(1) Number of pages 148

(2) Date of repair 16-11-87

(3) Initials of the Referencer

TAMIL NADU ARCHIVES

GOVERNMENT OF TAMIL NADU

P.W. DEPARTMENT

G.O. No. / B.P. No. 217 W

Press. / Mis.

Dated 26-1-1886 ~~198~~.

Not to be folded or roughly handled.

Archives—I 10,006-9 88

GOVERNMENT OF MADRAS.

PUBLIC WORKS DEPARTMENT.

Buildings and Roads.
Civil Works.

Read—the following papers :—

From the Right Reverend the Lord Bishop of Madras, to the Chief Secretary to Government, dated Ootacamund, 30th April 1885, No. 327.

I have the honor to request that you will lay before the Government the accompanying papers regarding the remodelling of the lightning conductor of the church at St. Thomas' Mount, at a cost of Rs. 1,715, in accordance with G.O., dated 21st February 1884, No. 483 W., Public Works, paragraph 3.

No. 899, Ecclesiastical.

Approved, and transferred to the Public Works Department.

Ootacamund,
5th May 1885.

(Signed) E. F. WEBSTER,
Chief Secretary.

From R. F. CHISHOLM, Esq., Consulting Architect to Government, to the Chief Engineer, Public Works Department, dated Chepâk, 29th July 1885, No. 666.

I have the honor to return the papers regarding the protection of St. Thomas' church by lightning conductors.

2. It will be seen from the plans which I have had made of the church that, if it is to be protected by vertical rods, two terminals upwards of 25 feet high must be constructed at the points A and B, and that the steeple must be raised upwards of 25 feet. All this is unnecessary.

3. If the present conductor is made perfect with a proper fall to earth at the west end and a copper tape (1½″ × ⅛″) is run all round the parapet with a terminal at the east end and a fall to earth the building will be properly protected according to the rules of the Lightning Rod Conference. This system is shown clearly on the plan by red lines.

From Colonel H. L. PRENDERGAST, R.E., Superintending Engineer, V Circle, to the Chief Engineer, Public Works Department, dated Chepâk, 19th January 1886, No. 4324.

With reference to your endorsement, No. 1316 C., of 21st July 1885, on the Consulting Architect's letter, No. 666, of 29th July 1885 (returned), I have the honor to submit, for sanction, a plan and estimate of Rs. 554 for remodelling the lightning conductor of the church at St. Thomas' Mount.

2. The present conductor is given a proper fall to earth, and a copper tape 1½ by ⅛ inch is run all round the parapet with a terminal and earth connection.

Order—dated 26th January 1886, No. 217 W., Public Works.

The estimate, amounting to Rs. 564, for remodelling the lightning conductor of the English church at St. Thomas' Mount, is sanctioned.

2. This sanction has been registered as Provincial, No. 290 W. of 1885-86, and classified as Civil Buildings, Original Works.

(True Extract.)

Major, R.E.,
Under Secy. to Govt., P.W.D.

To the Superintending Engineer, V Circle, with two plans.
" Examiner, Public Works Accounts, with estimate for note and return to the Superintending Engineer, V Circle.
" Ecclesiastical Department.

Exd. E. Fernandes.
Spare Copies.

BUILDINGS AND ROADS.
CIVIL WORKS.

Govt. of (1886) Madras.

PUBLIC WORKS.

Dated January, 188 .

Recd. Encl.

G.O., 26th Jan. 1886, No. 217 W.

JANUARY.

English Church at St. Thomas' Mount

Estimate for re-modelling the lightning conductor of the —, sanctioned.

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.

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

Exd. E. C. Shunker.

Spare Copies

1

BUILDINGS AND ROADS.
CIVIL WORKS.

Govt. of [1878] Madras.

PUBLIC WORKS.

DISTRICT ENGINEERS,
&c. &c. &c.

Dated March 21st.

Read

Read.

G. O., 21st March 1878, No. 1,[illegible] W.

MARCH.

Nos. 311-312.

Application of Lightning Conductors for the protection of Powder Magazines and other buildings.—Circular from the Government of India forwarding instructions issued by the British War Department for the com-

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20

GOVERNMENT OF MADRAS.

PUBLIC WORKS DEPARTMENT.

11th April 1878, No. 1,806 W.

Buildings and Roads.
Civil Works.

Read the following paper :—

No. 137. From the Deputy Secretary to the Government of India, Public Works Department, (Civil Works—Miscellaneous,) to the Secretary to the Government of Madras, Public Works Department, dated Fort William, 1st April 1878, Circular No. 35 P.W.

In continuation of Circular No. 23 P.W., dated the 5th ultimo, the undersigned is directed to circulate, for general information and guidance, extract from an address delivered by Dr. Mann at the annual general meeting of the Meteorological Society, held on the 19th January 1876, regarding the protection of buildings from lightning.

(Signed) CHARLES POLLARD, Col., R.E.,
Dy. Secy. to the Govt. of India.

Extract from an Address delivered by Dr. Mann at the Annual General Meeting of the Meteorological Society held on 9th January 1876.

In the report of the Council which has afforded me the opportunity for these remarks there is one other topic touched upon which I may perhaps also be permitted very briefly to allude to, on account of the part I have personally taken, and the interest which I have found, in suggesting its consideration to my colleagues. I allude to the establishment of a permanent committee for investigating the phenomena of atmospheric electricity and the effects of lightning, and for the diffusion of sound principles in reference to provisions made for defence against the destructive meteor.

In taking up the thread of what I desire to say upon this theme, I can hardly neglect to draw your attention to the very admirable and interesting account of the accident from lightning at Roundham Head, near Torquay, with which we were favored at one of our Sessional Meetings in the past year by Mr. D. Pidgeon, who was able to give force to his instructive narrative by the argument of "Magna pars fui," which is always interesting from the mouth of one who is relating effects which he has himself experienced. I should also add that this narrative which was printed in the October number of our Quarterly Journal, has rendered us a double service, and has laid a double obligation upon us, on account of the example which it sets in its very clear and exact description of facts, and in its very full and sagacious selection of essential characteristics of the way in which it is desirable such communications should be presented for the discussions of our Committee.

One of the most notable facts which is brought under notice in this communication from Mr. Pidgeon, is the rupture of the links of the mooring chains attached to the bottom of the stays of the flag-staff. The staff itself, which was involved in this accident, consisted of a stout mast fifty feet high, stayed with four galvanized iron guy ropes at about twenty-five feet from the ground. Each wire rope terminated about twelve inches above the ground in half-inch cable chains, which were carried down to an anchorage in a sub-soil of very dry red sand-stone conglomerate.

The entire mast above the attachment of the guys was shattered into splinters by the lightning discharge; and three of the mooring chains below were broken across, several links in each chain being severed. About twenty links altogether were fractured, and of these some were above, and some within, the ground. Several of broken links had been considerably corroded by rust, but in those the parts severed were the undiminished portions of the iron, and not the segments which had been eaten away by the corrosion. In one place a bent hook of one-tenth of an inch iron wire, which had been used as a substitute for a previously damaged link, was uninjured by the discharge, although several of the links in the same stretch of chain were severed. The broken surfaces in the damaged links were bright and crystalline, and gave no indications of the metal having been subjected to great heat. It is much to be regretted that the whole of the broken links of these chains were not carefully preserved for a further examination of their conducting capacity. Mr. Pidgeon very kindly did what he could to recover them after his attention had been drawn to their scientific value, but unfortunately without success.

Some important practical considerations bear immediately upon the history of these damaged chains. The great increase in the molecular disturbance set up by the discharge at the lower extremity of the conducting system in consequence of the insufficiency of the earth contact is very well illustrated. The distribution of the disruptive discharge through all the several branches of the earth contact is also expressed. Three of the four mooring chains, which were directed out to four opposite points of the compass, were severed. But the most important circumstance connected with the breaking of these chains is the number of the links which were affected by the disruption, and that those which were injured were broken through the parts of largest metallic area, and not through the lines of diminished section where it might have been expected the greatest resistance to the electrical transmission would have been found. Prof. Melsens, of Brussels, one of the Foreign Members of our Committee, whose attention I have drawn to this circumstance, thinks that the highly crystalline condition of the iron of the broken links indicates that those parts of the chain had already undergone considerable molecular disintegration and change subsequently to their first attachment to the guy ropes, in consequence of the incessant vibration to which they had been subjected under the play of the wind, and he believes that they had been thereby reduced to their lowest cohesive capacity at the spots where the disruption occurred. He takes the uninjured integrity of the new piece of fibrous wire of so much smaller dimensions as furnishing a substantial proof of this view of the matter.

In further illustration of the point which is here glanced at, namely, the power of electrical discharges of high tension to produce molecular disturbance in even conducting metallic substance, I have another very curious instance to place before you. Some years ago it happened during a severe thunderstorm in Natal, that a small house of public entertainment, known as the German house, and standing upon the high road between the seaport and the capital, was struck by lightning and burned. Upon one part of the ruin, where there had been a tin box containing money, the curious object which I now present to the meeting was afterwards found, as all that remained of the tin box and the money. It consists of a fragment of a half sovereign in gold inseparably welded to a little piece of tinned sheet iron. The entire fragment weighs 75 grains, and of these about 30 grains are gold, and the rest iron. Something more than half of the gold coin has disappeared, and the remnant is eaten out into an irregular crescentic form, with one blunt horn projecting beyond the iron. The rest of the gold piece, comprising about one-third of a square inch of superficial area, is metallically connected with the iron by an actual brazing together of the particles of the iron and the gold, and the tinned surface of the iron beyond the attachment is bronzed by a thin film of gold particles that have been scattered over it at the instant of the brazing. The fragment of the iron plate is an inch long, by three-fifths of an inch broad. The "gnawed out" aspect of the gold coin, where the remnant has been left by the electric tooth which has consumed the rest, is very curious. A marginal band of lighter-colored gold, that looks as if it had been alloyed so far, either with tin or iron, is set round the sinuous edge of the erosion, and there is a central "pivot-head" like spot in the middle of the attachment of the iron and gold which is characterised by the same "amalgam-like" hue.

Professor Melsens, who is Professor of Physics and Chemistry at the School of Veterinary Medicine of the Belgian Government in Brussels, and to whom I have already made some allusion as one of the Foreign Members of our Lightning Rod Committee, has been for some time engaged with a very interesting series of experiments in regard to the capacity of copper and iron to transmit electrical force, and to the disintegrating effects that are produced by discharges of high tension. When I was recently in Brussels, the Professor did me the favor to show me many of these experiments at his laboratory, and to explain his views at some length, and it gives me great satisfaction to have this opportunity to make a somewhat public acknowledgment of the consideration and courtesy which I received at his hands upon that occasion, as well as of the readiness he has shown at other times to give me his aid and counsel.

In one of his experiments, Mons. Melsens undertakes to demonstrate that the old electrical dogma, which affirms that an electrical discharge of necessity takes the shortest and easiest path, is one that needs to be entertained with distrust and doubt. The Professor has constructed a kind of gridiron of metal, which has a straight stem of large size passing as a direct road through its centre, and also a series of roundabout lateral passages formed by small wires ranging on the right and on the left of the central stem. When energetic discharges from a Rhumkorff coil are passed through the short, direct, and amply capacious route of the large central stem, smart shocks are simultaneously communicated to any finger that is presented to the small lateral wires. The electrical discharge here manifestly passes through the whole metallic mass, and not only through the most direct path of its straight central stem. A considerable amount of the escaping force goes out of its way to traverse the roundabout and devious route of small capacity, although the broad straight path of large capacity is open immediately before it. The equal distribution of the electrical discharge through many possible routes of conducting material is also ingeniously and pleasingly shown by offering a number of very fine wires of equal capacity to the discharge, when the fact that they all contribute in an equal degree to the conveyance of the force is proved by the entire series of wires being "curled" and waved after the discharge in consequence of the molecular disturbance that has been set up in them during the passage. Professor Melsens also draws attention to the remarkable and interesting circumstance, that in this experiment all the several wires are curled and wave in exactly the same way, each wire having its undulations in the same place, and of the same length, like the nodal arrangements in the vibrations of a stretched string of equal tension and size, but the "facile princeps," so far as interest is concerned, of the numerous experiments of Mons. Melsens, is, I think, one in which he investigates the relative "tenacity" of copper and iron when subjected to the disintegrating dispersion of electrical discharges of high tension. The arrangement consists in placing very fine wire of copper and of iron in the path of a powerful battery discharge. The wires are carefully selected, and adjusted so as to be of precisely the same size and length, and the same discharge is passed through both the copper and the iron. The discharge employed is that of fifteen very large Leyden jars grouped together as a battery. After the discharge has been passed, it is found that the copper wire is dissipated into a trail of black dust, while the iron wire is not even broken across, but is "beaded" along its entire length by a series of successive protuberances. In this experiment it is clearly demonstrated that copper, which is almost universally accepted as the most reliable metal for powerful electrical discharges, is much more easily disintegrated by their action than iron, notwithstanding the well-known fact that it is more heated by them than copper.

I gladly availed myself, during my agreeable visit to Professor Melsens, of the opportunity to examine very carefully, under his competent guidance, the details of the arrangements which he has adopted for the protection of the fine old Hotel de Ville of Brussels from the injurious effects of lightning—a work which is now of European celebrity. In this system of defence, iron rods of adequate size are carried out to all the salient projections of the building, and are there protruded into the air in a series of pointed terminals, of which some are grouped around and above the gilted statue of St. Michael, that stands at the top of the central tower of the facade, overlooking the city from its giddy height of 298 feet. There are about 428 points, large and small, and the rods which descend from these points are collected below into a group of eighteen main stems, which are enclosed together in a wooden case, and then made into a continuous metallic mass, by pouring around them, in the interior of the case, molten zinc. On emerging from this connected block beneath, the eighteen rods are sorted out into three parcels, which thus contain six rods each. The first of these series of six is then carried down to a large iron cylinder, sunk ten feet into the moist ground, and firmly soldered to it. The second parcel is soldered in a similar way to one of the large iron pipes of the water supply of the town; and the third parcel is soldered to one of the large iron mains of the gas service of the town. By these admirable expedients a multiple earth contact is finally secured, which, to use Mons. Melsens' own words, comprises not less than twenty millions of kilogrammes, or twenty-two thousand English tons of cast iron tubes. Some of the other public buildings of Brussels have been furnished with lightning conductors upon a similar comprehensive plan, but from conversation with Mons. Melsens, I gleaned that he entertains the bold and magnificent design of getting the entire town some day connected into one continuous system of protection, which shall be to the entire city what the bristling points and multitudinous rods of the Town Hall now are to its gables and pinnacles: a purpose to which the very great compactness of the town obviously lends itself.

The great leading characteristic of this very noble work of Mons. Melsens, which most impresses itself upon the mind of the intelligent and critical observer, who looks down upon the bristling points from a near approach to St. Michael's Footstool, and then examines the subterranean earth contacts, as I did in the pleasant company of the distinguished electrician, is the boldness and uncompromising completeness with which the fundamental ideas of a very ample development of air terminals above, and of earth contacts beneath, is acted upon; an allegiance to correct theory and principle which I cannot but think it would be well for our own electrical engineers to keep more prominently in mind than is sometimes done in our own practice. Within the last few weeks a letter has been sent to me by my friend, the Secretary of the Society of Arts, suggesting that there must be a serious mistake in the printed report of a statement I was said to have made that the French electricians employ 1,196 square yards of earth contact for lightning conductors, because 1,196 square yards are equivalent to nearly a quarter of an acre! And again, it is no uncommon thing to hear even practical electricians in England speak of a lightning rod as being sufficient for its work if its base is but placed as low in the earth as the foundations of the building that is to be protected. It will, however, be at once perceived what an important bearing upon this too confident doctrine Mons. Melsens' demonstrations of the erratic propensity of the impulsive meteor to travel by devious ways when in states of high tension, have. In the assumption that if the lightning be but furnished with a metallic conduit, so far as the vertical extension of a building is concerned, that is all that can be reasonably required, sight is entirely lost of the great practical principle that the erratic tendency of lightning—or, in other words, the high tension of its energy—is enormously increased with each fresh impediment that is offered to its free outflow from the lightning rod below; and that a lightning rod which is

BUILDINGS AND ROADS.
CIVIL WORKS.

Govt. of (1878) Madras
PUBLIC WORKS.

To

DISTRICT ENGINEERS,
&c. &c. &c.

Dated April 11th.

Drast

Recd.

G. O., 11th April 1878, No. 1,[illegible] W

APRIL.

Nos. 137-138.

Protection of Buildings from Lightning.—Circular of the Government of India forwarding Dr. Mann's lecture about—communicated to District Engineers.

GOVERNMENT OF MADRAS.

PUBLIC WORKS DEPARTMENT.

Buildings and Roads.
Civil and Military Works.

Order—dated 21st February 1884, No. 483 W., Public Works.

In modification of the practice at present followed with regard to the submission of plans and estimates for buildings required by other departments, the Government direct that the following procedure be invariably adopted in future.

2. Plans and estimates for buildings required by the Revenue Department should be submitted by the Executive Engineer to the Superintending Engineer, who, after scrutiny, will forward them to the Collector of the district for approval and counter-signature. If the Collector be satisfied as to the suitableness of the proposed accommodation, &c., he will transmit the papers through the Board of Revenue to Government in the Revenue Department, by whom, if approved, they will be transferred to the Public Works Department for disposal, after final scrutiny by the Chief Engineer.

3. In the case of plans and estimates for court-houses, the documents will be forwarded by the Superintending Engineer to the District Judge for transmission, through the High Court, to Government in the Judicial Department, and the same principle will be followed with regard to estimates for Registration, Police, Jail, and other Civil Departments. The Superintending Engineer will forward the documents to the Head of the Department concerned, who will submit them to Government in the Department of the Secretariat from which he receives his orders.

4. The course at present adopted with regard to estimates for Military buildings is laid down in G.O. No. 1381 W., dated 14th June 1880, but here also a modification of practice appears desirable. In future such plans and estimates will be forwarded by Superintending Engineers for approval to the General Officer Commanding the District or Division. The General Officer will transmit the papers to the Quartermaster-General, who,* after obtaining the approval of His Excellency the Commander-in-Chief, will submit them direct to Government in the Military Department. After approval in the Military Department they will be transferred to the Public Works Department for disposal, after final scrutiny by the Chief Engineer.

5. It must be understood that these orders apply only to works which are beyond the power of sanction of local authorities, and are not intended to alter the procedure laid down in G.O., No. 3211 W., dated 6th December 1882, with regard to the submission of Local Fund projects.

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* Note.—In the case of Ordnance, Commissariat or other departmental buildings, the approval of the head of the department should be obtained before the plans and estimates are submitted to His Excellency the Commander-in-Chief.

6. The Secretary, Code Committee, will take the necessary steps for embodying these rules in the Public Works Code, in modification of paragraphs 1168 and 1335.

(True Extract.)

(Signed) J. SHAW-STEWART, Colonel, R.E.,
Secretary to Govt., P.W.D.

To Superintending Engineers.
To the Consulting Architect to Government.
" Examiner, Public Works Accounts.
" Public, &c., Departments.
" Revenue Department.
" Military "

Exd. A. Grubert.
Spare Copies

BUILDINGS AND ROADS.
CIVIL AND MILITARY WORKS.

Govt. of 1884 Madras.

PUBLIC WORKS.

Dated February, 21st.

Recd. *Encl.*

G.O., 21st Feb. 1884, No. 483 W.

FEBRUARY.

Buildings required by other Departments

Modification of the practice for the submission of plans and estimates for—.

GOVERNMENT OF MADRAS.

PUBLIC WORKS DEPARTMENT.

General.
Account.

Read—the following papers :—

From Brigadier-General R. C. STEWART, Quartermaster-General, to the Secretary to Government, Public Works Department, dated Ootacamund, 3rd October 1884, No. 1487-A.

I have the honor, by order, to forward, herewith, the schedules of military works, major and minor, required to be provided for in the budget list of 1885-86, together with a list of the more important major works, classified as per *margin* and entered in the order of their urgency, which His Excellency the Commander-in-Chief would wish submitted for the special consideration of Government, with the following observations :—

Class A.—Works actually in progress to complete which grants are wanted.
Class B.—Urgent works not yet commenced for which grants are required.

Class A.—The works under this classification being actually in progress, the necessity of suitable grants being allotted for their completion needs no comment.

Class B. I.—Last year it was hoped that the first two items in this class, viz., "Gymnasium, British infantry, Fort St. George," and "Accommodation, native cavalry regiment, Bangalore," would, by the opening of the current year, belong to class A; but this hope has not yet been realised. His Excellency would therefore urge upon Government the necessity of providing funds at an early date for the commencement of these important works.

II. *Item No.* 3.—"Bakery at Wellington" was also expected to belong to class A this year, but this has not been the case up to date; and as, in His Excellency's opinion, the work is one of special urgency, he hopes Government will allot funds at an early date for its commencement.

III. *Item No.* 4.—"Accommodation for a native infantry regiment, Bangalore." The 14th regiment, native infantry, for whom these buildings are required, have arrived at Bangalore and are now engaged in building their lines at that station, and it is very desirable that funds should be allotted as soon as possible, so that a commencement may be made for providing the necessary subsidiary buildings.

IV. *Item No.* 5.—"Military prison at Bangalore." This work is, in His Excellency's opinion, of great importance and very urgent, and he therefore hopes funds will be provided for it next year.

V. *Item No.* 6.—"Water-supply to barracks, Royal artillery and British infantry, Bellary." This is a work the importance of which is strongly urged by the medical authorities.

VI. *Item No.* 7.—"Armourer's shop, 2nd Light cavalry, Bellary." This is a work very much needed and of real importance, and should not be delayed.

VII. *Item No.* 8.—"Store-rooms and workshops for the Pioneer regiment at Bangalore." It having been decided that a Pioneer regiment shall be always located at Bangalore, and as the 1st Madras Pioneers may be expected to arrive there in the course of a few months, it is very desirable that these buildings should be furnished for their equipment, &c., as soon as possible.

VIII. *Item No.* 9.—"Stabling for Royal artillery, two batteries, Saint Thomas' Mount." The Commander-in-Chief would again urge upon Government the great importance of having their horses properly sheltered, and accordingly recommends an early allotment of funds for the commencement of this work.

IX. *Items Nos. 10 and 11.*—"Additional hospital accommodation for women and children" and a "church" at Wellington. These are urgent requirements and should therefore not be delayed.

X. *Item No. 12.*—"Coffee shops, Royal artillery, Saint Thomas' Mount." These are, in His Excellency's opinion, urgently required for the two field batteries at Saint Thomas' Mount.

2. The other works in the schedule, although not entered in class B, are nevertheless considered to be really necessary, and it is only because an undue demand for funds would have to be made in connection with them that they are omitted therefrom.

3. In conclusion, His Excellency would strongly urge upon Government the necessity, from the foregoing remarks, of appealing to the Government of India for a large and liberal grant for military works in the coming year, so that none of the many important original works included in class B may be allowed to stand over any longer.

Class A.—Works commenced for completion of which grants are required.

Command.	Station.	Item No.	Work.	Cost.	Remarks.
Eastern District.	Madras ...	1	Gunpowder mills, alterations and additions to.	RS. 1,99,830	
		2	(a) Coast batteries, completion of	...	(a) The Superintending Engineer, V Circle, reports that the work will be completed in the current official year.
		3	Armament, Fort St. George, mounting of, &c.,	42,000	
	St. Thomas' Mount.	4	Barracks, Royal artillery, completion of.	1,27,730	
Western District.	Malapuram.	5	Barracks for detachment. ...	1,31,610	
Bangalore Division.	Bangalore ...	6	Entrenchment ... ... Ordnance depôt	16,100 16,780	
	Trichinopoly.	7	Accommodation for two regiments, native infantry, combined.	21,140	
Eastern District.	Madras ...	8	Quarters for warrant and non-commissioned officers, Commissariat Department.	26,740	

Class B.—Works of special urgency not yet commenced for which grants are absolutely required.

Command.	Station.	Item No.	Work.	Cost.	Remarks.
Eastern District.	Fort St. George.	1	Gymnasium, British infantry, Fort St. George.	RS. 11,570	
Bangalore Division.	Bangalore...	2	Accommodation, native cavalry regiment.	29,600	
	Wellington.	3	Bakery for depôt (including latrine).	32,000	
	Bangalore...	4	Accommodation for one native infantry regiment (less magazine.)	14,610	
Bangalore Division.	Bangalore ..	5	Additions to the military prison.	8,335	

Class B.—Works of special urgency not yet commenced for which grants are absolutely required—*cont.*

Command.	Station.	Item No.	Work.	Cost.	Remarks.
Ceded Districts.	Bellary ...	6	Water-supply to barracks, Royal artillery and British infantry.	RS. 3,000	An estimate for Rs. 27,639 was received, but returned for revision.
Do. ...	Do. ...	7	Armourers' shops 2nd Light cavalry.	2,695	
Bangalore Division.	Bangalore	8	Store-rooms and workshops for the Pioneer regiment.	3,600	
Eastern District.	St. Thomas' Mount.	9	Stables for Royal artillery, two batteries.	20,160	
Bangalore Division.	Wellington.	10	Additional hospital accommodation for women and children.	5,000	
Eastern District.	St. Thomas' Mount.	11	Coffee shops, three in number — one for each, north, south and new artillery barracks.	9,600	

Ootacamund,
3rd October 1884.

(Signed) A. G. HUTCHINS, Major,
Offg. Deputy Quartermaster-General.

Office note from the Superintending Engineer, V Circle, dated 8th October 1884, No. 2622.
Do. from the Examiner of Public Works Accounts, dated 9th October 1884, No. 506.
From the Government of India, dated 2nd October 1884, No. 904 M.W.

Order—dated 18th October 1884, No. 2556 W., Public Works.

Ordered that the schedules of military requirements on account of public works under Buildings and Roads in the Madras Presidency for 1885-86 be forwarded to the Government of India in the Military Department.

2. Ordered also that the lists of military works be printed and circulated to Superintending Engineers, in view to the necessary projects being prepared in detail.

3. The Superintending Engineers should lose no time in submitting the necessary plans and estimates for the unsanctioned works included in the schedules as none of them can find place in the budget estimates for 1885-86 unless regular plans and estimates have been sanctioned.

(Here enter No. 2557 W., dated 18th October 1884.)

(True Extract.)

(Signed) J. SHAW-STEWART, Colonel, R.E.,
Secretary to Govt., P.W.D.

To Superintending Engineers.
To the Examiner, Public Works Accounts.
„ Military Department.
„ Financial „

Exd. E. Fernandez.
Spare Copies

GENERAL
ACCOUNT.

Govt. of (1884) Madras.
PUBLIC WORKS.

Dated October, 1884.

Recd.

G.O., 18th Oct. 1884, No. 2556 W

OCTOBER.

Military Works for 1885-86

Orders on schedules of demands on account of—.

Appendix to G.O., No. 2556 W., dated 18th O

BUILDINGS AND ROADS.

Schedule of the probable requirements of the Madras Presidency on account of Im

Head of Classification.	Executive Division.	Locality.	Item No.	Projects and Works.	Class.	Ordinar		
						Major Works.		
						Works in progress.	New Works.	Total.
						RS.	RS.	RS.
Accommodation for troops—Buildings for European troops in the plains—Permanent.	Presidency ..	Fort St. George.	1	Converting a racket court into a covered gymnasium.	B.	..	11,570	11,57
	Do. ..	Do. ..	2	Armourer's shop for the British infantry regiment.	B.	..	5,000	5,000
	Do. ..	Do. ..	3	Drainage of fort and barracks	B.	..	10,300	10,300
	Do. ..	Do. ..	4	Wash-house outside the barracks	B.	..	2,500	2,500
	Do ..	Do. ..	5	Garrison bazaars to be done away with and new cook-houses to be built on its site, in the mean time the kitchens to be better ventilated.	B.	..	4,500	4,500
	Chingleput ..	St. Thomas' Mount.	6	New barracks for Royal artillery	A.	30,000	..	30,000
	Do. ..	Do ..	7	Coffee shops, three in number, one for each—north, south and the new artillery barracks.	B.	..	9,000	9,000
	Do. ..	Do. ..	8	Constructing six blocks of stables for two field batteries of Royal artillery.	A.	10,150	..	10,150
	Do. ..	Do. ..	9	A wheeler and collar maker's shop for the new double-storied barracks.	B.	..	5,000	5,000
	Do. ..	Pallāvaram ..	10	One mortuary room for each of the three hospitals, Nos. 1 to 3.	B.	..	3,000	3,000
	Presidency ..	Bangalore ..	11	Additions to the military prison	B.	..	8,325	8,325
	Do. ..	Do. ..	12	Quarters for a school master and mistress, Royal artillery.	B.	..	6,200	6,200
	Do. ..	Do. ..	13	Fourth-class gymnasium	B.	20,000	..	20,000
	Bellary ..	Bellary ..	14	Water supply to barracks, Royal artillery and British infantry.	B.	..	3,000	3,000
	Do. ..	Do. ..	15	Alterations and additions to the military provost prison in the fort and to the adjoining disused liquor godowns.	B.	..	11,200	11,200
	Do. ..	Do. ..	16	Swimming bath for 2nd battalion, Royal Fusiliers.	B.	..	12,600	12,600
	Do. ..	Do. ..	17	New gun shed with collar maker's and wheel shop combined for the Royal artillery.	B.	..	5,663	5,663
	Do. ..	Do. ..	18	Infectious disease ward and cook house for the station hospital.	B.	..	6,140	6,140
	Nilgiri ..	Wellington ..	19	Additional hospital accommodation for women and children.	B.	..	5,000	5,000
	Do. ..	Do. ..	20	Gymnasium	B.	..	21,835	21,835
	Do. ..	Do. ..	21	Drinking water to be laid on to hospital ..	B.	..	5,000	5,000
	Coimbatore ..	Malapuram ..	22	Barracks for detachment, British infantry ..	A.	40,000	..	40,000
	Do. ..	Cannanore ..	23	Plunge bath on standard plan for European infantry barracks.	B.	..	4,000	4,000
	Do. ..	Do. ..	24	Improving latrines for the British infantry ..	B.	..	2,750	2,750
Accommodation for troops—Buildings for native troops.	Vizagapatam ..	Vizianagram ..	25	Regimental store-room including storage for the camp equipage.	B.	..	5,000	5,000
	Do. ..	Do. ..	26	Three public latrines for the use of the native infantry regiment.	B.	..	3,150	3,150

...ober 1884.

...erial Military Works for 1885-86.

Works. Minor Works.	Total.	Repairs.	Establishment.	Tools and Plant.	Suspense.	Grand Total.	Remarks.
RS.	RS.	RS.	RS.	RS.	RS.	RS.	
..	..	..	..	..	..	..	Estimate of Rs. 11,570 sanctioned in G.O., No. 590 W., dated 4th March 1884. Item No. 1 of class B works, budget of 1884-85.
..	..	..	..	..	..	..	Estimate awaited.
..	..	..	..	..	..	..	Do.
..	..	..	..	..	..	..	Do.
..	..	..	..	..	..	..	Do.
..	..	..	..	..	..	..	Estimate of Rs. 1,35,950 sanctioned in G.O., No. 288 W., dated 4th February 1884. Item No. 1, class A works, budget of 1884-85.
..	..	..	..	..	..	..	Estimate awaited.
..	..	..	..	..	..	..	Estimate of Rs. 20,160 sanctioned in G.O., No. 2747 W., dated 1st October 1883. Item No. 1 of class B works, budget of 1884-85.
..	..	..	..	..	..	..	Estimate awaited.
..	..	..	..	..	..	..	Do.
..	..	..	..	..	..	..	Estimate of Rs. 6,325 sanctioned in G.O., No. 958 W., dated 5th April 1884.
..	..	..	..	..	..	..	Estimate awaited.
..	..	..	..	..	..	..	Estimate of Rs. 44,560 sanctioned in G.O., No. 1560, dated 21st June 1876.
..	..	..	..	..	..	..	Estimate awaited.
..	..	..	..	..	..	..	Do.
..	..	..	..	..	..	..	Do.
..	..	..	..	..	..	..	Estimate of Rs. 5,663 sanctioned in G.O., No. 914 W., dated 3rd April 1884.
..	..	..	..	..	..	..	Estimate of Rs. 6,145 sanctioned in G.O., No. 320 W., dated 7th February 1884.
..	..	..	..	..	..	..	Estimate awaited.
..	..	..	..	..	..	..	Do.
..	..	..	..	..	..	..	Do.
..	..	..	..	..	..	..	Estimate of Rs. 1,31,510 sanctioned in G.O., No. 580 W., dated 3rd March 1884. Item No. 2, class A works, budget of 1884-85.
..	..	..	..	..	..	..	Estimate of Rs. 4,600 sanctioned in G.O., No. 418, of 10th February 1876.
..	..	..	..	..	..	..	Estimate of Rs. 2,780 sanctioned in G.O., No. 1058, dated 4th April 1879.
..	..	..	..	..	..	..	Estimate awaited.
..	..	..	..	..	..	..	Do.

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Appendix to G.O., No. 2536 W., dated 18th October 1884.

LIST of Military Works estimated to cost Rs. 2,500 each or under and for which funds are required in the Public Works Budget for 1885-86.

Division or District.	Station.	Description of buildings, &c., and for what corps, departments, needed.	Approximate Estimate of Cost.	Remarks by the Standing Barrack Committee as to the necessity of the buildings; references to former Applications, Orders of Government, &c.	Remarks by the Officers Commanding Divisions or Districts.	Remarks by the Commander-in-Chief.
		Transport Department.	RS.			
Bangalore Division.	Bangalore ...	I. Accommodation for 200 mule saddles and 35 sets of harness. II. Sheds for 56 carts, 12 trollies and 12 light carts. III. Sheds for 50 sick carts ... IV. A room for veterinary medicines and instruments.	1,545	Urgently required, as the whole of the sick carts, dhoolies, &c., are now in charge of the department.	A very necessary requirement; the present harness room altogether insufficient; the harness cannot, without difficulty, be properly overhauled. The carts, dhoolies, undoubtedly deteriorate by being kept in the open.	Very necessary.
		Royal Artillery.				
	Do. ...	A new latrine for the Staff Sergeant's quarters for Horse Artillery, the present one being old and condemned on sanitary grounds.	2,100	Required on sanitary grounds ...	Urgently required on sanitary grounds as reported by the committee in 1882.	Very necessary.
	Do. ...	Quarters for a Battery Quartermaster Sergeant, Royal Horse Artillery.	1,100	......	Conversion recommended as approved by His Excellency the Commander-in-Chief last year.	Approved.
	Do. ...	Cook-house for Sergeant's Mess of two field batteries.	1,470	Very necessary	A very necessary requirement.	Necessary.
	Do. ...	Latrine with six seats for the use of two field batteries.	620	Necessary for use of men at stables.	Urgently required	Do.
	Do. ...	Stone drains to forage yard and lines, Royal Horse Artillery.	1,440	Sanctioned when funds are available. Considered desirable.	I consider that surface drains would meet the requirements in this case and could be executed by the Sappers at less than half the cost.	The suggestion of the General Officer Commanding approved of.

Schedule of the probable requirements of the Madras Presidency on account of Imperial Military Works for 1885-86—*cont.*

Head of Classification.	Executive Division.	Locality.	Item No.	Projects and Works.	Class.	Original Works.					Repairs.	Establishment.	Tools and Plant.	Suspense.	Grand Total.	Remarks.
						Major Works.			Minor Works.	Total.						
						Works in progress.	New Works.	Total.								
						RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	
Accommodation for troops—Buildings for native troops—*cont.*	Presidency	Madras	27	Additional sepoy huts for the native infantry regimental lines at Perambúr.	B.	..	27,400	27,400	..	..	..	..	..	..	..	Estimate awaited.
	Do.	Do.	28	Four latrines for the native infantry regimental lines at Perambúr.	B.	..	4,000	4,000	..	..	..	..	..	..	..	Do.
	Do.	Bangalore	29	Public buildings for a regiment of native cavalry.	B.	..	25,237	25,237	..	..	..	..	..	..	..	Estimate of Rs. 25,237 sanctioned in G.O., No. 47 W., dated 18th January 1884. Item No. 24 of class B works, budget for 1884-85.
	Do.	Do.	30	Accommodation for one regiment of native infantry.	B.	..	14,610	14,610	..	..	..	..	..	..	..	Estimate awaited.
	Do.	Do.	31	Store-rooms and workshops for a Pioneer regiment.	B.	..	3,608	3,608	..	..	..	..	..	..	..	Do.
	Chingleput	Pallávaram	32	New lines for one regiment of native infantry	B.	..	35,000	35,000	..	..	..	..	..	..	..	Do.
	Do.	Do.	33	Regimental magazine for a native infantry regiment.	B.	..	4,500	4,500	..	..	..	..	..	..	..	Do.
	Bellary	Bellary	34	Armourer's shop, Light cavalry	B.	..	2,695	2,695	..	..	..	..	..	..	..	Estimate of Rs. 2,695 sanctioned in G.O., No. 2169 W., dated 14th September 1881. Item No. 25 of class B works, budget of 1884-85.
	Do.	Do.	35	School-house for the 27th regiment, native infantry.	B.	..	3,030	3,030	..	..	..	..	..	..	..	Estimate of Rs. 3,030 sanctioned in G.O., No. 149 W., dated 17th January 1884.
	Coimbatore	Quilon	36	Store-room for native infantry	B.	..	5,000	5,000	..	..	..	..	..	..	..	Estimate awaited.
	Do.	Do.	37	Magazine for native infantry barracks	B.	..	3,000	3,000	..	..	..	..	..	..	..	Do.
	Do.	Do.	38	Latrine with wells for native infantry barracks.	B.	..	3,150	3,150	..	..	..	..	..	..	..	Do.
	Trichinopoly	Trichinopoly	39	Constructing public buildings for two regiments of native infantry.	A.	21,140	..	21,140	..	..	..	..	..	..	..	Estimate of Rs. 35,650 sanctioned in G.O., No. 2194 W., dated 5th September 1884. Item No. 2 of class B works, budget for 1884-85.
Ordnance Works	Presidency	Fort St. George.	40	Armament of Fort St. George	A.	30,000	..	30,000	..	..	..	..	..	..	..	Estimate of Rs. 42,035 sanctioned in G.O., No. 2970 W., dated 15th October 1883. Item No. 6, class A works, budget for 1884-85.
	Do.	Madras	41	Demolishing and re-erecting the present wheel shops of the gun-carriage factory at Madras.	B.	..	7,350	7,350	..	..	..	..	..	..	..	Estimate awaited.
	Do.	Do.	42	Extra accommodation as store-rooms in the gun-carriage factory.	B.	..	6,000	6,000	..	..	..	..	..	..	..	Do.
	Do.	Do.	43	Improvements to the gunpowder factory	A.	20,000	..	20,000	..	..	..	..	..	..	..	The total sanction of estimates amounts to Rs. 2,45,492. Item No. 7, class B works, budget for 1884-85.
Commissariat Buildings.	Do.	Do.	44	Quarters for warrant and non-commissioned officers of the Commissariat Department.	A.	11,740	..	11,740	..	..	..	..	..	..	..	Estimate of Rs. [illegible] sanctioned in G.O., No. 1836 W., dated 21st May 1883. Item No. 3 of class B works, budget for 1884-85.
	Do.	Do.	45	Constructing a shed in the camp equipage depôt.	B.	..	5,300	5,300	..	..	..	..	..	..	..	Estimate awaited.
	Do.	Do.	46	Lines for 17 petty officers and [illegible] cattle attendants attached to Transport Department.	B.	..	48,000	48,000	..	..	..	..	..	..	..	Do.
	Do.	Do.	47	Godown for workshops and sheds for keeping 99 army transport and 24 ambulance carts, doolies &c.	B.	..	5,300	5,300	..	..	..	..	..	..	..	Do.
	Do.	Bangalore	48	Quarters for a Conductor, Transport Department.	B.	..	4,220	4,220	..	..	..	..	..	..	..	Do.
	Chingleput	Guindy	49	Converting the late Superintending Engineer's office at Guindy into a Commissariat slaughter-house.	B.	..	11,800	11,800	..	..	..	..	..	..	..	Estimate of Rs. 11,800 sanctioned in G.O., No. 1299 W., dated 12th May 1884.
	Do.	Do.	50	Quarters for station butcher	B.	..	4,740	4,740	..	..	..	..	..	..	..	Estimate awaited.
	Nilgiri	Wellington	51	Bakery	B.	..	27,090	27,090	..	..	..	..	..	..	..	Estimate of Rs. 32,000 sanctioned in G.O., No. 1838 W., dated 20th July 1884.
Fortifications	Presidency	Bangalore	52	Constructing a fortified post and ordnance depôt at Agaram.	A.	2,800	..	2,800	..	..	..	..	..	..	..	Estimate of Rs. 34,880 sanctioned in G.O., No. 3060 W., dated 20th October 1882. Item No. 4, class B works, budget for 1884-85.
				Total		1,85,840	3,99,745	5,85,585	80,194	6,65,779	*3,70,000	2,32,228	16,858	..	12,84,865	

* Includes Rs. 70,000 on account of municipal taxes on military buildings.

List of Military Works estimated to cost Rs. 2,500 and upwards and for which funds are required in the Public Works Budget for 1885-86—*contd.*

Division or District	Station	Description of buildings, &c., and for what corps, department, or trade	Approximate Estimate of cost	Remarks by the Standing Barrack Committee as to the necessity of the buildings, reference to former applications, Orders of Government, &c.	Remarks by the Officers Commanding Divisions or Districts	Remarks by the Commander-in-Chief
[illegible]—*contd.*		*Royal Artillery—contd.*				
	Wellington ...	Removing the present cement floors of latrines Nos. 1, 2, 3, 4, and 5 barracks and cement sinks and relaying the same with 12-inch square tiles.	1,580	G.O. No. 1473, dated 4th June 1874, G.O. No. 1213, dated 9th June 1874. Very necessary.	Recommended	Necessary.
	Do. ...	Bath-rooms to Nos. 1, 2, 3, 4 and 5 blocks for Pay Sergeant.	2,500	Necessary	Much required and very necessary.	Very necessary.
	Do. ...	Brick-tile flooring instead of present cemented to cover passages from married quarters to latrine.	1,000		The flooring of these passages with tiles would eventually be a saving to the Government.	Do.
	Do. ...	Purveyor stores to be enlarged, as the space is insufficient for bedding, clothing and furniture.	3,000	Do.	The storage space is at present quite insufficient; I therefore recommend the outlay.	Do.
	Do. ...	Supplying some cooking stoves to Staff Sergeant's quarters similar to those in married quarters.	600		Recommended	Do.
		Parade Barracks.				
	Bangalore ...	Latrine to native followers	1,000	Necessary	Very necessary; they have now a small latrine built by the regiment.	Do.
	Do. ...	Transport Department.—Converting Sergeant's quarters into Sub-Conductor's quarters	1,000	Very necessary as the present quarters are very small.	A necessary requirement ...	Do.
		12th Royal Lancers.				
	Do. ...	Latrine with ... seats for use of men while at drill.	500	Considered necessary	Very necessary	Necessary.
	Do. ...	To have a cook-house built for a coffee shop.	200	Desirable; brought forward for the first time.	Very much required	Very desirable.
Bangalore		*Camp Equipage Godowns.*				
	Do. ...	Laying down one-inch water-pipe from main pipe to Camp Equipage stores, length 830 feet.	1,170	Considered it necessary in case of fire, damp, or other accident, as the building is isolated from the barracks and contains nearly the whole of the camp equipage of the station (brought forward for the first time).	Very necessary, the original pipes *(sic)* when these buildings ceased to be barracks. I consider the estimate greatly over drawn.	Desirable, but cost seems excessive.
		Commissariat Department.				
	Do. ...	Alterations to Staff Sergeant's quarters (2) by raising floor and roof.	2,000	Very necessary on sanitary grounds as the building is very low and floor lower than the surrounding grounds.	Urgently required for sanitary reasons.	Very necessary.
		South Station Hospital.				
	Do. ...	Stabling for Apothecary's quarters.	400	Necessary; brought forward for first time.	Desirable	Necessary.
		15th Regiment Native Infantry.				
	Do. ...	I. Place of arms; light from roof. II. Modification of doors, windows, and arm racks for a regiment of 8 companies in lieu of 10 companies. III. Surface V drains round building. IV. Place of arms enlarged. Prisoner's room. V. Native Infantry Hospital ...	700	Desirable; brought forward for the first time.	These improvements are very necessary.	Do.
		Parade Barracks.				
	Do. ...	Lining with stone the drain east and west of barrack limits.	1,538	G.O. No. 2755 W., dated 5th July 1878. Desirable.	It is desirable to have these drains constructed; a good size V drain would answer the requirement.	Necessary as advised by Officer Commanding.
		Commissariat Department.				
	Do. ...	To build or render present building used as such (but built for a native) quarters for the station butcher.	525	Desirable; sanctioned when funds are available.	Urgently required; the present building is quite unsuitable for the residence of an European.	Very necessary.

List of Military Works estimated to cost Rs. 2,500 each or under and for which funds are required in the Public Works Budget for 1885-86—*cont.*

Division or District.	Station.	Description of buildings, &c., and for what corps, departments, needed.	Approximate Estimate of Cost.	Remarks by the Standing Barrack Committee as to the necessity of the buildings; references to former Applications, Orders of Government, &c.	Remarks by the Officers Commanding Divisions or Districts.	Remarks by the Commander-in-Chief.
Bangalore Division—*cont.*		*Commissariat Department—cont.*				
	Bangalore	To improve the road leading from slaughter-house to circular road, cavalry barracks, to enable meat-carts to travel to and fro without breaking down and injuring meat by jolting.	1,400	Necessary; sanctioned when funds are available.	It is very necessary that this road should be put in thorough repair; could be done for half the cost by Sapper labor.	To be done by Sappers as soon as funds are provided.
		Royal Horse Artillery.				
	Do. ...	Boarding floor of recreation room.	1,340	Brought forward for the first time.	Desirable.	When funds are available.
Eastern		*Arsenal.*				
	Fort St. George.	A verandah to Section II, VI and VII, Store.	400	Very much needed for the storage of serviceable fire engines which are now kept out.	Recommended.	Approved.
	Do. ...	A store-room in the forge workshop.	520	Very much needed, the present one being too small.	Do.	Do.
	Do. ...	Railings to miscellaneous workshop and a door between them and armourer's shop.	790	Very much needed.	Do.	Do.
	Do. ...	A shed in the new park	410	Very much needed for painting canvas.	Do.	Do.
	Do. ...	A new bridge across the trench in new park.	510	Very much needed; but if outer works are demolished the bridge will not be required.	Now recommended as it has been decided that the outworks be not demolished.—*Vide* G.O., 9th July 1884, No. 3227.	When funds are available.
	Do. ...	A good water tap for the quarters of the Superintendent of Fire Engines.	200	Very much needed ...	Recommended	Approved.
	Do. ...	The verandah of the European Infantry Officer's Mess-house to be extended.	1,800	Required, as the present verandah is too small.	Recommended. The mess-house has a very small verandah and would be much improved by a verandah along the surface of the building.	Do.
	Do. ...	"I" room, inner and outer compartments, be adopted for theatrical performances for British Infantry.	1,000	Very desirable	Recommended	Do.
		Station Hospital.				
	Madras ...	Two huts for the reception of infectious cases in the compound of Station Hospital. The huts should be capable of holding three beds for the treatment of cases among the men, and two beds for women, and should according to regulation contain 7,200 cubic feet of space and 4,800 cubic feet, respectively. They should be about 20 feet long by 20 feet broad by 18 feet high, and 18 feet long by 18 feet broad by 15 feet high, respectively.	750	At present all cases of infectious disease have to be isolated and treated in tents; this arrangement is fairly satisfactory during the cold months of the year, but during the hot weather it is most undesirable, as the tents become so hot that it is injurious to the men to be kept in them.	Do.	Recommended.
		Body Guard.				
	Do. ...	Dispensary for veterinary department for Body Guard.	1,300	Necessary	Do.	When funds are available.
		Native Infantry Lines, Perambúr.				
	Do. ...	A new regimental school at the Perambúr Lines.	1,375	Much required; estimate for Rs. 1,375 for converting Staff Sergeant's quarters, No. II, into a school-house for Native Infantry Regiment at Perambúr sanctioned when funds are available. G.O., No. 312 W., dated 6th February 1884.	Do.	Approved.

List of Military Works estimated to cost Rs. 2,500 each or under and for which funds are required in the Public Works Budget for 1885-86—*cont.*

Division or District.	Station.	Description of buildings, &c., and for what corps, departments, &c.	Approximate Estimate of Cost.	Remarks by the Standing Barrack Committee as to the necessity of the buildings, reference to former applications, orders of Government, &c.	Remarks by the Officers Commanding Divisions & Districts.	Remarks by the Commander-in-Chief.
[illegible]—*cont.*		*Native Infantry Lines, [illegible].*	RS.			
	Madras ...	An armourer's shop ...	2,000	The present armourer's shop is not on the standard plan and have no facilities for browning arms which has to be done in the open.	Recommended	When funds are available.
		Native Infantry Lines, Royapuram.				
	Do. ...	One latrine on the north side of the regimental lines at Royapuram.	1,200	Latrine on the south side has been completed, that on north side is required.	Do.	Recommended.
		Gun Powder Factory.				
	Do.	Breaking-down house ... 1 Breaking-down machine 1 house for 6 horse-power engine and boiler.	500	G.O., No. 53 of 7th January 1875.	Recommended as being apparently portion of the scheme for the thorough renewal of Gun Powder Factory—*vide* items in the list of major works.	Approved.
	Do.	Powder Magazine. Wooden flooring and thorough repair.	1,100	G.O., No. 1601 of 31st March 1875.		Do.
		Commissariat Department.				
	Do. ...	A detached godown for the storage of wheat and [illegible] outside in the Government Bakery.	1,765	There is no place at present should emergency demand the storage of wheat without endangering the safety of the bread stuffs by the introduction of weevils into the main building. Estimate sanctioned, G.O., No. 1899 W., dated 8th July 1883, Public Works.	Recommended	Do.
	Do. ...	The levelling of the bakery compound and a system of drainage to carry off the washing of the bakery.	250	There is no drainage water-lodges, and for sanitary purposes it is necessary that the ground should be levelled and a proper system of drains laid down.	Do.	When funds are available.
Eastern	St. Thomas' Mount.	Sinking a well, erecting a moat and trough apparatus, public cattle depôt.	1,200	Required in the public cattle depôt in consequence of there being no water nearer than a tank 250 yards distance from the lines, which, in the hot season, is perfectly dry; during the period the bullocks have to be taken to the river for water.	Recommended	Do.
	Do. ...	Improvements to the lightning conductor to expense magazine, Royal Artillery.	1,500	It is absolutely necessary, the present one having been condemned by the Telegraph Department.	Do.	Most important.
	Pallávaram ...	An armourer's workshop for Native Infantry Regiment.	820	At present none	Do.	Approved.
	Do. ...	Store-room for regimental camp equipage for the use of Native Infantry Regiment.	1,500	Do.	Strongly recommended; much needed; the old dák bungalow is at present used as a store-room.	Do.
	Do. ...	Tiled shed suitable for the accommodation of about 250 sepoys from Madras during the musketry season, and recruits at other times at Meenumbaukum.	...	At present none. Urgently required.	The well is recommended, but the erection of a tiled and permanent shed is not recommended as it does the men good to camp out every now and again.	Well approved; sheds unnecessary.
	Do. ...	Sinking a well at do.	318		... ...	...
	Poonamallee...	Lightning conductors on the new hospital.	1,800	Very urgently required; the building is about the highest point in the station.	Recommended	Most important.
	Do. ...	North-east block, old barracks, required to be converted from married into single quarters.	1,000	When a large party of men arrive in the station a portion have to be accommodated in the men hospital wards.	Can only be converted when the new family quarters are completed and if it is decided to maintain Poonamallee as a depôt.	When funds are available.
	Do. ...	New family quarters. Required a wall to shut off the new married quarters from main road.	1,000	......	Recommended if the depôt is to be maintained.	Approved.
	Vellore	School-house for a Native Infantry Regiment. Materials only being supplied by the Public Works Department.	2,150	This building is very much needed for the use of the regiment in garrison, as the Muhal in the fort, at present occupied as a school, is at a considerable distance from the lines.	Much needed; construction of a school-house has been sanctioned for execution when funds are available. G.O., No. 318 W., dated 7th February 1884.	To be constructed by the men.

List of Military Works estimated to cost Rs. 2,500 each or under and for which funds are required in the Public Works Budget for [illegible]—cont.

Division or District	Station.	Description of buildings, &c., and for what corps, departments, needed.	Approximate Estimate of Cost.	Remarks by the Standing Barrack Committee as to the necessity of the buildings, references to former applications, orders of Government, &c.	Remarks by the Officers Commanding Divisions or Districts.	Remarks by the Commander-in-Chief.
			RS.			
		Commissariat Department—cont.				
District—cont.	Vizianagrum...	Bath-room for hospital of the Native Infantry Regiment.	300	Much required, there being no accommodation which could be used for the purpose.	Recommended ...	Approved.
	Do. ...	Hospital wall to be completed ...	286	Present wall encloses three sides of the hospital, while on the fourth side, and nearest the regimental lines, there is none. If wall is completed all ingress and egress will be confined to the regular entrance, and a better watch kept over the movements of patients.	Do.	When funds are available.
	Do. ...	Powder Magazine with surrounding walls on standard pattern.	[illegible]	Much required, the present magazine having been condemned and have no protecting walls round it. The shelves being built into the walls are continually attacked by white ants.	Do.	Approved.
	Do. ...	Armourer's workshop	[illegible]	Much required; the work has been sanctioned G.O., No. [illegible], dated [illegible] April [illegible]. Progress of work stopped on account of famine in [illegible] and not since completed.	Do.	Do.
	Berhampore ..	School-house for a Native Infantry Regiment. Materials only being supplied by the Public Works Department.	[illegible]	A school-house is absolutely required for the use of the regiment, the present building (regimental property) having fallen in and being utterly unsuited for the purpose. G.O., No. 1451 W., dated 29th June 1884.	Do.	To be constructed by the men.
Eastern	Cuttack ...	School-house for a Native Infantry Regiment. Materials only being supplied by the Public Works Department.	2,162	The school is temporarily occupying a place for cleaning arms where the accommodation is insufficient.	Do.	Do.
	Vizianagrum.	A small public latrine near the barrack buildings.	300	Required for the use of men of the guard and men at school or on duty, the regimental lines being about half a mile distant.	Do.	Recommended.
Western District.	Cannanore ...	Station Hospital. Sinking a well.	700	Much required. The water-supply is very scanty during the hot weather.	Strongly recommended ...	Strongly recommended.
	Do. ...	European Infantry. Replacing the present flooring of the European Infantry cells with concrete in chunam and asphalte.	1,100	Recommended. The present laterite flooring is in a very bad state—*vide* G.O., No. 1675 W., dated 5th July 1884.	Recommended	Recommended.
	Do. ...	Ordnance Department. Raising the parapet of the magazine redoubt on a level with its eaves and moving the guard-room from inside to outside the ditch.	1,900	Desirable as a precautionary measure.	Do.	Very desirable.
	Do. ...	European Infantry. Replacing the laterite flooring of the recreation room with concrete in chunam and asphalte.	2,140	Recommended. The laterite perishes rapidly—*vide* G.O., No. 1675 W., dated 5th July 1884.	Recommended, but not very urgent.	Recommended.
	Do. ...	European Infantry. Replacing the present wooden railings round the barracks with open laterite work.	639	Recommended on economic grounds. The wooden railings are expensive and require constant removal.	Recommended	Do.
	Malapuram ...	European Infantry. The sick cart-shed to be rebuilt.	1,550	Present shed is dangerous, being of thatch. G.O., No. 2590 W., dated 4th October 1882.	The present shed is in ruins and the site is required for a ward for contagious diseases. Recommended.	An inexpensive shed should suffice.
	Mangalore ...	Substituting asphalte in room of chunam floors in wards and surgery of hospital, 33rd Regiment Native Infantry.	695	Recommended on sanitary grounds.	Recommended	Recommended.

List of Military Works estimated to cost Rs. 1,500 each or under and for which funds are required in the Public Works Budget for 1885-86—contd.

Division or District.	Station.	Description of buildings, &c., and for what corps, department, needed.	Approximate Estimate of Cost.	Remarks by the Standing Barrack Committee as to the necessity of the buildings; reference to Orders, applications, Orders of Government, &c.	Remarks by the Officers Commanding Divisions or Districts.	Remarks by the Commander-in-Chief.
Western District—contd.	Mangalore ...	*Europeans—Native Infantry.* Forge troughs and cupola in the armourer's workshop; also a screen as per clause E, paragraph 13 of G.O.C.C., No. 12, dated 12th February 1874.	Rs. 780	Original estimate for 500 sanctioned—see G.O., No. 2730, dated 11th Sept. 1878; G.O., No. 2260 W., dated 4th October 1882.	Recommended	Recommended.
	Calicut ...	Native Infantry. An armourer's shop.	1,794	Much needed; the existing building is unsuited to present requirements. Browning &c. would be carried on.	Not urgent	When funds are available.
Under Execution.	Bellary ...	*Royal Artillery and British Infantry.* Completion of system of drainage from wash-houses and family quarters.	1,500	Entered in last year's list as a major work. The estimate has since been reduced and sanctioned in G.O., No. 1125 W., dated 6th May 1884.	Much needed and about to be carried out.	Very necessary.
	Bellary ...	*Station Hospital.* A compound wall with two gates to enclose the female hospital attached to the Station Hospital.	1,500	Entered in last year's list; much needed. Sanctioned in G.O., No. 3065 W., dated 20th December 1883.	Much required to ensure privacy to the patients.	When necessary.
	Do. ...	*2nd Cavalry.* Permanent shoeing shed or suitable forge.	480	Much wanted as there is no proper place in which the farrier can make shoes.	A building of some sort is certainly required.	Suitable forge necessary.
Ceded Districts—	Do. ...	*20th Regiment Native Infantry.* A new well to be dug	600	Greatly required. There is at present only one well for the use of the corps and the water from this is stated by the Medical Officer to be full of organic matter and impurity.	This is much required. This regiment has only two wells from which to draw drinking water, of these, one "The Subadarbeb" fails every summer. It is now being deepened but does not promise well. The water is of doubtful quality.	Very necessary.
	Do. ...	*27th Regiment Native Infantry.* Latrine 35' long by 18' wide for use of the left half battalion.	600	Entered in last year's list. The estimate was then Rs. 1,500 and was considered by His Excellency the Commander-in-Chief as excessive. The latrine is very much required.	This is much wanted	Necessary.
	Do. ...	*Commissariat Department.* Floor of the bran, flour, bread and store-rooms and of the office to be asphalted.	670	Would be a very great improvement. The Executive Commissariat Officer complains that the contents of the rooms are damaged by rats, &c.	This would be a great improvement.	When funds are available.
	Do. ...	*Barrack Department.* Servants' house and stables for Barrack Sergeant's quarters.	336	Very much required. Sanctioned in G.O., No. 3181, dated 29th June 1882.	Very much wanted	Very necessary.
		Total ...	80,194			

Ootacamund,
3rd October 1884.

(Signed) A. G. HUTCHINS, Major,
Offg. Dy. Quartermaster-General.

83 13

18th October 1884, No. 2557 W., Public Works.

PUBLIC WORKS DEPARTMENT.

General.
Account.

Letter—from

Colonel J. SHAW-STEWART, R.E.,
Secretary to the Government of Madras,
Public Works Department,

To

The SECRETARY to the GOVERNMENT of INDIA,
Military Department.

Sir,

In forwarding the accompanying proceedings of this Government, No. 2556 W., dated 18th October 1884, with schedules of demands on account of military works for 1885-86, I am directed to solicit the particular attention of the Government of India to paragraph 3 of the Quartermaster-General's letter, No. 1487-A, dated 3rd October 1884, conveying the strong recommendation of His Excellency the Commander-in-Chief that a liberal grant may be made for this service.

I have the honor to be,
Sir,
Your most obedient servant,

(Signed) J. SHAW-STEWART, Colonel, R.E.,
Secretary to Govt., P.W.D.

Fort St. George,
18th October 1884.

Exd. E. Fernandez.
Spare Copies

GENERAL
ACCOUNT.

Govt. of [1884] Madras,

PUBLIC WORKS.

Dated October, 1884.

Recd.

Endt.

18th Oct. 1884. No. 2557 W.

OCTOBER.

Military Works for 1885-86

Forwarding schedules of demands on account of —.

No. 2,934.

CIRCULAR.

Letter from the Director-General of Telegraphs in India, No. 3,868, dated 14th December 1880.

Communicated to the officers of the Public Works Department in continuation of the papers circulated with memorandum No. 1,596, dated 24th June 1880.

2. The critiques at the end of Mr. Brough's memorandum refer to the papers on Lightning Conductors circulated with G.O., No. 1,454 W., dated 21st March 1878, to which attention is also invited.

(By Order.)

Major, R.E.,
Dy. Chief Engineer, P.W.D.

Chepauk,
23rd December 1880.

To the Superintending Engineers.
,, the Superintendents of Works.
,, the Consulting Architect.

Spare Copies

30 40

Calcutta,
The 14th of December 1880.

No. 3,868.

From

THE DIRECTOR-GENERAL of TELEGRAPHS in INDIA,

To

THE CHIEF ENGINEER, PUBLIC WORKS DEPARTMENT,
Madras.

Sir,

In reply to your letter No. 624, dated 4th ultimo, I am desired to forward copy of the paper written by the late Mr. Brough on the subject of Lightning Conductors.

I have the honor to be,
Sir,
Your most obedient servant,
(Signed) F. G. TREVE,
Personal Asst. to the Director-General of Telegraphs in India.

PROTECTION OF BUILDINGS FROM LIGHTNING.

General Principles of Protection.—The principle on which objects are protected from the destructive effects of lightning is by enclosing them in a shell which offers an infinitely more conductive path to an electrical discharge than that presented by the objects themselves. For example, if an ordinary house, built of brick or stone and wood, were covered throughout, on the top, bottom, and four sides, with sheet copper, then the house, its inmates and contents would be safe from the ravages of lightning.

Theoretically System need not be connected to Earth.—So long as the protective shell includes the base of the edifice, as well as its top and sides, it is not necessary, so far as the safety of the structure itself, of its inmates and contents, from the *direct* action of lightning, is concerned, that the shell shall be in connection with a conductive stratum of the earth; it might in fact be insulated from the earth, for instance rest on dry soil or on masonry arches.

But must be in practice.—But then the ground, or the arches on which the shell rested, would be exposed to injury from lightning to be rent asunder, or thrown down; and thus foundations of the building might be seriously disturbed.

Practical plan of Protection.—Hence, while adhering to this principle of protection, its application is modified in practice. The top and sides of the building are furnished, as before, with the protecting screen but the covers of the sides are continued down into the earth until they reach the uppermost permanently conductive stratum met with below the site of the building. The conducting shell still exists, for we have artificially provided its top and sides, while its base is naturally afforded by the conductive stratum of the earth.

The Foundations are protected.—By constructing the protective shell in this way, not only the building itself, its inmates and contents are screened from the direct effects of lightning, but its foundations are also protected from disturbance.

Maximum ratio to be preserved between conductivity of shell and objects to be protected.—Since it will obviously be always desirable to maintain the greatest possible ratio between the conductivity of the protective shell, and that of the objects to be protected, special precautions may sometimes be taken with advantage to insulate the latter from the earth. For instance a magazine would be safer if raised on a masonry plinth, or on arches, than if built directly on damp ground. Further, lineal arrangements of conductive bodies, such as iron pillars, iron gas pipes, copper bell-wires, window bolts, chandeliers, pier-glasses, &c., between the summit and the base of the building should be avoided. Lastly, the more perfectly the protective shell is insulated from the objects to be protected, the less will be the chance of lateral discharge. Protectors, therefore, should not be attached to objects by means of pointed conductors, such as staples, nails or screws.

Continuous shell usually replaced by net-work.—Apart from the consideration that apertures are usually required in the walls of a building to give access to its interior, and to admit light and air, it would, at any rate in the case of extensive buildings, to cover the top and sides of an edifice with a continuous protective shell; and experience shows this not to be necessary. In practice, therefore, the continuous shell is replaced by a net-work of conductors, the size of the meshes of the net being determined with reference to the nature of the objects to be protected.

Special Cases.—Buildings containing metallic bodies, such as engines and machines, or explosives, such as gunpowder and cartridges, will obviously require special treatment, and it would be necessary in their cases that the net-work should approach nearer to the condition of a continuous conductive shell, than in the case of ordinary dwelling-houses.

Wrought-iron Girders.—In many modern buildings, iron girders and joists are employed. The roof and each floor, excepting the ground floor, reposes on a perfect net-work of conductors, which very simple precautions will suffice to maintain in metallic continuity and which may then certainly with advantage be thrown into circuit with the protective system.

Conducting Roofs.—In the case of a building having a conducting roof, such as a roof of galvanized corrugated iron, one portion of the protective shell will be already provided, if precautions be only taken to insure metallic continuity among the several pieces composing the roof.

If, however, such a roof be covered with any insulating substance such as asphalte or masonry, this substance will be liable to injury and will require protection.

Conducting Edifices.—In the case of a building whose roof and walls constitute a conducting shell, as for example the wrought-iron churches occasionally seen in England, no further precautions will be necessary than to insure the metallic continuity of the several parts of the structure, and to connect the whole to earth. Obviously a single earth connection would generally suffice in the case of such a building, on account of the great metallic mass connecting any one point of its exterior with any other.

Buildings of one Dimension.—We have hitherto been speaking of buildings of three dimensions, but structures having sensibly only one dimension are met with, such as flagstaffs, factory chimneys, church spires, clock towers, &c. In this case the protective shell will obviously take the form of a linear conductor extending from the summit to the base of the structure.

The Vertical Conductor.—We have now been led to the case of the simplest practical form of lightning protector, viz., the vertical linear conductor, and we shall consider it first; but, before doing so, it may be well to point out that if the flagstaff, spire, chimney, or tower, is itself constructed of sufficiently conductive materials, for example of iron, then obviously the proper course will be, not to furnish it with a separate protector, but to take precautions to insure its metallic continuity from summit to base, and provide it with earth connections if necessary.

Requirements.—In this case we have to put the conductivity of the protector into competition with that of a wooden or masonry column. It is clear, therefore, that so far as conductivity goes, a comparatively thin metallic wire would suffice to form the conductor. For instance, 200 feet of the ordinary galvanized iron telegraph wire employed in India could offer a resistance of less than one half an ohm.

But the current produced in the conductor by a severe discharge of lightning would be so strong that the heat generated by its passage would fuse such a thin wire. We must, therefore, not be satisfied with providing a wire of sufficient conductivity to compete with the wooden or masonry column, but also one that will not be liable to fusion.

Choice of a Metal.—Experience shows that the two metals universally employed as conductors in telegraphy, viz., copper and iron, are those which are the most suitable for the construction of lightning protectors.

In favor of copper we have its greater conductivity, and its greater chemical permanence.

In favor of iron, its higher temperature of fusion (2786° F. against 1994° F.), its greater specific heat (0·1098 against 0·0949), the fact that it can be entirely protected by an inexpensive process from oxidation by being coated with the highly conductive metal, zinc (galvanizing), and that from its smaller intrinsic value it is less liable to be stolen.

It is true that iron is cheaper than copper, but on the other hand it is less conductive, so that practically there is little or no choice as regards first cost.

On the whole, except when a light conductor is a desideratum, or for aesthetic reasons it is sought to make the conductor as little conspicuous as possible, it will be desirable to employ iron in preference to copper.

Minimum Sectional Area.—Experience tends to show that ½ square inch for iron conductors, and ⅛ square inch for copper, is sufficient.

Hollow Conductors.—Theory indicates that, conserving the same sectional area, a hollow conductor is better than a solid one, because its capacity is greater, and the potential of a discharge traversing it could be proportionately reduced.

Copper tubes are admissible when closed at the extremities with solid plugs of the same metal. But there are grave objections to the use of iron tubes. The rust which accumulates within them, when they can be neither cleaned, nor painted, spreads to the joints and causes discontinuity. Besides gas piping, which is the material commonly employed, is made of an inferior quality of metal.

Quality of Copper.—In selecting copper for conductors, it must be remembered that the conductivity of copper varies enormously with its quality. Impure copper may conduct less than iron. Lake Superior is the best, Burra Burra is very good, while Rio Tinto is the worst.

Quality of Iron.—Malleable iron of good quality, such as Lowmoor, should be employed.

Cylindrical Conductors.—If the conductor is to be kept at a little distance from the wall of the structure, and only supported at certain intervals, then a circular section is to be preferred; and iron should be employed in the form of rod, while copper may be employed in the form of rod and tube. The minima dimensions to be employed are—iron rod, 1 inch in diameter; copper rod, ½ inch in diameter; or copper tube, ⅛ inch thick and ⅝ inch in diameter.

Slip for Expansion.—The conductor should not be fixed rigidly in its supports, but given freedom of slip, in order to allow for the expansion and contraction of the metal produced by changes of temperature.

Flat Conductors.—If, on the other hand, the conductor is to be laid along the wall of the building, the copper band or iron bar will be the most convenient to employ. The minima dimensions to be employed are—copper band, 1½ × ⅛ inches; or iron bar, 2 × ¼ inches.

Bends for Expansion.—In this case the effects of contraction and expansion must be allowed for by putting bends in the metal at each interval between its points of attachment.

Iron Wire Cable.—Another form of conductor available which possesses the great advantage that it may be made in a continuous length free from joints, is galvanized iron wire cabling. The wires of which the cable is made should not be less than ⅛ inch in diameter, as they would be liable to rust through. A suitable cable may be obtained by twisting seven wire ropes of the requisite length, each composed of seven strands of No. 9 B.W.G. (diam. = 0·149) galvanized iron telegraph wire, six laid round one, and then laying these seven ropes up into a cable, six helically round one. the diameter of such a cable would be 1"·341, if the strands and ropes are packed as closely together as possible.

Joints.—The next point for consideration is that, except in the case of very short conductors, it will not be possible, unless galvanized iron wire cable be employed, to obtain single pieces of metal of the requisite length. Two or more pieces will, therefore, have to be joined together.

In uniting metals with a view to establishing electrical continuity between them, it must be remembered that two perfectly clean surfaces, each of sufficient area, must be brought into contact with one another, and maintained in that condition.

By clean surfaces is to be understood bright metallic surfaces, free from oxide, salts, grease, dust, damp, or any other foreign matter.

The area of the surfaces to be brought into contact must not obviously be less than the sectional area of the conductor.

It will be clear that if an ordinary rivetted joint be made and left exposed to the weather, it will not fulfil the required conditions, because air and moisture will have access to the lap of the joint, chemical action will set in, causing the surfaces in contact to become coated with oxide or salts, and the resistance of the joint will be increased and its continuity impaired.

A rivetted joint, if thoroughly dried and then painted immediately after it is made, so as to exclude air and moisture, will answer in copper; but would still be dangerous in iron.

The best joints are carefully fitted screwed joints, or soldered, brazed, or welded joints. But the precaution of drying and painting over all joints should invariably be taken.

As it is necessary that the two metallic surfaces should be brought into direct contact, no packing or white lead must be employed in screwed joints.

In the case of brazed or soldered joints in which fluxes are used, all superfluous flux must be removed before the joint is dried and painted. If an acid flux has been employed (such as spirit of salts or Sal ammoniac) the joint must be first washed with an alkaline solution (such as one of sujee-muttee) and then rinsed with clean water, before drying and painting.

The fewer joints used the better; and, therefore, the longest lengths of metal procurable should always be employed.

Special precaution must be taken to protect joints between two different metals (such as copper and iron) in order to prevent galvanic action. But joints between different metals must be avoided as much as possible.

In the case of galvanized iron conductors, simple bolted joints are admissible. The bolt holes should be punched or drilled before the conductors are galvanized; and both the bolts and their nuts should be galvanized all over, including the screw threads. The nuts must be screwed well home.

In the case of magazines, powder factories, &c., where danger might be incurred by the slightest disruptive discharge at the joints they should all be soldered (if not brazed or welded) in addition to rivetting, screwing, or bolting. This holds good also of joints on thatched roofs, and in all places where danger of fire is to be apprehended.

Upper extremity of Conductor.—The upper extremity of the conductor must be carried up well above the summit of the object it is designed to protect. It may be made a rule that it shall be carried up as far as it can be unsupported with due regard to stability.

Theory indicates that the potential at the tip of a point projecting from a charged conductor is infinite and experience shows that actually such a point has the power of gradually dissipating the charge from the conductor. The upper end of a lightning protector should, therefore, terminate in a point; as its influence will be to tend to prevent electrical accumulation in the atmosphere above it, and to reduce the potential of any charged cloud that may drift over it by silent discharge.

The end of the conductor may be turned off to a point on a lathe, or hammered up on an anvil. In the case of a galvanized iron conductor the painting should be done before the conductor is galvanized.

In the case of a wire cable, the cut ends of the wire should be galvanized. A galvanized iron ring should be fitted round the end to prevent the strands opening. The central rope may be left projecting a length equal to its diameter above the level of the surrounding six ropes; and the central wire of the central rope may be left projecting in the same way.

Re-entering Angles to be avoided.—Sometimes, in order to follow the contour of the structure, it will be necessary to bend a vertical conductor. In any such case a sharp re-entering angle should not be made, as it would tend to determine lateral discharge into the building.

Paint.—Copper conductors may be painted up to within a foot of the point. Galvanized iron conductors do not require painting.

Ungalvanized iron conductors must be painted all over.

Ground Line.—Special precautions must be taken to protect the conductor from decay in the neighbourhood of the ground line. For 2 feet above and 2 feet below the ground line, the conductor should be coated with a mixture of tar and sand to be applied hot.

Lower extremity of Conductor.—In all cases the conductor itself must be continued down for a distance of 4 feet below the surface of the ground. If the conductor end here, it should terminate preferably in a point.

Earth Connections.—The lower extremity of the conductor has to be brought into electrical connection with a conducting stratum of the earth.

The two great points in which ordinary vertical protectors fail, and which must therefore receive the particular care of the Engineer, are the *points* and the *earth connections*.

In India iron water-mains which answer the purpose admirably are only found in a few large cities, and, therefore, special earth connections have generally to be established.

It may happen that the upper stratum of the earth below the site of the building to be protected is sufficiently conducting, as, for example, in the neighbourhood of Calcutta, where the lowest spring level is near the surface of the ground.

In any case the best season for putting down the earth connections is just before the setting in of rains, or in some cases somewhat earlier as then the spring level will be at its lowest.

The conductor is to be continued down to a distance of at least 1 foot below the lowest spring level.

If the conductor be of copper, its end must be reveited and soldered to a plate measuring 4′ × 3′ (or thereabouts) of ⅛ inch sheet copper, which is to be set up vertically beneath it. The joint between the conductor and the plate must be first painted and then coated with a mixture of tar and sand to be applied hot. The plate must be cleaned, if necessary, before attaching the conductor to it, by heating it and plunging it while hot into cold water.

If the conductor be of iron rod or bar precisely the same procedure is to be adopted, but the earth-plate must consist of ¼ inch galvanized sheet iron.

If necessary, the earth-plate must be supported by some simple means in its vertical position, care being taken that the supports, which should be of stone or wood, screen as little of its surface as possible.

If the conductor be a galvanized iron wire cable, then it must be carried down at least two feet below the lowest spring level; and from that point, the seven ropes composing the cable must be separated and radiated away horizontally, each to a distance of 10 yards. When circumstances will not admit of this being done, a galvanized iron-plate may be employed; the end of the cable must be opened out and each wire soldered separately to the plate.

It is to be observed that occasionally better earth is to be found near the surface than by going deeper down. For example, at Jubbulpore the superficial stratum is fairly conductive, but by going deeper a bed of sandstone is reached which is an extremely bad conductor.

When good earth cannot be found at any reasonable depth below the site of the building, but a well, tank, or damp ground exists at a moderate distance from the spot, then the earth connection must be carried to such a place along the bottom of a trench three feet deep.

If the conductor consist of a wire cable it will be very easy to do this; for the cable wire will only have to be continued to the selected site, and then the connections established in the manner already laid down.

When the conductor consists of copper or iron bar or rod it may also be carried in the same way to the spot selected; but it may be more convenient to adopt the following plan. Terminate the conductor at a depth of 4 feet below the ground line. In a trench 3 feet deep put down seven galvanized iron wire ropes (which need not be laid up into a cable) from the conductor to the site for the earth connections. Solder each wire of the ropes separately to the bottom of the conductor, and establish the earth connection in the manner already laid down.

When no good earth can be found in the neighbourhood of the building, and it becomes necessary to establish the earth connections in an unsuitable superficial stratum, such as light dry soils, shingle, sand, or even ordinary vegetable soils in the dry state, then the following precautions must be adopted.

The conductor must be bent and carried away from the building along the bottom of a trench 4 feet deep for a distance of not less than ten yards. At this point a circular pit 4 feet in diameter is to be dug, across the middle of the bottom of which an earth-plate is to be set up vertically, and the connection formed between the plate and the conductor in the usual way. Then the pit on both sides of the plate is to be filled in with charcoal and old scrap iron up to the level of the upper edge of the plate, so as to form a tolerably conductive mass. From the centre of the upper surface of the mass, carry up vertically a pipe 6 feet in length, and fill in the earth around it to the level of the surface of the ground. Provide the top of the pipe with a keyed cover. If practicable lead the surface drainage and the discharger from the down pipes of the roof up to the pits mouth, so that the water may percolate down into it. In the dry season, have water poured down the pipe according to necessity. In this case it will be an advantage to have the building to be protected raised from the ground and its foundations kept dry. It would also be advantageous to under-run the building with conductor connected to earth; this can be easily done if the building is raised on a plinth or arches. Further precautions are to insulate the conductor from the walls and to avoid conductive lines within the building.

Preliminary Earth Tests.—In all cases where any doubt exists as to the nature, the quality of the soil should be electrically tested before establishing earth connections in it, as it would obviously be a useless expense to put down connections in one place which might have subsequently to be taken up and removed to another site.

Conditions to be fulfilled by the Vertical Conductor.—The vertical conductor when set up and completed should fulfil two electrical conditions.

The resistance from its summit to its base should be only the fraction of an ohm. The resistance of the conductor can always be computed from its known dimensions; and the measured value should agree with the value then calculated. It may be stated that, in round numbers, in the case of conductors such as we have been considering, a conductor 100 feet high would offer a resistance of 1/100 of an ohm.

The second condition is that the resistance of the earth connection, measured from the base of the conductor, should be less than a certain fixed maximum determined by experience. This maximum is 10 ohms.

Buildings of three Dimensions.—We must now proceed to consider the common case viz., that of building of three dimensions. These have to be protected by means of a network of conductors.

The vertical conductors of the system will clearly have to be constructed precisely in the same way as the simple vertical conductors which we have already exhaustively considered; while the horizontal conductors will simply consist of conductors of the same sectional area as the verticals, and united to them by means of joints made with all the precautions above laid down on the subject.

The best position for the principal vertical conductors will obviously be at those parts of the building most liable to be struck by lightning; such as the external angle of the walls, domes, towers, or other parts rising above the general level of the roof. Conductive lines occurring in the walls of a building, for instance gas pipes, should be protected by a vertical conductor.

All the principle vertical conductors should be provided with earth connections.

Buildings vary so much in form that it is impossible to lay down rules for the arrangement of the conductors which will meet all cases. The following examples will, however, help to guide the Engineer.

Thatched bungalows with roofs running up to a point may be protected by a single conductor following the slope of the roof, and terminating above its apex (see Fig. 2). If the roof terminate in a short ridge, the conductor should follow the ridge (see Fig. 3). The conductor should not, in order to avoid any chance of the thatch being ignited by a flash of lightning, rest on the thatch itself but on supports fixed at intervals. If the conductor be bent into curves backwards and forwards, and the bends be set in the vertical plane, there will be no necessity for special supports (see Fig. 4).

A long narrow building may be protected by a single conductor run along the centre of the roof and connected to earth at each end. If the building is excessively long intermediate earth connections will be necessary (see Fig. 5).

Buildings with terraced roofs are best protected by a conductor run horizontally round the top of the walls, and a vertical conductor at one corner. If there be a dome at one corner covering a spiral staircase, the vertical conductor should be put at that corner (see Fig. 6).

If the building be more extensive, a second vertical conductor should be furnished at the opposite corner to the first, and the opposite angles of the horizontal conductor should be connected together (see Fig. 7).

If the side walls of a building rise considerably above the level of surrounding objects, as is often the case in large public edifices, they will also require protection. If there be metallic down pipes, they should invariably be connected together at the top and bottom and put into circuit with the protective system.

When the ridge cover, or eaves gutter, is of metal, it should also be connected with the system.

All external metallic surfaces, such as the copper doors and window shutters of magazines, should be connected with the conductor.

Underground Structures.—All underground buildings in dry soil require protection (men have been killed working in a mine); and underground magazines should be invariably protected with the same precaution as if they were above ground.

Casemated Batteries of modern construction in which the magazines are distributed throughout the basement story requires protection. It will generally be convenient to have one or two horizontal conductors on the parapet or terreplein extending the whole length of the battery, attached to vertical conducters connected to earth.

Iron Shields in casemated works must be put in connection with the conductors. This may be effected either through iron racers in their rear, or by means of horizontal bands extending from one shield to the other externally.

(*N.B.*—The last two paragraphs are taken from Sir Frederick Chapman's "Instructions.")

Mussoorie, (Signed) R. S. BROUGH.
10th September 1880.

REMARKS ON SIR FREDERICK CHAPMAN'S MEMORANDUM.

1.—*Nil.*

2.—Right; but for terminal "plane" *read* "surface."

3.—Right.

4.—Right.

5.—*Nil.*

6.—Right.

7.—This rule is absurd. It is just as necessary, while it is proportionately easier to protect small magazines.

8.—Right.

9.—Good; but involved and obscure.

10.—Right.

11.—*Nil.*

12.—Right.

13.—This is equivalent to saying that "the sectional area of copper conductors should not be less than ¼ square inch = 1⅔ sq. cm. about."

14.—The same as "the sectional area of iron conductors not to be less than ¾ square inch."

15.—Right.

16.—Right; but it is an important point also which I have never seen noticed anywhere that the specific heat of iron is 10 per cent. greater than that of copper. Considering the difference of the sectional area of the metals employed this must have a great influence.

17.—Right; but the words "especially at points where two lengths of metal are joined together" should be omitted.

18.—Good.

19.—The slip in horizontal conductors can rarely be sufficient on account of friction, while the slip must be *nil* when the conductors are attached to verticals at both extremities.

20.—This is true. The thing that is really requisite at the joints is, what electricians call, "perfect metallic contact." This may be got by brazed, soldered, or welded joints; or by well-fitting screw joints, all to be invariably protected from damp by paint. In the case of galvanized iron conductors efficient contact can be obtained by simple mechanical pressure of the two parts together, *e.g.*, by means of a bolt, and nut well screwed home. This is a great advantage in using galvanized iron. In fact, nothing can compete with galvanized iron, except copper when a neat and slightly jot is wanted.

21.—The screwed joints are well designed, but I doubt the safety of rivetted copper joints, but they may answer perhaps if thoroughly dried when made and subsequently scrupulously protected from air and damp, by a thick and continuous coat of well-adhering paint.

22.—This rule is of questionable utility and might be interpreted to allow a latitude which ought not to be permitted. No joint ought to exist anywhere that might cause any form of disruptive discharge. This may, however, be a necessary *precaution*, but it should be put less ambiguously.

23.—What is necessary is to bring two clean metallic surfaces into thorough contact *and keep them in that condition.* The screwed joints of hollow iron gas pipes would certainly rust in India without special protection in the way of drying and subsequent painting.

24.—Screws working in slots, or anky kind of free joints, especially in iron, are quite inadmissible.

25.—The last part of this paragraph is very important; junctions of dissimilar metals should be avoided whenever possible.

26.—This paragraph states facts in a straightforward and sensible manner.

27.—The statement contained in the first line of this paragraph is, as I have already pointed out on several occasions, most misleading. A lightning rod determines a line of maximum induction between the electrified cloud and the earth, and consequently tends to determine discharge. What is meant by the air withstanding the "potential" of the cloud is not clear; we might just as well talk of a dam withstanding the "level" of the water! The thing which is actually withstood in both cases is a mechanical stress.

28.—Right.

29.—Why 5 feet I do not know; 500 feet would be more effective still. The maximum height that can be obtained at a moderate cost and with perfect stability would, I should think, exceed 5 feet, but would, in the absence of instruction, depend of course on the ingenuity of the Engineer. Even assuming the maximum protective radius given in paragraph 26, the 5 feet rods should be spaced at 2 × 5 + 2 × 5 = 20 feet apart, not 30. When the rod is of galvanized iron, its point need *not* be gilt, but only galvanized—another advantage in this form of conductor.

30—33.—*Nil.*

34.—The fork of two or more points, instead of a single point, is only useful with respect to the neutralizing power of the lightning discharger before disruptive discharge takes place; the more points the less the resistance obviously and the greater the power of silent discharge. Such forks are not easy to construct efficiently, and should only be employed in the case of very lofty rods, *e.g.*, rods on factory chimneys, church spires, &c., when the dissipating power may become an important factor in the construction of the lightning protector.

35.—The word "external" ought to be inserted after "all" and before "metal surfaces."

36.—*Nil.*

37.—"Sharp re-entering angles," I think ought to be in the last sentence.

38.—This is right; but the only way of ascertaining whether the "earth" is good or not is by electrical tests.

39.—This is absurd.

40.—This is very good.

41.—*Nil.*

42.—The earth connections suggested are bad and clumsy. I think the word "metallic," or "iron" preferably, should be inserted before "water-pipes."

43.—Right; but no inspection can take the place of electrical tests.

44.—*Nil.*

45.—Right.

46.—I have always regarded zinc as a metallic "element," and was not aware that it could be "*decomposed.*" The rusting of the iron, which always occurs at bare places, is the objectionable thing, and not the "decomposition" or oxidation of the zinc.

47.—Right. (Signed) R. S. BROUGH.

7th September 1880.

REMARKS ON SIR W. SNOW HARRIS'S MEMORANDA.

Appendix A.

8. *Remark* 1—*Page* 10.—It is true there is no danger of "Lateral Discharges" so long as (1) the electrical continuity is so perfect that the lightning protectors offer no perceptible resistance from their summits to the ground, and (2) that the resistance of the earth connections is very small. So soon, however, as one or other of these conditions is not fulfilled, then there is a danger of lateral discharge.

Defective joints and imperfect earth connections may, therefore, produce lateral discharge.

Sir W. Snow Harris's remarks must, therefore, be regarded as only applying to perfect lightning conductor.

9. *Remark* 2—*Page* 10.—Regarding the attraction of lightning—see my remark on Sir F. Chapman's 27th paragraph.

Sir W. S. Harris appears to forget that the hot air and gases coming up a chimney are very fair conductors. In fact, chimneys with fire burning in them are the great sources of danger in ordinary dwelling-houses.

At the same time it is highly probable that the conductor on the clock tower was so bad that it offered more resistance than the hot air in the chimney.

This illustration is, therefore, most infelicitous.

10. *Remark* 3—*Page* 11.—The first two paragraphs are fairly clear and good; but the analogy drawn in the third paragraph on page 12 is absurd.

11. *Page* 12.—Good.

12. *Page* 13.—The case quoted in the footnote is really not in point. The height of the mainmast above the top of the foremast (*i.e.*, the difference of level between the top of the two masts) was probably only a small fraction of the distance between the two masts.

I never heard of any one objecting to painting the conductors, except at their points. Paint does not of course interfere with the conductivity of the conductors, but it would impede the diffusing action of the points. For ordinary conductors, this is quite a minor point, and they may be painted all over, although galvanising is of course preferable.

The remarks in the last paragraph regarding painting the rods are very just.

13. *Page* 13.—Nil.

Appendix B.

1. *Page* 14.—Putting Sir W. S. Harris's opinion into modern language is as follows: Keeping the same sectional area of metal in the conductor, a tube is preferable to a solid rod, because its inductive capacity is greater, and the potential of the discharge would be *pro tanto* reduced.

This is an important point, because the tendency to disruptive discharge varies as the square of the potential. Practically, however, when the points and earth connections are good it is unimportant.

2. *Page* 15.—Right.

3 and 4.—Nil.

7th September 1878.

(Signed) R. S. BROUGH.

(?)-58

TMENT.

Enclosure to P. W. D. Circular No. 24 Public Works.

[*Issued with Army Circulars, dated 1st May 1879.*]

[illegible]

INSTRUCTIONS AS TO THE APPLICATION
OF
LIGHTNING CONDUCTORS
FOR THE
PROTECTION OF POWDER MAGAZINES AND OTHER BUILDINGS.

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 in prominent points, the top of a hill for example, under which circumstances the 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 asphalte and concrete, it is necessary to provide rods or points projecting above the asphalte, 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 [illegible] 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 ⅙ that of copper.

13. Copper lightning conductors should be of the following dimensions: rods ½ inch in diameter, tubes ¾ inch in diameter and ⅛ inch thick, or bands 1½ inches wide and ⅛ inch thick.

14. Iron lightning conductors should be either solid rods 1 inch in diameter, or bands 2 inches wide and ¼ 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 II*a*., II*b*., III*a*. and III*b*., 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 IV*a*., IV*b*. and IV*c*., 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

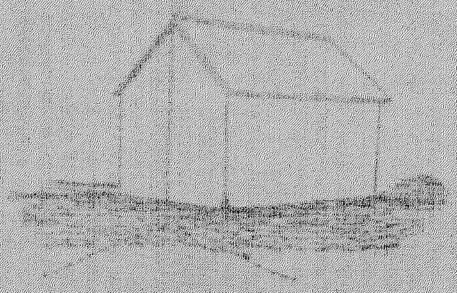
considered that they afforded protection over a circle whose radius was equal to twice their height; but in England, the limit is usually considered the radius of their height from the ground. This may be sufficiently correct for all practical purposes, but such a radius of protection cannot always be 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.

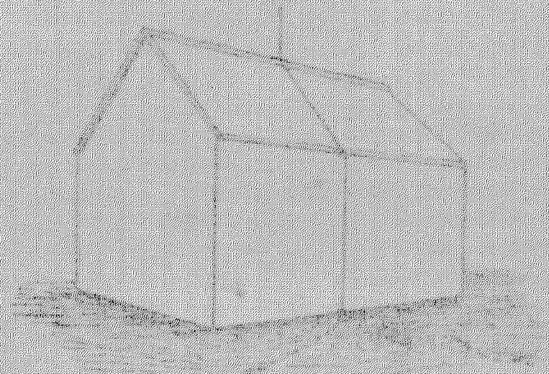
28. From this we may conclude that the angle of a building which a thunder-cloud approaches, may receive the discharge, while another but more distant angle is provided with a conductor; and that for important buildings containing explosive materials, every prominent elevated part ought to be provided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

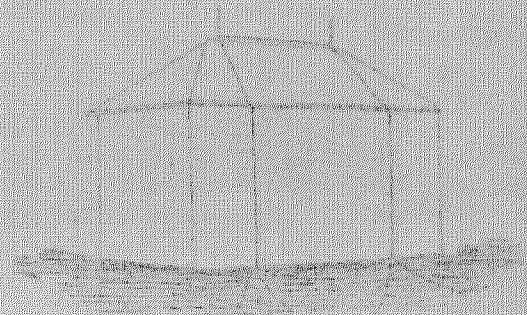
30. Small simple buildings, not exceeding 20 feet in length, may be protected by one vertical conductor at the end, the point rising not less than five feet above the ridge of the roof; a horizontal conductor should be provided on the ridge.

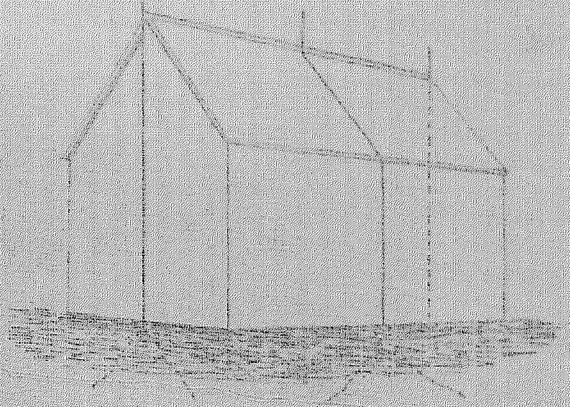


31. A building from 20 feet to 40 feet long should be protected by one vertical conductor in the centre of its length, with a horizontal conductor on the ridge.



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 point, or bunch 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 or a pinnacled 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 connections may be conveniently attached along the ridge or eaves. When the ridge covering is of iron, or gutters are of metal, they should invariably be connected with the system. All metal surfaces, whether lead, copper, or zinc, in ridges, roofs, gutters, or coverings to dormer windows, should be connected with the conducting system.

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

Lead.	Tin.	Iron.	Zinc.	Copper.
1	[illegible]	[illegible]	4	12

[illegible] must be carefully considered in connecting [illegible], such 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 seriously 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. Rough, dry sand, or ordinary [illegible] which would be 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 conducted 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.

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* 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 meter in the basement, and lit the gas, by which the buildings were nearly set on fire.

APPENDIX A.

Lightning Conductors, Principles, and Instructions relative to their application to Powder Magazines and other Buildings, by the late Sir W. Snow Harris, F.R.S.

1. Thunder and Lightning result from the operation of a peculiar natural agency through an interval of the atmosphere contained between the surface of a certain set of clouds, and a corresponding area of the earth's surface directly opposed to the clouds. It is always to be remembered that the earth's surface and the clouds are the terminating planes of the action, and that buildings are only exposed to Lightning because they are points as it were in, or form part of, the earth's surface in which the whole action finally terminates. Hence, buildings, under any circumstances, will be always open to strokes of Lightning, and no human power can prevent it, whether having conductors or not, or whether having metals about them or not, as experience shows.

2. Whenever this peculiar agency (whatever it be), active in the operation of nature, and characterised by the general term Electricity or Electric Fluid, is resisted in its passage by substances which are found to resist its progress—such, for example, as air, glass, resinous bodies, dry wood, stones, &c.—then an explosive form of action is the result, attended by such an evolution of light and heat, and by such an enormous expansive force, that the most compact and massive bodies are rent in pieces, and inflammable matter ignited. Nothing appears to stand against it; granite rocks are split open, oak and other trees of enormous size rent in shivers, and masonry of every kind frequently laid in ruins. The lower masts of ships of the line, 3 feet in diameter and 110 feet long, bound with hoops of iron half-an-inch thick and 5 inches wide, the whole weighing about 18 tons, have been in many instances torn asunder, and the hoops of iron burst open and scattered on the decks. It is, in fact, this terrible expansive power which we have to dread in cases of buildings struck by Lightning, rather than the actual heat attendant on the discharge itself.

3. When, however, the electrical agency is confined to bodies, such as the metals, and which are found to oppose but small resistance to its progress, then this violent expansive or disruptive action is either greatly reduced or avoided altogether; the explosive form of action we term Lightning vanishes, and becomes, as it were, transformed into a sort of continuous current action of a comparatively quiescent kind, which, if the metallic substance it traverses be of certain known dimensions, will not be productive of any damage to the metal; if, however, it be of small capacity—as in the case of a small wire—it may become heated and fused; in this case the electrical agency, as before, is so resisted in its course as to admit of its taking on a greater or less degree of explosive and

heating effect, as in the former case. It is to be here observed that all kinds of matter oppose some resistance to the progress of what is termed the Electrical Discharge, but the resistance through capacious metallic bodies is comparatively so small as to admit of being neglected under ordinary circumstances: hence it is that such bodies have been termed Conductors of Electricity, whilst bodies, such as air, glass, &c., which are found to oppose very considerable resistance to electrical action, are placed at the opposite extremity of the scale, and termed Non-Conductors or Insulators. The resistance of a metallic copper wire to an ordinary electrical discharge from a battery was found so small, that the shock traversed the wire at the rate of 576,000 miles in a second. The resistance, however, through a metallic line of Conduction, small as it be, increases with the length, and diminishes with the area of the section of the conductor, or as the quantity of metal increases.

4. It follows from these established facts, that if a building were metallic in all its parts—an iron magazine for example—then no damage could possibly arise to it from any stroke of Lightning which has come within the experience of mankind, *e.g.*, a man in armour is safe from damage by lightning; in fact, from the instant the electrical discharge in breaking with disruptive and explosive violence through the resisting air (3) seizes upon the mass at any point of it, from that instant the explosive action vanishes (4) and the forces in operation are neutralized upon the terminating planes of action, *viz.*, the surface of the earth (2) and opposed clouds.

5. All this plainly teaches us that in order to guard a building effectually against damage by Lightning, we must endeavour to bring the general structure, as nearly as may be, into that passive or non-resisting state it would assume, supposing the whole were a mass of metal.

6. To this end, one or more conducting channels of copper, depending upon the magnitude and extent of the building, should be systematically applied to the walls. These conducting channels should consist either of double copper plates united in series one over the other, as in the method of fixing such Conductors to the masts of Her Majesty's ships; the plates being not less than 3½ inches wide, and of $\frac{1}{16}$th and $\frac{1}{8}$th of an inch in thickness; or the Conductors may with advantage be constructed of stout copper pipe, not less than $\frac{1}{8}$th of an inch thick, and 1½ to 2 inches in diameter; in either case the Conductors should be securely fixed to the walls of the building, either by braces, or copper nails, or clamps. They should terminate in solid metal rods above, projecting freely into the air, at a moderate and convenient height above the point to which they are fixed, and below they should terminate in one or two branches leading outward about a foot under the surface of the earth; if possible, they should be connected with a spring of water or other moist ground.

It would be proper, in certain dry situations, to lead out in several directions, under the ground, old iron or other metallic chains, so as to expose a large extent of metallic contact to the surface of the earth.

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 permanent elevated chimney, it would be desirable to lead a pointed conducting tube along it to the metals of the roof, all of which answer the conditions above specified (4).

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 (1) 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 masts with a crash as if the ship's broadside had been fired, and the solid metal itself has been found melted. In all these cases electrical discharge, robbed by the Conductor of its explosive violence, has traversed the line of points to the sea, through the ship and through the copper bolts driven through the ship's solid timbers, without the least damage to the surrounding masses, whether metallic—as in the case of the extensive iron knees on the lower decks—or not. Persons have been either close by or actually leaning against the Conductors at the time, without experiencing any ill consequence.

9. REMARK 2.—It has been also incontestably shown that metallic bodies have not any specific attractive force or affinity for the matter of Lightning; metals are as little attractive of Lightning as wood or stone; all matter is equally indifferent to Electricity, so far as regards a specific attraction; hence, the idea that metals attract or invite Lightning, is a popular but very unlearned error, contradicted by the most satisfactory evidence, and the whole course of experience; in short, we find that Lightning falls indiscriminately upon trees, rocks, and buildings, whether the buildings have metals about them or not.

In May 1841, Lightning struck one of the high cylindrical chimneys at the Royal William Victualling Yard, Plymouth, and rent it for 60 feet down. This chimney is built of granite, is 120 feet high, and has *not a particle of metal 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 stood 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 unassailed by the great thundercloud, which spread its lightnings 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 attractions, 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 rain-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 does 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 continued; 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 bring 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 powder magazines, with capacious metallic Conductors to the earth, would be unobjectionable, and a source of security.

Metallic pontoons and vessels having a continuous metallic connection with the earth are also unobjectionable.

A good method of Conduction 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, dispersion, 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 terminations 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.

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* It has been recommended to place Lightning Conductors some feet distant from the buildings, or otherwise insulate them from the walls by glass or rods; all this is clearly opposed to the principles 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 [illegible] Lodge, in Jamaica, the residence of [illegible], 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 case of Gunpowder Magazines, on the assumption 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, 28th July 1857. 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 depot 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. Is it possible to conceive that an agency which can rend 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 [illegible], an inch thick or less, supposing its course were from any cause determined in that direction?

#31

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 those 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.

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* 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.

APPENDIX B.

Supplementary Paper.

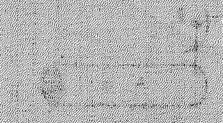
Lightning Conductors for Magazines and other Buildings.

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

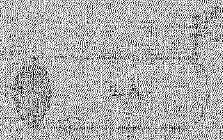
This question has been usually considered in relation to the heating effects of an electrical discharge upon comparatively small Conductors, in which the resistance to the discharge is considerable. In this case a given quantity of electricity melts the same quantity of metal, under whatever form it be placed; whether in a solid or a hollow cylinder for example; at least such is to be inferred from the experiments hitherto conducted. See a paper by Mr. Snow Harris, *Phil. Trans.* for 1827, on Conductors of Electricity, &c., last four paragraphs. In this regard 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 mass, is inconsiderable; such a case as this brings us to the consideration of *certain* statical laws of Electrified Conductors; since for an *evanescent 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 2 A, whose surfaces are 1 and 2, or 2 A double the surface of A; let the masses be the same if you wish.

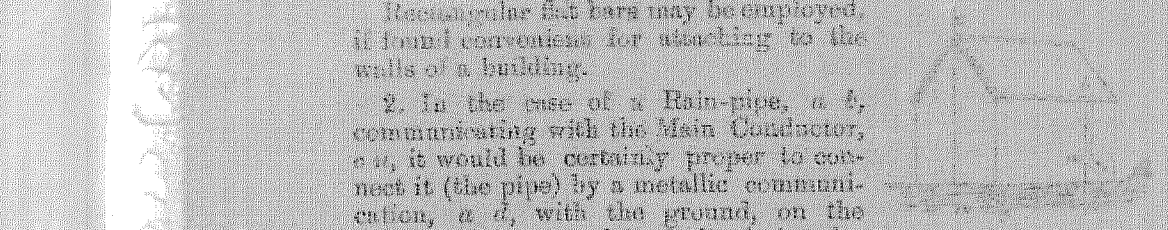


Then if a given quantity of Electricity be disposed on, or pervade the smaller surface A, an electroscope E will evince a high intensity, and will stand out violently as it were; whereas the same quantity disposed on 2 A will repose with so much more quietude on the double surface, that the electroscope E will evince but little comparative action. See *Phil. Trans. for* 1834, page 229, 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, *e 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

Expensive. Still, there is no doubt but that a good and efficient Conductor might be formed of galvanized iron;* it should be two inches diameter, firmly screwed together, at joints of extra thickness, [illegible] pure copper tubing of a given thickness, however, is always to be preferred.

4. In the case of a dry or rocky soil, it is certainly desirable to complete, as far as possible, the conducting power of the ground about the building, either by leading old iron chains out from the walls in several directions, or by leading a flow of water over it [illegible] the building. The surface of the earth being, as remarked [illegible] one of the terminating planes of the electrical action; the [illegible] as far as possible, for the expansion of the [illegible] 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, d, on a dry or rocky soil, old iron chains, b c, b d, b e, &c., may be led out from Conductor a b, in various directions, to the extent of about 10 or 15 yards, and to a few (two or three) inches under the surface of the earth, and it would be further desirable, in such cases, to lead a flow of rain, as 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.

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* The [illegible] is not wholly in favor of the durability of the galvanized coating [illegible]

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No. 294.

From

THE DIRECTOR-GENERAL OF TELEGRAPHS
IN INDIA,

To

THE SECRETARY TO THE GOVERNMENT
OF MADRAS, PUBLIC WORKS DEPT.

Simla, the 28th of May 1880.

SIR,

REFERRING to your letter, No. 1222-W, dated 21st instant, I have the honor to inform you that, since writing my No. 44, dated 12th ultimo, the lightning conductors of the Powder Magazines in Fort William have been tested. A copy of the Electrician's letter, No. 46, dated 14th May, with its accompanying report, describing the condition in which he found them, is annexed for your information.

2. With reference to the state of affairs therein disclosed, I have the honor to suggest that, before incurring the expense of applying electrical tests to the lightning conductors at Madras and Bangalore, they be carefully examined with the view of discovering and rectifying faults, obvious to even an ordinary visual examination, and of rendering the conductors as mechanically perfect as possible.

I have the honor to be,
Sir,
Your most obedient Servant,
R. MURRAY, Colonel,
Director-General of
Telegraphs in India.

No. M. 80 1155 C 4-6-85
+ given to J. 1-8-85

No. 46.

From

The ELECTRICIAN,

To

The DIRECTOR-GENERAL of TELEGRAPHS

in INDIA,

Dated Alipore, the 11th May 1890.

Sir,

Referring to your No. 5486, dated the 20th March 1890, herewith enclosed, return of which is requested, I have the honor to enclose for your perusal a memorandum of the tests made of the lightning conductors of the Magazines in Fort William, and some remarks on the same.

My object in forwarding these papers is to show that, in common with the conductors of the Dum-dum and Ishapore factories, the entire system is defective and dangerous, and to state that the best chance of having it properly reconstructed is to place the work in the hands of Mr. King, the Executive Engineer of the Public Works Department, who reconstructed the systems at Dum-dum and Ishapore, in accordance with the instructions issued from this Office.

It seems also evident that the Public Works Department are not in possession of any proper instructions for fitting their Magazines and other buildings with lightning conductors, and it will therefore save our Department much time and trouble, if a carefully prepared Code of Instructions for erecting and maintaining any system of conductors were issued to them; such a Code would certainly take time to prepare, but from my reports on the Dum-dum and Ishapore factories from a paper written by the late Mr. R. S. Brough, and from our general knowledge on the subject, a sufficiently complete one could no doubt be prepared.

I would request the favor of your returning the enclosures to me, for submission to the Garrison Engineer as directed in your letter.

I have, &c.,

(Signed) W. P. JOHNSTON,

Offg. Electrician.

MEMORANDUM

Prince of Wales' Magazine.—The lightning conductors of this building are in a dangerous condition, and the following works must be carried out.

The iron rod is to be connected metallically to the copper rod next to it. Special precaution must be taken to protect the joint between the copper and the iron from the weather, in order to prevent galvanization and the joint must be thoroughly dried and then painted over immediately.

Many of the joints in the rods and bands are defective, and they must be remade by a good workman, and it must be remembered that two perfectly clean surfaces, each of sufficient area, must be brought into perfect contact with each other and maintained in that condition, by clean surfaces is to be understood, bright metallic surfaces, free from oxide, grease, damp, or other foreign matter.

Soldered, brazed, or welded joints are the best, and the precaution of drying and painting over all joints should be taken.

All these earth connections are defective and perfectly useless. They consist of iron chains, the connecting links of which have rusted and offer considerable electrical resistance. All these iron chains must be removed and the rods and bands that enter the earth must be increased by a length of 6 feet, and must each be placed in perfect metallic connection with a copper plate 42 inches by 42 inches and ¼ inch thick, in order to offer a sufficient surface for diffusion. The copper plates themselves must be buried vertically 6 feet in the earth, or in earth permanently moist.

There should be no difficulty in obtaining good earths in the fort. The top of one of the conductors has broken off, and it is merely hanging on, it must be properly joined again.

The Overseer in charge states that the rods were repaired last year, but the results are perfectly useless.

Grand Magazine.—The iron rod facing east must be connected to the others as before explained. The copper rod on the ridge is broken, thus causing this building to be, if possible, in a more dangerous condition than the one just noticed. This break must be joined over by means of perfect joints. All the earth connections are perfectly useless and must be reconstructed as before noticed, the resistance of the con-

Section "a" is enormous, over 1,000 years, this building must be treated in the same manner as the Prince of Wales' Magazine.

King's Magazine.—It will be seen from the sketch of lightning conductors of this building are also in a most dangerous and unsafe condition, and require complete reconstruction in every respect.

Duke of York's Magazine.—Ditto.

Royal Magazine.—If possible, worse than the others.

CALCUTTA, }
May 14th, 1880. } (Signed) W. P. JOHNSTON,

Offg. Electrician,
Government Telegraphs.

PUBLIC WORKS DEPARTMENT.

No. 1598.

CIRCULAR MEMORANDUM.

CIRCULATED to Superintending Engineers and Superintendents of Works, with the request that all lightning conductors within their charges may be carefully examined and their present state reported on.

(Signed) R. H. SANKEY, Col., R.E.,
Chief Engineer, P.W.D.

CHEPAUK, }
24th *June* 1880. }

To all Superintending Engineers,
" the Superintendents of Works.

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Plate 1.

LIGHTNING CONDUCTORS

GENERAL ARRANGEMENT FOR THE PROTECTION OF A MAGAZINE OR LARGE BUILDING

N.B. The Conductors [illegible]
The system being [illegible]
[illegible]

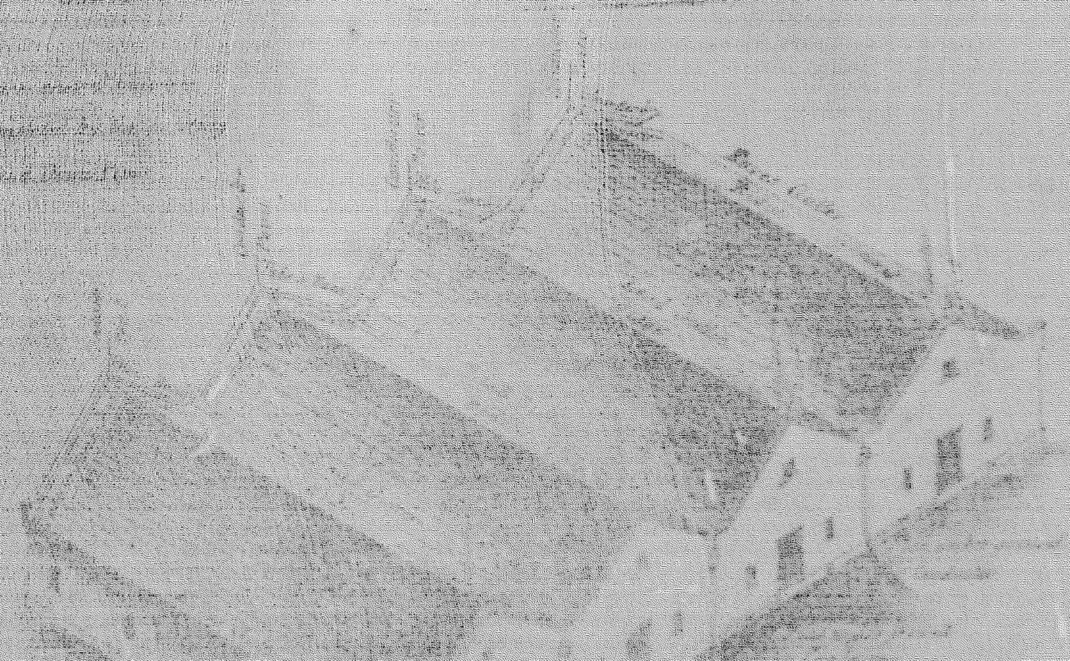
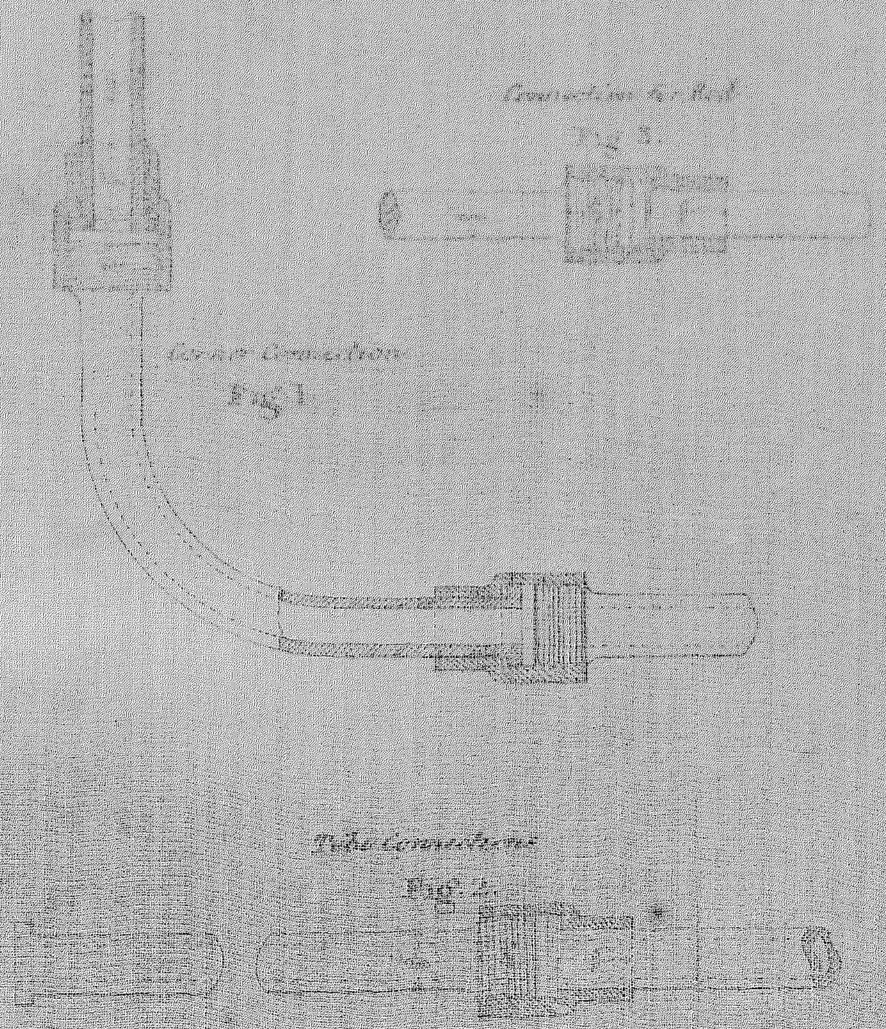


Plate II.

LIGHTNING CONDUCTORS.

CONNECTIONS FOR COPPER CONDUCTORS.

Scale Half Size



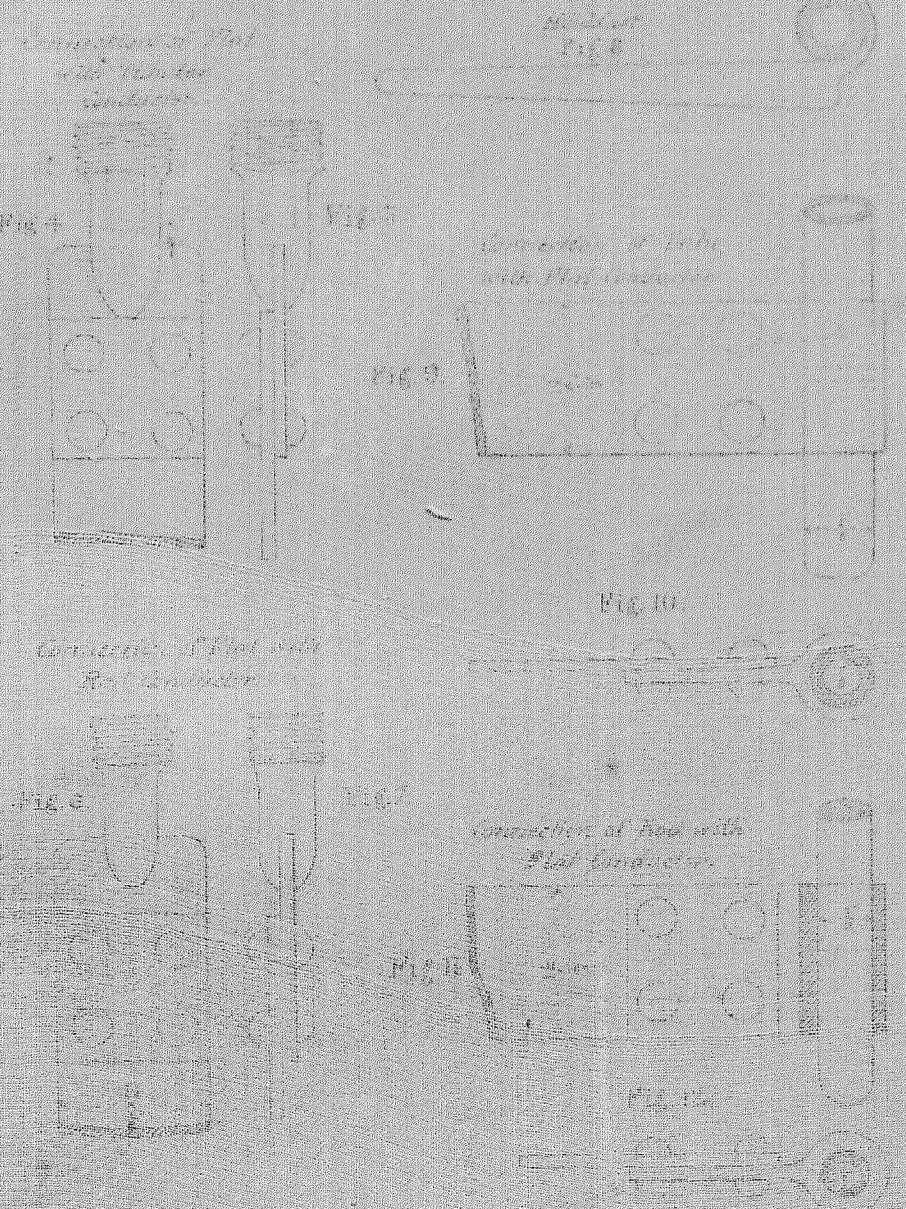
N.B. Soldered Joints are always to be preferred where practicable.

13 38

LIGHTNING CONDUCTORS

CONNECTIONS FOR COPPER CONDUCTORS

Scale Half Size


Connection of Flat with Tubular Conductor
Fig. 4
Fig. 5
Model of Fig. 8
Connection of Tube with Flat Conductor
Fig. 9
Fig. 10
Connection of Flat with Rod Conductor
Fig. 6
Fig. 7
Connection of Rod with Flat Conductor
Fig. 11
Fig. 12

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

TRANSFER BY T. [illegible] AND LITH BY [illegible] GOVT LITH PRESS [illegible]

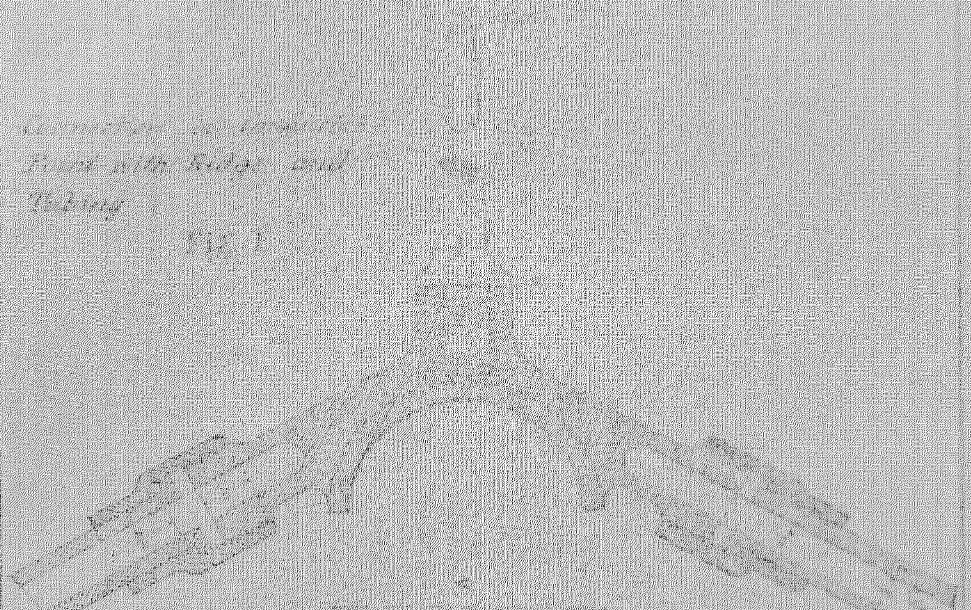
LIGHTNING CONDUCTORS

RIDGE CONNECTIONS FOR COPPER CONDUCTORS

Scale Half Size

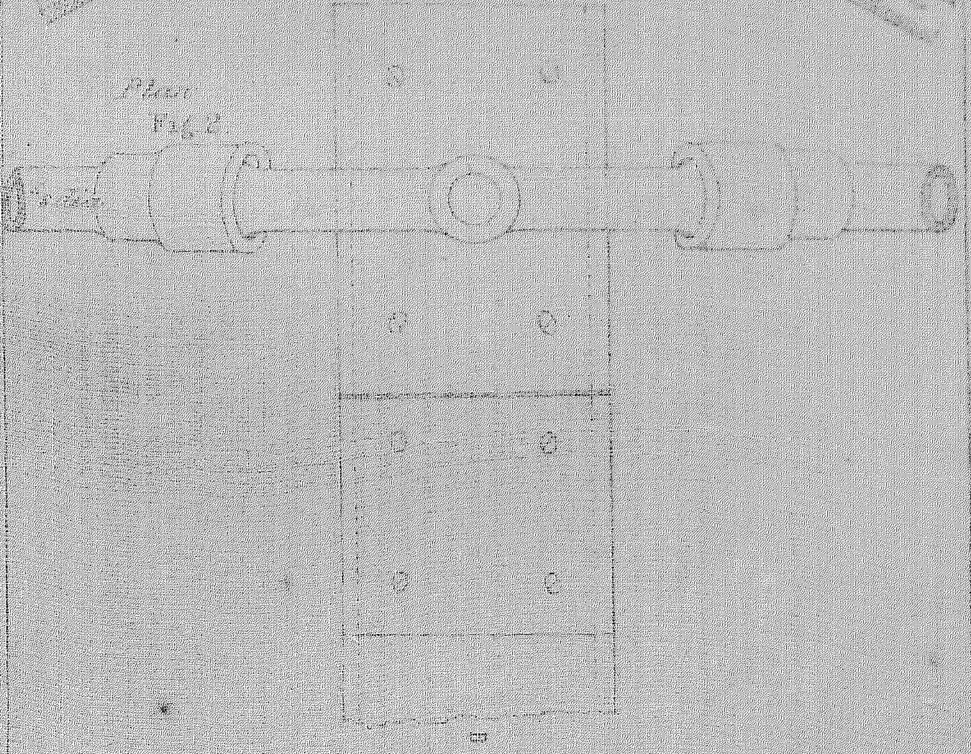
Connection of Conductor Point with Ridge and Tubing

Fig. 1



Plan

Fig. 2



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

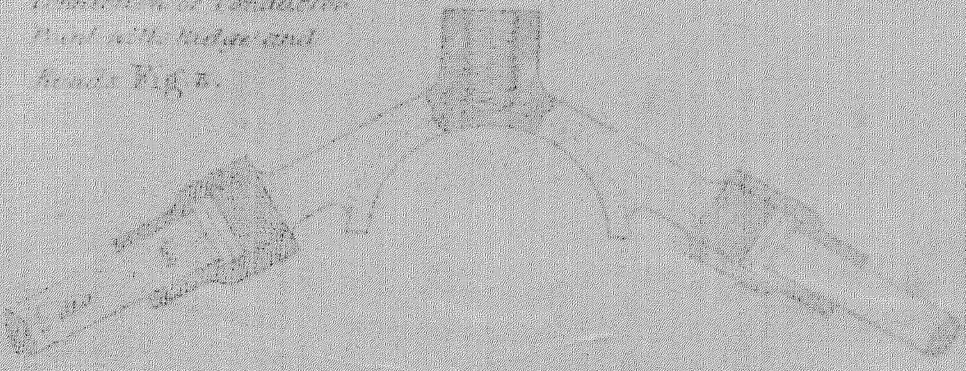
TRANSFERRED BY [illegible] AND LITHO BY [illegible]

LIGHTNING CONDUCTORS

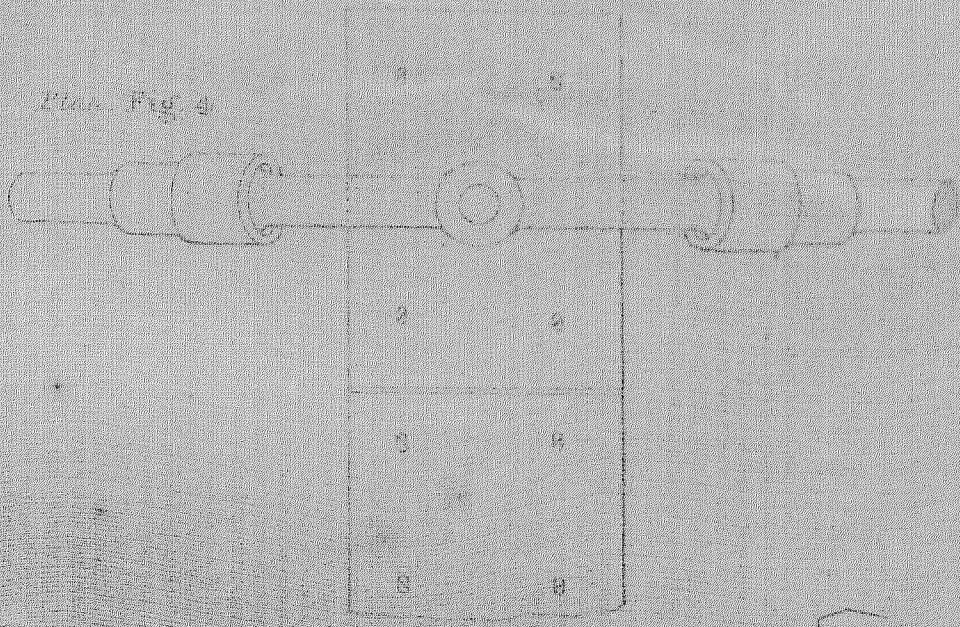
RIDGE CONNECTIONS FOR COPPER CONDUCTORS.

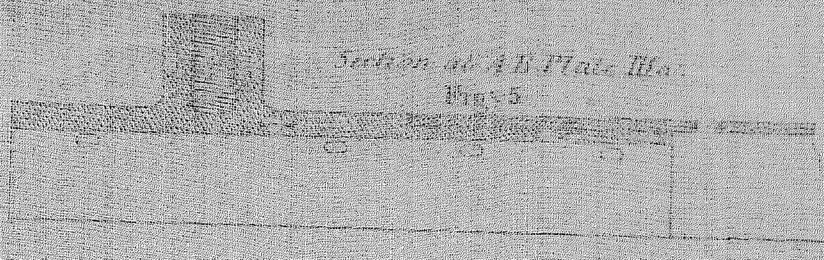
Scale Half Size.

Connection of Conductor
Rod with Ridge and
Bends Fig. 3.



Plan. Fig. 4





Section at A B Plate IIIa.
Fig. 5.

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

16 A

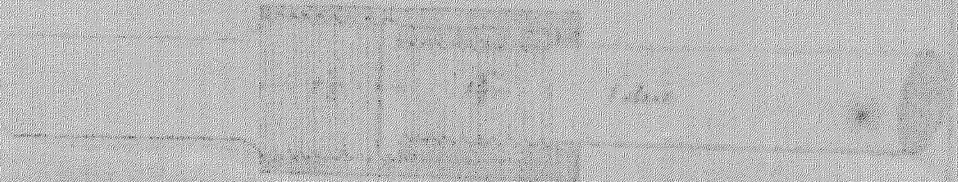
LIGHTNING CONDUCTORS.

CONNECTIONS FOR IRON CONDUCTORS

Scale Half Size

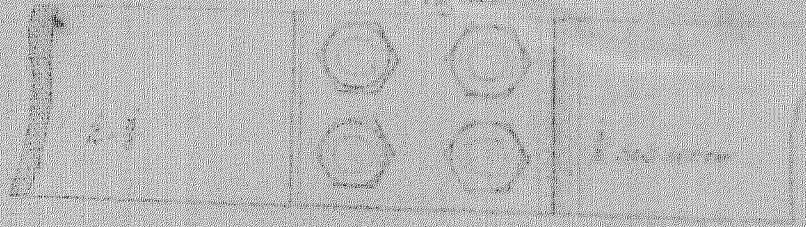
Expansion Joint

Fig. 1.



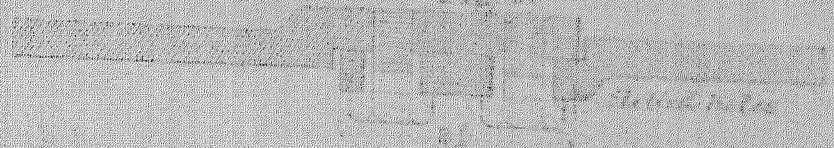
Connection for Flat Bars

Fig. 2.



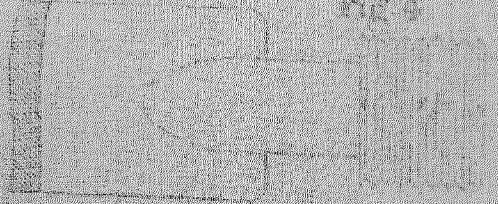
Section

Fig. 3.



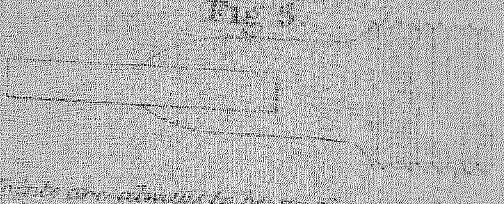
Connection for Flat
Bar with iron Rod.

Fig. 4.



Side View

Fig. 5.



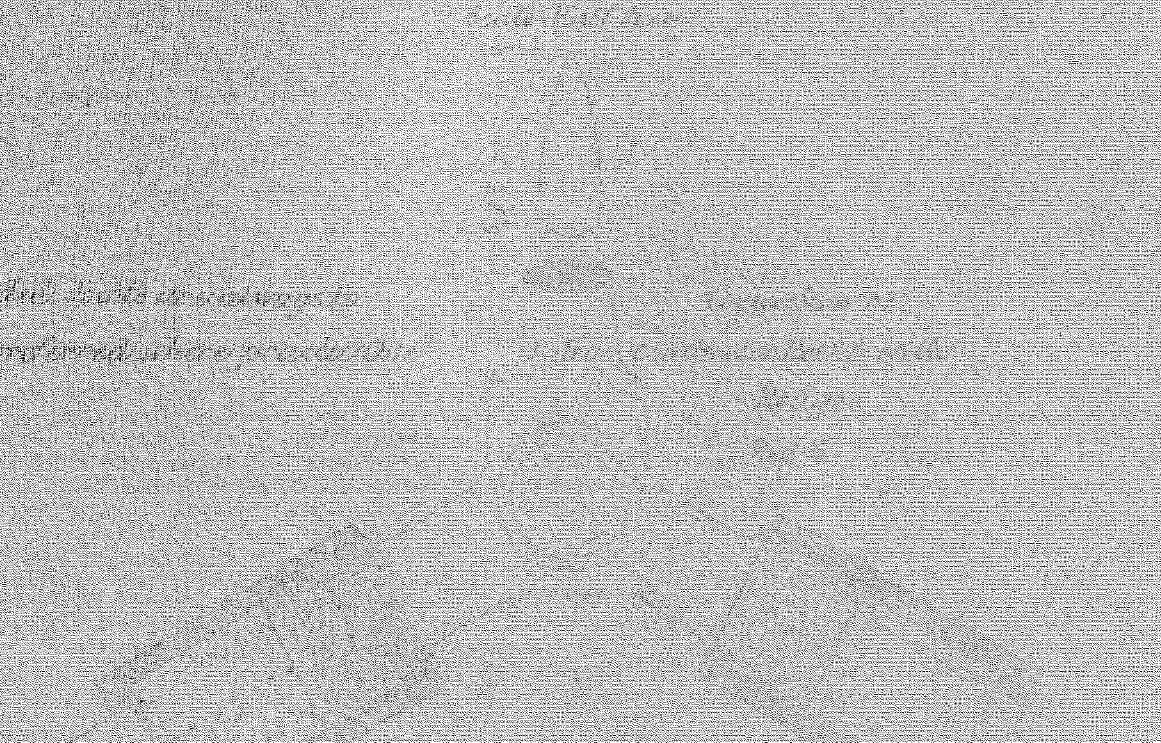
N.B. Welded Joints are always to be preferred where practicable.

Plate No. 6

LIGHTNING CONDUCTORS

CONNECTIONS FOR IRON CONDUCTORS.

Scale Half Size.



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

Plate No.

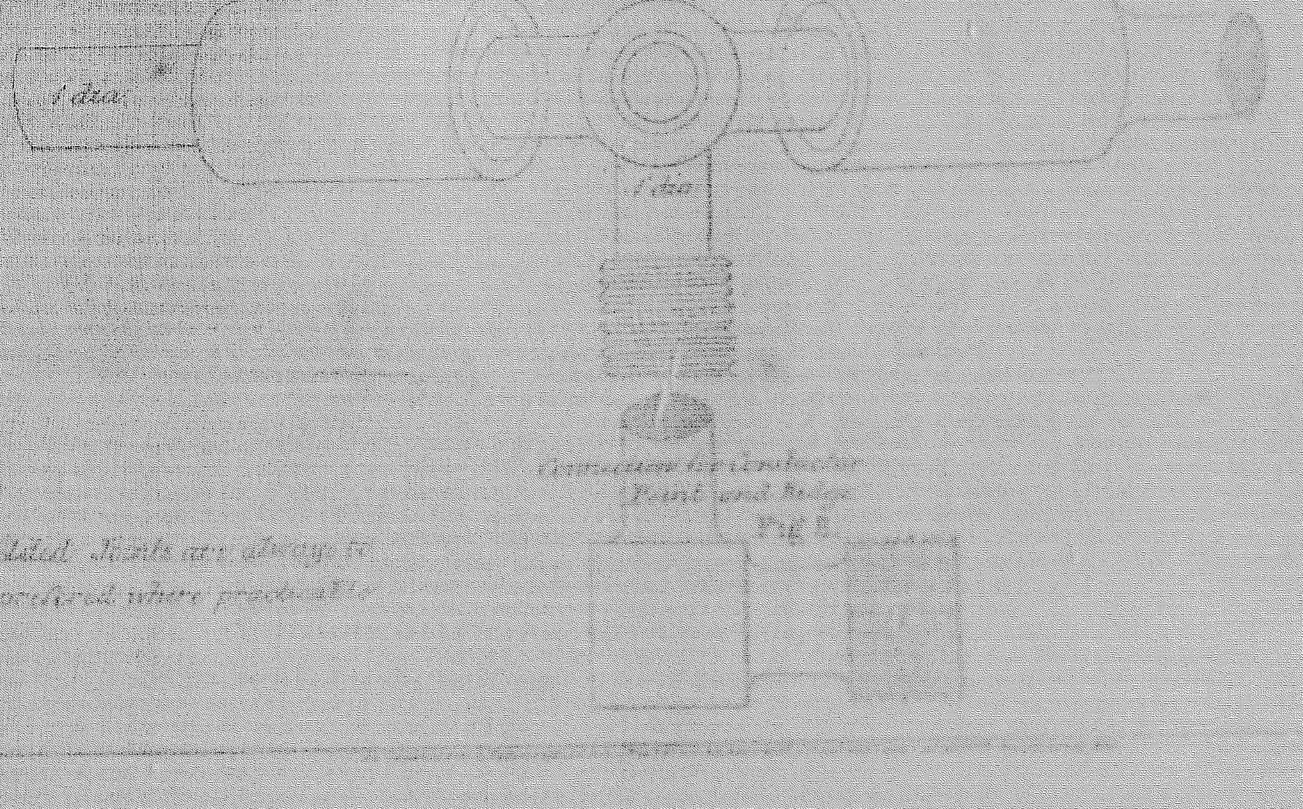
LIGHTNING CONDUCTORS.

CONNECTIONS FOR IRON CONDUCTORS.

Scale Half size

Plan

Fig 7.



Connection for Conductor Point and Ridge

Fig 8.

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

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

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

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PREFACE.

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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.

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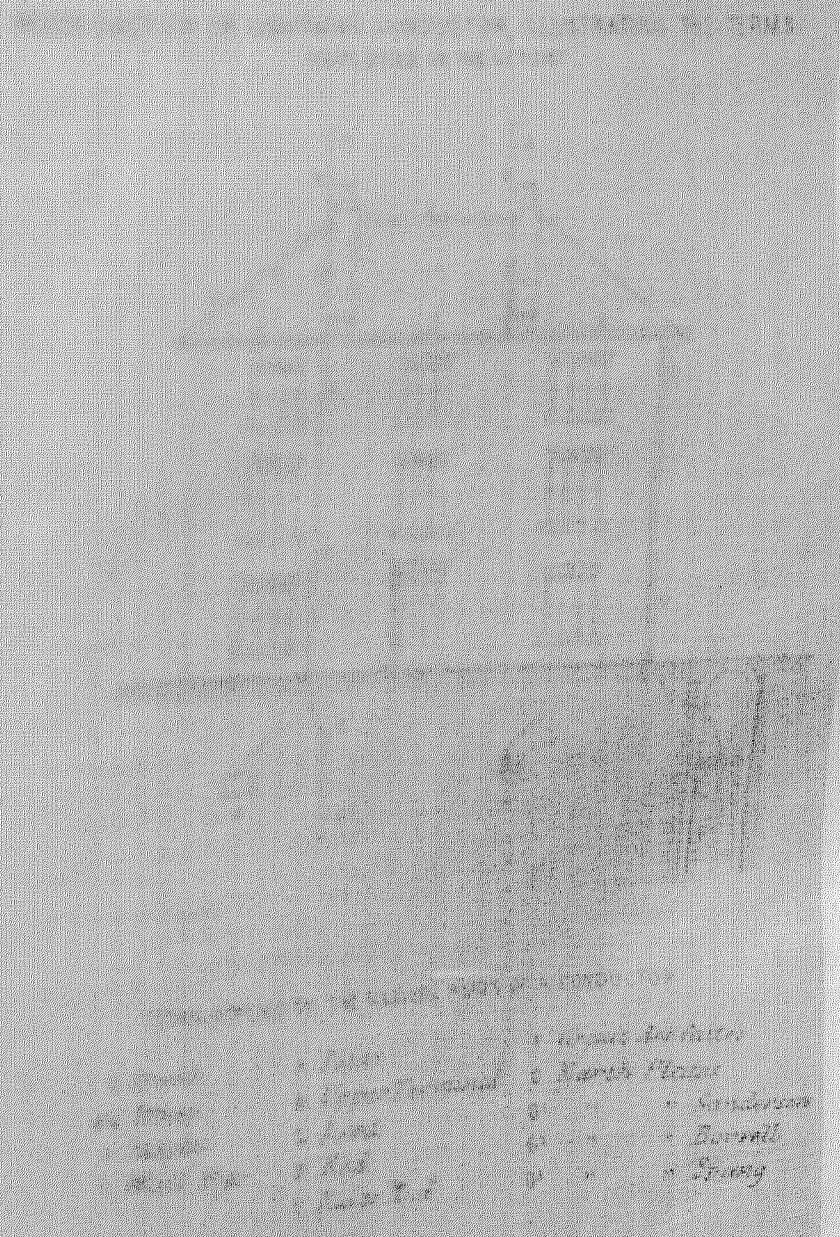

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REPORT.

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, *cæteris 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

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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 D, p. 124.]

At the same time, having regard to the importance of silent discharge from sharp points, we suggest that at one foot below the extreme tip 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 ½ 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, ⅙th that of copper, and the cost of iron to be ⅑th that of copper, this would make the cost of copper for equal conducting power $\frac{3}{2}$ths, or 50 per cent. dearer than iron. But there are other matters to be considered: (1)

[illegible]

SHAPE OF ROD.—This depends upon a subject which until lately [illegible] importance of the sectional [illegible] of a conductor; a matter which has [illegible] among electrical authorities. [illegible] Harris, for example, held diametrically [illegible] Appendix F, p. (80), and I, p. (196).] [illegible] evidence that in the case of steady [illegible] upon sectional area alone, and [illegible] experiments by Mr. Preece and [illegible] show that, in the case of sudden [illegible] lightning discharges are probably [illegible] considerable. On the other [illegible] evidence that the facility with which [illegible] conductors is affected by the

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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); Flat.

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 them 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 instructions set forth on pages 15 and 16 should be followed. The objections to tape, Appendix A, pages (5) and (10), 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, 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.

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* Spang, "A Practical Treatise on Lightning Protection," p. 131.

We agree with M. Borel in thinking that serious evil arises from using wires 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 1 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 rope, 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 1,909 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 riveted joints, however well they may be made mechanically, are certain to open and become in time faulty by the expansion and contraction due to changes of temperature, admitting moisture, and thus causing corrosion and resistance. No joint can possibly be electrically perfect that is not completely surrounded with metal; careful soldering, in addition to mechanical coupling or screwing, is the only certain mode of ensuring this. Soldering is a method that has borne the test of experience, and its success as a means of ensuring 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 joints, 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 H, pages (99) and (118).)

ATTACHMENT TO BUILDINGS.—The evidence against the use of glass or other material in order to insulate the conductor is overwhelming, and insulators 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 upon conductors are traceable to these conductors having imperfect earth terminals. We know of many cases in which the earth connections have been miserably imperfect, or entirely neglected, where the above-ground portion has been perfectly satisfactory. In fact, though it must be admitted that the case found by Dr. Mann,* of one 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 easily too many of which the Middlesboro' case, Appendix I, page [illegible], is a perfectly fair type.

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* Quarterly Journ. Met. Soc., Vol. [illegible], p. [illegible].

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 favour 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."*

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* On page [illegible], 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.

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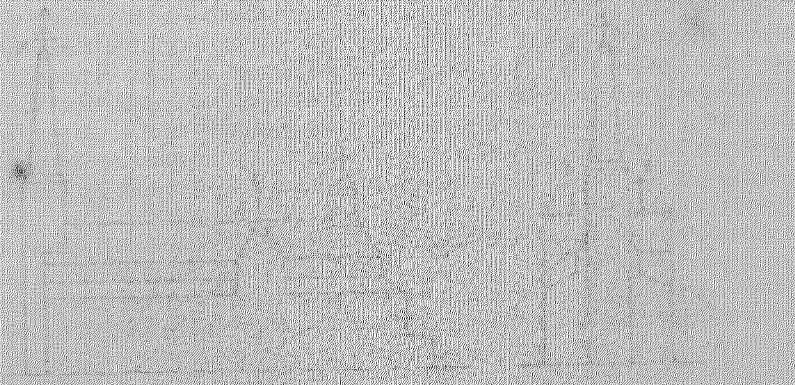

According to this rule, the church of Ste. Croix (see Appendix F, p. (141)) would require four upper terminals, one on steeple, one on chancel, and one in the middle of each half of the transept.

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-

[illegible] Conductors; alterations will be made by landlords and [illegible], and, by want of every precaution during erection, the conductor will thus lose the 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 at each side of a chimney or shaft. This is a very efficient arrangement [illegible] a means for testing from the ground. It has also been proposed to employ an insulated wire alongside or even within the rod, connected to the terminal at the top and to the testing apparatus at the base.

A testing apparatus has been devised by Mr. [illegible] (Lightning Conductors, p. 68). M. Mascart, Appendix A, p. [illegible]; Captain Bucknill, R.E., Appendix M, p. [illegible]; and Mr. [illegible], Appendix N, p. [illegible], have also introduced apparatus for this purpose. The [illegible] Preece, Appendix K, p. [illegible], and M, p. [illegible], is perhaps the [illegible] 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 the earth connection should be periodically tested. As [illegible] 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 [illegible] 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 [illegible] 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. [illegible].)

EXTERNAL MASSES OF METAL.—Large constructive and decorative ironwork, such as guttering, flashings, cresting, finials, vanes, &c., and all masses of metal 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 utilised as a partially protective system. The ventilators of soil pipes may also be employed in this way, and even made sightly 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. × 3 ft. and $\frac{1}{16}$ 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 mines 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. GRYLLS 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.

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In reply to your reference as to the sufficiency of the provision made in the Estimate for protecting the Church at St Thomas' Mount from lightning, the S.E. shows that the requirements laid down in Appendix A of Standard Specification have not been completely met.

The main objection is that the terminal is not sufficiently high to protect the whole of the building. As the space protected by a lightning rod is that included within a cone of which the rod is the height & the base is a circle described with length of rod as radius, it follows that about a third of the building remote from the spire, lying without that cone, is not protected.

To protect the church fully another terminal or two will be required & as the non-protected space is a building with a terraced roof it is not easy to arrange the terminals so as not to be unsightly. In this case it seems to me that something like a belfry or small ornamental pediment might be raised above wall at end of church, to carry a conductor of suitable design.

Perhaps Mr Chisholm would be the best man to design something to meet the case. A lot of badly arranged & unmeaning looking spikes over the building will have a decidedly unpleasing effect.

C.A.

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The sketch of the English Church at St. Thomas' Mount here submitted clearly shows that, according to para 4 of the standard specifications the enclosed terminal is not at all sufficiently high to protect the building of itself — the spire terminal must be aided by three or four other terminals, suitably placed, thoroughly to render the whole church safe — subject to your approval to add but one terminal would necessitate making it very high — about 40 ft. above the church roof — the pencil figures which I have inserted for easy reference, show this — and would not even 35 ft. be too great a height for such an upper terminal?

The sketch affords an

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local information and,
in this case, circumstances
would greatly aid in decid
the best arrangement of
the terminals. —
In all other particulars
the instructions contained
in appendix A of the
standard specification
have been well attended
to in the preparation of
the present estimate for
installing the lightning
conductors at the English
church at St Thomas
Mount.

20/6/85

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Ay.S. 126/6.
C. 26.6.85 — 7.85

Superintending Engineer

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Before sanctioning this estimate, it would be satisfactory to ascertain from the S.E. whether the proposals have been framed in accordance with the recommendations of the "Lightning Rod Conference," — Vide Appendix A to Standard Specification.

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Superintending Engineer

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P. W. DEPARTMENT.

No.481 C, dated 26th. February 1883.

MEMORANDUM.

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.

Superintending Engineer's Office,
5th Circle, Madras,
Chepauk, 24th April 1885.

No. 298

From

The SUPERINTENDING ENGINEER,
5th Circle,

To

The Venerable the Archdeacon
of Madras.

Venerable Sir,
~~Sir,~~

Enclosures. 3.

1 Estimate
1 Specification
1 Report.

I have the honor to forward to you, for disposal under G. O. No. 483 W. dated 21st February 1884, para 3, an Estimate of Rs 1715 for remodelling the Lightning Conductor of the Church at the Mount, as suggested by the Government Telegraph Department.

I have the honor to be
Sir,
Your most Obedt. Servant

Col. R.E.
Superintending Engineer

From

The Superintending Engineer,

Circle,

To

The

Dated 188

Recd

61

Ootacamund, 30 April 1885.

No. 327.

To The Hon'ble
The Chief Secretary to Government,
Ootacamund.

Sir,

I have the honor to request that you will lay before the Government the accompanying papers regarding the re-modelling of the Lightning Conductor of the Church at St. Thomas's Mount at a cost of ~~Rs~~ 1715, in accordance with G.O. 21st February 1884, No. 483 W. Public Works, para 3.—

I have the honor to be,
Sir,
Your most Obed^t Servant,
F. Madras.

Ref. [illegible]

[illegible] 5 May /85

Referred & and transferred to the [illegible] department

[illegible]

1/5

G.O. No. 483 W. 21.2.84

M.S. 24/5

CURRENT NO. 6 [illegible]

From the Lord Bishop of Madras

No. 327

Dated 30th

Rd 30 April /85

Encls five (including 1 plan)

No. 157 Ed May 27th 1885

Subject.

Remodelling of the Lightning Conductor of the Church at St. Thomas' Mount.

63

P.W.D.

Consulting Architect's Office,
Chepauk, Madras,
29th July 1885.

No. 666

From
The Consulting Architect to the Government of Madras.

To
The Chief Engineer, Public Works Department.

Enclosures.
Origl. papers returned.
1 Tracing

I have the honor to return the papers regarding the protection of St. Thomas Church by lightning Conductors.

2 It will be seen from the plans which I have had made of the church, that if it is to be protected by vertical rods ~~two~~ terminals upwards of 25 feet high must be constructed at the points A and B and that the steeple must be raised upwards of 25 feet. All this is unnecessary.

3 If the present Conductor is

made perfect with a proper fall to earth at the west end and a copper tape ($1\frac{1}{2}" \times \frac{1}{8}"$) is run all round the parapet with a terminal at the east end and a fall to earth the building will be properly protected according to the rules of the Lightning Rod Conference. This system is shown clearly on the plan in red lines.

I have the honor to be
Sir, &c. &c.
Your most obdt. Servant
(Sigd.) R F Chisholm

No. 1316 C dd 31st July 1885 Consg. Archt. to Govt.

Forwarded in original (return requested) to the S.E. V Circle for the early submission of an estimate framed on the lines indicated by the Consg Architect
(By order)
C Bowen Major R.E.
Under-Secretary to Govt
P.W.D.

1885.

P. W. DEPARTMENT.

Current No. 6698

From Consg: Architect to Govt.

Enclos.—

No. 666
Dated 29th July 1885
Received 30 — " —

Subject.

St Thomas Church protecting from lightning strokes.

Disposal.

No. 1316 C Dated 31st July 1885

Forwarded in original (return requested) to the S.E. V Circle for the early submission of an estimate framed on the lines indicated by the Consg: Architect.

(By order)
C Bowen Major R.E.
Under Secy to Govt P.W. Dep.

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to earth at the west
a copper tape (1½" × ⅛")
round the parapet
-minal at the east on
pall to earth the lin
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I have

Your mos

B. Cl

No. 1316 C d/ 31st July 1888. Consg. Arc

Forwarded in ori-
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to the S.E. V Circle for the
early submission of
an estimate framed
on the lines indicated
by the Consg. Architect
(By order)
C. Moore Major R.E.
Under-Secretary to Govt.
P.W.D.

497 H d/ 21.2.84
1196 C d/ 6.7.88
1115 C d/ 18.6.88
1316 C d/ 31.7.88

P. W. D.

Roads and Buildings.

I am very doubtful as to the sufficiency of the proposal [illegible] found here, but shall [illegible] to the question of [illegible] or refer the point.
In the mean time S.E. may frame an Estimate framed on the lines indicated by Mr. Chisholm.
CU
30.7.85

From
The Consulting Architect
to the Government of Madras.

To
The Chief Engineer
P.W. Dept.

No. 666

Dated 29th July 1885.
Received

No. 1316 C [illegible]

No. of Enclosures.

Subject.
Protecting St. Thomas Church from Lightning strokes.

66

No. 4324.

Superintending Engineer's Office,
5th Circle, Madras,
Chepauk, 17 Jany 1886.

From
The Superintending Engineer,
5th Circle,

To
The Chief Engineer
P.W. Department.

Enclosures.
2. P.W. Endorsement No 1316 C of 21st July/85 with its enclosure (tracing plan).
1 Estimate
1 Plan tracing
4

Sir,

With reference to your Endorsement No. 1316 C of 31st July 1885, on the Consulting Architects' letter No. 666 of 29th July 1885 (returned), I have the honor to submit for sanction a plan and Estimate of Rs 554 for remodelling the lightning Conductor of the Church at Saint Thomas' Mount.

The present conductor is given a proper fall to earth, and a copper tape ½ by ⅛ inch is run all round the parapet with a terminal and earth connection.

I have the honor to be
Sir
Your most obedt Servant
[illegible] Prendergast Col. R.E.
Supg: Engineer 5 Circle

The Chief Engineer
P.W. Department

Dated 19th January 18

4

No. 4324.

Church at St. Thomas Mount.

Submits for sanction an estimate of Rs. 554 for remodelling the Lightning Conductors of the

22/1/56

P.W. Department.

Memorandum

on the Supdg. Engineer V Circle No. 1210 of 24th June 1855.

Ch.Q 4103 / 5225 / 5585

The Supdg. Engr. V Circle has submitted an estimate for remodelling the lightning conductors of the English Church at St. Thomas' Mount.

It appears to the Chief Engineer that the proposed terminal is not sufficiently high to protect the whole of the building and it is therefore desirable to have another

another or two terminals for the present non-protected area.

The building, however, has a terraced roof and it is no easy matter to arrange the terminals so as not to be unsightly.

The Consulting Architect (to whom the papers are forwarded) is therefore requested to submit a design for a small belfry or small ornamental pediment to be raised above the wall at the end of the church to which a lightning Conductor

To be returned with reply

Conductor of suitable design could be attached without being too conspicuous.

CB
3.7.55

To
The Consulting Architect to pvt.
A.E. v. C. for infn.

Desca
5/7/55

Issue No 187 E of 27.5.85
G O No 683 W of 22.7.85

No. 10 / 0 c of 18th Jan

69

70

Public Works Department, 1885-86.

Current No. 203
Letter No. 199
Dated the 5th May/85
From the Secy to Govt – Eccl. Dept.

Sanction.
CU.
18.5.85

NOTE OF REMARKS.

The accompanying is an estimate for remodelling the lightning conductors of the English Church at St Thomas' Mount, and amounts to Rs. 1,715.

2. An officer of the telegraph department having been deputed to test the existing lightning conductors of the Church found them to be very defective — The estimate now submitted provides for remodelling them so thoroughly and correctly as to insure the perfect future safety of the building from lightning.

3. It is stated in the report that – "The Government Telegraph department

27.5.85

"will be asked to test the conductors when built up before the building is handed back" — the church has been struck by lightning [illegible] of late time"

— The estimate has been approved in the Eccles. Department

18th May/85
B/A

S. W. Dept.

No. 151 Ed/ May 27th 1885

Memorandum.

Adverting to letter from the Superintending Engineer V Circle to the Venble the Archdeacon of Madras, No. 298 d/ 24th April 1885, forwarding an estimate amounting to Rs 1715 for remodelling the lightning conductor of the church at St. Thomas' Mount, the undersigned has the honour to inquire whether the proposals have been framed in accordance with the recommendations of the "Lightning Rod Conference" vide appendix A to Standard Specifications.

S. E. V Circle with 3 enclos:

Despd 27/5.

27.5.85

No 151 W. of 6 May 19th [illegible]

PUBLIC WORKS DEPARTMENT

PROCEEDINGS OF THE MADRAS GOVERNMENT.

A.

Under date the

Read the following

From the Lord Bishop of Madras - U.O. No. 327 d/30th April 1885

Endorsement thereon by the Ecclesiastical Department U.O. No. 1774 d/8th May 1885

The estimate amounting to Rs 1715, for remodelling the lightning conductors of the English Church at Saint Thomas' Mount, is sanctioned, upon the understanding that the proposals are in accord with the recommendations of the "Lightning Rod Conference", whose Report forms Appendix A to the Standard Specification

2. This sanction has been registered as Provincial No. W of 1885-86, and classified as Civil Buildings.

C.A.
19.5.85

To The Superintending Engineer V Circle
with 3 enclos.
" Examiner P. W. Accts
" Ecclesiastical Deptt.

J.B.

Dt 19/5

73 No. 217 W.

PUBLIC WORKS DEPARTMENT.

PROCEEDINGS OF THE MADRAS GOVERNMENT.

Under date the
January 26 1886
Read the following

Letter from the Lord Bishop of Madras &c. No. 337 of 30-4-85.
Endorsement from the Ecclesiastical Depts. No. 1779 of 5-5-85.
Letter from the Consg. Architect Govt. No. 1166 of 29-7-85.
- Do - from Actg. Supdg. Engineer V Circle - No. 4326 of 9-1-86.

The estimate amounting to Rs. 554, for remodelling the lightning conductor of the English Church at St. Thomas' Mount is sanctioned.

2 The sanction has been registered as Permanent No. 200 of 1885-86, and classified as Civil Buildings, Original Works.

25/1/86

To
The S.E. V Circle
with 2 plans
" Examiner P.W. Accts.
Extracts for note and return to the S.E. V C.
" Ecclesiastical Dept.

Desp. 4/1/86

26-1-86

480

Govt. of Madras

PUBLIC WORKS