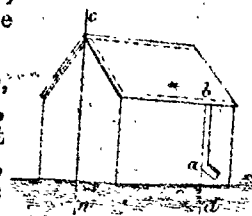
Then if a given quantity of Electricity be disposed on, or pervade the smaller surface A , an electroscope E will evince a high intensity, and will stand out violently as it were; whereas the same quantity disposed on $2A$ will repose with as much more quietude on the double surface, that the electroscope E will evince but little comparative action. See *Phil. Trans.* for 1834, page 220, for the laws of this action.



It is hence important to give the charge free room of expansion by increasing the surface of the Conductor, so as to reduce the mechanical activity of the shock, considered as an evanescent charge to the least possible. This question is still open to much valuable investigation; a large number of facts might be quoted bearing on it.

Rectangular flat bars may be employed, if found convenient for attaching to the walls of a building.

2. In the case of a Rain-Pipe, $a b$, communicating with the Main Conductor, $c n$, it would be certainly proper to connect it (the pipe) by a metallic communication, $a d$, with the ground, on the principles above explained; it admits of a certain quantity of the charge expanding into a general surface of conduction to the earth as explained in preceding papers.



REMARK.—All those substances termed imperfect Conductors, such as the masonry of a building, a ship's mast, &c., are nevertheless Conductors to a certain extent; they will always be able to transmit a given quantity of Electricity without explosive action. In any case of a ship or building struck by lightning, doubtless some Electricity always passes off in this way up to the limit of conducting power; one great end of the Conductor is to relieve the wood or masonry of the quantity it cannot discharge without explosion; by thus completing the conducting power of the general mass we use up, as it were, in connection with the Conductors, all the useful conduction of the wood of a ship's mast or the masonry of a building, and so convert into a source of safety what would otherwise be inefficient to the security of the building; all this is consistent with principles before explained, relative to resistance.

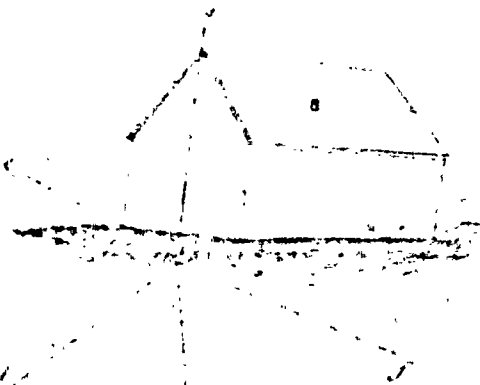
3. Whether Conductors of iron may not be employed for buildings, copper being expensive and liable to be stolen, &c.?

The common conductors of small iron rod or wire are very objectionable, they commonly rust out at the joints, and have fallen to pieces and have been often knocked in pieces by Lightning. If iron be employed, which it certainly may be, and with advantage, it should be coated with zinc, a modern practice, or what is called "*galvanized*." Zinc is even a better Conductor than iron, and being spread over the surface, would not be open to the objection of making a Conductor of two metals of unequal conducting powers; in the case of the charge being constrained to pass out of the one into the other, in continuation, as for example out of a into b , zinc has one-third the conducting power of copper; iron has only about one-fifth the conducting power of copper.

Where the Conductors are capacious as respects the intensity of the shock, and are not heated sensibly, the transmission of the charge, as a question of mere conduction, approaches a ratio of equality; in heavy shocks of Lightning the differences are important.

Still, there is no doubt but that a good and efficient Conductor might be formed of galvanised iron;* it should be wrought-iron, and the best form would be galvanised iron pipe of two inches diameter, firmly screwed together, in joints of extra thickness, as in certain gas pipes; copper tubing of a given thickness, however, is always to be preferred.

6. In the case of a dry or rocky soil, it is certainly desirable to complete, so far as possible, the conducting power of the ground about the building, either by leading old iron chain out from the walls in several directions, or by leading a flow of water over it if possible; the distance and direction of such artificial ground conduction must depend on circumstances of situation of the building. The surface of the earth being, as remarked in former paper, one of the terminating planes of the electrical action; the indication is to provide, so far as possible, for the expansion of the final shock passing through the Conductor, without which the Conductor is more or less insulated. Fortunately a thunder-storm is usually attended by heavy rain.



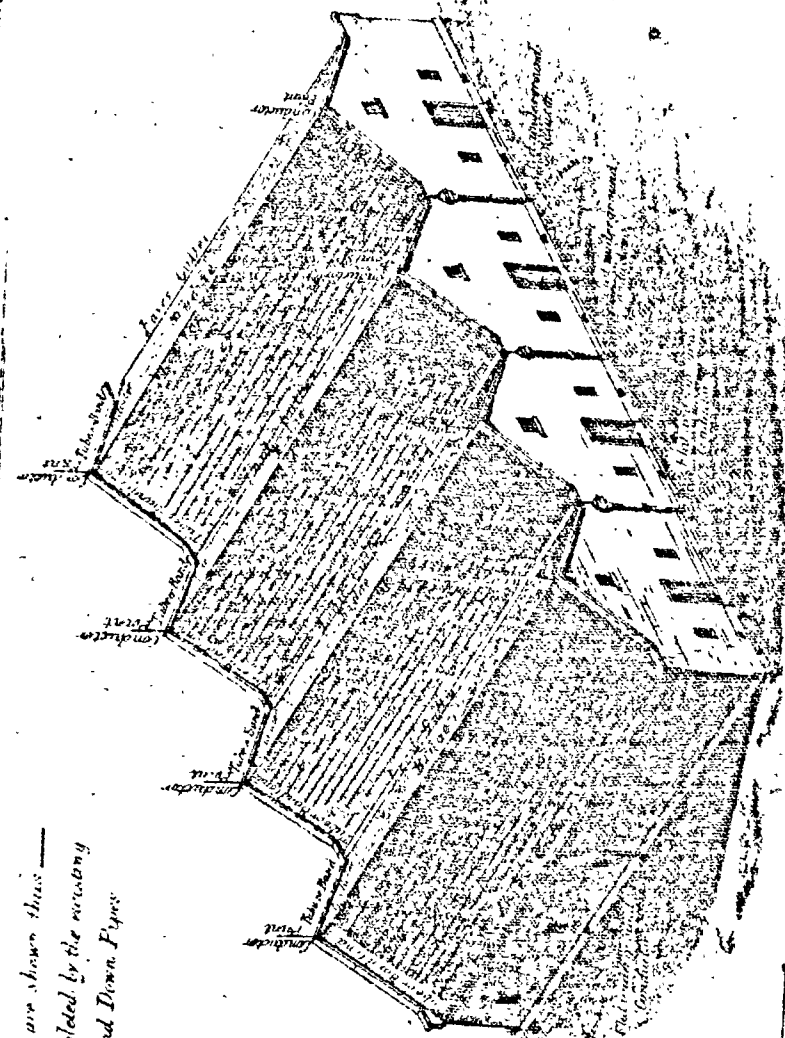
In the case of a Building, B, on a dry or rocky soil, old iron chains, *b c*, *b d*, *b e*, &c., may be let out from Conductor *a b*, in various directions, to the extent of about 10 or 15 yards, and from a foot to eighteen inches under the surface of the earth, and it would be further desirable, in such cases, to lead a flow of rain, so far as possible, over the surface of the ground about or near the Conductor; the termination of the Conductor in a large surface of moist earth would be even preferable to its termination in a spring of water, sunk deep, as in a well, into the ground; the action here is a superficial action of expansion in all directions. We see in the tin leaf coatings of the electrical jar, that the charge is in no degree influenced by the thickness of metal.

W. SNOW HARRIS.

* Experience is not wholly in favour of the durability of the galvanised coating iron.

Plate I.

LIGHTNING CONDUCTORS.
GENERAL ARRANGEMENT FOR THE PROTECTION OF A MAGAZINE OR LARGE BUILDING

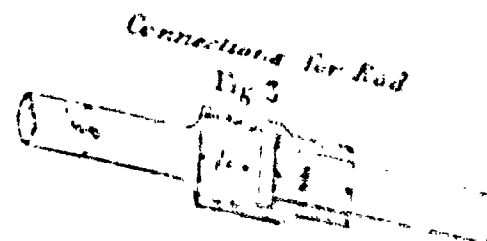


N.B. The Conductors are shown thus —
The system being completed by the existing
Copper Flues Gutter and Down Pipes

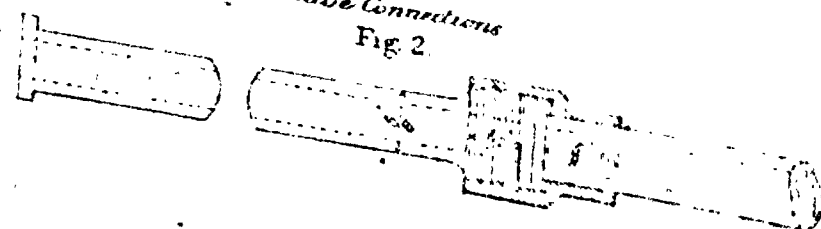
LIGHTNING CONDUCTORS CONNECTIONS FOR COPPER CONDUCTORS Scale Half Size.



Corner Connection
 Fig 1.



Connections for Rod
 Fig 3



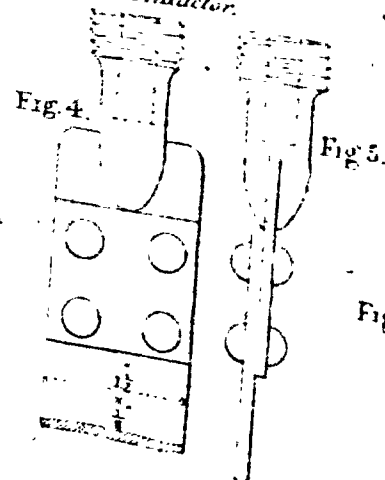
Tube Connections
 Fig 2.

N.B. Soldered Joints are always to be preferred where practicable

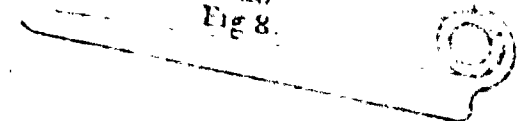
LIGHTNING CONDUCTORS. CONNECTIONS FOR COPPER CONDUCTORS Scale Half Size.

Plate 116

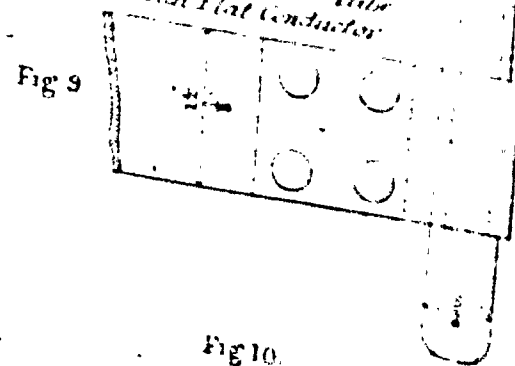
Connection of Flat
 with Tubular
 Conductor.



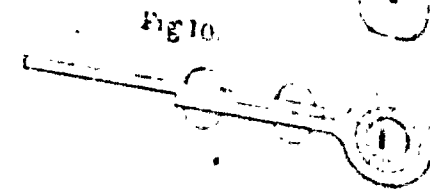
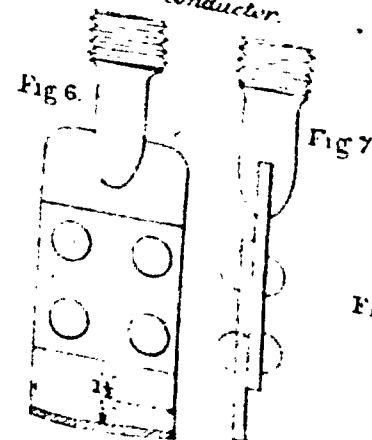
IL-Drast
 Fig 8.



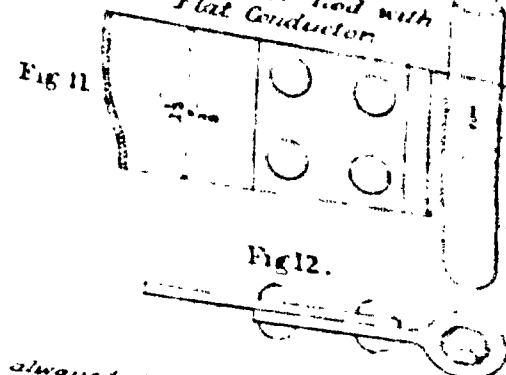
Connection of Tube
 with Flat Conductor



Connection of Flat with
 Rod Conductor.



Connection of Rod with
 Flat Conductor

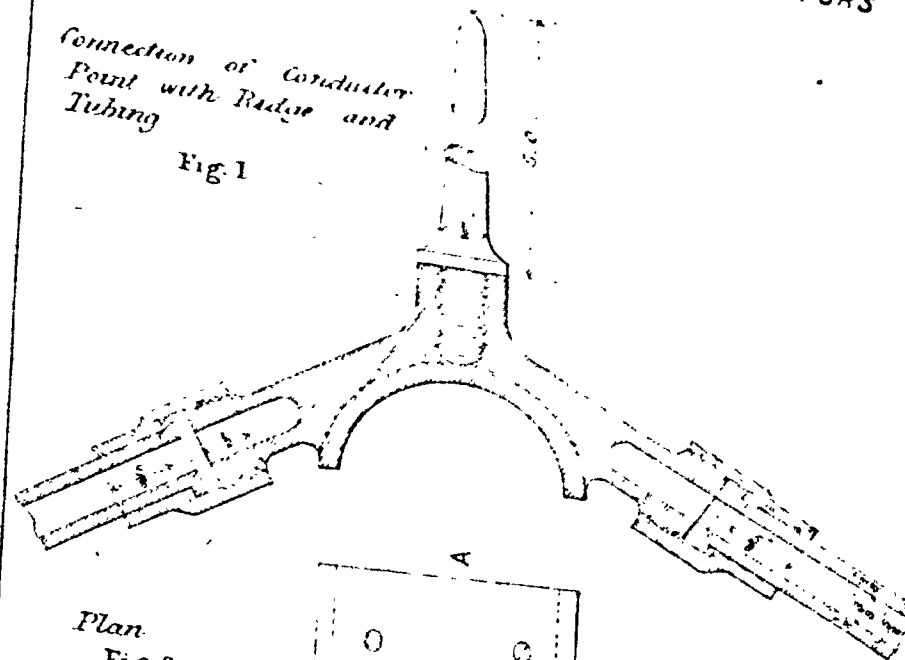


N.B. Soldered Joints are always to be preferred where practicable.

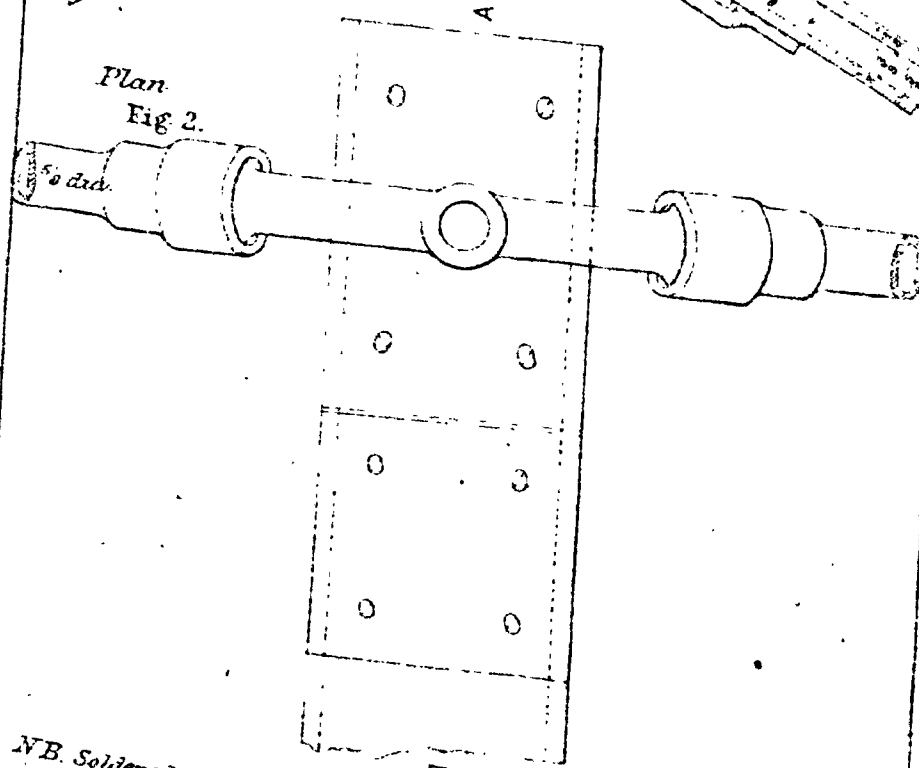
LIGHTNING CONDUCTORS. RIDGE CONNECTIONS FOR COPPER CONDUCTORS Scale Half Size

Connection of Conductor
Point with Ridge and
Tubing

Fig. 1



Plan
Fig 2.

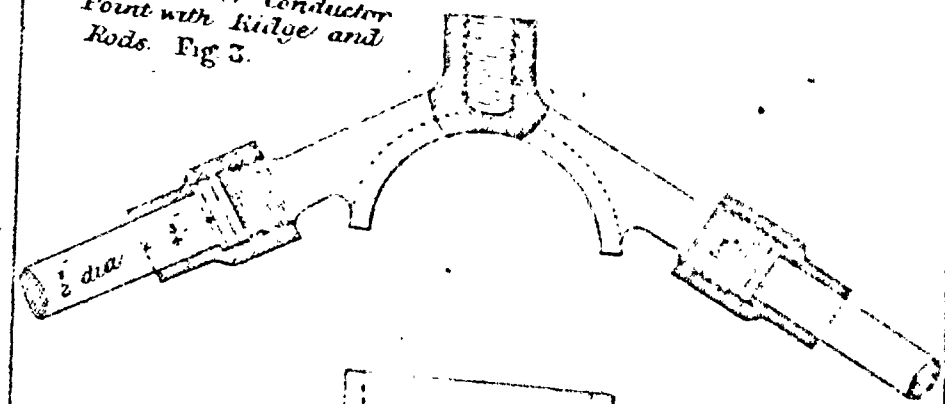


NB. Soldered Joints are always to be preferred where practicable

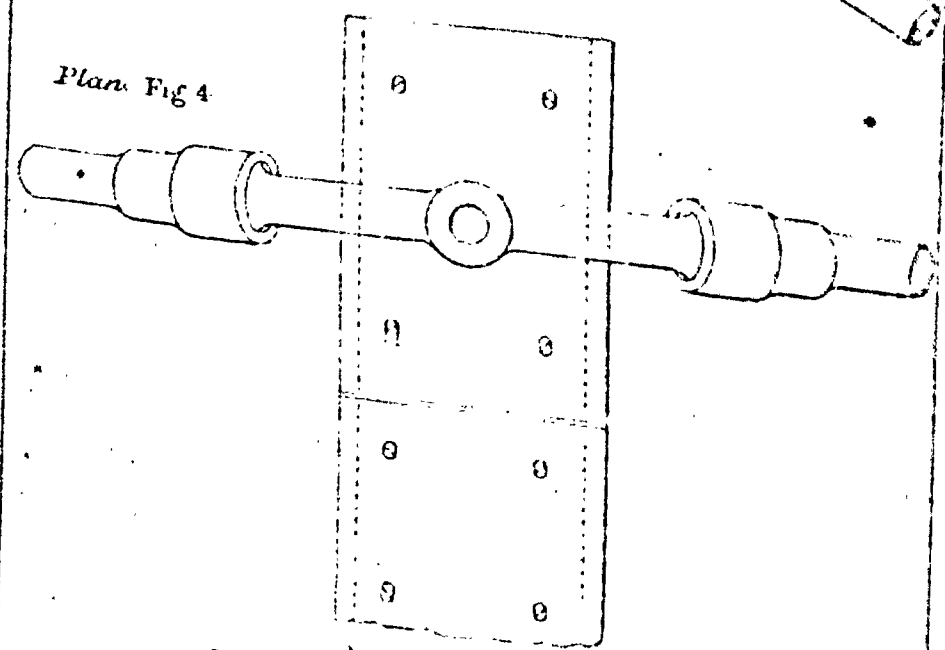
L.F.H.S. P.W.O. 7.1.78

LIGHTNING CONDUCTORS RIDGE CONNECTIONS FOR COPPER CONDUCTORS. Scale, Half Size.

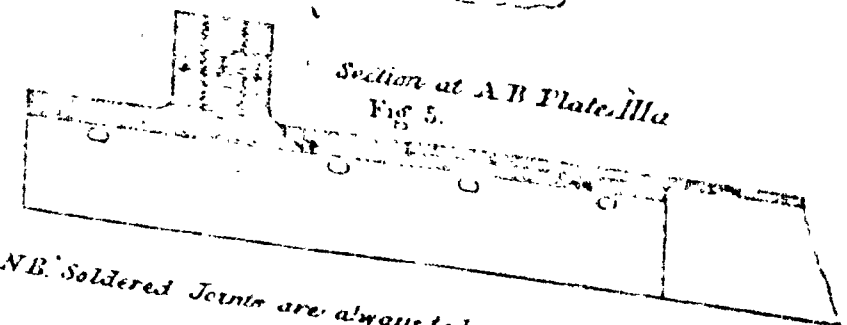
Connection of Conductor
 Point with Ridge and
 Rods. Fig 3.



Plan Fig 4



Section at A B Plate IIIa
 Fig 5.



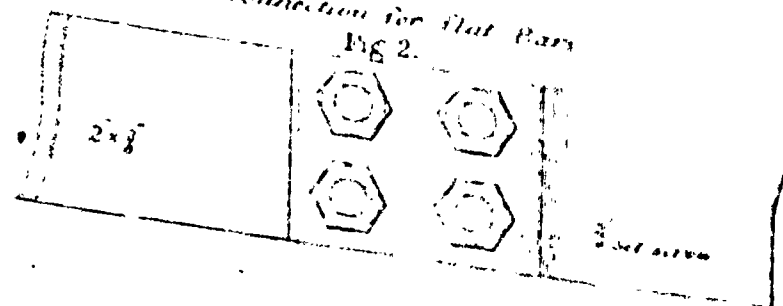
N.B. Soldered Joints are always to be preferred where practicable.

LIGHTNING CONDUCTORS CONNECTIONS FOR IRON CONDUCTORS Scale, Half Size Expansion Joint

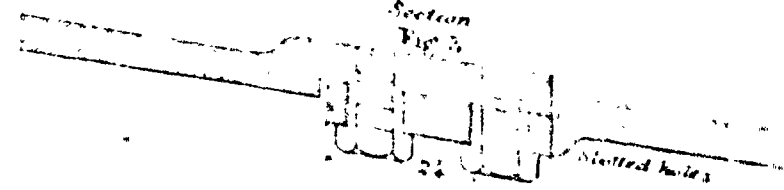
Fig. 1



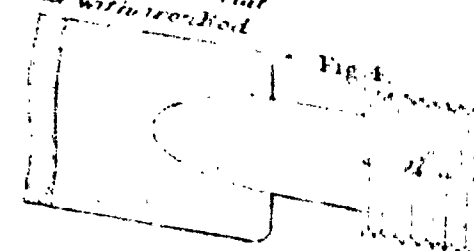
Connection for Flat Bars
 Fig. 2.



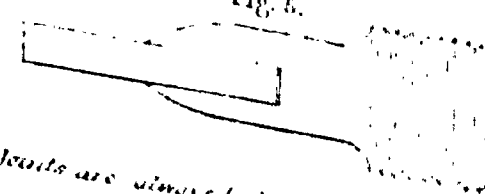
Section
 Fig. 3.



Connection for Flat
 Bar with treacher
 Fig. 4.



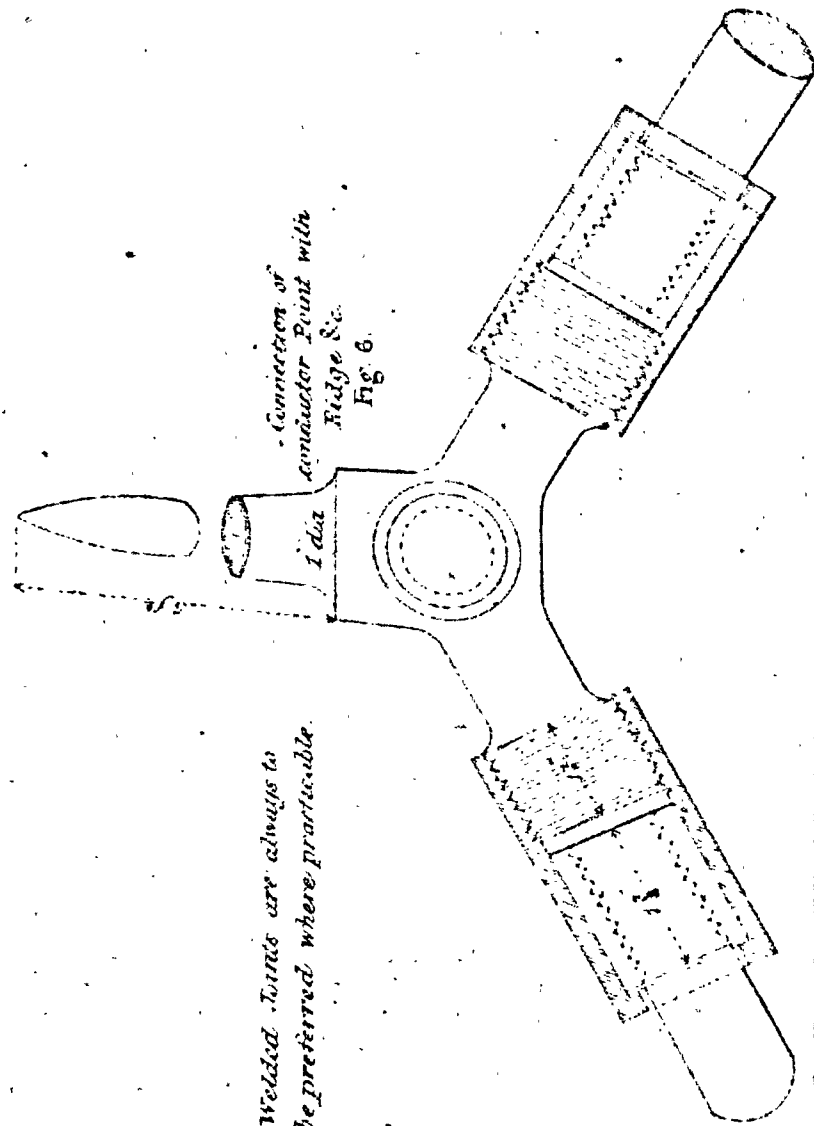
Side View
 Fig. 5.



N.B. Welded Joints are always to be preferred where practicable

LIGHTNING CONDUCTORS.
CONNECTIONS FOR IRON CONDUCTORS.

Scale, Half Size.



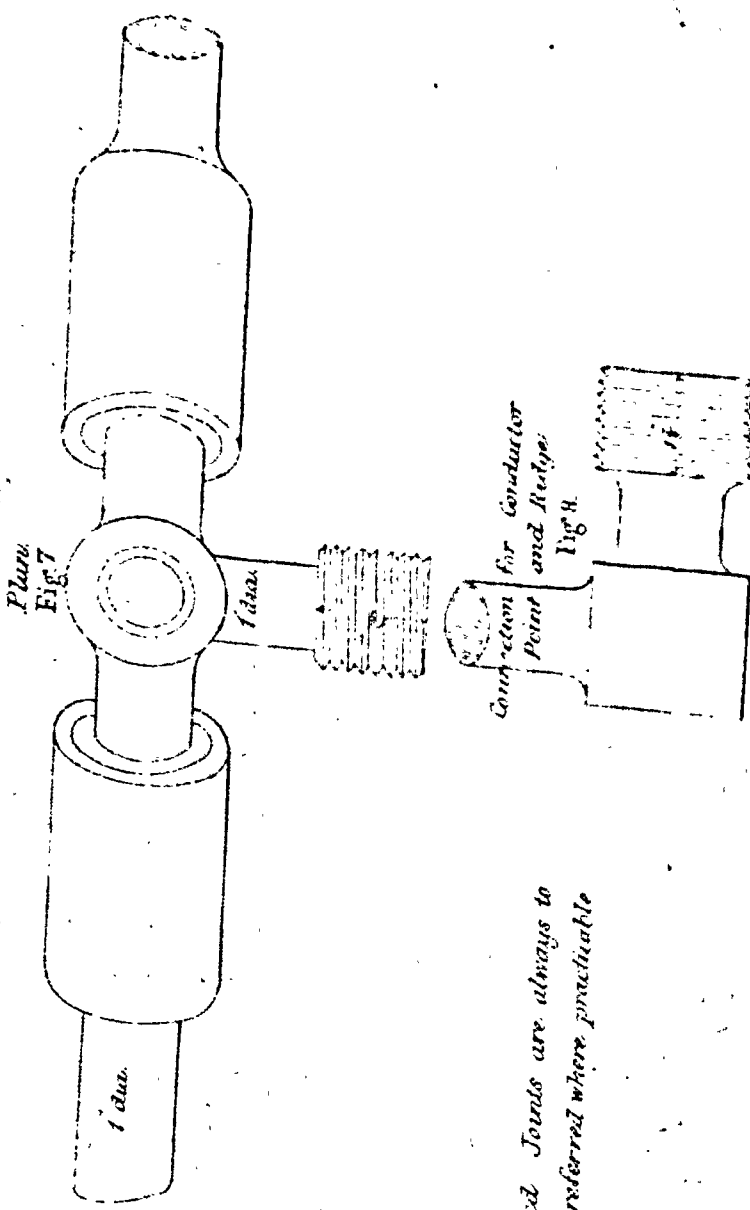
W.B. Welded Joints are always to be preferred where practicable.

ENGINEERING AND ROAD
CIVIL WORKS.

Plate No.

LIGHTNING CONDUCTORS.
CONNECTIONS FOR IRON CONDUCTORS.

Scale: Half Size.



N.B. Welded Joints are always to be preferred where practicable

ES AND
ER AND
IA
IAN AND

1877.

e under-
ssued by
nductors

E.,
India.

L. Brander.

ENGINEERING AND ROAD
CIVIL WORKS

Circular No. 74 Public Works.
GOVERNMENT OF INDIA.
PUBLIC WORKS DEPARTMENT.
CIVIL WORKS.
Miscellaneous.

To

THE GOVERNMENTS OF MADRAS, BOMBAY, BENGAL, NORTH-WESTERN PROVINCES AND
ODDH, IN THE PUBLIC WORKS DEPARTMENT, GENERAL BRANCH.
THE CHIEF COMMISSIONERS, CENTRAL PROVINCES, BRITISH BURMAH, MYSORE AND
COORG, AND ASSAM.
THE RESIDENT AT HYDERABAD.
THE AGENT TO THE GOVERNOR GENERAL FOR CENTRAL INDIA AND RAJPOOTANA.
THE SUPERINTENDENT OF PORT BLAIR, AND CHIEF COMMISSIONER, ANDAMAN AND
NICOBAR ISLANDS.
THE INSPECTOR GENERAL OF MILITARY WORKS.
THE PRINCIPAL, THOMSON COLLEGE.
THE DEPARTMENT OF REVENUE, AGRICULTURE AND COMMERCE.

Fort William, December 19, 1877.

In continuation of Circular No. 66 P W of the 7th ultimo, the under-
signed is directed to forward, for information, copy of "Instructions," issued by
the British War Department, regarding the application of Lightning-conductors
for the protection of Powder Magazines and other buildings.

Ray D. K. Smith Captain, R. E.,
Asstt. Secy. to the Govt. of India.

To, the Secretary to the Govt. of Madras.
P. W. Department, General Branch.

GOVERNMENT OF INDIA.
PUBLIC WORKS DEPARTMENT.
CIVIL WORKS.
Miscellaneous.

To

The Governments of Madras, Bombay, Bengal, North Western Provinces and Oudh, in the Public Works Department, General Branch.
The Chief Commissioners, Central Provinces, British Burmah, Mysore and Coorg, and Assam.
The Resident at Hyderabad.
The Agents to the Governor General for Central India and Rajpootana.
The Superintendent of Port Blair, and Chief Commissioner, Andaman and Nicobar Islands.
The Inspector General of Military Works.
The Principal, Thomason College.
The Department of Revenue, Agriculture and Commerce.

Circular No. 74 Public Works.

Dated December 19, 1877.

Received

Forwards, for information, copy of "Instructions," issued by the British War Department regarding the application of Lightning-conductors for the protection of Powder Magazines and other buildings.

No. 659, P. W. D. Press-22-12-77-440.

All communications should be addressed to the Secretary.

No. 94
GOVERNMENT OF INDIA.
PUBLIC WORKS DEPARTMENT.

*Civil Works.
Miscellaneous.*

*To The Secretary to the Govt of Madras.
Public Works Department.*

Fort William, 13th March 1878.

Sir,

In reply to the request made in your letter No. 1076 of the 1st current asking to be supplied with 50 additional copies of the "Instructions" issued by the British War Department, regarding Lightning Conductors for protection of Powder Magazines, &c. forwarded with Public Works Department Circular No. 74 dated 19th December 1877, I am directed to say that there are no more spare copies available in this Office.

*I have the honor to be,
Your most obedt. servant,
F. J. S. Smith, Capt. R.E.
Asst. Secretary to the Govt of India.*

J.W.

1454 Wd 21st March 78
 Communicated to
 District Engineer
 for information and
 to the Military Dept.
 Gt. W. H.
 20-3-78

1.3.78 to 1076
 24-11-77 - 1749 W

1450
 D. Engineer
 Can be used with copies
 Can be used for instructions
 1 Dec 27-1-78
 1000

with order

No 1076 of 1 March 78

The Secy to the
 Govt of India

Sir

I have the honor
 to request that this Office
 may be supplied with
 50 additional spare
 Copies of the "Instructions"
 issued by the British
 War Dept. regarding
 Lightning Conductors for
 protection of Powder
 Magazines, &c, forwarded
 with your Circular
 No 74 Public Works of
 19 Dec 77

Gt. W. H.
 25-2-78

R.F.

15-7-06

1359/2401

Govt. of (1878) Madras.
PUBLIC WORKS.

To

Dated

Issued

Recd.

Encl.

G. O., 24 Mar 1878, No. 14871

J.C. - 21/1-78

Nos.

7 Murad No. 3896 clon

Application of lightning
conductors for the
of powder magazines &
other buildings -

Circular from the Govt.
of India forwarding
instructions issued by
the British War Dept.
for the - Comd: of Brit
mags and other buildings
Sept C.

Int. Secy

14546

17/18/78

(1) Number of pages 42
 (2) Date of repair 30-5-86
 (3) Initials of the Referencer low

TAMIL NADU ARCHIVES

GOVERNMENT OF TAMIL NADU

P. W. D. DEPARTMENT

G.O. No.	1, 454 W	Press.
B.P. No.		Mis.
Dated 21 - 3 - 1878 197		

Not to be folded or roughly handled

V.S.M.

GOVERNMENT OF MADRAS.
PUBLIC WORKS DEPARTMENT.

21st March 1878. No. 1,454 W.

Buildings and Roads.
Civil Works.

Read the following papers:—

No. 311. From the Assistant Secretary to the Government of India, Public Works Department, (Civil Works—Miscellaneous,) to the Secretary to the Government of Madras, Public Works Department, General Branch, dated Fort William, 19th December 1877, Circular No. 74, Public Works.

In continuation of Circular No. 66 P.W. of the 7th ultimo, the undersigned is directed to forward for information copy of "instructions" issued by the British War Department regarding the application of lightning conductors for the protection of powder magazines and other buildings.

(Signed) G. T. SKIPWITH, Captain, R.E.,
Asst. Secy. to the Govt. of India.

No. 311-A. From the same Officer, dated Fort William, 13th March 1878, No. 92 M.

In reply to the request made in your letter No. 1,076 of the 1st current, asking to be supplied with 50 additional copies of the "instructions" issued by the British War Department regarding lightning conductors for protection of powder magazines, &c., forwarded with Public Works Department Circular No. 74, 19th December 1877, I am directed to say that there are no more spare copies available in this office.

No. 312. ORDER THEREON, 21st March 1878, No. 1,454 W.

COMMUNICATED to District Engineers for information and to the Military Department.

(True Extract.)

(Signed) E. A. FOORD, Colonel, R.E.,
Secretary to Government, P.W.D.

(True Copy.)

Colonel,
Under Secy. to Govt., P.W.D.

To District Engineers,
To the Consulting Architect,
" Consulting Engineer for Railways, } with copies of instructions.
" Military Department.

Exd. B. C. Shanker.

Spare Copies

Cont. of 11878; *Public Works.*
PUBLIC WORKS.

ENGINEERS

Enclosure to P. W. D. Circular No. 74 Public Works.

[Issued with Army Circulars, dated 1st May, 1875.]

INSTRUCTIONS AS TO THE APPLICATION

OF

LIGHTNING CONDUCTORS

FOR THE

PROTECTION OF POWDER MAGAZINES
AND OTHER BUILDINGS.

Gen. No. 5.
236.

1. The principles on which buildings should be protected against lightning are set forth in Appendices A and B, which papers were drawn up by the late Sir William Snow Harris, F.R.S. These principles are still generally held to be sound, and should be carefully considered with reference to any system of lightning conductors. In consequence, however, of the progress of electrical science, some modifications are necessary in the application of these principles.

2. In considering the application of conductors for the protection of buildings, it should be understood that the terminating plane of the action of lightning is sometimes beneath the surface of the ground; where, from the presence of moisture, the earth forms a good medium for the diffusion of electricity.

3. Light, dry soil, such as shingle and sand, or even ordinary vegetable soils when in a dry condition, may, for the present purpose, be regarded in most cases as non-conducting matter resting upon the electric surface of the earth.

4. Lightning conductors should therefore invariably be continued through these intervening substances into soil which is permanently damp.

5. Underground magazines are usually in dry soil, or soil rendered dry by careful drainage.

6. When large quantities of explosives are stored in underground magazines, such as the main magazine of a fort, they should be fitted with lightning conductors on the same principles as ordinary magazines above ground. The same rule holds good as regards underground magazines situated on prominent points, the top of a hill for example, under which circumstances like precautions should be taken.

7. Small expense magazines under ground need not, as a rule, be provided with lightning conductors.

8. Casemated batteries of modern construction, in which the magazines are distributed throughout the basement story, must be provided with lightning conductors.

9. The arrangements will vary with the plan and extent of the work; but it will generally be convenient to have one or two horizontal conductors on the parapet or terreplein, extending from end to end of the battery, attached to vertical conductors connected with the earth. The flagstaff should have a conductor, terminating in the truck, or a point above the truck, and in large works, several points, projecting 5 feet above the top of the building, must be provided. Iron verandahs and iron railings form good conductors when they are properly connected with the earth.

10. An iron building is, of itself, a good conductor, but when it is covered with non-conducting substances, such as asphalt and concrete, it is necessary to provide rods or points projecting above the asphalt, and in all cases there must be a proper connection with the earth. Iron shields in casemated works must be placed in connection with the conductors: this may be effected through the iron racers in their rear, or by means of horizontal bands, extending from one shield to another, externally.

11. Copper is recommended by the late Sir William Snow Harris as the best material for lightning conductors. It possesses great conductivity, is not liable to corrosion, and is very durable.

12. Where, however, conductors are exposed to mechanical injury or are liable to be stolen, and where attendant circumstances are not such as to promote corrosion, iron may be employed, using proportionately larger dimensions to provide for its smaller conductivity, which is only about $\frac{1}{3}$ th that of copper.

13. Copper lightning conductors should be of the following dimensions: rods $\frac{1}{2}$ inch in diameter, tubes $\frac{3}{4}$ inch in diameter and $\frac{1}{8}$ inch thick, or bands 1 $\frac{1}{2}$ inches wide and $\frac{1}{8}$ inch thick.

14. Iron lightning conductors should be either solid rods 1 inch in diameter, or bands 2 inches wide and $\frac{1}{8}$ inch thick.

15. In deciding upon the metal to be employed in any system of lightning conductors, the relative qualities of the two metals, copper and iron, must be weighed in connection with the circumstances of each particular case. Copper possesses higher conductivity, and is less liable to injury from corrosion, but it is very much more expensive, more liable to mechanical injury, and more likely to be stolen. Its fusing temperature (1994° Fahrenheit) is much lower than that of iron.

16. The fusing temperature of iron is 2786° Fahrenheit. In this respect it has a marked advantage over copper, but it readily becomes rusty, and when rusted its electrical resistance is immensely increased. Roughly speaking, an equal amount of conducting

power may be obtained in iron and copper for the same cost, the number of conductors purchasable for the same price in the former being far in excess of those in the latter metal, and in suitable positions the more numerous conductors would, no doubt, provide perfectly efficient protection.

17. In applying lightning conductors, the expansion and contraction of the metal must be provided for, especially at points where two lengths of metal are joined together.

18. This may be done by introducing suitable bends, at intervals, in long lines of horizontal conductor.

19. In vertical lines, and in some cases in horizontal lines, the effect of expansion and contraction may be sufficiently provided against by giving freedom to slip through the bearing collars.

20. Soldered or welded joints are not absolutely necessary, but they should be employed where practicable.

21. The joints hitherto used in the Royal Engineer Department, under the recommendation of the late Sir William Snow Harris, shown in Plates IIa., IIb., IIIa. and IIIb., attached hereto, should be adopted for copper conductors where soldered joints cannot be employed.

22. Soldered or welded joints should be employed in all positions where the brush or discharge, which might occur with unsoldered joints, would be liable to ignite dust or any inflammable substance.

23. Iron rods may be welded or connected by joints, similar to those recommended for copper conductors, or by screw junctions such as are used in forming the connections of gas-pipes, the end of the rod inserted into the socket being equal in length at least to its diameter, but no white lead, which is a bad conductor of electricity, should be made use of in the joints. (See Plate IVa., IVb. and IVc., attached hereto.)

24. Flat iron bands, where welding is not considered advisable, may be connected by rivets or screws working in slots to allow for expansion and contraction; each of the surfaces in contact should be of at least six times the sectional area of the band.

25. Copper bands should be connected by rivets or screws working in slots, and with similar precautions as to the area of the surfaces in contact. Joints between different metals may be soldered, screwed, or riveted, the extent of the surfaces in contact being regulated by the dimensions of the metal possessing the least conducting power. In all cases of contact between two metals, precautions should be taken to prevent access of moisture, which would induce local galvanic action with its attendant metallic decomposition.

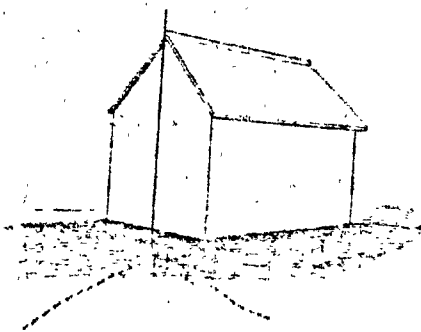
26. It is not possible to assign the precise limits of the protecting power of conductors. The French philosophers formerly considered that they afforded protection over a circle whose radius was equal to twice their height; but in England, the limit is usually considered the radius of their height from the ground. This may be sufficiently correct for all practical purposes; but such a radius of protection cannot always be relied upon.

27. Conductors of themselves have no attraction for lightning, which seeks them only on account of the facility they afford for the combination of the opposed states of the electricity of the clouds and of the earth beneath them, separated by the atmosphere which is a bad conductor. A lightning conductor, buildings, trees, or any object on the surface of the earth, is only to be regarded as diminishing the resistance due to the air. When an electrified cloud is passing over the earth and its potential is just counteracted by the resistance of the air, a body, however small, which reduces this resistance, will cause a discharge. Even a change in the nature of the soil over which the cloud is passing may have this effect, and it is very frequently produced by a fall of rain.

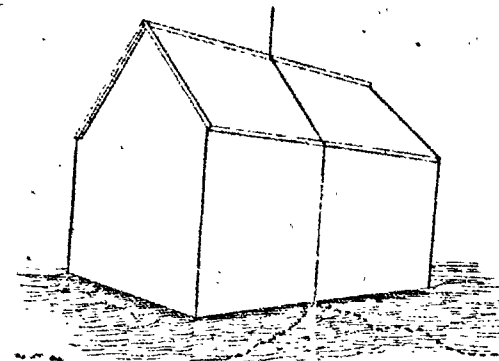
28. From this we may conclude that the angle of a building which a thundercloud approaches, may receive the discharge, while another but more distant angle is provided with a conductor; and that for important buildings containing explosive materials, every prominent elevated part ought to be provided with a lightning conductor.

29. For a building of uniform height, a solid rod, pointed and rising not less than five feet above it, should be provided at each end, and at intervals of about 15 yards along its length. When the rod is of iron, its point should be gilt.

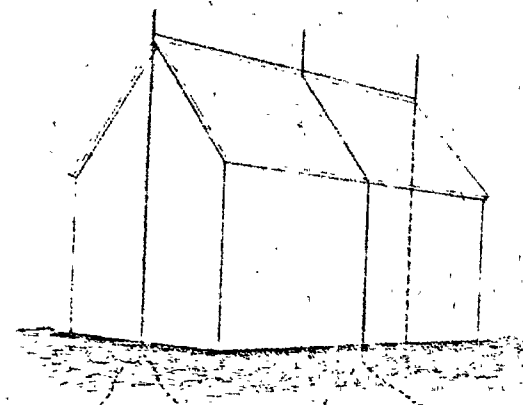
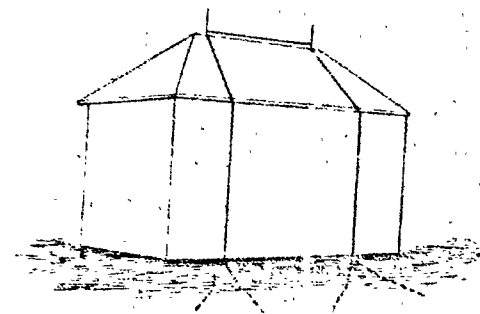
30. Small simple buildings, not exceeding 20 feet in length, may be protected by one vertical conductor at the end, the point rising not less than five feet above the ridge of the roof; a horizontal conductor should be provided on the ridge.



31. A building from 20 feet to 40 feet long should be protected by one vertical conductor in the centre of its length, with a horizontal conductor on the ridge.



32. A building exceeding 40 feet in length should have two, and if exceeding 100 feet in length, three conductors.



33. Larger and more complicated buildings should be protected upon similar principles, as shown in Plate I., attached hereto.

34. A fork, or brush of three or four points instead of one, has been recommended for the top of a lightning conductor; the practical value of this arrangement is not apparent unless the points are widely separated; but for a single rod on a prominent point, this construction may be adopted. All parts of buildings which are of marked elevation and prominence should be fitted with a lightning conductor.

35. Where several lightning conductors are used in a single building, they should be connected horizontally. Such connection may be conveniently effected along the ridge or eaves. When the ridge covering or eaves gutters are of metal, they should invariably be connected with the system. All metal surfaces, whether lead, copper, or iron, in ridges, roofs, gutters, or coverings to doors or windows, shall be connected with the conducting system.

36. The relative conductivity of the ordinary metals used in building, is given by the late Sir William Snow Harris, as follows:—

Lead.	Tin.	Iron.	Zinc.	Copper.
1	2	2½	4	12

Lead, on account of its low conducting power, cannot be altogether depended on, and this must be carefully considered in connecting the lead, used in a building, to the system.

37. Long lengths of horizontal conductor, without sufficient intermediate earth connections, must be avoided. Should there be any failure of continuity in such a conductor without intermediate earth connections, the current might leave the conductor and pass to earth by the most favourable course, and this would be attended with danger. Sharp angles in conductors are objectionable.

38. Good earth connections are most important. Any fault in the earth connection itself manifestly impairs efficiency, and a very bad earth connection is a source of absolute danger. Lightning conductors should, where practicable, be led into springs or wells of water, or into ground which is permanently wet. The sea or any large body of water, except a watertight tank, forms an excellent earth connection. Shingle, dry sand, or ordinary vegetable mould in a dry condition, are not efficient connections, and lightning conductors should invariably be led through these into ground that is permanently damp. Several earth connections should always be provided in all large systems of lightning conductors, so that, should one be defective, the discharge may be effected through the others.

39. Conductors should be led into moist ground, by means of a trench or trenches extending to a depth of at least 18 inches below the surface, and in which a length of not less than 30 feet of metal should be in actual contact with moist earth.

40. Where practicable, it is desirable to lead a flow of water, from the down pipes from the roof, over the ground in the vicinity of the lightning conductors and earth connections.

41. Where a lightning conductor terminates in rocky, or more or less dry soil, special precautions are necessary: it should be led into a trench, so disposed as to obtain all the moisture possible from the ground. These trenches should extend from its foot to distances of from 10 to 40 yards, according to the amount of moisture.

42. The connections in the trenches may be of railway or other old iron formed into a continuous metallic surface, the trenches being filled up with cinders or coal ashes, and the water from the down pipes being led over them as already recommended. Water-pipes form excellent earth connections, but gas-pipes should never be used for this purpose, instances having occurred where a heavy lightning discharge has damaged the gas-pipes and lit the gas.*

43. Lightning conductors should be frequently inspected, to ascertain that they are in perfect condition and properly connected with the earth. Particular attention should be paid to the joints, especially when they connect different metals.

44. The state of the conductors should be noticed in the Inspectional Reports, in which the efficiency or otherwise of all joints and earth connections, and the extent of oxidation of iron conductors should be distinctly specified. It must be borne in mind that in the case of an iron rod or band, the metallic portion only can be looked upon as efficient, oxide of iron being a very inferior conductor.

45. In order to obviate the ill effects of rust, iron employed in the construction of lightning conductors should be galvanized.

46. When galvanized iron is used, particular care should be taken to see that the coating of zinc covers the conductor thickly and effectively; damp would produce galvanic action, and the zinc in the vicinity of the smallest exposed iron surface would be quickly decomposed.

47. Should it be necessary to bring the zinc coating in contact with other metals, and especially with copper, every precaution should be adopted to exclude moisture, for the above reason.

WAR OFFICE,

6th April, 1875.

FRED. E. CHAPMAN,

Inspector-General of Fortifications.

* A remarkable accident of this nature occurred at Halifax, Nova Scotia, in the Summer of 1871, during a heavy thunderstorm, the electric discharge, in traversing the gas-pipes of the old Provincial Buildings, fused a portion which was composed of white metal composition, near the metre in the basement, and lit the gas, by which the buildings were nearly set on fire.

7. All the metals in the roof and other parts of the building, of whatever kind, should, so far as possible, have metallic communication with these main Conductors; and in case of any prominent elevated chimney, it would be desirable to lead a pointed conducting tube along it to the metals of the roof, all of which satisfies the conditions above specified (6).

8. REMARK 1.—It is now proved beyond all question that the electrical discharge never leaves perfect conducting lines of small resistance in order to pass out upon bad conducting circuits, in which the resistance is very great; that is an established law of nature. Hence, a stroke of Lightning upon such conducting lines (7) will be confined to the Conductors, as constituting a line of discharge of less resistance than any other line of discharge through the building, which can be assigned. The apprehension of "Lateral Discharge" therefore from the Conductor is quite absurd, and is not countenanced by any fact whatever; if any doubt could possibly exist, it would be now most completely set at rest by the experience of the permanent Conductors applied to the masts of Her Majesty's ships. In very many instances, furious discharges of Lightning have fallen on the mast with a crash as if the ship's broadside had been hit, and the whole point aloft has been found melted; in all these cases electrical discharge, guided by the Conductor of its explosive violence, has traversed the line of action to the sea, through the ship's side through the copper bolts driven through the ship's side (8), without the least damage to the ship or the mast, whether metallic or not. Persons have been killed by or actually leaning against the Conductors at the time, without experiencing any ill consequence.

9. REMARK 2.—It has been shown that the attractive force or affinity for the electrical discharge is equally and directly to the metals of the building, as to the metals of the Conductor; hence, the idea of the Conductor being a mere attraction, is a popular but very unphilosophical notion. The most satisfactory evidence, and the most direct, is that the Conductor is not attracted by the electrical discharge, and that the discharge is not attracted by the Conductor, whether the building has metal about it or not.

In May 1811, Lightning struck one of the high cylindrical chimneys at the Royal William Victualling Yard, Plymouth, and sent it for ever to rest. This chimney is built of granite, is 120 feet high, and has a diameter of 10 feet in its construction; but what renders the circumstance more especially applicable to the present case is the fact, that within 100 yards of this chimney stands a clock tower of equal altitude, having a weathercock and various metallic projections; a dome covered with metal, and a large Conductor along it to the ground; yet was this clock tower unharmed by the great thunder-cloud, which spread its Lightning over an area of certainly not less than two miles; and

further, the point of the chimney at which the damage ceased was just where it passed through a massive *metallic roof*, connected by large Conductors with the ground.

If no other case were on record similar to this, this case alone, according to the best inductive philosophical reasoning, would be sufficient to overturn the whole assumption of the attraction of Conductors for the matter of Lightning, and the vulgar error that such Conductors invite to the buildings the very destruction which they are set up to avoid. In this, as in numerous other recorded cases, the Lightning fell on a structure which, according to the popular error, held no "invitation" by metallic points or attraction, in preference to a structure which did hold out such invitation—a fact totally at variance with the whole assumption.

10. REMARK 3.—A building, as is hence clear, may be struck and damaged by Lightning without having a particle of metal in its construction; if there be metals in it, however, and they happen to be in such situations as will enable them to facilitate the progress of the electrical discharge, so far as they go, then the discharge will fall on them in preference to other bodies offering more resistance (3) (4), but not otherwise; if metallic substances be not present, or if present, they happen to occupy places in which they cannot be of any use in helping on the discharge in the course it wants to go, then the electricity seizes upon other bodies, which lie in that course, or which can help it, however small their power of doing so, and in this attempt such bodies are commonly, but not always, shattered in pieces. The great law of the discharge is,—progress between the terminating planes of action (2), viz., the clouds and earth, and in such line or lines as, upon the whole, offer the least mechanical impediment or resistance to this operation, just as water falling over the side of a hill in a ruin storm, picks out, or selects as it were by the force of gravity, all the little furrows or channels which lie convenient to its course, and avoids those which it do not. If in the case of Lightning you provide through the instrumentality of efficient Conductors, a free and uninterrupted course for the electrical discharge, then it will follow that course without damage to the general structure; if you do not, then this irresistible agency will find a course for itself through the edifice in some line or lines of least resistance to it, and will shake all imperfect conducting matter in pieces in doing so; moreover, it is to be especially remarked in this case, that the damage ensues, not where the metals are, but where they ceased to be continual; the more metal in a building therefore the better, more especially when connected by an uninterrupted circuit with any medium of communication with the earth.

Such is, in fact, the great condition to be satisfied in the application of Lightning Conductors, which is virtually nothing more than the perfecting a line or lines of small resistance in given directions, less than the resistance in any other lines in the building, which can be assigned in any other direction, and in which, by a law of nature, the electrical agency will move in preference to any others.

The popular objections to Lightning Conductors on the ground that they invite Lightning to the building, that we do not know the quantity of electricity in the clouds, and that hence they may cause destruction, are now quite untenable, and have only arisen out of a want of knowledge of the nature of electrical action. What should we think of a person objecting to the use of gutters and rain-pipes for a house, on the ground of their attracting or inviting a flow of water upon the building; and since we do not know the amount of rain in the clouds, it is possible that the building may be thereby inundated, yet such is virtually the argument against Lightning Conductors.*

11. It follows from the foregoing principles, that a magazine constructed entirely of iron or other metal, would be infinitely more safe on lightning atoms than if built with masonry in the usual way: and the rest for magazines, with capacious metallic Conductors to the earth, would be unobjectionable, and a source of security.

Metallic spitters and ridges having continuous metallic connection with the earth are also unobjectionable.

A good method of Conductors for magazines built of masonry, would be such as already described (7), regard being had to the position of the building, its extent, and most prominent points, also to the nature, state, and condition of the soil, whether it be moist or dry, alluvial, calcareous, or of hard rock; we must also consider the extent, disposition, and peculiar position of the metallic bodies entering into the general structure of the building, whether the roof be flat, or pointed, or angular in various parts.

The pointed projecting extremities of the Conductors, one or more in the case may be, will be commonly sufficient; but, in buildings having tall chimneys or other elevated prominent points, at a distance from the Main Conductor, it will be requisite to guard such chimneys or other parts by a pointed rod, led along them to the metals of the roof, or directly connected with the Main Conductors, by metallic connections.

[illegible]

12. Pointed terminations of the Conductors in the air are so far important that they tend to break the force of a discharge of Lightning when it falls on them. In fact, before the great shock actually takes place, under the form of a dense explosion, a very large amount of the discharge, which otherwise would be concentrated, runs off, as it were, through the pointed Conductor; but they have no other influence.*

With respect to these pointed terminations, no great care need be taken about them, except that they should consist of solid copper rod of about three-quarters of an inch in diameter and about a foot in length, and be united by brazing to the conducting tube, elevated at such convenient height above the walls of the building as the nature of the case may suggest.

As a support to the Conductor, when raised above the wall, we may employ a small staff or spar of wood fixed to the masonry.

It has been occasionally the practice to gild the points of Lightning Conductors, or make them of platinum, or otherwise bestow an extraordinary amount of care on perfecting the point, all of which is not only unnecessary but in some instances detrimental to the action of the Conductor; if, for example, the Conductor be constructed of copper (a metal of high conducting power), then it would be manifestly prejudicial to terminate it in a platinum point, platinum being a metal not having one-half the conducting power of copper.

Much has been said relative to the oxidation of the surface of the metal, but this is of very little moment to the line of conduction, and, in the case of copper, it is trifling. Under any circumstances the metallic oxide is better than the bad or non-conducting air, which is always in contact with the surface of the metal; besides, we observe that in many cases the wires of the Electrical Telegraph transmit currents of electricity with perfect freedom, even when enclosed in gutta-percha or other non-conducting matter.

With respect then to the point—it will be sufficient if the terminating solid rod be roughly pointed; almost any termination of the Conductor, even if a ball, a foot in diameter, would be virtually a point when opposed to a thousand acres of charged clouds.

13. Copper linings to the doors and window-shutters of magazines are not objectionable, if requisite, as a precaution against fire; but they are useless as a means of keeping out lightning; on the other hand, it is not easy to conceive a case in which the explosion of the gunpowder is to be apprehended from the action of Lightning on the doors or windows; supposing, however, such metallic linings desirable as a precaution against common cases of fire, then the masses of metal should, according to the principles already laid down (7) have metallic communication with the general system of conduction in the building and the Main Conductor.

* A pointed Conductor has been supposed to protect by attraction over a circular area, equal to twice the radius of its elevation, which is a pure piece of hypothesis contradicted by experience, *e. g.*, ships have been struck and damaged by Lightning on the foremast, a pointed Conductor being upon the mainmast.

The popular objections to Lightning Conductors on the ground that they invite Lightning to the building, that we do not know the quantity of electricity in the clouds, and that hence they may cause destruction, are now quite untenable, and have only arisen out of a want of knowledge of the nature of electrical action. What should we think of a person objecting to the use of gutters and rain-pipes for a house, on the ground of their attracting or inviting a flow of water upon the building; and since we do not know the amount of rain in the clouds, it is possible that the building may be thereby inundated, yet such is virtually the argument against Lightning Conductors.*

11. It follows from the foregoing principles, that a magazine constructed entirely of iron or other metal, would be infinitely more safe in lightning-storms than if built with masonry in the usual way; and the fact that iron magazines, with capacious metallic Conductors to the earth, would be undisturbable, and a source of security.

Metallic gutters and ridges having continuous metallic connection with the earth are also undisturbable.

A good method of Conductors for magazines built of masonry, would be such as already described (7), regard being had to the position of the building, its extent, and most prominent points, the nature, state, and condition of the soil, whether it be sand or clay, alluvial, calcareous or of hard rock; we must also consider the extent, disposition, and peculiar position of the metallic bodies entering into the general structure of the building, whether the roof be flat, or pointed, or angular in various parts.

The pointed projecting extremities of the Conductors, one or more as the case may be, will be commonly sufficient; but, in buildings having tall chimneys or other elevated prominent points, as a precaution from the Main Conductor, it will be requisite to connect such chimneys or other parts by a pointed rod, led along from the metal of the roof, or directly connected with the Main Conductors, by metallic communications.

It has been recommended to place Lightning Conductors some feet distant from the buildings, or otherwise separate them from the walls by glass or resin; all this is clearly opposed to the principle upon which the Conductors are applied; we should not place a rod in 10 feet distant from a house if we wish to carry off run from the roof. A lamentable result of the practice of placing Lightning Conductors distant from a building recently occurred at Exmouth Lodge, in Jamaica, the residence of J. Kenne, Esq. A lightning rod, of small dimensions of iron, had been set up within 10 feet of the south-east angle of the building, as practiced frequently in cases of Gunpowder Magazines, on the supposition that the Rod would attract the Lightning, and secure the building. So far from this, the building itself was struck in a heavy thunder-storm, 25th July 1867. The south-east angle was shattered in pieces; the escape of the family appears to have been miraculous; whilst the Lightning Rod, 10 feet distant, remained untouched. If this building had been a deposit of Gunpowder, it would certainly have blown up.

To detach or insulate the Conductors is to run away from our own principle, which is, that the Conductor is the channel of communication with the ground, in which the electrical discharge will move in preference to any other course. To detach or insulate the Conductor, is to provide for a contingency at once subversive of our principle. As it is possible to conceive that an agency which can rent large rocks and trees, break down perhaps a mile of dense air, and lay the mast of a ship weighing 18 tons in ruins, is to be arrested in its course by a ring of glass or pitch, an inch thick or less, supposing its course were from any cause determined in that direction?

12. Pointed terminations of the Conductors in the air are so far important that they tend to break the force of a discharge of Lightning when it falls on them. In fact, before the great shock actually takes place, under the form of a dense explosion, a very large amount of the discharge, which otherwise would be concentrated, runs off, as it were, through the pointed Conductor; but they have no other influence.*

With respect to these pointed terminations, no great care need be taken about them, except that they should consist of solid copper rod of about three-quarters of an inch in diameter and about a foot in length, and be united by brazing to the conducting tube, elevated at such convenient height above the walls of the building as the nature of the case may suggest.

As a support to the Conductor, when raised above the wall, we may employ a small staff or spar of wood fixed to the masonry.

It has been occasionally the practice to gild the points of Lightning Conductors, or make them of platinum, or otherwise bestow an extraordinary amount of care on perfecting the point, all of which is not only unnecessary but in some instances detrimental to the action of the Conductor; if, for example, the Conductor be constructed of copper (a metal of high conducting power), then it would be manifestly prejudicial to terminate it in a platinum point, platinum being a metal not having one-half the conducting power of copper.

Much has been said relative to the oxidation of the surface of the metal, but this is of very little moment to the line of conduction, and, in the case of copper, it is trifling. Under any circumstances the metallic oxide is better than the bad or non-conducting air, which is always in contact with the surface of the metal; besides, we observe that in many cases the wires of the Electrical Telegraph transmit currents of electricity with perfect freedom, even when enclosed in gutta-percha or other non-conducting matter.

With respect then to the point—it will be sufficient if the terminating solid rod be roughly pointed; almost any termination of the Conductor, even if a ball, a foot in diameter, would be virtually a point when opposed to a thousand acres of charged clouds.

13. Copper linings to the doors and window-shutters of magazines are not objectionable, if requisite, as a precaution against fire; but they are useless as a means of keeping out lightning; on the other hand, it is not easy to conceive a case in which the explosion of the gunpowder is to be apprehended from the action of Lightning on the doors or windows; supposing, however, such metallic linings desirable as a precaution against common cases of fire, then the masses of metal should, according to the principles already laid down (7) have metallic communication with the general system of conduction in the building and the Main Conductor.

* A pointed Conductor has been supposed to protect by attraction over a circular area, equal to twice the radius of its elevation, which is a pure piece of hypothesis contradicted by experience, e. g., ships have been struck and damaged by Lightning on the foremast, a pointed Conductor being upon the mainmast.

The popular objections to Lightning Conductors on the ground that they invite Lightning to the building, that we do not know the quantity of electricity in the clouds, and that hence they may cause destruction, are now quite untenable, and have only arisen out of a want of knowledge of the nature of electrical action. What should we think of a person objecting to the use of gutters and rain-pipes for a house, on the ground of their attracting or inviting a flow of water upon the building; and since we do not know the amount of rain in the clouds, it is possible that the building may be thereby inundated, yet such is virtually the argument against Lightning Conductors.*

11. It follows from the foregoing principles, that a magazine constructed entirely of iron or other metal, would be infinitely more safe in lightning storms than if built with masonry in the usual way; metallic roofs for magazines, with capacious metallic Conductors to the earth, would be unobjectionable, and a source of security.

Metallic gutters and ridges having continuous metallic connection with the earth are also unobjectionable.

A good method of Conductors for magazines built of masonry, would be such as already described (7), regard being had to the position of the building, its extent, and most prominent points, also to the nature, state, and condition of the soil, whether it be moist or dry, alluvial, calcareous, or of hard rock; we must also consider the extent, disposition, and peculiar position of the metallic bodies entering into the general structure of the building, whether the roof be flat, or pointed, or angular in various parts.

The pointed projecting extremities of the Conductors, one or more as the case may be, will be commonly sufficient; but, in buildings having tall chimneys or other elevated prominent points, at a distance from the Main Conductor, it will be requisite to guard such chimneys or other parts by a pointed rod, led along them to the metals of the roof, or directly connected with the Main Conductors, by metallic connections.

* It has been recommended to place Lightning Conductors some feet distant from the buildings, or otherwise to insulate them from the walls by glass or resin; all this is clearly opposed to the prime plan upon which the Conductors are applied; we should not place a rain-pipe 10 feet distant from a house if we wish to carry off rain from the roof. A lamentable result of the practice of placing Lightning Conductors distant from a building recently occurred at Compton Lodge, in Jamaica, the residence of J. Senior, Esq. A Lightning rod, of small dimensions of iron, the product of J. Senior, Esq. A Lightning rod, of small dimensions of iron, had been set up within 10 feet of the south-east angle of the building, as practised frequently in cases of Gunpowder Magazines, on the assumption that the Rod would attract the Lightning, and secure the building. So far from this, the building frequently received heavy thunder-storms, 28th July 1867. The south-east angle of the building, and where the Rod stood, remained untouched. If this Rod had been placed in place; the escape of the family appears to have been miraculously averted; the escape of the family appears to have been miraculously averted; the escape of the family appears to have been miraculously averted. If this Rod had been placed in place; the escape of the family appears to have been miraculously averted; the escape of the family appears to have been miraculously averted. If this Rod had been placed in place; the escape of the family appears to have been miraculously averted; the escape of the family appears to have been miraculously averted.

It is not the intention of the Conductors to run away from one's own principle, but to attract the Lightning, and secure the building. So far from this, the building frequently received heavy thunder-storms, 28th July 1867. The south-east angle of the building, and where the Rod stood, remained untouched. If this Rod had been placed in place; the escape of the family appears to have been miraculously averted; the escape of the family appears to have been miraculously averted. If this Rod had been placed in place; the escape of the family appears to have been miraculously averted; the escape of the family appears to have been miraculously averted.

12. Pointed terminations of the Conductors in the air are so far important that they tend to break the force of a discharge of Lightning when it falls on them. In fact, before the great shock actually takes place, under the form of a dense explosion, a very large amount of the discharge, which otherwise would be concentrated, runs off, as it were, through the pointed Conductor; but they have no other influence.*

With respect to these pointed terminations, no great care need be taken about them, except that they should consist of solid copper rod of about three-quarters of an inch in diameter and about a foot in length, and be united by brazing to the conducting tube, elevated at such convenient height above the walls of the building as the nature of the case may suggest.

As a support to the Conductor, when raised above the wall, we may employ a small staff or spar of wood fixed to the masonry.

It has been occasionally the practice to gild the points of Lightning Conductors, or make them of platinum, or otherwise bestow an extraordinary amount of care on perfecting the point, all of which is not only unnecessary but in some instances detrimental to the action of the Conductor; if, for example, the Conductor be constructed of copper (a metal of high conducting power), then it would be manifestly prejudicial to terminate it in a platinum point, platinum being a metal not having one-half the conducting power of copper.

Much has been said relative to the oxidation of the surface of the metal, but this is of very little moment to the line of conduction, and, in the case of copper, it is trifling. Under any circumstances the metallic oxide is better than the bad or non-conducting air, which is always in contact with the surface of the metal; besides, we observe that in many cases the wires of the Electrical Telegraph transmit currents of electricity with perfect freedom, even when enclosed in gutta-percha or other non-conducting matter.

With respect then to the point—it will be sufficient if the terminating solid rod be roughly pointed; almost any termination of the Conductor, even if a ball, a foot in diameter, would be virtually a point when opposed to a thousand acres of charged clouds.

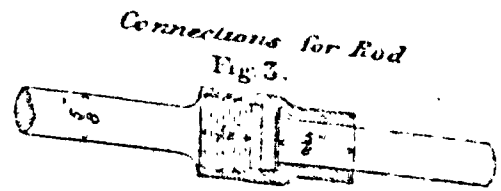
13. Copper linings to the doors and window-shutters of magazines are not objectionable, if requisite, as a precaution against fire; but they are useless as a means of keeping out lightning; on the other hand, it is not easy to conceive a case in which the explosion of the gunpowder is to be apprehended from the action of Lightning on the doors or windows; supposing, however, such metallic linings desirable as a precaution against common cases of fire, then the masses of metal should, according to the principles already laid down (7) have metallic communication with the general system of conduction in the building and the Main Conductor.

* A pointed Conductor has been supposed to protect by attraction over a circular area, equal to twice the radius of its elevation, which is a pure piece of hypothesis contradicted by experience, e. g., ships have been struck and damaged by Lightning on the foremast, a pointed Conductor being upon the mainmast.

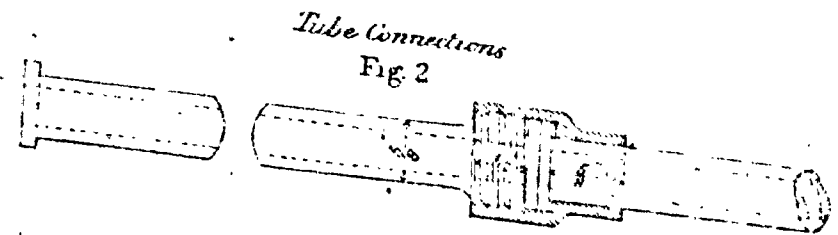
LIGHTNING CONDUCTORS CONNECTIONS FOR COPPER CONDUCTORS Scale: Half Size



Corner Connections
Fig 1.



Connections for Rod
Fig 3.



Tube Connections
Fig 2

N.B. Soldered Joints are always to be preferred where practicable.

APPENDIX B.

SUPPLEMENTARY PAPER.

Lightning Conductors for Magazines and other Buildings.

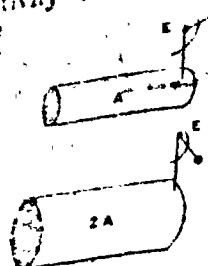
1. Whether a hollow or solid Conductor be the more desirable, the quantity of metal being the same?

This question has been usually considered in relation to the heating effects of an electrical discharge upon comparatively small Conductors, in which the resistance to the discharge is considerable. In this case a given quantity of electricity melts the same quantity of metal, under whatever form it be placed, whether as a solid or a hollow cylinder for example; at least such is to be inferred from the experiments hitherto continued. See a paper by Mr. Snow Harris, *Phil. Trans.* for 1812, on Conductors of Electricity, &c., last four paragraphs. In this case it is immaterial whether the Conductor be solid or hollow, provided the mass be the same.

Another and very important view, however, is to be taken of this question, as being applicable to a case in which the mass of metal is considerable, and the heating effect so small as to admit of being neglected; in this case the resistance of the mass, as a conductor, is not considerable; such a case as this brings us to the consideration of certain statical laws of Electrified Conductors; since for an enormous portion of time, during which a shock of Lightning traverses a Lightning Conductor, we may consider the Conductor as being more or less charged with electricity, tending to pass in a given direction, — viz. the direction of the Conductor.

Now it is proved, that in a case of this kind, the greater the extent of surface over which the Electricity can expand, the less the intensity or activity in any one point; in fact the intensity approaches the second power or square of the surface inversely, so that a given quantity of Electricity, disposed on twice the extent of surface, has only one-fourth the activity or intensity, whilst twice the quantity on the same surface has four times the activity considered in any one point. Take, for example, two Conductors, A and $2A$, whose surfaces are 1 and 2, or $2A$ double the surface of A ; let the charges be the same if you wish.

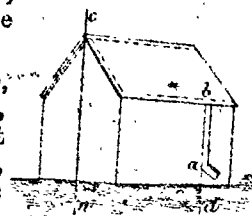
Then if a given quantity of Electricity be disposed on, or pervade the smaller surface A , an electroscope E will evince a high intensity, and will stand out violently as it were; whereas the same quantity disposed on $2A$ will repose with as much more quietude on the double surface, that the electroscope E will evince but little comparative action. See *Phil. Trans.* for 1834, page 220, for the laws of this action.



It is hence important to give the charge free room of expansion by increasing the surface of the Conductor, so as to reduce the mechanical activity of the shock, considered as an evanescent charge to the least possible. This question is still open to much valuable investigation; a large number of facts might be quoted bearing on it.

Rectangular flat bars may be employed, if found convenient for attaching to the walls of a building.

2. In the case of a Rain-Pipe, $a b$, communicating with the Main Conductor, $c n$, it would be certainly proper to connect it (the pipe) by a metallic communication, $a d$, with the ground, on the principles above explained; it admits of a certain quantity of the charge expanding into a general surface of conduction to the earth as explained in preceding papers.



REMARK.—All those substances termed imperfect Conductors, such as the masonry of a building, a ship's mast, &c., are nevertheless Conductors to a certain extent; they will always be able to transmit a given quantity of Electricity without explosive action. In any case of a ship or building struck by lightning, doubtless some Electricity always passes off in this way up to the limit of conducting power; one great end of the Conductor is to relieve the wood or masonry of the quantity it cannot discharge without explosion; by thus completing the conducting power of the general mass we use up, as it were, in connection with the Conductors, all the useful conduction of the wood of a ship's mast or the masonry of a building, and so convert into a source of safety what would otherwise be inefficient to the security of the building; all this is consistent with principles before explained, relative to resistance.

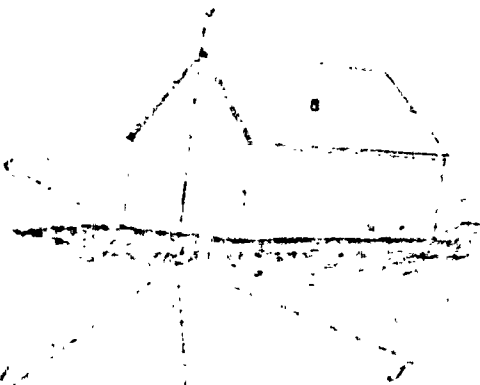
3. Whether Conductors of iron may not be employed for buildings, copper being expensive and liable to be stolen, &c.?

The common conductors of small iron rod or wire are very objectionable, they commonly rust out at the joints, and have fallen to pieces and have been often knocked in pieces by Lightning. If iron be employed, which it certainly may be, and with advantage, it should be coated with zinc, a modern practice, or what is called "*galvanized*." Zinc is even a better Conductor than iron, and being spread over the surface, would not be open to the objection of making a Conductor of two metals of unequal conducting powers; in the case of the charge being constrained to pass out of the one into the other, in continuation, as for example out of a into b , zinc has one-third the conducting power of copper; iron has only about one-fifth the conducting power of copper.

Where the Conductors are capacious as respects the intensity of the shock, and are not heated sensibly, the transmission of the charge, as a question of mere conduction, approaches a ratio of equality; in heavy shocks of Lightning the differences are important.

Still, there is no doubt but that a good and efficient Conductor might be formed of galvanised iron; it should be wrought-iron, and the best form would be galvanised iron pipe of two inches diameter, firmly screwed together, in joints of extra thickness, as in certain gas pipes; copper tubing of a given thickness, however, is always to be preferred.

6. In the case of a dry or rocky soil, it is certainly desirable to complete, so far as possible, the conducting power of the ground about the building, either by leading old iron chain out from the walls in several directions, or by leading a flow of water over it if possible; the distance and direction of such artificial ground conduction must depend on circumstances of situation of the building. The surface of the earth being, as remarked in former paper, one of the terminating planes of the electrical action; the indication is to provide, so far as possible, for the expansion of the final shock passing through the Conductor, without which the Conductor is more or less insulated. Fortunately a thunder-storm is usually attended by heavy rain.



In the case of a Building, B, on a dry or rocky soil, old iron chains, *b c*, *b d*, *b e*, &c., may be let out from Conductor *a b*, in various directions, to the extent of about 10 or 15 yards, and from a foot to eighteen inches under the surface of the earth, and it would be further desirable, in such cases, to lead a flow of rain, so far as possible, over the surface of the ground about or near the Conductor; the termination of the Conductor in a large surface of moist earth would be even preferable to its termination in a spring of water, sunk deep, as in a well, into the ground; the action here is a superficial action of expansion in all directions. We see in the tin leaf coatings of the electrical jar, that the charge is in no degree influenced by the thickness of metal.

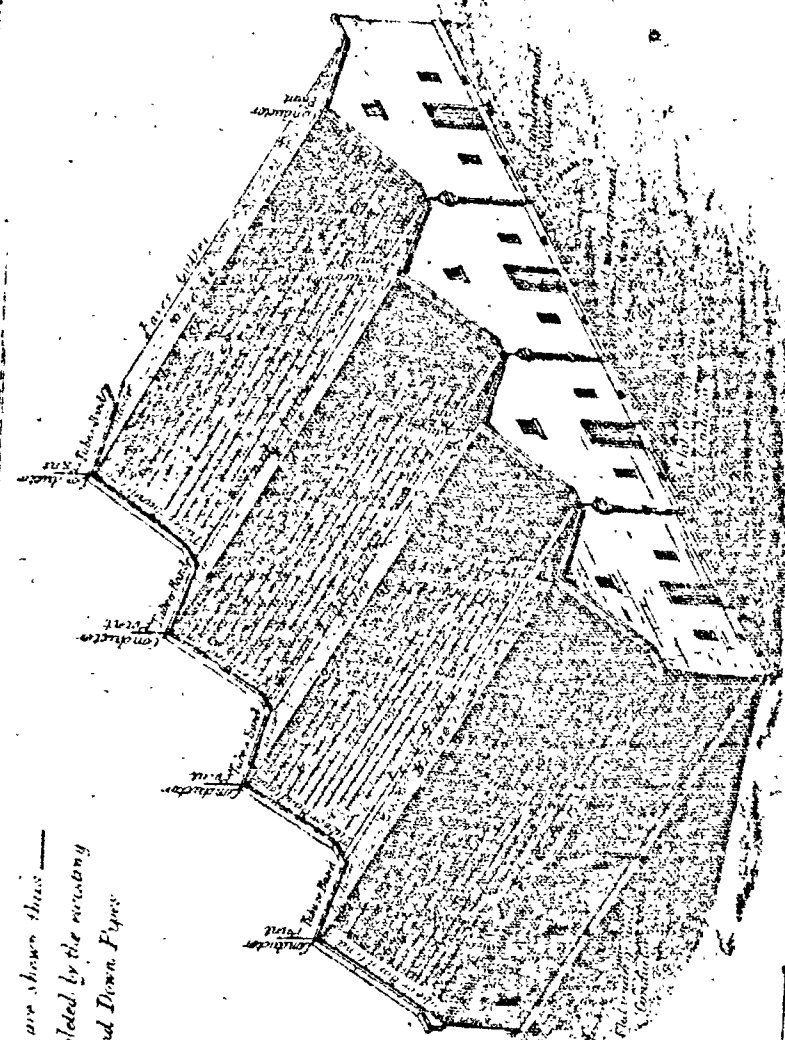
W. SNOW HARRIS.

* Experience is not wholly in favour of the durability of the galvanised coating iron.

No. 659, P. W. D. Press—22-12-77—410.

Plate I.

LIGHTNING CONDUCTORS.
GENERAL ARRANGEMENT FOR THE PROTECTION OF A MAGAZINE OR LARGE BUILDING



N.B. The Conductors are shown thus —
The system being completed by the existing
Copper Fane Gutter and Down Pipes

Page 72.

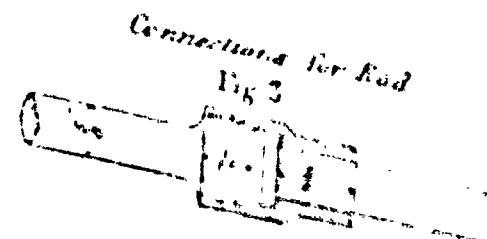
LIGHTNING CONDUCTORS

CONNECTIONS FOR COPPER CONDUCTORS

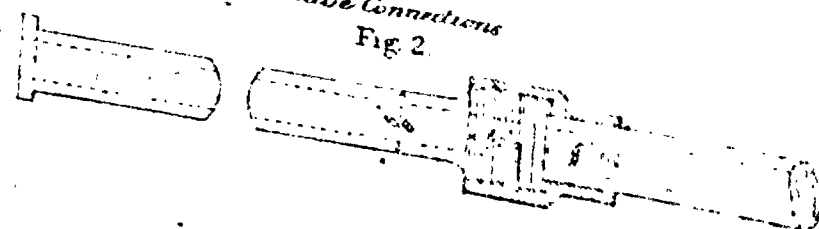
Scale Half Size.



Corner Connection
Fig 1.



Connections for Rod
Fig 3



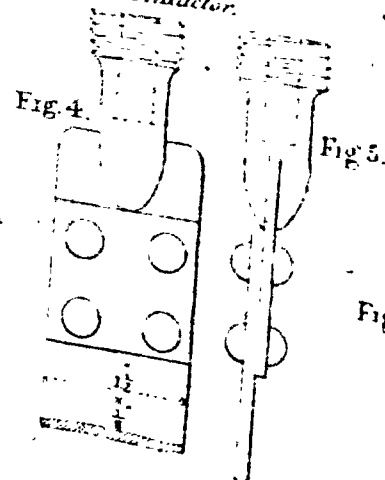
Tube Connections
Fig 2.

N.B. Soldered Joints are always to be preferred where practicable

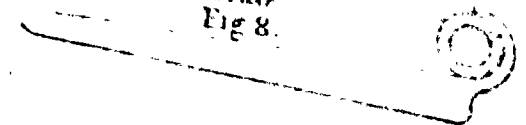
LIGHTNING CONDUCTORS. CONNECTIONS FOR COPPER CONDUCTORS Scale Half Size.

Plate 116

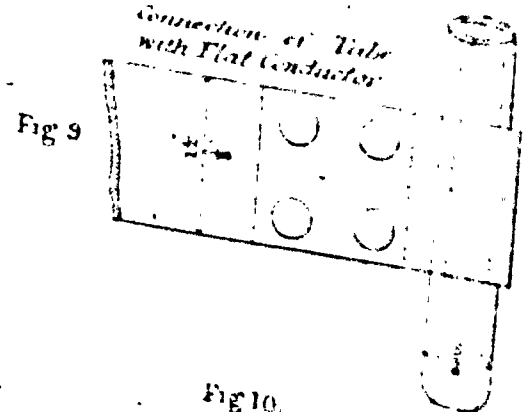
Connection of Flat
 with Tubular
 Conductor.



IL-Drast
 Fig 8.



Connection of Tube
 with Flat Conductor



Connection of Flat with
 Rod Conductor.

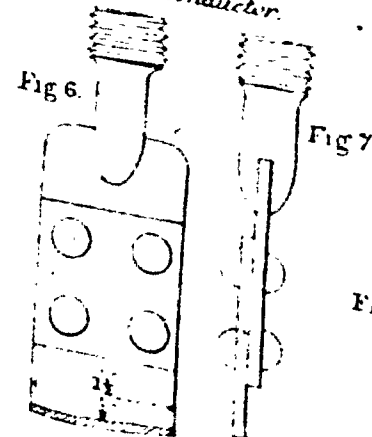
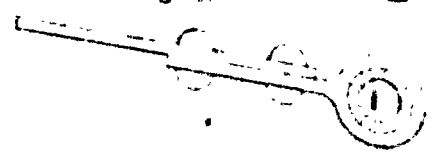


Fig 10.



Connection of Rod with
 Flat Conductor

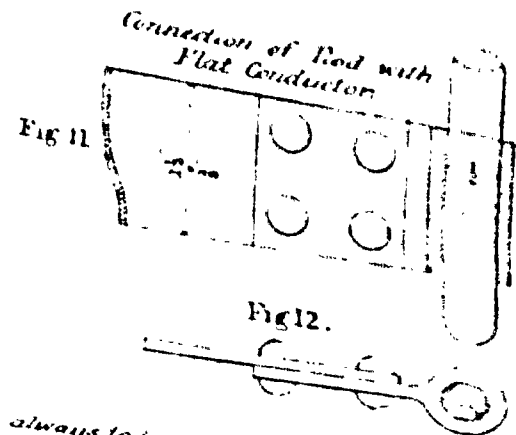
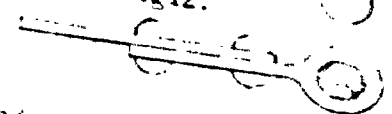


Fig 12.

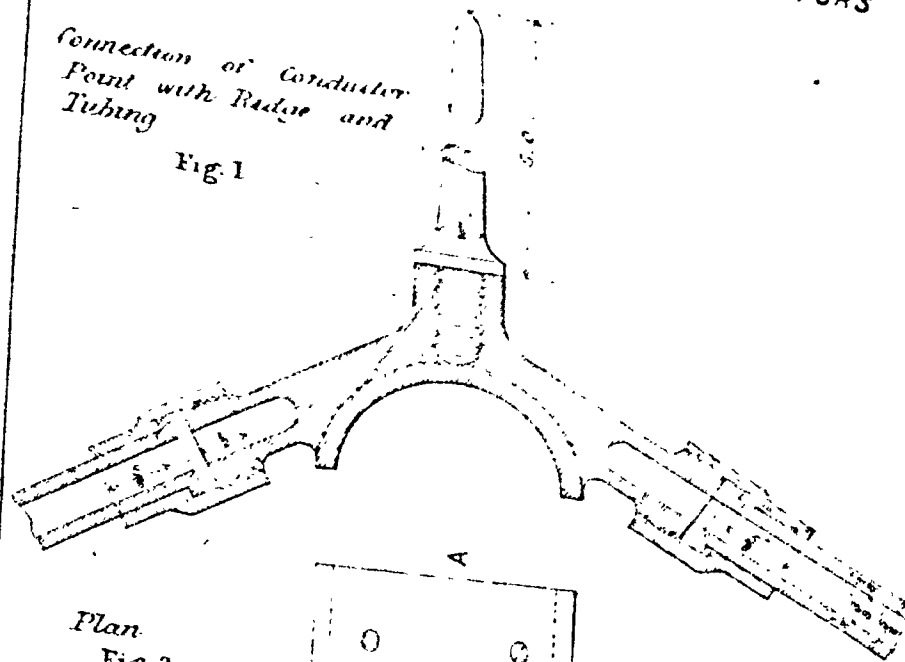


N.B. Soldered Joints are always to be preferred where practicable.

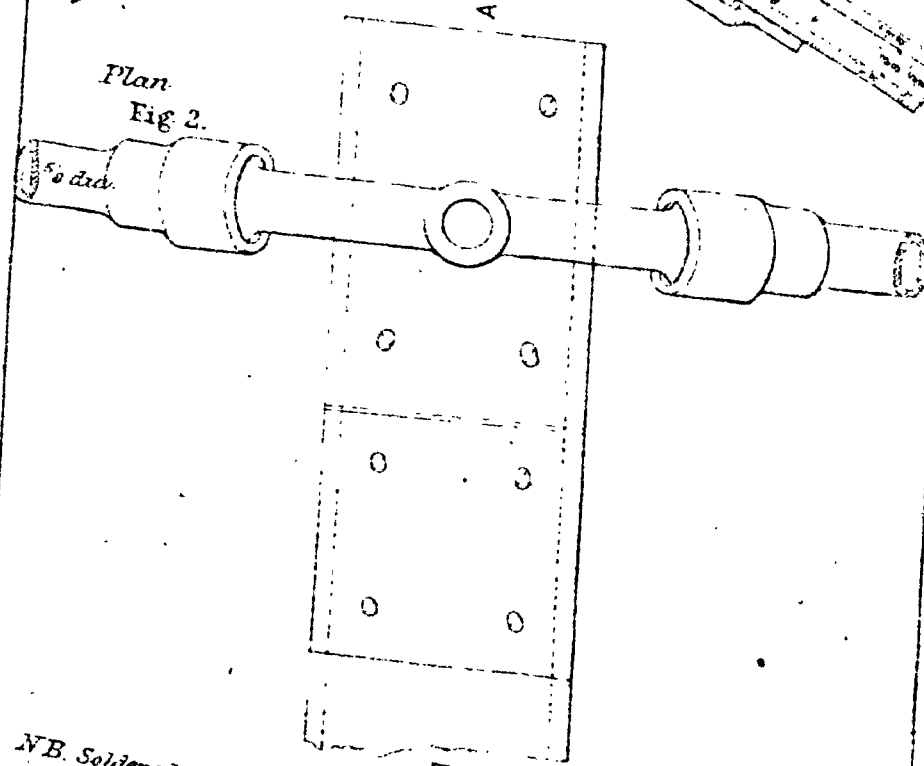
LIGHTNING CONDUCTORS. RIDGE CONNECTIONS FOR COPPER CONDUCTORS Scale Half Size

Connection of Conductor
Point with Ridge and
Tubing

Fig. 1



Plan
Fig 2.

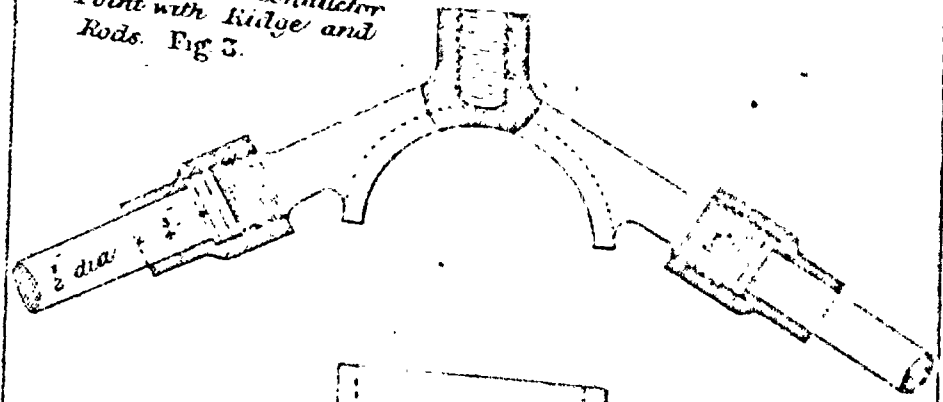


NB. Soldered Joints are always to be preferred where practicable

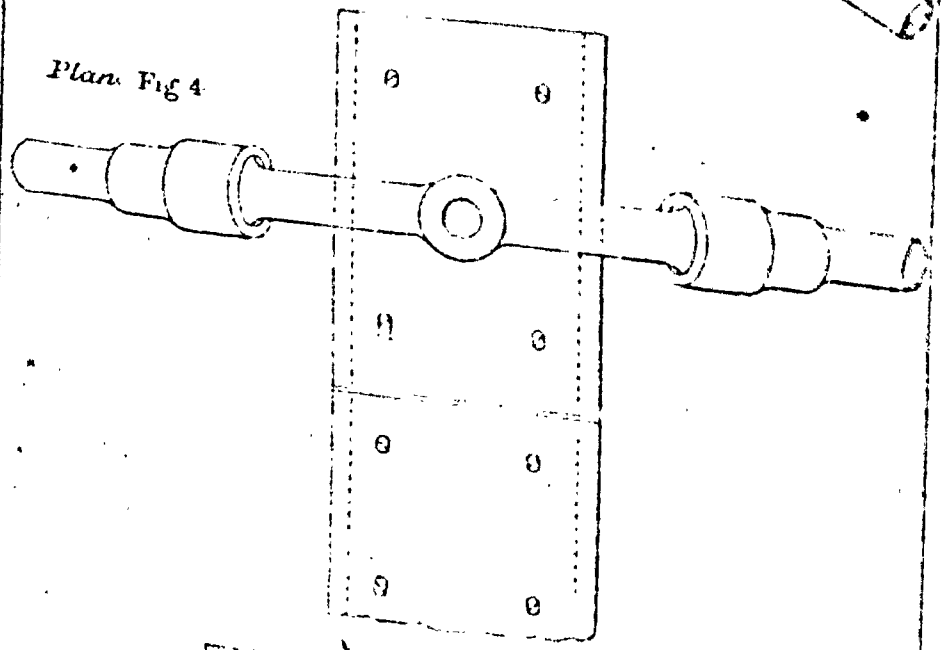
L.F.H.S. P.W.O. 7.1.78

LIGHTNING CONDUCTORS RIDGE CONNECTIONS FOR COPPER CONDUCTORS. Scale, Half Size.

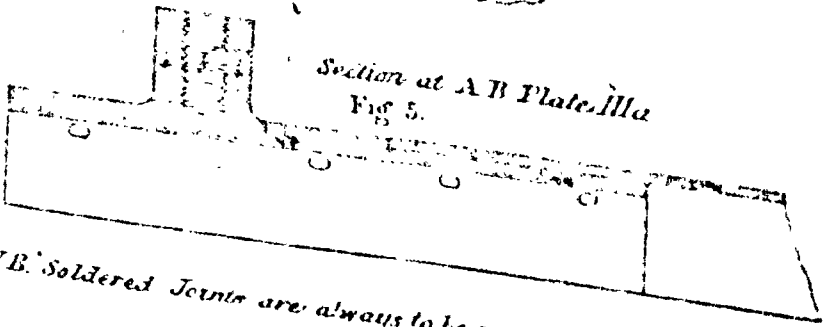
Connection of Conductor
 Point with Ridge and
 Rods. Fig 3.



Plan Fig 4



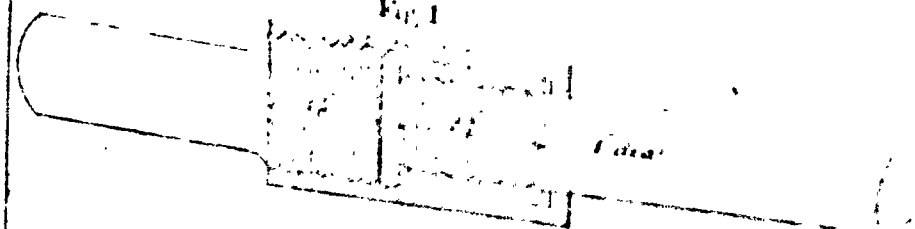
Section at A B Plate IIIa
 Fig 5.



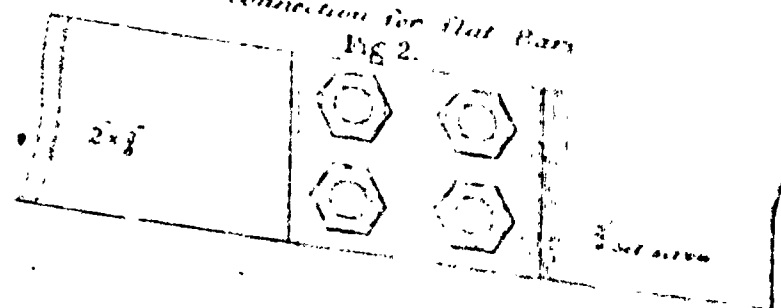
N.B. Soldered Joints are always to be preferred where practicable.

LIGHTNING CONDUCTORS
 CONNECTIONS FOR IRON CONDUCTORS
 Scale, Half Size
 Expansion Joint

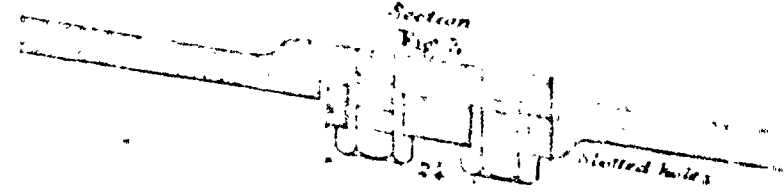
Fig. 1



Connection for Flat Bars
 Fig. 2.

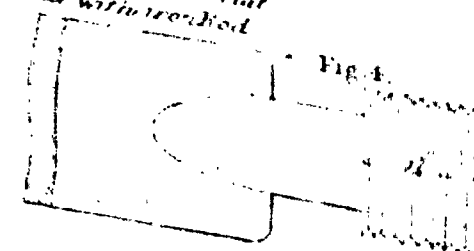


Section
 Fig. 3.

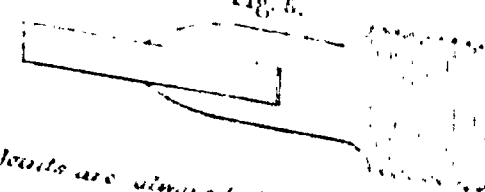


Connection for Flat
 Bar with treacher

Fig. 4.



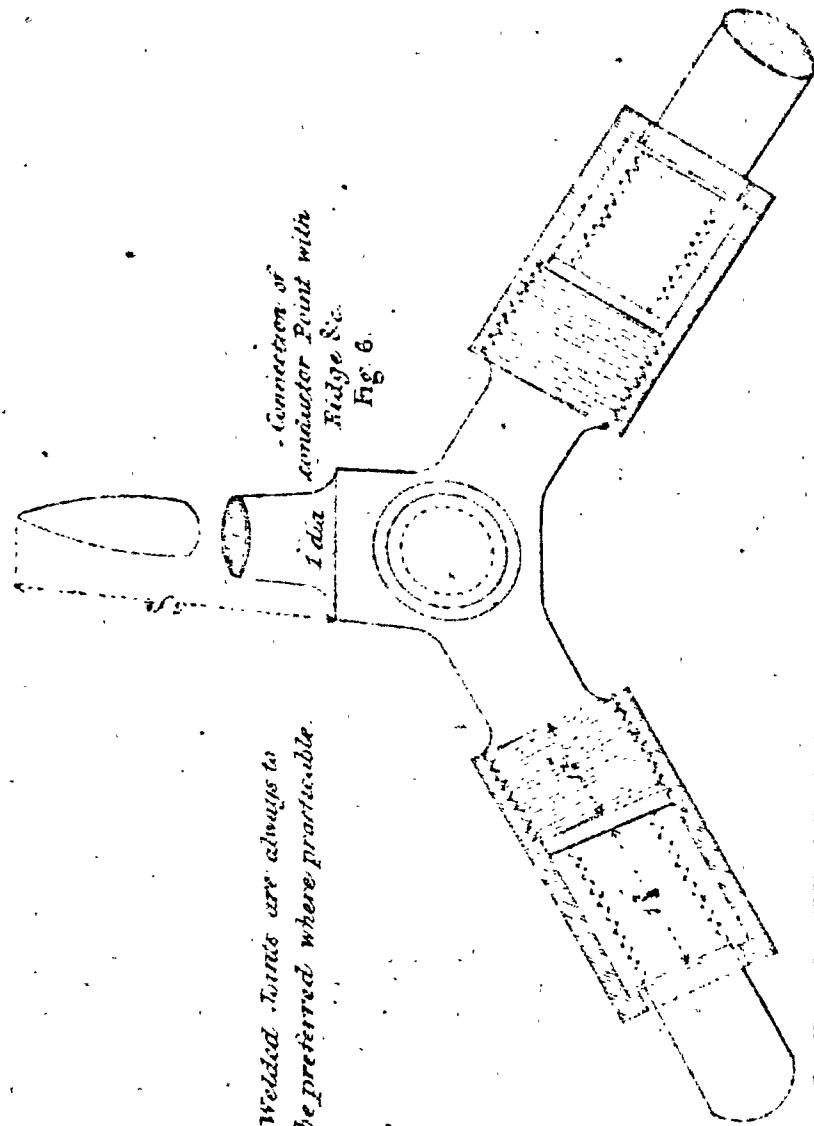
Side View
 Fig. 5.



N.B. Welded Joints are always to be preferred where practicable

LIGHTNING CONDUCTORS.
CONNECTIONS FOR IRON CONDUCTORS.

Scale, Half Size.



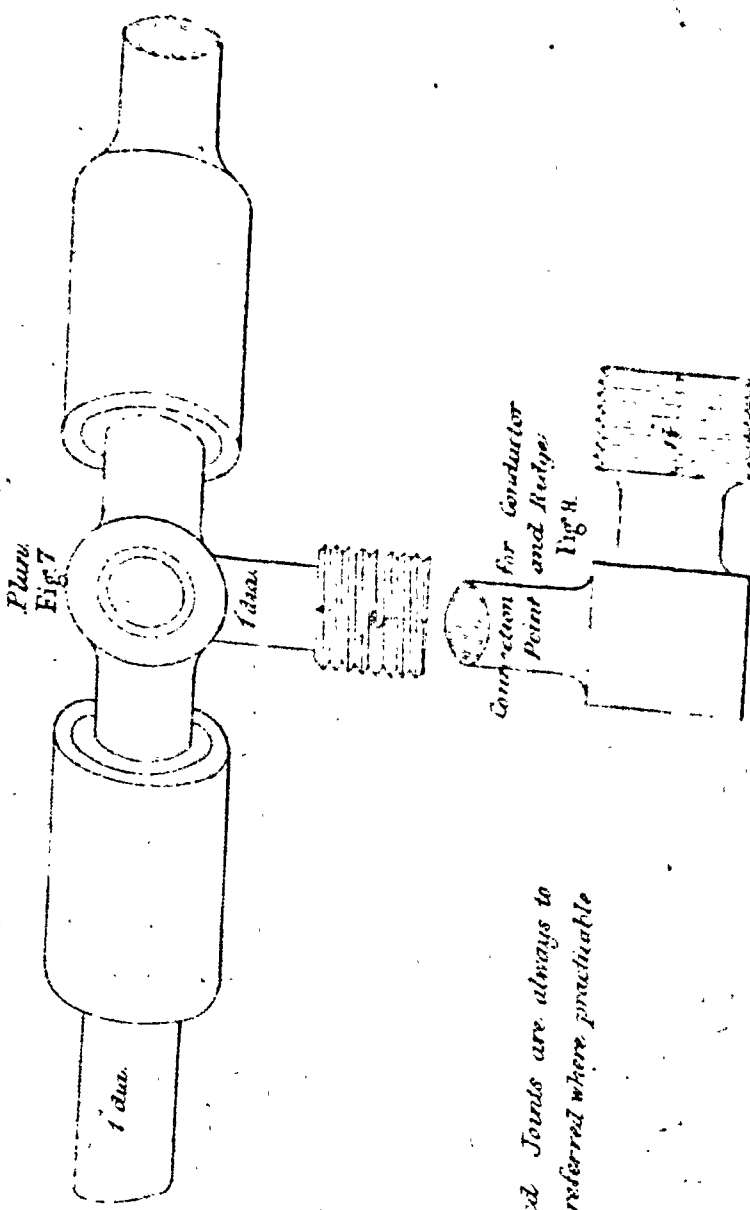
W.B. Welded Joints are always to be preferred where practicable.

ENGINEERING AND ROAD
CIVIL WORKS.

Plate No.

LIGHTNING CONDUCTORS.
CONNECTIONS FOR IRON CONDUCTORS.

Scale: Half Size.



N.B. Welded Joints are always to be preferred where practicable

ES AND
ER AND
IA
IAN AND

1877.

e under-
ssued by
nductors

E.,
India.

L. Brander.

ENGINEERING AND ROAD
CIVIL WORKS

Circular No. 74 Public Works.
GOVERNMENT OF INDIA.
PUBLIC WORKS DEPARTMENT.
CIVIL WORKS.
Miscellaneous.

To

THE GOVERNMENTS OF MADRAS, BOMBAY, BENGAL, NORTH-WESTERN PROVINCES AND
ODDH, IN THE PUBLIC WORKS DEPARTMENT, GENERAL BRANCH.
THE CHIEF COMMISSIONERS, CENTRAL PROVINCES, BRITISH BURMAH, MYSORE AND
COORG, AND ASSAM.
THE RESIDENT AT HYDERABAD.
THE AGENT TO THE GOVERNOR GENERAL FOR CENTRAL INDIA AND RAJPOOTANA.
THE SUPERINTENDENT OF PORT BLAIR, AND CHIEF COMMISSIONER, ANDAMAN AND
NICOBAR ISLANDS.
THE INSPECTOR GENERAL OF MILITARY WORKS.
THE PRINCIPAL, THOMSON COLLEGE.
THE DEPARTMENT OF REVENUE, AGRICULTURE AND COMMERCE.

Fort William, December 19, 1877.

In continuation of Circular No. 66 P W of the 7th ultimo, the under-
signed is directed to forward, for information, copy of "Instructions," issued by
the British War Department, regarding the application of Lightning-conductors
for the protection of Powder Magazines and other buildings.

Frederick Smith Captain, R. E.,
Asstt. Secy. to the Govt. of India.

To, the Secretary to the Govt. of Madras.
P. W. Department, General Branch.

GOVERNMENT OF INDIA.
PUBLIC WORKS DEPARTMENT.
CIVIL WORKS.
Miscellaneous.

To

The Governments of Madras, Bombay, Bengal,
North Western Provinces and Oudh, in the
Public Works Department, General Branch.
The Chief Commissioners, Central Provinces,
British Burmah, Mysore and Coorg, and
Assam.
The Resident at Hyderabad.
The Agents to the Governor General for Central
India and Rajpootana.
The Superintendent of Port Blair, and Chief
Commissioner, Andaman and Nicobar
Islands.
The Inspector General of Military Works.
The Principal, Thomason College.
The Department of Revenue, Agriculture and
Commerce.

Circular No. 74 Public Works.

Dated December 19, 1877.

Received

Forwards, for information, copy of "Instructions," issued by the British War Department regarding the application of Lightning-conductors for the protection of Powder Magazines and other buildings.

No. 659, P. W. D. Press-22-12-77-440.

All communications
should be addressed
to the Secretary.

No. 94
GOVERNMENT OF INDIA.
PUBLIC WORKS DEPARTMENT.

*Civil Works.
Miscellaneous.*

*To The Secretary to the Govt of Madras.
Public Works Department.*

Fort William, 13th March 1878.

Sir,

*In reply to the request made in
your letter No 1076 of the 1st current asking to be
supplied with 50 additional copies of the "Instruc-
tions" issued by the British War Department, &
regarding Lightning Conductors for protection of
Powder Magazines, &c forwarded with Public Works
Department Circular No 74 dated 19th December
1877, I am directed to say that there are no more
spare copies available in this Office.*

*I have the honor to be,
Your most obedt servant,
J. S. Smith Capt R.E.
Asst Secretary to the Govt of India*

J.W.

1454 Wd 21st March 78
 Communicated to
 District Engineer
 for information and
 to the Military Dept.
 Gt. W. H.
 20-3-78

1.3.78 to 1076
 24-11-77 - 1749 W

1450
 S. Eng. 12
 Can be used with copies
 Can be used for instructions
 12-11-78
 1000

with order

No 1076 of 1 March 78

The Secy to the
 Govt of India

Sir

I have the honor
 to request that this Office
 may be supplied with
 50 additional spare
 copies of the "Instructions"
 issued by the British
 War Dept. regarding
 Lightning Conductors for
 protection of Powder
 Magazines, &c, forwarded
 with your Circular
 No 74 Public Works of
 19th Dec 77.

Gt. W. H.
 25-2-78

R.F.

15-7-06

1359/2401

Govt. of (1878) Madras.
PUBLIC WORKS.

To

Dated

Issued

Recd.

Encl.

G. O., 24 Mar 1878, No. 14871

J.C. - 21/1-78

Nos.

7 Murad No. 3896 clon

Application of lightning
conductors for the
of powder magazines &
other buildings -

Circular from the Govt.
of India forwarding
instructions issued by
the British War Dept.
for the - Comd: of Brit
mags and other buildings
Sept C.

Int. Secy

14546

17/18/78