

C. No. 3107.
Letter No. 688.
Dated the 21st May 1881.
From the Sup^r of Works
Presidency.

Note of Remarks

The Revised Estimate
for Providing Lightning
Conductor to St. John's
Church at Bangalore,
Amounting to Rs. 1880.
has been approved of
& countersigned by the
Chaplain & President
of the Church Committee.
Vide Chief Engr's Memo.
No. 1095. Dated 4th May 1881.

27th May 1881.

[Signature]

No 1435W.

PUBLIC WORKS DEPARTMENT.

PROCEEDINGS OF THE MADRAS GOVERNMENT.

Under date the 8th June 1881

Read the following:—

From the Sup^r of Works } ^{2758 25 April}
Presidency } R. E. No. 688 dated 21st
May 1881.

The revised estimate
amounting to Rs. 1880
for providing a lightning
conductor to St. John's
Church at Bangalore
is sanctioned for execution
when funds are available.

2. This sanction has been
registered as Provincial
No. 33 B of 1881-82 and
is classified as Civil
Buildings Original Works.
It cancels the sanction
accorded in G.O. No. 324
N. dated 14th August 1876.

[Signature]

to an estimate of Rs. 570

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B.A. 1135 N 98 June 1891

L. of W. & Co. Presy
with 4 Encls ✓

to P. & Co. with
duplicate Ab. Encl ✓

Ecclesiastical Dept ✓
Des. 48
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29.10.87

15.3.80, L. 633 AL

P. W. D E P A R T M E N T .
No. 481 C, dated 26th. February 1883.

M E M O R A N D U M .

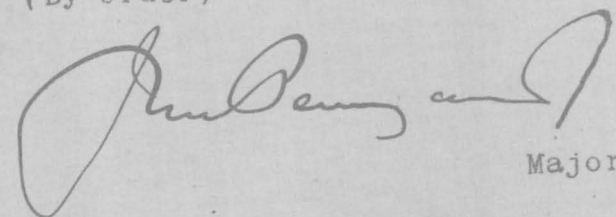
The accompanying Appendix A. to the Standard Specifications of the P.W. Department is circulated for information & guidance.

2. The Appendix is uniform with the new edition of the P.W. Code, as the revised edition of Standard Specifications which will shortly issue, will be in the same form.

3. Early application should be made for any additional copies required by Superintending Engineers.

4. Copies required by Local Fund Boards will be supplied at (3) three annas each.

(By Order)



Major R.E.

Dy. Chief Engineer P.W.D.

To

Supg. Engrs.
Consg. Archt. to Govt.
Genl. Supt. P.W. Stores.
Secy. Code Committee.
Board of Revenue.

With copies of Appendix A.

with order

No 203 dated 23rd June 1881.

P. W. Depart^t

Circular.

The Chief Engineer desires to call the attention of the officers of the Department to the necessity for economy in their proposals for the protection from lightning of such edifices as churches.

2. In most cases it will generally suffice if the conductor provides efficiently for the protection of the steeple. The other portions of the building, especially when moderately low may, without much fear, be left exposed

/By order/

C. Stanton Captain R.E.

Asst. Dy. Chief Engineer P. W. D.

To

Supg. Engineers.

Supts. of Works.

Govt. Architect

Genl. Supt. P. W. Stores & Workshops.

No 136, C

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Enclosure will be sent
by the Registrar to the
Chief of the Gazette Office

N. 1240W.
with order

9/10/81

APPENDIX A
TO
STANDARD SPECIFICATIONS.
LIGHTNING ROD CONFERENCE.
REPORT

OF THE
DELEGATES FROM THE FOLLOWING SOCIETIES, VIZ. :

METEOROLOGICAL SOCIETY.

C. BROOKE, F.R.S., *Past President* [THE LATE].
E. E. DYMOND, F.M.S., *Vice-President*.
G. J. SYMONS, F.R.S., *President*.

ROYAL INSTITUTE OF BRITISH ARCHITECTS.

PROF. LEWIS, F.S.A., *Vice-President*.
J. WHICHCORD, F.S.A., *Past President*.

SOCIETY OF TELEGRAPH ENGINEERS AND OF ELECTRICIANS.

LATIMER CLARK, M. INST. C.E., *Past President*.
W. H. PREECE, F.R.S., M. INST. C.E., *Past President*.

PHYSICAL SOCIETY.

PROF. W. G. ADAMS, F.R.S., *Past President*.
PROF. G. CAREY FOSTER, F.R.S., *Past President*.

CO-OPTED MEMBERS.

PROF. W. E. AYRTON, F.R.S.
PROF. D. E. HUGHES, F.R.S.

*With a Code of Rules for the Erection of Lightning Conductors ;
and various Appendices.*

EDITED BY THE SECRETARY, G. J. SYMONS, F.R.S.

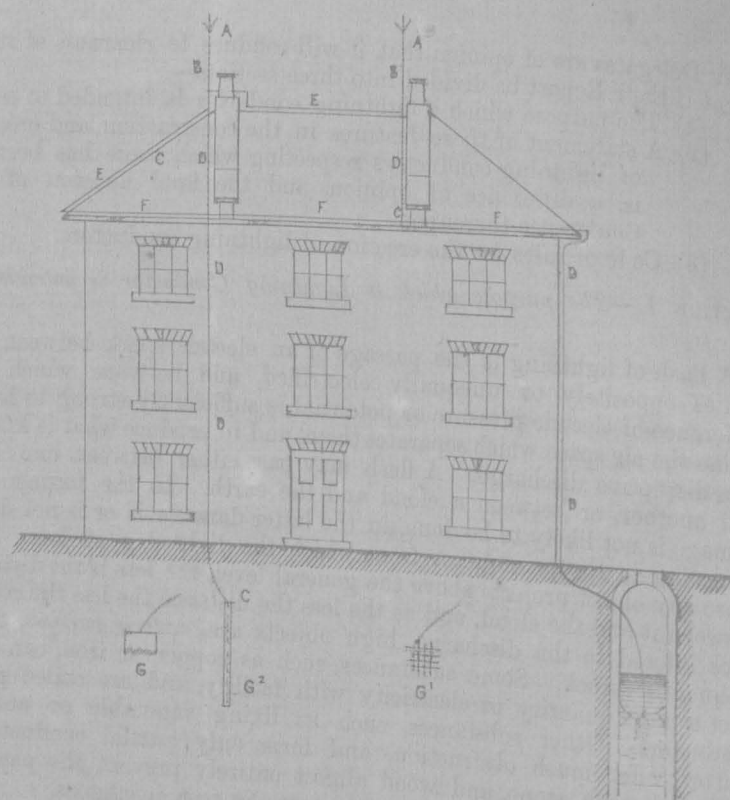
PREFACE.

* * *
At the meeting, July 6th, 1880, the Secretary handed in a sketch of a house with various parts of the lightning conductor marked upon it, and obtained from the delegates definite names for each portion, in order that in framing the report there might be no uncertainty as to what was meant by any special term, great confusion in this respect having previously existed.

The terms adopted have been : *Conductor*.—The whole arrangement for the protection of a building. *Point*.—The upper termination of the conductor, whether blunt or sharp, single or bifurcated. *Upper terminal*.—That portion of the conductor which is between the top of the edifice and the point. *Joint*.—Any connection between any two parts of the conductor. *Rod*.—The main portion of the conductor, whether it consist of rope, tape, tube or solid rod. *Circuit des Faîtes*.—A rod running round the eaves of a house, the battlements of a tower, &c. *Earth plate*.—The termination of the conductor in the ground, the pattern being indicated by special terms.

The accompanying lithograph will, it is hoped, supply all additional necessary particulars.
* * *

INDEX SKETCH OF LIGHTNING CONDUCTOR, ILLUSTRATING THE TERMS
EMPLOYED IN THE REPORT.



TERMS APPLIED TO THE VARIOUS PARTS OF A CONDUCTOR

✓ Crutch	A Point	F Circuit des faites
Strap	B Upper Terminal	G Earth Plates
Staple	C Joint	G¹ " " Sanderson
Wall Eye	D Rod	G² " " Borrell
	E Ridge Rod	G³ " " Spang

REPORT.

THE Delegates are of opinion that it will conduce to clearness of statement if their Report be divided into three sections—

- (1) The purpose which a lightning conductor is intended to serve.
- (2) A statement of those features in the construction and erection of lightning conductors respecting which there has been, or is, a difference of opinion, and the final decision of the Conference thereupon.
- (3) Code of rules for the erection of lightning conductors.

SECTION I.—*The purpose which a Lightning Conductor is intended to serve.*

A flash of lightning is the passage of an electric spark between two bodies oppositely or unequally electrified, and between which the difference of electric pressure or potential is sufficiently strong to break across the air space which separates them, and to produce what is known as a disruptive discharge. A flash may pass either between one cloud and another, or between a cloud and the earth. In the former case damage is not likely to be done, in the latter damage is or is not done, according to the point at or from which the lightning strikes. The more any object projects above the general level, the less is the distance between it and the cloud, and as the less the distance the less the resistance offered to the discharge, high objects are, *ceteris paribus*, most frequently struck. Some substances, such as copper or iron, can conduct a large quantity of electricity with facility, and are called good conductors. Other substances, such as living vegetable or animal matter, offer much obstruction, and form only partial conductors; while dry earth, stone, and wood almost entirely prevent the passage of electricity, and are very bad conductors—in fact, insulators.

For instance, a man may with perfect impunity clasp a copper rod an inch in diameter, the bottom of which is well connected with moist earth, while the top of it receives a violent flash of lightning. But if the electricity does not find a path prepared for it, it will utilise such partial conductors as may be reasonably near, for example—the heated air from a kitchen chimney, the soot inside, and then the metal range at the bottom; here, however, stone or dry material is generally found, which will not conduct it, and then it dashes across the kitchen at some gas or water pipe, or some pump or drain leading to damp earth, doing serious damage on the way: or it may meet some tree in its course and rend it from top to bottom, and if the human body intervene life may be destroyed. Mechanical injury is inflicted only where the conduction for the discharge is imperfect.

A lightning conductor fulfils two functions: it facilitates the discharge of the electricity to the earth, so as to carry it off harmlessly, and

it tends to prevent disruptive discharge by silently neutralising the conditions which determine such discharge in the neighbourhood of the conductor.

To effect the first object a lightning conductor should offer a line of discharge more nearly perfect, and more accessible, than any other offered by the materials or contents of the edifice we wish to protect. To effect the second object the conductor should be surmounted by a point or points. Fine points and flames have the property of slowly and silently dissipating the electrical charges; they, in fact, act as safety valves.

If all these conditions be fulfilled; if the points be high enough to be the most salient features of the building no matter from what direction the storm cloud may come, be of ample dimensions and in thoroughly perfect electrical connection with the earth, the edifice with all that it contains will be safe, and the conductor might even be surrounded by gunpowder in the heaviest storm without risk or danger.

All accidents may be said to be due to a neglect of these simple elementary principles. The most frequent sources of failure are conductors deficient either in number, height, or conductivity, bad joints, or bad earth connections. There is no authentic case on record where a properly-constructed conductor failed to do its duty.

SECTION II.—*A Statement of those features in the construction and erection of Lightning Conductors, respecting which there has been, or is, a difference of opinion, and the final decision of the Conference thereupon.*

Points.	Joints.	Height of Upper Terminal.
Material for Conductor.	Protection of Rod.	Testing Conductors.
Size of Rod.	Attachment to Building.	Internal Masses of Metal.
Shape of Rod.	Earth Plates.	External Masses of Metal.
(Rods, Tubes, Tape, Rope, Plait.)	Space Protected.	

POINTS.—Starting with the extreme top, we have first to deal with the question of points. The utility of points was hotly contested rather more than a century since, and an abstract of the discussion will be found in Appendix F, page (79), and difference of opinion still exists as to their precise functions and value. The decision as to the best form of points is complicated by two opposing requirements (1), the sharper the point the more rapid the silent discharge of electricity, and, therefore, the more effective the conductor; but (2) the sharper the point the more easily is it destroyed by oxidation, or fused, should a heavy disruptive discharge fall upon it.

Attempts have been made by the use of gold, silver, and platinum, to obtain a sharp point which should not only be durable, but, owing to its high melting point, resist fusion by a disruptive discharge. But such metals are very expensive, and the statements in Appendix F, pages (67, 69, 73, 103, 123, 128, and 139), prove that even platinum points are often damaged. Copper points whose sectional area is less than .05 of a square inch are very liable to be melted. Lightning has even fused a copper rod .10 sq. in. in sectional area, i.e., 0.35 in. in diameter, and there are many rods still standing of which the extremity has been melted into a button or knob.

For these reasons it seems best to separate the double functions of the point, prolonging the upper terminal to the very summit, and merely bevelling it off, so that, if a disruptive discharge does take place, the full conducting power of the rod may be ready to receive it, and, therefore, that there may be no risk of melted particles of metal setting fire to the building, as has occurred. [Appendix F, p. (93).]

At the same time, having regard to the importance of silent discharge from sharp points, we suggest that at one foot below the extreme top of the upper terminal there be firmly attached, by screws and solder, a copper ring, bearing three or four copper needles, each 6 inches long and tapering from $\frac{1}{4}$ inch diameter to as fine a point as can be made; and with the object of rendering the sharpness as permanent as possible, we advise that they be platinized, gilded, or nickel-plated.

Vanes, finials, and ornamental ironwork so frequently form the upper portion of edifices, that it is essential to consider their relation to the conductor. They should always be in perfect metallic connection with the conductor. The possibility of such metal work inducing the charge to desert the conductor for some other path is sometimes suggested, but it could not happen unless the conductor were out of order, e.g., of inadequate conducting power, or had an imperfect earth-contact.

With respect to factory chimneys, a different practice prevails in England from that which is nearly universal on the Continent. In this country one straight rod is usually carried up on one side of the chimney to a height above the top about equal to the diameter of the chimney. On the Continent two arches of iron are put crosswise over the aperture of the chimney, and a vertical rod is carried up from the intersection. In both systems the upper terminal suffers from the corroding effect of the fumes from the chimney. Dr. Mann thought, Appendix F, p. (132), that considering the ready path for lightning afforded by the heated smoke discharged from chimneys, a coronal conductor should be placed upon them, as well as a multiple point. Messrs. Gray say, Appendix A, p. (9): "For high chimney shafts we fit a copper band round the top, and four points thereon connected to main down rod." The Edinburgh Gas Works chimney, 341 feet high and 14 feet across at the top, was fitted with a conductor under the advice of Faraday, Appendix F, p. (89). It had an iron plate on the top; Faraday directed that the rod should be connected with this plate, and the upper terminal should rise vertically 6 feet above it.

We are of opinion that a coronal or copper band, with stout copper points, each about 1 ft. long, at intervals of 2 or 3 ft. throughout the circumference, will make the most durable and generally useful protector for a factory chimney, but these points should be gilded or otherwise protected against corrosion.

MATERIAL FOR CONDUCTOR.—Iron and copper are practically the only two metals which need consideration; brass, which has sometimes been used, is so perishable that its employment is a self-evident error. We will assume the conductivity of equal lengths and weights of iron to be, in the case of steady currents of electricity, $\frac{1}{4}$ th that of copper, and the cost of iron to be $\frac{1}{4}$ th that of copper, this would make the cost of copper for equal conducting power $\frac{4}{3}$ ths, or 50 per cent. dearer than iron. But there are other matters to be considered: (1)

the great weight and bulk of iron rods; (2) their deterioration by rust; (3) the serious obstruction offered by a rusty joint; (4) the suddenness of lightning discharge which modifies the conductivity; and lastly, that iron is so much more rigid than copper that (except in the form of iron wire rope, of which we shall speak hereafter) it can rarely be used in greater lengths than 20 feet, and thus numerous joints become necessary, whereas every needless joint should be avoided.

As regards galvanizing, we think it scarcely judicious to trust entirely to it for protection against oxidation, for many instances of imperfect galvanizing have come to our knowledge.

On the other hand copper becomes brittle, not only when exposed to the air, but also by the passage through it of powerful charges of atmospheric electricity. Franklin used iron, and it is employed in America and on the Continent much more generally than copper, and it is less tempting to the thief.

Nevertheless, as the cost of erection bears a considerable ratio to the cost of the rod itself, and as iron possesses the disadvantages above stated, we think that in all ordinary cases a copper rod will in the end prove the cheapest, as it will certainly be the most durable.

SIZE OF ROD.—This is perhaps the most difficult subject which has to be determined. We greatly regret the shortness of Table I in Appendix K; but we think that it must be assumed from it that lightning has fused a copper rod $\cdot 10$ in. ($\frac{1}{16}$ th) in area, i.e., weighing 6 ounces to the foot. We have also the Caterham case, Appendix I, p. (214), where a copper tube weighing $5\frac{3}{4}$ ounces per foot was heated to redness.

The saving of cost which might be effected by using, for very low buildings, rather slighter rods than for ordinary edifices is not worth considering. In a 30 feet rod it could hardly amount to 10s. We therefore recommend as the *minimum* to be used:—

Material.	Pattern.	Diameter. in.	Sectional Area of Metal. sq. in.	Weight per foot. oz.
Copper	... Rope	...	...	...
"	... Round Rod	...	...	6
"	... Tape	...	...	7
Iron	... Round Rod	...	...	6
		...	...	35

SHAPE OF ROD.—This depends upon a subject which until lately was warmly discussed, viz., upon the relative importance of the sectional area, and of the superficial area of a conductor; a matter which has been the subject of active discussion among electrical authorities. Faraday and Sir W. Snow Harris, for example, held diametrically opposite views respecting it. [Appendix F, p. (89), and I, p. (195).] There is abundant and conclusive evidence that in the case of steady electric currents, conductivity depends upon sectional area alone, and not at all upon extent of surface, and experiments by Mr. Preece and Dr. Warren De la Rue tend to show that, in the case of sudden discharges from condensers, to which lightning discharges are probably analogous, the influence of form is not considerable. On the other hand, there is equally conclusive evidence that the facility with which currents of short duration pass through conductors is affected by the

form and arrangement, as well as by the sectional area of the conductors. Upon the whole we agree with the opinion quoted below, from a writer recognised in the United States as a high authority on lightning conductors, who, after describing and engraving more than fifty patterns of rods, says:—*

"The alleged improvements in the said conductors are, in nearly all cases, worthless, or of a trifling and unimportant character. The fact is, the said conductors are quite inferior, and contain no essential improvement upon the ordinary round iron rod used during the days of Franklin."

In Europe the only forms at all generally employed are:—

Rods (round or square); Tubes; Tape; Ropes (wire, or wire with hemp centres); Plait.

Rods (round or square).—The advantages and disadvantages of rods are easily stated. The advantages are their durability and their rigidity, the latter being of importance for long upper terminals. The disadvantages are the necessity for numerous joints, and the difficulty of avoiding serious disfigurement to the building to which they are attached.

Tubes have much the same merits and demerits, with the additional objection that they are necessarily of larger diameter than solid rods, and therefore more conspicuous. They have also an additional disadvantage in that they are generally joined together by screw collars. The cutting of the thread in the tube seriously diminishes the sectional area, and the joint so made is electrically defective. If tubes are used, the joints should be made as directed in the code of rules under the head of joints.

Tape is a form of rod which is of comparatively recent introduction, and possesses many advantages. Foremost among these is the length which can be supplied in a single piece. Where, as at the junction with an upper terminal, a joint is needed, it is easily made by clamping or rivetting the two surfaces together and then imbedding the whole in a mass of solder. No kind of coupling known to us is, in our opinion, equal to this very simple one. Owing to the flexibility of the tape it can be made to follow closely the outlines of a building, or may be countersunk in it, and painted over, but, as stated further on, abrupt bends should be avoided, and the precautions and instruction set forth on pages 15 and 16 should be followed. The objections to tape, Appendix A, pages (5) and (16), will be found to be objections, not to tape *per se*, but to bad practice on the part of some persons who have fitted it up and availed themselves unduly of its flexibility.

Ropes.—For many years past rope constructed of twisted strands of copper or of iron wires has been largely employed for lightning rods. There is on record a very remarkable case of the complete destruction of a brass wire rope, an event which, if it had been repeated, might justly have been regarded as a serious objection to the use of ropes. This case is fully reported in Appendix F, pages (62-63); and from it some French electricians have concluded that lightning may single out some wires from a rope and travel along them in preference to the rest,

* Spang, "A Practical Treatise on Lightning Protection," p. 121.

even when the whole of them are hardly sufficient to give it a free passage. Whatever may have been the explanation, this accident seems to be unique, and even if we accept the explanation given, the only extra precaution which it calls for is the soldering of each extremity of the several wires forming the rod, and at every joint, into a single mass.

We agree with M. Borrel in thinking that serious evil arises from using wire of too small diameter, which involves an additional number of interstices for the lodgement of dirt, smoke, and water, and at the same time renders the wires too thin effectually to resist oxidation. We have had before us rope $\frac{3}{8}$ in. in diameter, composed of 49 strands of a copper wire about No. 19 B.W.G., say 0.04 in. in diameter. On the contrary, one firm speaks of employing No. 10 B.W.G., i.e., 0.14 in. diameter, and in special cases Nos. 8 and even 7, which would be about 0.17 in. and 0.19 in. diameter respectively: these would not be open to the objection we have raised.

The objection to thin wires is necessarily greater with iron ropes, even if galvanized, than with copper, for irrespective of the doubt as to the perfect galvanizing of every part, there is the greater brittleness, and consequent risk of damage from defective continuity.

Ropes with Hemp Centres.—One English firm sent us a specimen of 6-strand copper rope with a hemp core, and we understand that the same pattern is occasionally used both in iron and copper in France. We do not know the precise object aimed at—probably flexibility—but considering the perishableness of such a core, its variation in length with the hygrometric state of the air, and its invariability when the copper is varying with temperature, we cannot regard it as a wise construction.

Plait.—This form of rod was probably designed in the belief that the essential element in a lightning rod was plenty of surface. It is made in two sizes, with copper wire, about No. 16 B.W.G., plaited into a sort of ribbon. It invites oxidation as much as is possible, and is in our opinion neither durable nor trustworthy. The original form of this rod was ridiculously bad; for it consisted of 13 copper wires and 1 zinc one. Every time that it became wet, feeble electric action was set up, and the zinc wire was gradually destroyed, without the slightest benefit to anybody.

JOINTS.—The most fruitful sources of danger in rods are *bad joints*, not necessarily those that are mechanically bad, but those that are so electrically. A joint is said to be electrically bad when it offers resistance to the passage of electricity through it. *There should be no resistance whatever.* A careful inspection by Capt. Bucknill, R.E. (Appendix M, p. 243), has proved that bad joints in lightning rods are very abundant, though they appear perfectly sound; and everyone who has measured the electrical condition of conductors confirms this fact. Bad joints have the same effect as lengthening the conductor; and, in one case, one bad joint was found to have the same effect on a discharge of electricity as a conductor 1,900 miles long. It is evident that such rods may be worse than useless, for other parts of the building may offer easier paths for the discharge to the earth. If the joint be imperfect, and the rod convey a charge to earth, heat will be generated

at the joint, the rod may be fused, and the discharge be diverted to the building.

Screwed, scarfed, and rivetted joints, however well they may be made mechanically, are certain to rust and corrode in time, owing to the expansions and contractions due to changes of temperature admitting moisture, and thus causing corrosion and resistance. No joint can possibly be electrically perfect that is not *metallically continuous* and careful soldering in addition to screwing, scarfing, or rivetting, is the only certain mode of securing this. Soldering is a method that has borne the test of experience, and its success as a means of securing perfect joints leaves no excuse for its omission. The fewer joints the better, but where there are joints they can only be made electrically secure by careful soldering.

PROTECTION OF ROD.—The lower part of copper rods is sometimes stolen for the sake of the metal. This can be guarded against by putting it inside a length of iron gas-barrel, extending from some distance below ground to 10 ft. above it.

PAINTING.—Iron conductors, even if they are galvanized, should be painted throughout, except at the points, which should be gilded or nickel-plated.

In France and Belgium painting is resorted to to a considerable extent, and the practice was recommended by the late Professor Joseph Henry, and followed very largely in America. [Appendix F, pages (99) and (113).]

ATTACHMENT TO BUILDINGS.—The evidence against the use of glass or other material in order to insulate the conductor is overwhelming, and insulation may be regarded as unnecessary and mischievous. The essentials are (1) that the rod be attached to the building by fastenings of the same metal as itself, (2) that the fastenings be of adequate strength, (3) that they be of such form as not to compress or distort the rod, (4) that they allow play for its expansion and contraction, (5) that they hold it firmly enough to prevent all the weight falling on any one bearing.

Where practicable it is well to take the rod down that face of the house which is most exposed to rain.

EARTH PLATES.—This portion of the lightning conductor is of the utmost importance, but has hitherto been the most neglected. The majority of cases in which lightning has caused injury very near to or upon conductors are traceable to those conductors having imperfect earth terminals. We know of many cases in which the earth terminals have been miserably imperfect, or entirely neglected, when the above-ground portion has been perfectly satisfactory. In fact, though it may be admitted that the case found by Dr. Mann,* of the lightning rod of a church tower, the lower end of which was thrust into an empty glass bottle, is an exceptionally bad one; yet there are sadly too many, of which the Middlesboro' case, Appendix I, page (217), is a perfectly fair type.

* Quarterly Journ. Met. Soc., Vol. II, p. 420.

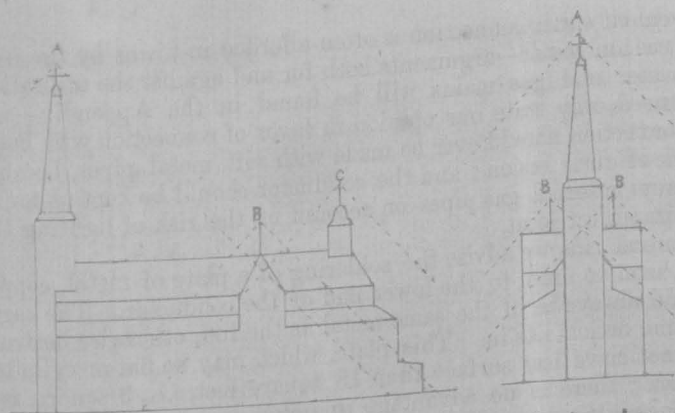
A convenient earth connection is often afforded in towns by the iron mains for gas and water—arguments both for and against the utilisation of both water and gas mains will be found in the Appendix—we, therefore, need only state our opinion in favor of connection with both. But no connection should ever be made with soft metal pipes, because of the risk of their fusion; and the conductor should be kept as far as possible from internal gas pipes on account of the risk of lighting the gas at an imperfect joint.

As a general rule we advise the soldering of a plate of metal, copper to copper, iron to iron, to the lower end of the conductor. The earth plate should always be of the same metal as the rod, otherwise destructive galvanic action sets in. This plate, which may be flat or cylindrical, must not have less surface than 18 square feet, *i.e.*, 9 square feet on each face; there is no advantage in notching or pointing it. A hole must be dug, or well sunk, to receive this plate, and the hole must be so deep that the earth surrounding the plate shall *never* be dry. Any available drain or other water should be allowed to soak into the earth, over the site of the plate. After the hole has been dug, and the plate lowered into position, it should be filled with cinders, or coke. In extremely dry rocky localities, it is sometimes impossible to fulfil these conditions: then the best thing to do is to bury three or four hundredweight of iron at the foot of the conductor, still using the earth plate and the coke, and taking especial care that the rain-water and sink pipes discharge over it.

All drains, water-courses, in fact, everything which will assist in distributing the charge over a large extent of moist earth should be utilised by leading branches from the earth plate to them, or a long length of the rod may be laid in a drain if it be one which will be constantly wet.

SPACE PROTECTED.—The question as to the extent of the space which will probably be protected by a lightning rod is one which is of very great practical importance, because it governs the number and height of the upper terminals which are required for the protection of any given building. The index to the Appendix shows that "Protection, Area of," is discussed upon twenty-nine pages in different parts of the Appendix. It has been laid down that the space protected was a cone, having the point for its apex, and a base whose radius was equal to twice the height of the point, while the latest French official instructions, Appendix F, p. (67), state that a point will "effectively protect a cone having the point for its apex, and a base whose radius is 1.75 of its height." The English War Department instructions considerably reduce this space by asserting, Appendix F, p. (71), that "no precise limit can be fixed to the protecting power of conductors. In England the base of the protected cone is usually assumed to have a radius equal to the height from the ground; but though this may be sufficiently correct for practical purposes, it cannot always be relied upon."*

* On page (96), two instances are recorded in which, if the evidence can be trusted, the stroke fell within a radius equal to the height, but it is only right to say that the facts are not very clearly recorded.



According to this rule, the church of Ste. Croix (see Appendix F, p. (141)) would require four upper terminals, one on steeple, one on chancel, and one in the middle of each half of the transept.

From theoretical considerations stated by Mr. Preece, Appendix F, p. (137), he arrives at the conclusion that "A lightning rod protects a conic space whose height is the length of the rod, whose base is a circle having its radius equal to the height of the rod, and whose side is the quadrant of a circle, whose radius is equal to the height of the rod."

At present we have not sufficient data to enable us theoretically to calculate the space protected by a lightning rod, and therefore we are compelled to draw up our rules upon the question entirely from experience, and here we find that, with the doubtful exceptions already mentioned, there is no recorded instance of a building being struck by lightning within a conical space, the radius of whose base was equal to its height, and we think that the adoption of this rule may reasonably be expected to yield that security in the future, which as far as we know it has done in the past.

HEIGHT OF UPPER TERMINAL.—This matter is one which may be left entirely to the option of individual architects and engineers, subject, of course, to the opinions expressed under the heading "Space Protected." In France extremely long *tiges*, or upper terminals, generally 33 feet long, are used; but it is obvious that they are necessarily very strong and heavy, and both by their weight and by the great leverage which they exert when there is any wind, they must produce serious vibrations in the roof. In England hitherto the opposite error is almost universal, and we seldom see a conductor carried high enough to protect all the building to which it is attached. The question of appearance comes in here, but concerning it we need only remark that while in England care seems generally taken to conceal the conductors, in France they are, to a certain extent, made features of the edifice. With a proper exercise of taste, the terminals of the lightning conductors can be made to assist the ornamentation of the building, as has been done in many cases.

TESTING CONDUCTORS.—Periodical examination and careful testing of the lightning conductor are requisite to maintain the system in efficient order. Points will corrode from oxidation and fusion; joints will get loose and bad through the action of weather and workmen; connections will decay both above and below ground; imperfec-

tions will develop themselves; alterations will be made by landlords and tenants; and, in spite of every precaution during erection, the conductor will thus lose its efficiency if it be not *maintained* in thorough order. For this purpose inspection should be both visual and electrical. In order to facilitate the electrical examination of the conductor, some firms have erected a double rod, connected with one upper terminal, one on each side of a chimney or shaft; this is a very efficient arrangement, for it provides a means for testing from the ground. It has also been proposed to carry an insulated wire alongside or even within the rod, connected to the terminal at the top, and to the testing apparatus at the bottom.

A testing apparatus has been devised by Mr. Anderson (*Lightning Conductors*, p. 60). M. Borrell, Appendix K, p. (226), Captain Bucknill, R.E., Appendix M, p. (244), and Mr. Vyle, Appendix M, p. (244), have also introduced apparatus for the purpose. The system in use in Paris, Appendix K, p. (225), and M, p. (245), is perhaps the simplest and cheapest, and is effective as regards testing the efficiency of the conductor, but not that of the earth connection.

The efficiency both of the conductor and of its earth terminal should be annually tested. As this testing involves some skill and familiarity with electrical apparatus it would be advantageous if some competent person were officially appointed, either by the Government or by some recognised authority, to perform this duty.

INTERNAL MASSES OF METAL.—All large and long masses of metal, such as beams, girders, pipes, hot-water systems, and large ventilators fixed in the interior of buildings, should be electrically connected with the earth, or with the conductor; but the soft metal gas-pipes should never be used as conductors. The inlet and outlet pipes of large meters should always be, independently of the meter, electrically connected with each other, for two remarkable cases of the explosion of a meter have occurred through the presence of a joint in the pipe electrically bad owing to the use of India-rubber packing. Appendix M, p. (239.)

EXTERNAL MASSES OF METAL.—Large constructive and decorative ironwork, such as guttering, flashings, railings, finials, vanes, &c., and all masses of metals used in building, should be connected to each other, and to the earth direct, or to the conductor. In fact, the gutters and water pipes are already frequently utilized as a partially protective system. The ventilators of soil pipes may also be employed in this way, and even made slightly by the addition of an ornamental finial fitted with points, but care must be taken that the joints are metallic and not made with red lead or putty; and it must not be forgotten that the conductivity of lead is very small, so that undue reliance must not be placed upon pipes made of that metal.

SECTION III.—Code of Rules for the Erection of Lightning Conductors.
The following Code of Rules should be carefully attended to in drawing out a specification for a Lightning Conductor, the reasons for each being given in the previous Sections and in the Appendix:—

Points.—The point of the upper terminal should not be sharp, not sharper than a cone of which the height is equal to the radius of its base. But a foot lower down a copper ring should be screwed and soldered on to the upper terminal, in which ring should be fixed three or four sharp copper points, each about 6 in. long. It

is desirable that these points be so *platinized*, *gilded*, or *nickel-plated* as to resist oxidation.

Upper Terminals.—The number of conductors or points to be specified will depend upon the size of the building, the material of which it is constructed, and the comparative height of the several parts. No general rule can be given for this; but the architect must be guided by the directions given at pp. 12 and 13. He must, however, bear in mind that even ordinary chimney stacks, when exposed, should be protected by short terminals connected to the nearest rod, inasmuch as accidents often occur owing to the good conducting power of the heated air and soot in a chimney (p. 5).

Insulators.—The rod is not to be kept from the building by glass or other insulators, but attached to it by metal fastenings. (See p. 11.)

Fixing.—Rods should preferentially be taken down the side of the building which is most exposed to rain. They should be held firmly, but the holdfasts should not be driven in so tightly as to pinch the rod, or prevent the contraction and expansion produced by changes of temperature.

Factory Chimneys.—These should have a copper band round the top, and stout, sharp, copper points, each about 1 ft. long, at intervals of two or three feet throughout the circumference, and the rod should be connected with all bands and metallic masses in or near the chimney. (See p. 7.) Oxidation of the points must be carefully guarded against.

Ornamental Ironwork.—All vanes, finials, ridge ironwork, &c., should be connected with the conductor, and it is not absolutely necessary to use any other point than that afforded by such ornamental ironwork, provided the connection be perfect and the mass of ironwork considerable. As, however, there is risk of derangement through repairs, it is safer to have an independent upper terminal. (See p. 7.)

Material for Rod.—Copper, weighing not less than 6 oz. per foot run, and the conductivity of which is not less than 90 per cent. of that of pure copper, either in the form of tape or rope of stout wires—no individual wire being less than No. 12 B.W.G. Iron may be used, but should not weigh less than 2½ lb. per foot run. (See pp. 7 to 10.)

Joints.—Although electricity of high tension will jump across bad joints, they diminish the efficacy of the conductor; therefore every joint, besides being well cleaned, screwed, scarfed, or rivetted, should be thoroughly soldered. (See p. 10.)

Protection.—Copper rods to the height of 10 feet above the ground should be protected from injury and theft, by being enclosed in an iron pipe reaching some distance into the ground.

Painting.—Iron rods, whether galvanized or not, should be painted; copper ones may be painted or not according to architectural requirements.

Curvature.—The rod should not be bent abruptly round sharp corners. In no case should the length of the rod between two points be more than half as long again as the straight line joining them. Where a string course or other projecting stone work will admit

of it, the rod may be carried straight through, instead of round the projection. In such a case the hole should be large enough to allow the conductor to pass freely, and allow for expansion, &c.

Extensive Masses of Metal.—As far as practicable it is desirable that the conductor be connected to extensive masses of metal, such as hot-water pipes, &c., both internal and external; but it should be kept away from all soft metal pipes, and from internal gas-pipes of every kind, respecting which see page 14. Church Bells inside well protected spires need not be connected.

Earth Connection.—It is essential that the lower extremity of the conductor be buried in permanently damp soil; hence proximity to rain-water pipes, and to drains, is desirable. It is a very good plan to make the conductor bifurcate close below the surface of the ground, and adopt two of the following methods for securing the escape of the lightning into the earth. A strip of copper tape may be led from the bottom of the rod to the nearest gas or water main—not merely to a lead pipe—and be soldered to it; or a tape may be soldered to a sheet of copper 3 ft. $\times$ 3 ft. and $\frac{1}{8}$ in. thick, buried in permanently wet earth, and surrounded by cinders or coke; or many yards of the tape may be laid in a trench filled with coke, taking care that the surfaces of copper are, as in the previous cases, not less than 18 square feet. Where iron is used for the rod, a galvanized iron plate of similar dimensions should be employed.

Inspection.—Before giving his final certificate, the architect should have the conductor satisfactorily examined and tested by a qualified person, as injury to it often occurs up to the latest period of the works from accidental causes, and often from the carelessness of workmen. (See p. 13.)

Collieries.—Undoubted evidence exists of the explosion of fire-damp in collieries through sparks from atmospheric electricity being led into the mine by the wire ropes of the shaft and the iron rails of the galleries. Hence the head-gear of all shafts should be protected by proper lightning conductors.

(Signed) W. GRILLS ADAMS.
(") W. E. AYRTON.
(") LATIMER CLARK.
(") E. E. DYMOND.
(") G. CAREY FOSTER.
(") D. E. HUGHES.
(") T. HAYTER LEWIS.
(") W. H. PREECE.
(") G. J. SYMONS.
(") JOHN WHICHCORD.

December 14th, 1881.

N. B.—The appendices referred to above are those printed with the complete Report of the Lightning Rod Conference. The references are retained for the convenience of officers who may possess the work or who may desire to refer to it.

No 1435 W.

PUBLIC WORKS DEPARTMENT.

INGS OF THE MADRAS GOVERNMENT.

UNDER date the 8th June 1881

Read the following:—

2758 25th April 4

10/10 } N. E. No. 688 dated 21st
May 1881.

The revised estimate
amounting to Rs. 1880
for providing a lightning
conductor to St. John's
Church at Bangalore
is sanctioned for execution
when funds are available.
2. This sanction has been
registered as Provincial
No. 33 B of 1881-82 and
is classified as Civil
Buildings Original Works.
It cancels the sanction
accorded in G.O. No. 3247
N. dated 14th August 1878.
to

Note by Budget Section.

C. No. 3107.
Letter No. 688.
Dated the 21st May 1881.
From the Sup^t. of Works
Presidency.

Note of Remarks

The Revised Estimate
for Providing Lightning
Conductor to St. John's
Church at Bangalore,
Amounting to Rs. 1880.
has been approved of
& countersigned by the
Chaplain & President
of the Church Committee.
Vide Chief Engr's Memo.
No. 1095. Dated 4th May 1881.

27th May 1881.

[Signature]

No 1435W.

PUBLIC WORKS DEPARTMENT.

PROCEEDINGS OF THE MADRAS GOVERNMENT.

Under date the 8th June 1881

Read the following:—

From the Sup^t. of Works
Presidency —

2758 25th April

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May 1881.

The revised estimate
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is sanctioned for execution
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2. This sanction has been
registered as Provincial
No. 33 B of 1881. 82 and
is classified as Civil
Buildings Original Works.
It cancels the sanction
accorded in G.O. No. 324
H. dated 14th August 1878.

[Signature]