(1) பக்கங்களின் எண்ணிக்கை 46

(2) புதுக்கித் திருப்பிய நாள் 6/88

(3) ஆதாரங்குறிப்பவர் சுருக்கொப்பம்

தமிழ்நாடு ஆவனைக் காப்பகம்.

தமிழ்நாடு அரசு

பொதுப்பணித் துறை

அரசாணை எண். மு. கோப்புத் தாள் எண். 845 W	அச்சகம் பலவகை

நாள் : 14-3-1888 ~~198~~.

மடிக்கவோ கண்டபடி கையாளவோ கூடாது

ஆவண. எண்-1—18,000—15-6-87.

அ.மு.வுத்துல்லா.

1/845

GOVERNMENT OF MADRAS.

PUBLIC WORKS DEPARTMENT.

Buildings and Roads
Military Works.

READ—the following papers :—

From Major J. E. BROADBENT, R.E., Assistant Secretary to the Government of India, Military Department, to the Secretary to the Government of Madras, Public Works Department, dated Fort William, 13th February 1888, No. 318 M.W.

In continuation of Military Department No. 2496 M.W., dated the 14th December 1887, I am directed to forward ten additional copies of "Instructions as to the application of Lightning Conductors for the protection of Powder Magazines and other Buildings."

From the Secretary to the Government of India, Military Department, to the Secretary to the Government of Madras, Public Works Department, dated Fort William, 7th March 1888, No. 513 M.W.

In reply to your letter, No. 766 C., dated the 22nd February 1888, I am directed to state, for the information of the Governor in Council, that Military Department No. 2496 M.W., dated 14th December 1887, a copy of which is asked for, is merely a docket forwarding two copies of the "Instructions for the application of Lightning Conductors."

ORDER—dated 14th March 1888, No. 845 W., Public Works.

Communicated to officers of the Public Works Department for information and guidance, in continuation of G.O., No. 3187 W., dated 12th November 1883.

(True Extract.)

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

To Superintending Engineers.
To the Consulting Architect to Government,
" Chief Engineer for Irrigation,
} with copies of the Instructions.

Exd. J. Moses.
Spare Copies

BUILDINGS AND ROADS.
MILITARY WORKS.

Govt. of {1888} Madras.

PUBLIC WORKS.

Dated March, 14th.

Recd. *Encl.*

G.O., 14th March 1888, No. 845 W.

MARCH.

Lightning Conductors

Letter from the Government of India forwarding copies of the "Instructions as to the application of — for the protection of Powder Magazines and other Buildings," communicated to officers of the Public Works Department.

2/845

GOVERNMENT OF MADRAS.

PUBLIC WORKS DEPARTMENT.

Buildings and Roads.
Civil Works.

READ—the following paper :—

Resolution of the Government of India, Public Works Department (Civil Works —Miscellaneous), dated Simla, 26th October 1883, No. 427 M.

Erection and testing of Lightning Conductors by Public Works Officers.

Read—

Letter No. 2131, dated 16th May 1883, from the Inspector-General of Military Works.
Public Works Department docket, No. 180 M., dated 19th May 1883, to the Director-General of Telegraphs.
Letter No. 704 M., dated 25th June 1883, from the Director-General of Telegraphs.
Letter No. 705 M., dated 12th July 1883, from the Director-General of Telegraphs.
Public Works Department letter No. 254 M., dated 14th July 1883, to the Director-General of Telegraphs.
Letter No. 706 M., dated 18th July 1883, from the Director-General of Telegraphs.

Observations—

It having been brought to notice that the calls made on the Telegraph Department under Public Works Department Code, Volume I, Rule 40, Section II, Chapter VII, with regard to inspection and testing of lightning conductors, are becoming more numerous than the former department can meet, and also that in the majority of cases the tests are of a character to be easily learnt and applied by others than experts in telegraphy, His Excellency the Governor-General in Council is pleased to decide that in future these duties shall be performed by the officers of the Public Works Department, and that the aid of the Telegraph Department shall only be invoked in the case of the protection of powder magazines and such other important buildings.

2. A Code of Instruction for the guidance of Public Works officers in these duties has been drawn up by the Director-General of Telegraphs under the orders of the Government of India, and copies can be obtained on application at the Government of India, Public Works Department Secretariat, Calcutta.

3. The necessary instruments and material for testing should be obtained on indent from the Telegraph Department.

4. If technical instruction in the use of the instruments be found necessary, application should be made in each case by the Executive Engineer to the Chief Superintendent of the Telegraph division, who will inform him where instruction can be obtained.

5. The orders in the Public Works Code will be modified in accordance with the above ruling.

Order—

Ordered, that copies of the Resolution be forwarded to the Local Governments, Administrations, and Officers marginally noted, for information and guidance; also to the Departments of the Government of India specified, for the purpose indicated.

The Governments of Madras, Bombay, Bengal, the North-Western Provinces and Oudh, and the Punjab, in the Public Works Department.
The Chief Commissioners, Central Provinces, British Burma, Assam and Coorg.
The Resident at Hyderabad.
The Agents to the Governor-General for Central India, Rajputana and Biluchistan.
The Accountant-General, Public Works Department.
The Military Department, for communication to the Inspector-General of Military Works.
The Foreign Department, for communication to the Chief Commissioner of Mysore.
The Director-General of Railways.
The Director-General of Telegraphs in India.

(Signed) W. S. TREVOR, Colonel, R.E.,
Secy. to the Govt. of India.

To the Secretary to the Government of Madras, Public Works Department.

ORDER—dated 12th November 1883, No. 3187 W., Public Works.

Communicated to officers of the Public Works Department, for information and guidance, in continuation of G.O., No. 2156 W., dated 21st August 1882.

2. The Government of India will be requested to supply this office with 60 copies of the "Code of Instruction" referred to in their "Observations."

(True Extract.)

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

To Superintending Engineers.
" the Consulting Architect to Government.

Exd. E. Fernandez.
Spare Copies

3/845

BUILDINGS AND ROADS.
CIVIL WORKS.

Govt. of {1883} Madras.

PUBLIC WORKS.

Dated November, 12th.

Read. *Encl.*

G.O., 12th Nov. 1883, No. 3187 W.

NOVEMBER.

Lightning Conductors

Resolution of the Government of India on the subject of the erection and testing of — by Public Works officers, communicated to the officers of the department.

4/845

[*Issued with Army Circulars, dated 1st November 1887.*]

REGULATIONS FOR THE ROYAL ENGINEER DEPARTMENT.

APPENDIX II.

APPENDIX TO PARAGRAPH 280.

Instructions as to the Application of Lightning Conductors for the Protection of Powder Magazines and other buildings.

General Principles.

Thunder-clouds.

(*a*) A thunder-cloud is a mass of vapour charged with electricity at extremely high pressure or potential. The origin of this charge has been variously ascribed to evaporation, to friction of air currents, as well as to all the changes in the physical condition of the earth's surface which are incessantly occurring.

Induced charge.

(*b*) A thunder-cloud acts by induction on the land or water beneath, or on clouds near it, and draws a charge of electricity of opposite kind to the surface. This induced charge re-acts upon the cloud in a similar manner, thereby forming a huge electrical condenser.

Disruptive discharge.

(*c*) When the difference of electrical pressure between the oppositely electrified cloud and earth, or cloud and cloud, is sufficiently strong to break across the air space which separates them, an electric discharge of a disruptive nature, with consequent disengagement of heat, takes place.

Clouds imperfect conductors.

(*d*) Clouds are imperfect conductors, and therefore do not part with all their charge at once. Hence a single discharge does not necessarily deprive a cloud of the whole of its charge; there may be several successive discharges.

Sites least liable to lightning.

(*e*) The surface of the earth is formed of fairly good conducting media, but there are some portions, such as sandy deserts and chalk downs, which, after long droughts, form non-conducting areas. Lightning is least to be feared in such situations, the induced charge not being so easily drawn to the surface.

Path of lightning.

(*f*) The lightning discharge between cloud and earth follows the line of least resistance, or, in other words, selects the easiest path. Objects which project above the general level are, therefore, *ceteris paribus*, most frequently struck. Dry air is practically a non-conductor of electricity, but moist or hot air possesses a certain conducting capacity. Hence rain or hail, and columns of rising smoke or steam, sometimes determine the direction of the discharge, which does not therefore always strike the highest points. Metals, which are the best conductors of all, generally determine the path of the electrical discharge.

(*g*) The lightning discharge does not always follow a single track; it frequently divides into several lines. When alternative routes are offered for its passage, the electric discharge will divide itself among them in direct proportion to their several conducting capacities, *i.e.*, inversely as their respective resistances. In its passage to earth, however, the discharge will not leave a line of good conductors for an inferior one, with which it is unconnected, except when the latter offers a much more direct path to earth, in which case a portion of the discharge may leave it. Again, when a conductor is bent abruptly through a considerable angle, the discharge may seek a shorter path to earth by bridging the air space connecting the nearest portions of the conductor, and a portion of the discharge is then very liable to be diverted to any alternative route which may present itself. This action is due to the attractive effect of induction.

Path of lightning.

(*h*) Atmospheric electricity is only destructive when it is overcoming high resistances. If the conductivity of its path to earth be sufficient, the discharge passes off harmlessly.

When the electric discharge bridges a gap or sharp bend in a conductor, or jumps from one conductor to another, a considerable mechanical effect is produced. The conductor may be broken, bent, or melted, both at the point where the discharge leaves and at that on which it jumps, and the effect is greater in proportion to the distance across which the discharge jumps. Hence the importance of ensuring perfect metallic continuity in the joints of all lightning conductors, of leading them to earth by the most direct route, of avoiding sharp bends, and of connecting all masses of metal in the line of probable discharge with the lightning conductor, so as to avoid the danger of lateral discharges across the air, or it may be through the building.

Effects of discharge.

(*i*) A lightning rod is a pointed conductor, in intimate connection with the earth, fixed on the salient feature of a building with the object of protecting it from the destructive action of lightning. It fulfils two functions:—

Double function of lightning rod.

1*st*. A lightning rod tends to *prevent* a disruptive discharge occurring by silently* neutralizing the conditions which determine the formation of an induced charge in its neighbourhood.

2*nd*. It *protects* the building to which it is attached by offering a path of high conductivity by which the discharge may be carried off harmlessly to earth.

(*j*) The *preventive* action of a lightning rod depends on the power of its pointed end. A thunder-cloud in the vicinity of a building draws a charge of electricity to the lightning rod, and this charge will escape from the point as fast as it can be induced, provided there be a sufficient number of sharp points all well connected with the earth. This power of points to dissipate a charge is due to the self-repulsive action of electricity of the same kind and to the law of distribution of electricity on a surface that the density is greatest at points or on portions of the surface of greatest curvature. It is essential, therefore, to foster this gradual or brush discharge by providing a sufficient number of sharp lightning rods in intimate connection with the earth by means of continuous metallic conductors, so as to collect or tap the induced charge, and to oppose the least possible resistance to its escape from the points.

Preventive action.

Further, the flow of electricity from the points being directed towards the charged cloud, some of the inducing charge may thereby become neutralized. Hence not only does a lightning rod tend to prevent the accumulation of electricity on the surface of the earth within its sphere of action, but it also tends to restore the clouds to their natural state, both of which concur in preventing lightning discharges.

(*k*) Should, however, this brush discharge of electricity from the points of the lightning rods be insufficient to prevent the accumulation of a charge and a lightning discharge take place, it would pass to the points, because the density and consequent attraction are greater there than anywhere in the neighbourhood, and also because the flow of electricity from the points reduces the mechanical resistance of the intervening air. The discharge in this case would, in all probability, be greatly modified by the previous escape of electricity from the points, and being conveyed to earth by a continuous conductor of ample capacity, would leave no trace of its passage. This may be termed the *protective* function of a lightning rod.

Protective action.

(*l*) A lightning rod in imperfect connection with the earth, due either to insufficient surface of conductor buried in the ground, or to defective joints, although it may save a building from actual damage by determining the path of the electric discharge to earth, is generally regarded as a source of danger, inasmuch as the sudden and disruptive discharge would be liable to fuse or scatter some portion of the conductor in its passage, and so leave the building unprotected from further strokes. Again, a lightning rod in such a condition, by allowing the

Defective lightning conductor a source of danger.

* The word silent is the conventional term used to describe a continuous brush discharge which generally is not audible. The brush discharge when very rapid is, however, accompanied by considerable noise, and is frequently visible at night.

S/845

comparatively slow accumulation of an induced charge, tends to attract or invite an electric discharge, while the resistance offered at the defective portions of the conductor may cause a portion of it to seek another path disruptively through the building. A faulty lightning conductor may thus prove worse than useless.

(*m*) The lightning rod terminal should be designed so as to combine, as far as possible, both its preventive and protective action (*vide* paragraph *i*). The requirements are somewhat antagonistic, because the sharper the point the more rapid is the brush discharge, but at the same time the more liable is it to be fused should a heavy disruptive discharge fall upon it. Attempts have been made to obtain a resisting point by the use of platinum tips, and silver or other alloys, but they enormously increase the cost, and have not proved reliable. The system which has been adopted is to separate the double function of a lightning rod by prolonging the upper terminal, and bevelling it off to a blunt right-angled cone of the effective section of metal capable of safely carrying off any disruptive discharge, and with a view to facilitate as much as possible the brush discharge, to add three or four very sharp-tapered points projecting upwards from a ring fixed about a foot below the top of the lightning rod.

Design of lightning rod.

(*n*) As regards the earth connections, it is most important that the electrical resistance which they offer shall be very far less than that offered by any alternative route in the line of probable discharge, such as the rain water or gas pipes outside a building. The earth connections should be the best which the nature of the soil will admit of, and all available means which will assist in tapping a large extent of moist earth in the immediate vicinity of the building should be utilised.

Earth connections.

(*o*) Except where the permanent water level is very near the surface, both deep and shallow earth connections are required, because after a long period of dry weather the induced charge may be collected on a damp substratum, whilst after rain it may be collected on the surface. The deep earths should be carried down to water bearing strata or to permanently moist soil, and the shallow earths should be arranged so as to offer a considerable surface of connection with the soil around the building.

Deep and shallow earths required.

(*p*) Earth connections should be buried throughout in small coke, which is a fairly good conductor of electricity, readily absorbing and retaining moisture. The contact surfaces between the metal conductor and the soil in which it is laid, are thereby much increased, and the tapping of any induced charge or the transmission of any discharge to earth facilitated. A layer of coke also tends to preserve copper from corrosion.

Coke for earth connections.

(*q*) The metals employed in lightning rod construction are iron, plain or galvanised, and copper. Roughly speaking, they cost the same for equal conductivity; but conductors made of iron are stronger, less easily fused, and less liable to be stolen. Copper conductors, on the other hand, have the advantage of being far more durable, and being smaller and lighter, they interfere less with architectural features, and are much cheaper to erect. Copper tape of high conductivity, which is now manufactured in long lengths, thereby obviating the necessity of numerous joints, has been adopted for all conductors on War Department buildings.

Metals employed as conductors.

(*r*) The size of conductor required for lightning rods is based on recorded instances of metal bars and rods which have been fused. The Lightning Rod Conference of 1881 recommended the following as the minimum sizes of conductors to be employed, viz.:—

Size of conductor.

Material.	Section.	Area sq. in.	Weight per ft.
Copper tape	$\frac{3}{4}'' \times \frac{1}{8}''$	0·09	6 oz.
„ rope	$\frac{1}{2}''$ diameter.	0·10	7 „
„ rod	$\frac{5}{16}''$ „	0·11	7 „
Iron rod	$\frac{9}{10}''$ „	0·64	35 „

The recorded instances of lightning rods which have been fused or damaged can invariably be traced either to faulty earth connections, defective joints, want of continuity or adequate sectional area in the conductor, or to the propinquity of neighbouring masses of metal unconnected with the conductor which have invited a portion of the discharge to leave the main conductor by providing an alternative route. There is no authentic record of a properly-constructed lightning rod having been injured or having failed to do its work, and there is every reason to infer that a smaller size of conductor would suffice to carry off any electrical discharge, provided perfect continuity and efficient earth connections could be permanently maintained. The size of conductor required for lightning conductors is, however, practically ruled more by

considerations of strength and surface for making good connections than by that of electrical resistance. The smallest size of copper tape to be used for the main conductors on War Department buildings is $1'' \times \frac{1}{8}''$.

(*s*) It may be accepted that a lightning rod will protect a space included in a cone having the point for its apex, and a base whose radius equals the height from the ground. Buildings protected on this principle would require very lofty lightning rods. It is considered that a number of smaller rods well connected together by conductors, carried along the salient features of a building, provide a more reliable protection than an equal amount of metal in higher rods spaced at greater intervals, and this is the system which has been adopted for the protection of all War Department buildings.

System of protection.

RULES.

I. A complete system of lightning conductors should be provided for all overground magazines, and for all buildings in which the manufacture or manipulation of explosives is carried on.

Buildings requiring protection.

II. Important underground magazines, although less exposed to lightning than overground buildings, should nevertheless be provided with conductors, because magazines are now so frequently filled with gunpowder in metal cases that a line of smaller electrical resistance than through the surrounding earth might be offered to the lightning through the body of the magazine.

Underground magazines.

III. Expense small arm ammunition magazines need not be fitted with lightning conductors, except in cases where they occupy very exposed sites, or have much metal connected with them. Steps should be taken to remove forthwith defective lightning conductors on these magazines, or to make them efficient should it be decided to retain them.

Expense magazines.

IV. The salient features of barrack buildings should be provided with lightning rods when experience has shown that the locality is attractive to lightning, more especially when any considerable mass of metal enters into their construction.

Barracks.

V. It is advisable to fix a lightning rod on any flagstaff that may be near a magazine, and also on all high chimney shafts.

Flagstaffs.

VI. All lightning conductors on War Department buildings should be brought as far as possible into conformity with these rules, but existing arrangements may generally stand, provided care be taken to improve defective earth connections and to make good all joints.

Existing conductors.

VII. Whenever lightning conductors are to be erected or reconstructed on any War Department magazine or building, the Commanding Royal Engineer of the District should invariably forward a special report, accompanied by descriptive drawings, to the Inspector-General of Fortifications, in order that the details and general arrangements may be approved before any steps are taken to carry out the work. In cases where a doubt may exist as to the necessity of erecting lightning rods (*vide* paragraphs III and IV), a report should be made specifying any peculiarities of the site; its height as compared with the neighbouring ground; liability of locality to thunderstorms; nature of soil and substrata, and depth of permanent water level; and full particulars of building, and of all masses of metal entering into its construction or placed near it.

Special report to be forwarded with plans.

VIII. The angles and prominent features of a building being the most liable to be struck, lightning rods should be fixed on gable ends, chimneys, turrets, &c., and they should be connected together by continuous conductors along the ridges.

Position of conductors.

IX. Lightning rods should be about 4 feet high, and spaced at intervals not exceeding 50 feet, so that no point on the building is more than 25 feet horizontally distant from a lightning rod.

Height and spacing.

X. The material to be exclusively employed for the construction of new lightning conductors is copper tape. It is manufactured in lengths of 300 feet and upwards. A conductivity of at least 95 per cent. of that of pure copper should be specified, and the tape should be soft and flexible, so as to admit of its following closely the outlines of a building. Copper tape

Specification of material.

$1'' \times \frac{1}{8}''$, weighing about $\frac{1}{2}$ lb. per foot, is the most suitable size for all ordinary conductors, and $1\frac{1}{2}'' \times \frac{1}{8}''$ may be used for very high chimney shafts.

XI. In situations where copper tape is liable to be stolen, it may be let into the walls of the building and cemented over, or otherwise concealed where it is accessible. The practice of protecting the lower portion of copper conductors on buildings by enclosing them in iron pipes at the base of a building is questionable.

Protection from theft.

XII. In order to guard against those accidental defects and disarrangements to which conductors are liable, buildings provided with lightning conductors should have, as a rule, at least two earth connections, the conductors leading to them being connected at the base of the building, either above the ground line, or by a conductor underground forming a "surface" earth (*see* paragraph XV). Each lightning rod should be connected direct to earth by the shortest path outside the building, and, where practicable, it is well to carry the conductor down that face of the building which is most exposed to prevailing wet. In the case of gabled buildings, the conductors should be taken down the barge courses in preference to the gable, so as to protect the angle of the building, and at the same time secure the advantage of the additional moisture in the ground near the rain-water down-pipes, and facilitate their connection thereto.

"Earth" connections.

XIII. When the level of water or permanently wet soil lies within a few feet of the surface, the conductors should terminate in earths offering each about 18 square feet of external surface. These may consist of copper plates, about $3' \times 3 \times \frac{1}{16}'$, rivetted to the ends of the conductors, and buried in water or wet soil from 15 to 25 feet from the building. A better plan, however, is to coil the end of the conductor spirally on a wooden frame, the external diameter of the coil being 4 feet, with 6-inch intervals between the turns. About 33 feet of tape are required for this earth connection; it obviates the necessity of any underground joint, taps a larger surface of earth, and, the tape being twice the thickness of the plate, it is more durable, besides being a cheaper arrangement.

Earth coils.

XIV. When the permanent water level is deep, it may be necessary to sink special wells for the earth plates, which should be of the same size as those specified in the previous paragraph. The wells should be carried down several feet below the water level in the driest seasons, and the lower portion of the well should be built dry.

Wells.

If coils of copper tape, however, be employed for earths, special wells are not necessary, because, there being no joints underground, the same necessity for periodical examination no longer exists. In this case the earth coils may be buried at the bottom of a pit sunk below the level of permanently wet soil.

Where the depth is considerable, two or more conductors may be connected to the same earth plate, and in the case of a coil of tape the inner, as well as the outer, end may be brought up to the surface of the ground so as to form two earth connections. In both cases the size of earths should be made proportionately larger.

XV. In addition to these deep earths it is necessary to provide surface "earths" laid in trenches, from 1 foot deep in clay soils to 2 feet deep in sand or shingle, through which the rain percolates more freely.

Surface "earths."

These surface earths may consist of that portion of the conductor which leads from the base of the building to the well or deep earth, or they may be arranged as separate conductors led in trenches away from the building. In the latter case, the deep and surface earths should be connected together by a conductor carried round the base of the building.

The length of each surface earth trench may be from 25 feet in ordinary soil to 50 feet in dry soil, and the width at bottom should be about 9 inches. A few inches of powdered coke should be spread both above and below the conductor, and the trench filled in with light soil. The rain-water down-pipes from the roofs may with advantage be led into these trenches.

XVI. In the case of forts and magazines near the sea, good earths can be obtained by laying a length of tape so that at least 5 square feet of it shall always be under water; or a coil of tape may be buried in permanently wet sand.

Sea earths.

When the distance to the sea is considerable, these earths should be supplemented by surface ones round the building, so as efficiently to tap any induced charge in its vicinity.

XVII. Iron water mains form good earth connections. Soft metal pipes and gas mains should not be used, but when they run close to the conductors from a building, they should be connected to the lightning conductor system. There are many recorded instances of both water and gas pipes which have been damaged by lightning springing on to them from neighbouring conductors, which would have been obviated had they been connected thereto. (*Vide* General Principle *h*).

Water mains.

XVIII. In extremely dry or rocky situations it is often impossible to obtain good earth connections except at a great distance. In such cases the best plan to adopt is to bury several hundredweight of old iron at the foot of the earth coil or plate in a mass of coke, leading the rain-water pipes so as to discharge into it.

Dry and rocky sites.

XIX. Coke, suitable for improving the earth connections of lightning rods (*vide* General Principle *p*), is procurable as a waste product of gas works. Clean smiths' ashes may also be used. A layer of about 3 inches should be spread both below and above the conductors in the trenches, and also round the earth plates or coils.

Coke for earth connections.

XX. The earth connections of flagstaffs near magazines should be led in a direction away from the building. Should, however, the horizontal distance between the flagstaff and the nearest lightning rod on the magazine be within 50 feet, or should any portion of the building lie within the zone protected by the flagstaff rod (General Principle *s*), then the magazine and flagstaff earths may be connected, or have an "earth" common to both. This rule is also applicable to shafts of powder mills, &c.

Flagstaff earths.

XXI. The rain-water pipes and gutters should never be utilised as a portion of the system of lightning conductors, to which, however, they should be connected.

External masses of metal.

All external masses of metal, such as copper sheeting on magazine doors and ventilators, &c., should also be connected to the nearest conductors by lengths of copper tape.

In the construction of magazines and other buildings in which the manipulation of explosives is carried on, the employment of external masses of metal should be avoided as far as possible.

XXII. Lines of rail near buildings protected by lightning rods should be connected to earth direct on both sides of the building, and when the line is carried inside the building it should be connected also to the system of lightning conductors. Iron railings round magazines should be connected direct to earth at intervals of about 50 feet.

Lines rail.

XXIII. All large and long masses of metal, such as beams, girders, pipes, hot-water systems, and large ventilators fixed in the interior of buildings should be electrically connected with the earth as well as with the conductor; but the soft metal gas-pipes should never be used as conductors; and the lightning conductors should be kept as far as possible from them, and also from all internal gas-pipes.

Internal masses of metal.

XXIV. Lightning conductors should not be insulated from the buildings to which they are attached. The copper tape should be laid on the ridges and walls, and secured by suitable fastenings screwed or nailed to the building. The holdfasts should be of gun-metal fixed by nails of hard copper, and they should allow free expansion or contraction, at the same time preventing all the weight falling on any one bearing.

Fixing conductors.

XXV. Powder mills, &c., with zinc or galvanised roofs, should be protected by copper conductors laid over them, but protected from actual contact by strips of wood, paint, or tarred felt. The zinc roof itself should be treated like any other external mass of metal, and should be thoroughly well connected to the conductors in several places. The system sometimes adopted of having sheet zinc lightning rods and copper tapes from the eaves of the roof to earth is very unreliable, because the lightning rods are of ineffective section, the zinc sheets are insulated from one another by a layer of oxide, and the joint between the zinc and copper is liable to failure.

Metal roofs.

XXVI. Chimney shafts should be protected by a ring of copper tape $1\frac{1}{2}'' \times \frac{3}{16}''$, placed round the outside of the top of the cap and a few inches below it, having stout copper points, projecting 1 foot above the top of the shaft, at intervals of 3 or 4 feet all round. A copper tape should be carried down on opposite sides of the shaft to earth from the ring; and these conductors should be connected at the base, a test clamp being added to enable the continuity of the conductors and the state of the earth connections to be ascertained when necessary.

Chimney shafts.

XXVII. Metallic continuity should be ensured at the joints of all conductors. Solder should never be used where this can be done by closely-fitting riveted or screwed joints. The solder is seldom properly sweated through the joint, and often consists of an imperfectly adhering mass of metal hiding up badly-fitting and dirty surfaces. Solder tends to set up galvanic action, which after a time will destroy the connection; and, in the case of copper conductors, its use is objectionable, because it interposes an alloy of high resistance and low melting point in the joint. Soldering conductors in the vicinity of magazines and powder factories

Joints in conductors.

is attended with so many restrictions and precautions that it is practically unsuited for War Department requirements.

For these reasons it is considered preferable to ensure a perfect metallic contact between copper tapes, by drawing the surfaces together by close rivetting or by screw clamps, and to exclude damp from the joint by paint or other means.

In rivetting copper tapes, five rivets should be used, and the holes should be bored, not punched. The "arris" being removed, and the surfaces brightened with emery, the joint should be brought together with a hollow punch before rivetting.

XXVIII. The connection between the lightning rod and the conductor is made by means of a slotted clamp similar in design to those employed for test or other joints. The lightning rod terminates at its lowe[illegible] remity in a $\frac{3}{4}$-inch bolt, which is screwed into the clamp, thereby making firm contact wi[illegible] one or more tapes inside it. This joint admits of visual inspection.

Joint between lightning rod and conductors.

XXIX. For the repair of old lightning conductors, however, it is sometimes necessary to use solder. For copper the solder usually employed consists of equal parts of tin and lead, which has a resistance nearly ten times that of copper. The surface of the joint should, therefore, be not less than $1\frac{1}{2}$ square inches.

Repair of old conductors.

Molten zinc should be used for soldering iron conductors. Being nearly twice as conductive as iron, the surface of the joint need not necessarily exceed that of the cross section of the conductor.

In both cases the joint should be put together previously by screws or rivets, and the soldered joint, especially in underground work, should be carefully protected from galvanic action by tarred tape.

XXX. Existing iron wire rope conductors may be connected to copper tapes in the following manner. Take a piece of sheet copper $4\frac{1}{2}'' \times 3''$ $\times \frac{1}{8}''$, and cut it down at one end to the size of the tape for a length of $1\frac{1}{2}''$, and rivet the tape to the sheet at this part; then bend the remainder of the sheet round the end of the rope, which has been previously frapped with fine wire, thus forming a tube which should be previously tinned inside. Sweat up the joint with zinc solder, and protect it by tarred tape bound tightly over it.

Connecting wire rope to copper tape.

XXXI. Copper tape conductors may be connected to iron water mains by filing about a foot of the top of the pipe bright, binding the tape on to it by wire, and soldering with zinc, or a short length of iron bar, $2'' \times \frac{1}{2}''$, may be rivetted and soldered to the copper tape, and then $\frac{1}{2}''$ screws studded together both through the bar and a flange of the pipe.

Connection to mains.

It is a good plan to coil several turns of the copper tape round the main, keeping it from actual contact by battens previous to fastening the end, so as to increase the earth connection should the joint ultimately fail.

The greatest care must in all cases be taken to protect the joint from galvanic action by layers of tarred rope, or by imbedding the main at the joint in cement.

XXXII. Metal surfaces on which the rays of the sun fall are exposed to a maximum range of temperature of about 144° Fahr. This range of temperature produces an expansion and contraction in copper conductors of about 1 inch in 60 feet, which should be provided for by forming small loops near the base of the lightning rods, and by allowing the conductor free play through the holdfast employed to fix it on the building. Conductors should never be screwed or nailed down. Vertical conductors on shafts, flagstaffs, and high walls should have small loops above every second or third holdfast, to take the weight of the conductor while still allowing for expansion and contraction. The holdfasts should in this case be about 4 feet apart.

Expansion of conductors.

XXXIII. Artisans, and especially painters employed on War Department works, should be cautioned never on any pretence to disconnect, move, or tamper with any portion of a lightning conductor without first obtaining the written authority of the Royal Engineer Officer in charge.

Conductors not to be tampered with.

XXXIV. Lightning conductor records should be kept in the office of the Commanding Royal Engineer of each district. In addition to the usual small scale plan, showing the details of the conductors, the position of the buildings protected and the earth connections should be marked on the lithographed plan. Copper conductors should be shown by red; and iron by blue lines. The lightning rods numbered 1, 2, 3, &c., conductors *a*, *b*, *c*, and earths E_1, E_2, E_3, &c., to correspond with a descriptive record containing as many of the following particulars as possible:—

Record plans.

(1) Date of erection or reconstruction of lightning rods.
(2) Character of soil and substrata, and depth of permanent water level or wet soil.
(3) Full particulars of lightning rods, conductors, and earth connections, nature of joints and connections, &c.

(4) Details of all external or internal masses of metal entering into construction of building, and how connected to conductors.
(5) Position of test joints, if any. Nearest earth available for testing, &c.
(6) Quantity of powder, &c., kept in store.
(7) Date of last inspection and *précis* of former tests, suggestions, &c., of inspecting officer.
(8) To whom notice of inspection should be sent, so that ladders may be ready for getting on the roofs, &c.

Periodical inspection.

XXXV. Lightning conductors should be periodically inspected, once a year, and the Inspector should forward, on the accompanying form, a report to the Inspector-General of Fortifications, through the Commanding Royal Engineer of the district.

The Commanding Royal Engineer should take steps to have every portion of the system of lightning conductors visually examined by a competent mechanic, in order that all defects may be remedied, so far as the means at his disposal will admit, before the periodical inspection.

Annual Inspection of Lightning Conductors.

District

Name of fort, battery, magazine, &c.

State of soil when inspected.

Date of inspection.

Lightning rod.		Conductor.		Earths.		
Number.	State of points and connections.	Letter.	Condition.	Letter.	Condition.	Tests.
1		*a*		E_1		
2		*b*				
3		*c*		E_2		
&c.		&c.		E_3		
				&c.		

Report of repairs or reconstruction.

XXXVI. In the case of lightning rods which require repair or reconstruction, the Inspector should submit, in addition, a special report, accompanied by tracings or hand-sketches, foolscap size, of the existing system of conductors, detailing fully the various defects either in design or construction, and his suggestions and proposals for their improvement.

Electrical tests.

XXXVII. The object of electrical tests of lightning conductors is to determine the resistance of the earth connections, and to localize the position of any defective joints or connections in the conductors. The resistance of the conductor itself is quite inappreciable (less than $\frac{1}{4}$ ohm per 1,000 yards for copper tapes 1" × $\frac{1}{8}$"), and could not be detected by the portable testing apparatus employed. The resistance of the earths depends on the nature of the soil, and its state of moisture at the time of the test. As a rough guide, however, it may be mentioned that the joint resistance of two earths, such as those described in paragraph XIII, 30 yards apart in damp soil, will not exceed 2 ohms.

System of testing.

XXXVIII. The best system of testing lightning conductors is to balance the resistance of each of the earths of the building against the remainder of the system, from which the state of the earths may be inferred with sufficient accuracy for all practical purposes. With this object test joints should be added to all magazines and shafts.

When the system of conductors is permanently rivetted up, the resistance of two small test earths, placed not less than 20 yards apart in water or moist soil, or of any two convenient earths unconnected with the system of lightning rods, such as a gas and a water pipe, is first ascertained. Then the sum of the resistance of each test earth in succession, and the earths of the

8/895

lightning conductor system is ascertained, and the joint resistance of the latter calculated from the resulting three equations. Thus:—

Let L = conductivity resistance of the leads,
Then the resistance of leads and test-earths ... ... $= L+e_1+e_2=A$
Resistance of leads, one test-earth, and the earths of lightning conductors ... ... $= L+e_1+E=B$
Resistance of leads, other test-earth and earths of lightning conductors .. .. $= L+e_2+E=C$

Then $E = \frac{1}{2}(B+C-A-L)$ (1)
$e_1 = \frac{1}{2}(A+B-C-L)$ (2)
$e_2 = \frac{1}{2}(A+C-B-L)$ (3)

Very short contacts should be made in order to avoid polarisation of the test plates. If the resistances be very unequal, the results obtained from these equations may not be very accurate.

Defective joints localized.

XXXIX. The resistance of the conductors from each lightning rod point to that part of the conductor from which the resistance of the earth connections was ascertained, is then found. As the resistance of the conductor should be practically *nil*, any resistance in excess of that of the leads must be due to defective joints, and the faults should be localized and marked for repair.

XL. Conductors made in short lengths and connected by joints, the metallic continuity of which has not been ensured by soldering, or by a good system of rivetting, if tested electrically, give results of little value.

Underground joints and earths, the nature of which are not known, should be dug up and examined when practicable.

9/845

No. 427M.

GOVERNMENT OF INDIA.

PUBLIC WORKS DEPARTMENT.

CIVIL WORKS.

Miscellaneous.

Simla, October 26, 1883.

RESOLUTION.

Erection and testing of Lightning Conductors by Public Works Officers.

Read—

Letter No. 2131, dated 16th May 1883, from the Inspector General of Military Works.

Public Works Department docket No. 180M., dated 19th May 1883, to the Director General of Telegraphs.

Letter No. 704M., dated 25th June 1883, from the Director General of Telegraphs.

Letter No. 705M., dated 12th July 1883, from the Director General of Telegraphs.

Public Works Department letter No. 254M., dated 14th July 1883, to the Director General of Telegraphs.

Letter No. 706M., dated 18th July 1883, from the Director General of Telegraphs.

OBSERVATIONS.—It having been brought to notice that the calls made on the Telegraph Department under Public Works Department Code, Volume I, Rule 40, Section II, Chapter VII, with regard to inspection and testing of lightning conductors, are becoming more numerous than the former Department can meet, and also that in the majority of cases the tests are of a character to be easily learnt and applied by others than experts in telegraphy, His Excellency the Governor General in Council is pleased to decide that in future these duties shall be performed by the officers of the Public Works Department, and that the aid of the Telegraph Department shall only be invoked in the case of the protection of powder magazines and such other important buildings.

2. A Code of instruction for the guidance of Public Works officers in these duties has been drawn up by the Director General of Telegraphs under the orders of the Government of India, and copies can be obtained on application at the Government of India, Public Works Department Secretariat, Calcutta.

3. The necessary instruments and material for testing should be obtained on indent from the Telegraph Department.

4. If technical instruction in the use of the instruments be found necessary, application should be made in each case by the Executive Engineer to the Chief Superintendent of the Telegraph Division, who will inform him where instruction can be obtained.

5. The orders in the Public Works Code will be modified in accordance with the above ruling.

ORDER.—Ordered, that copies of the Resolution be forwarded to the Local Governments, Administrations, and Officers marginally noted, for information and guidance; also to the Departments of the Government of India specified, for the purpose indicated.

The Governments of Madras, Bombay, Bengal, the North-Western Provinces and Oudh, and the Punjab, in the Public Works Department.
The Chief Commissioners, Central Provinces, British Burma, Assam, and Coorg.
The Resident at Hyderabad.
The Agents to the Governor General for Central India, Rajputana, and Baluchistan.
The Accountant General, Public Works Department.
The Military Department, for communication to the Inspector General of Military Works.
The Foreign Department, for communication to the Chief Commissioner of Mysore.
The Director General of Railways.
The Director General of Telegraphs in India.

J. J. Pearse Colonel, R.E.,
Secretary to the Government of India.

To,
The Secretary to the Govt of Madras,
C.W.D.

P.W. Ch. 9757

GOVERNMENT OF INDIA.

PUBLIC WORKS DEPARTMENT.

CIVIL WORKS.

Miscellaneous.

10/845.

12. S.C.

To

No. 427M.

Dated Simla, October 26, 1883.

Received 7/11/83

No. 1432. to 7.6.84
" 2156. to 11.8.82

Erection and testing of Lightning Conductors by Public Works Officers.

Govt. C. B. Press, Simla.—No. 243 P. W. D.—28-10-83.—368.

No 3187 W

PUBLIC WORKS DEPARTMENT.

A/

PROCEEDINGS OF THE MADRAS GOVERNMENT.

UNDER date the 12th Nov 1883

11/845

READ the following

Resolution of the Govt of India M. E. No: 427 M of 26th Octr 1883.

Communicated to Officers of the Public Works Department for information and guidance, in continuation of G. O. No: 2156 W dated 21st August 1882.

2. The Government of India will be requested to supply this office with 60 copies of the "Code of Instructions" referred to in their "observations" M. E. No: 348 W of 12th Nov 1883

To

The Secretary to the Govt of India P. W. Department

Sir,

I am directed to request that this office may be supplied, for distribution, with

with 60 copies of the "Code of Instruction" referred to in para 2 of the "Observations" communicated with Govt. of India Resolution No: 427 M dated 26th October 1883, relative to erection and testing of Lightning Conductors, by P. W. Officers.

CS.
8/11

Secd 20/11

Superintending Engineers
Consulting Architect to Govt

1

12/84

Govt. of 1883 Madras.

PUBLIC WORKS.

Dated 12 Dec 1883

Rect. Encl.

G. O., 12 Nov. 1883. No. 3167 to
B. 3188 do.

Nos.

Lightning Conductors

Resolution of the Govt. of India on the subject of the erection & testing of —— by R. E. Officers, communicated to the Officers of the Presy

130

1073/11

Issued with Army Circulars, dated 1st November 1887.

13/845

REGULATIONS FOR THE ROYAL ENGINEER DEPARTMENT.

APPENDIX II.

APPENDIX TO PARAGRAPH 280.

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

General Principles.

Thunder clouds.

(*a.*) A thunder-cloud is a mass of vapour charged with electricity at extremely high pressure or potential. The origin of this charge has been variously ascribed to evaporation, to friction of air currents, as well as to all the changes in the physical condition of the earth's surface which are incessantly occurring.

Induced charges.

(*b.*) A thunder-cloud acts by induction on the land or water beneath, or on clouds near it, and draws a charge of electricity of opposite kind to the surface. This induced charge re-acts upon the cloud in a similar manner, thereby forming a huge electrical condenser.

Discharges.

(*c.*) When the difference of electrical pressure between the oppositely electrified cloud and earth, or cloud and cloud, is sufficiently strong to break across the air space which separates them, an electric discharge of a disruptive nature, with consequent disengagement of heat, takes place.

Govt. of 1883 Madras.

PUBLIC WORKS.

Clouds imperfect conductors.

(*d.*) Clouds are imperfect conductors, and therefore do not part with all their charge at once. Hence a single discharge does not necessarily deprive a cloud of the whole of its charge; there may be several successive discharges.

Sites least liable to lightning.

(*e.*) The surface of the earth is formed of fairly good conducting media, but there are some portions, such as sandy deserts and chalk downs, which, after long droughts, form non-conducting areas. Lightning is least to be feared in such situations, the induced charge not being so easily drawn to the surface.

Path of lightning.

(*f.*) The lightning discharge between cloud and earth follows the line of least resistance, or, in other words, selects the easiest path. Objects which project above the general level are, therefore, *ceteris paribus*, most frequently struck. Dry air is practically a non-conductor of electricity, but moist or hot air possesses a certain conducting capacity. Hence rain or hail, and columns of rising smoke or steam, sometimes determine the direction of the discharge, which does not therefore always strike the highest points. Metals, which are the best conductors of all, generally determine the path of the electrical discharge.

Path of lightning.

(*g.*) The lightning discharge does not always follow a single track; it frequently divides into several lines. When alternative routes are offered for its passage, the electric discharge will divide itself among them in direct proportion to their several conducting capacities, i.e., inversely as their respective resistances. In its passage to earth, however, the discharge will not leave a line of good conductors for an inferior one, with which it is unconnected, except when the latter offers a much more direct path to earth, in which case a portion of the discharge may leave it. Again, when a conductor is bent abruptly through a considerable angle, the discharge may seek a shorter path to earth by bridging the air space connecting the nearest portions of the conductor, and a portion of the discharge is then very liable to be diverted to any alternative route which may present itself. This action is due to the attractive effect of induction.

(*h.*) Atmospheric electricity is only destructive when it is overcoming high resistances. If the conductivity of its path to earth be sufficient, the discharge passes off harmlessly.

Effects of discharge.

When the electric discharge bridges a gap or sharp bend in a conductor, or jumps from one conductor to another, a considerable mechanical effect is produced. The conductor may be broken, bent, or melted, both at the point where the discharge leaves and at that on which it jumps, and the effect is greater in proportion to the distance across which the discharge jumps. Hence the importance of ensuring perfect metallic continuity in the joints of all lightning conductors, of leading them to earth by the most direct route, of avoiding sharp bends, and of connecting all masses of metal in the line of probable discharge with the lightning conductor, so as to avoid the danger of lateral discharges across the air, or it may be through the building.

Double function of lightning rod.

(*i.*) A lightning rod is a pointed conductor, in intimate connection with the earth, fixed on the salient feature of a building with the object of protecting it from the destructive action of lightning. It fulfils two functions:—

1st. A lightning rod tends to *prevent* a disruptive discharge occurring by silently* neutralizing the conditions which determine the formation of an induced charge in its neighbourhood.

2nd. It *protects* the building to which it is attached by offering a path of high conductivity by which the discharge may be carried off harmlessly to earth.

Preventive action.

(*j.*) The *preventive* action of a lightning rod depends on the power of its pointed end. A thunder-cloud in the vicinity of a building draws a charge of electricity to the lightning rod, and this charge will escape from the point as fast as it can be induced, provided there be a sufficient number of sharp points all well connected with the earth. This power of points to dissipate a charge is due to the self-repulsive action of electricity of the same kind, and to the law of distribution of electricity on a surface that the density is greatest at points or on portions of the surface of greatest curvature. It is essential, therefore, to foster this gradual or brush discharge by providing a sufficient number of sharp lightning rods in intimate connection with the earth by means of continuous metallic conductors, so as to collect or tap the induced charge, and to oppose the least possible resistance to its escape from the points.

Further, the flow of electricity from the points being directed towards the charged cloud, some of the inducing charge may thereby become neutralized. Hence not only does a lightning rod tend to prevent the accumulation of electricity on the surface of the earth within its sphere of action, but it also tends to restore the clouds to their natural state, both of which concur in preventing lightning discharges.

Protective action.

(*k.*) Should, however, this brush discharge of electricity from the points of the lightning rods be insufficient to prevent the accumulation of a charge and a lightning discharge take place, it would pass to the points, because the density and consequent attraction are greater there than anywhere in the neighbourhood and also because the flow of electricity from the points reduces the mechanical resistance of the intervening air. The discharge in this case would, in all probability, be greatly modified by the previous escape of electricity from the points, and being conveyed to earth by a continuous conductor of ample capacity, would leave no trace of its passage. This may be termed the *protective* function of a lightning rod.

* The word silent is the conventional term used to describe a continuous brush discharge which generally is not audible. The brush discharge when very rapid is however, accompanied by considerable noise, and is frequently visible at night.

Govt. of 1883 Madras
PUBLIC WORKS.

Defective lightning conductor a source of danger.

(*l.*) A lightning rod in imperfect connection with the earth, due either to insufficient surface of conductor buried in the ground, or to defective joints, although it may save a building from actual damage by determining the path of the electric discharge to earth, is generally regarded as a source of danger, inasmuch as the sudden and disruptive discharge would be liable to fuse or scatter some portion of the conductor in its passage, and so leave the building unprotected from further strokes. Again, a lightning rod in such a condition, by allowing the comparatively slow accumulation of an induced charge, tends to attract or invite an electric discharge, while the resistance offered at the defective portions of the conductor may cause a portion of it to seek another path disruptively through the building. A faulty lightning conductor may thus prove worse than useless.

Design of lightning rod.

(*m.*) The lightning rod terminal should be designed so as to combine, as far as possible, both its preventive and protective action (*vide* paragraph *i*). The requirements are somewhat antagonistic, because the sharper the point the more rapid is the brush discharge, but at the same time the more liable is it to be fused should a heavy disruptive discharge fall upon it. Attempts have been made to obtain a resisting point by the use of platinum tips, and silver or other alloys, but they enormously increase the cost, and have not proved reliable. The system which has been adopted is to separate the double function of a lightning rod by prolonging the upper terminal, and bevelling it off to a blunt right-angled cone of the effective section of metal capable of safely carrying off any disruptive discharge, and with a view to facilitate as much as possible the brush discharge, to add three or four very sharp-tapered points projecting upwards from a ring fixed about a foot below the top of the lightning rod.

Earth connections.

(*n.*) As regards the earth connections, it is most important that the electrical resistance which they offer shall be very far less than that offered by any alternative route in the line of probable discharge, such as the rain water or gas pipes outside a building. The earth connections should be the best which the nature of the soil will admit of, and all available means which will assist in tapping a large extent of moist earth in the immediate vicinity of the building should be utilized.

Deep and shallow earths required.

(*o.*) Except where the permanent water level is very near the surface, both deep and shallow earth connections are required, because after a long period of dry weather the induced charge may be collected on a damp substratum, whilst after rain it may be collected on the surface. The deep earths should be carried down to water bearing strata or to permanently moist soil, and the shallow earths should be arranged so as to offer a considerable surface of connection with the soil around the building.

Communicated
to Officers of the
130

1073/11

15/845

Coke for earth connections.

(*p.*) Earth connections should be buried throughout in small coke, which is a fairly good conductor of electricity, readily absorbing and retaining moisture. The contact surfaces between the metal conductor and the soil in which it is laid, are thereby much increased, and the tapping of any induced charge or the transmission of any discharge to earth facilitated. A layer of coke also tends to preserve copper from corrosion.

Metals employed as conductors.

(*q.*) The metals employed in lightning rod construction are iron, plain or galvanized, and copper. Roughly speaking, they cost the same for equal conductivity, but conductors made of iron are stronger, less easily fused, and less liable to be stolen. Copper conductors, on the other hand, have the advantage of being far more durable, and being smaller and lighter, they interfere less with architectural features, and are much cheaper to erect. Copper tape of high conductivity, which is now manufactured in long lengths, thereby obviating the necessity of numerous joints, has been adopted for all conductors on War Department buildings.

Area of conductors.

(*r.*) The size of conducter required for lightning rods is based on the recorded instances of metal bars and rods which have been fused. The Lightning Rod Conference of 1881 recommended the following as the minimum sizes of conductors to be employed, viz.:—

Material.	Section.	Area sq. in.	Weight per ft.
Copper tape	½″ × ⅛″	0·09	6 oz.
,, rope	⅜ diameter.	0·15	7 ,,
,, rod	½″ ,,	0·11	7 ,,
Iron rod	⅝″ ,,	0·64	35 ,,

The recorded instances of lightning rods which have been fused or damaged can invariably be traced either to faulty earth connections, defective joints, want of continuity or adequate sectional area in the conductor, or to the propinquity of neighbouring masses of metal unconnected with the conductor which have invited a portion of the discharge to leave the main conductor by providing an alternative route. There is no authentic record of a properly constructed lightning rod having been injured or having failed to do its work, and there is every reason to infer that a smaller size of conductor would suffice to carry off any electrical discharge, provided perfect continuity and efficient earth connections could be permanently maintained. The size of conductor required for lightning conductors is, however, practically ruled more by considerations of strength and surface for making good connections than by that of electrical resistance. The smallest size of copper tape to be used for the main conductors on War Department buildings is 1″ × ⅛″.

System of protection.

(8.) It may be accepted that a lightning rod will protect a space included by a cone having the point for its apex, and a base whose radius equals the height from the ground. Buildings protected on this principle would require very lofty lightning rods. It is considered that a number of smaller rods well connected together by conductors, carried along the salient features of a building, provide a more reliable protection than an equal amount of metal in higher rods spaced at greater intervals, and this is the system which has been adopted for the protection of all War Department buildings.

RULES.

Buildings requiring protection.

I. A complete system of lightning conductors should be provided for all overground magazines, and for all buildings in which the manufacture or manipulation of explosives is carried on.

Underground magazines.

II. Important underground magazines, although less exposed to lightning than overground buildings, should nevertheless be provided with conductors, because magazines are now so frequently filled with gunpowder in metal cases that a line of smaller electrical resistance than through the surrounding earth might be offered to the lightning through the body of the magazine.

Expense magazines.

III. Expense small-arm ammunition magazines need not be fitted with lightning conductors, except in cases where they occupy very exposed sites, or have much metal connected with them. Steps should be taken to remove forthwith defective lightning conductors on these magazines, or to make them efficient should it be decided to retain them.

Barracks.

IV. The salient features of barrack buildings should be provided with lightning rods when experience has shown that the locality is attractive to lightning, more especially when any considerable mass of metal enters into their construction.

Flagstaffs.

V. It is advisable to fix a lightning rod on any flagstaff that may be near a magazine, and also on all high chimney shafts.

Existing conductors.

VI. All lightning conductors on War Department buildings should be brought as far as possible into conformity with these rules, but existing arrangements may generally stand, provided care be taken to improve defective earth connections and to make good all joints.

Special report to be forwarded with plans.

VII. Whenever lightning conductors are to be erected or reconstructed on any War Department magazine or building, the Commanding Royal Engineer of the District should invariably forward a special report, accompanied by descriptive drawings, to the Inspector-General of Fortifications, in order that the details and general arrangements may be approved before any steps are taken to carry out the work. In cases where a doubt may exist as to the necessity of erecting lightning rods (*vide* paragraphs III. and IV.), a report should be made specifying any peculiarities of the site; its height as compared with the neighbouring ground; liability of locality to thunderstorms; nature of soil and substrata, and depth of permanent water level; and full particulars of building, and of all masses of metal entering into its construction or placed near it.

Position of conductors.

VIII. The angles and prominent features of a building being the most liable to be struck, lightning rods should be fixed on gable ends, chimneys, turrets, &c., and they should be connected together by continuous conductors along the ridges.

Height and spacing.

IX. Lightning rods should be about 4 feet high, and spaced at intervals not exceeding 50 feet, so that no point on the building is more than 25 feet horizontally distant from a lightning rod.

Specification of material.

X. The material to be exclusively employed for the construction of new lightning conductors is copper tape. It is manufactured in lengths of 800 feet and upwards. A conductivity of at least 95 per cent. of that of pure copper should be specified, and the tape should be soft and flexible, so as to admit of its following closely the outlines of a building. Copper tape 1″ × ⅛″, weighing about ⅝ lb. per foot, is the most suitable size for all ordinary conductors, and 1½″ × ⅛″ may be used for very high chimney shafts.

Protection from theft.

XI. In situations where copper tape is liable to be stolen, it may be let into the walls of the building and cemented over, or otherwise concealed where it is accessible. The practice of protecting the lower portion of copper conductors on buildings by enclosing them in iron pipes at the base of a building is questionable.

"Earth" connections.

XII. In order to guard against those accidental defects and disarrangements to which conductors are liable, buildings provided with lightning conductors should have, as a rule, at least two earth connections, the conductors leading to them being connected at the base of the building, either above the ground line, or by a conductor underground forming a "surface" earth (see paragraph XV). Each lightning rod should be connected direct to earth by the shortest path outside the building, and, where practicable, it is well to carry the conductor down that face of the building which is most exposed to prevailing wet. In the case of gabled buildings, the conductors should be taken down the barge courses in preference to the gable, so as to protect the angle of the building, and at the same time secure the advantage of the additional moisture in the ground near the rain-water down-pipes, and facilitate their connection thereto.

XIII. When the level of water or permanently wet soil lies within a few feet of the surface, the conductors should terminate in

Earth coils.

earths offering each about 18 square feet of external surface. These may consist of copper plates, about 3 × 3 × ⅛", rivetted to the ends of the conductors, and buried in water or wet soil from 15 to 25 feet from the building. A better plan, however, is to coil the end of the conductor spirally on a wooden frame, the external diameter of the coil being 4 feet, with 6-inch intervals between the turns. About 33 feet of tape are required for this earth connection; it obviates the necessity of any underground joint, taps a larger surface of earth, and, the tape being twice the thickness of the plate, it is more durable, besides being a cheaper arrangement.

Wells.

XIV. When the permanent water level is deep, it may be necessary to sink special wells for the earth plates, which should be of the same size as those specified in the previous paragraph. The wells should be carried down several feet below the water level in the driest seasons, and the lower portion of the well should be built dry.

If coils of copper tape, however, be employed for earths, special wells are not necessary, because, there being no joints underground, the same necessity for periodical examination no longer exists. In this case the earth coils may be buried at the bottom of a pit sunk below the level of permanently wet soil.

Where the depth is considerable, two or more conductors may be connected to the same earth plate, and in the case of a coil of tape the inner, as well as the outer end, may be brought up to the surface of the ground so as to form two earth connections. In both cases the size of earths should be made proportionately larger.

Surface "earths."

In addition to these deep earths it is necessary to provide ...ce "earths" laid in trenches, from 1 foot deep in clay soils to 2 feet deep in sand or shingle, through which the rain percolates more freely.

These surface earths may consist of that portion of the conductor which leads from the base of the building to the well or deep earth, or they may be arranged as separate conductors led in trenches away from the building. In the latter case, the deep and surface earths should be connected together by a conductor carried round the base of the building.

The length of each surface earth trench may be from 25 feet in ordinary soil to 50 feet in dry soil, and the width at bottom should be about 9 inches. A few inches of powdered coke should be spread both above and below the conductor, and the trench filled in with light soil. The rain-water down-pipes from the roofs may with advantage be led into these trenches.

Sea earths.

XVI. In the case of forts and magazines near the sea, good earths can be obtained by laying a length of tape so that at least 5 square feet of it shall always be under water; or a coil of tape may be buried in permanently wet sand.

When the distance to the sea is considerable, these earths should

be supplemented by surface ones round the building, so as efficiently to tap any induced charge in its vicinity.

Water mains.

XVII. Iron water mains form good earth connections. Soft metal pipes and gas mains should not be used, but when they run close to the conductors from a building, they should be connected to the lightning conductor system. There are many recorded instances of both water and gas pipes which have been damaged by lightning springing on to them from neighbouring conductors, which would have been obviated had they been connected thereto. (*Vide* General Principle *h*).

Dry and rocky sites.

XVIII. In extremely dry or rocky situations it is often impossible to obtain good earth connections except at a great distance. In such cases the best plan to adopt is to bury several hundredweight of old iron at the foot of the earth coil or plate in a mass of coke, leading the rain-water pipes so as to discharge into it.

Coke for earth connections.

XIX. Coke, suitable for improving the earth connections of lightning rods (*vide* General Principle *p*), is procurable as a waste product of gas works. Clean smiths' ashes may also be used. A layer of about 3 inches should be spread both below and above the conductors in the trenches, and also round the earth plates or coils.

Flagstaff earths.

XX. The earth connections of flagstaffs near magazines should be led in a direction away from the building. Should, however, the horizontal distance between the flagstaff and the nearest lightning rod on the magazine be within 50 feet, or should any portion of the building lie within the cone protected by the flagstaff rod (General Principle *s*), then the magazine and flagstaff earths may be connected, or have an "earth" common to both. This rule is also applicable to shafts of powder mills, &c.

External masses of metal.

XXI. The rain-water pipes and gutters should never be utilized as a portion of the system of lightning conductors, to which, however, they should be connected.

All external masses of metal, such as copper sheeting on magazine doors and ventilators, &c., should also be connected to the nearest conductors by lengths of copper tape.

In the construction of magazines and other buildings in which the manipulation of explosives is carried on, the employment of external masses of metal should be avoided as far as possible.

Lines rail.

XXII. Lines of rail near buildings protected by lightning rods should be connected to earth direct on both sides of the building, and when the line is carried inside the building it should be connected also to the system of lightning conductors. Iron railings round magazines should be connected direct to earth at intervals of about 50 feet.

Internal masses of metal.

XXIII. All large and long masses of metal, such as beams, girders, pipes, hot-water systems, and large ventilators fixed in the interior of buildings should be electrically connected with the earth as well as with the conductor; but the soft metal gas-pipes should never be used as conductors; and the lightning conductors should be kept as far as possible from them, and also from all internal gas-pipes.

Fixing conductors.

XXIV. Lightning conductors should not be insulated from the buildings to which they are attached. The copper tape should be laid on the ridges and walls, and secured by suitable fastenings screwed or nailed to the building. The hold-fasts should be of gun-metal fixed by nails of hard copper, and they should allow free expansion or contraction, at the same time preventing all the weight falling on any one bearing.

Metal roofs.

XXV. Powder mills, &c., with zinc or galvanised roofs, should be protected by copper conductors laid over them, but protected from actual contact by strips of wood, paint, or tarred felt. The zinc roof itself should be treated like any other external mass of metal, and should be thoroughly well connected to the conductors in several places. The system sometimes adopted of having sheet zinc lightning rods, and copper tapes from the eaves of the roof to earth is very unreliable, because the lightning rods are of ineffective section, the zinc sheets are insulated from one another by a layer of oxide, and the joint between the zinc and copper is liable to failure.

Chimney shafts.

XXVI. Chimney shafts should be protected by a ring of copper tape 1½" × ⅛", placed round the outside of the top of the cap and a few inches below it, having stout copper points, projecting 1 foot above the top of the shaft, at intervals of 3 or 4 feet all round. A copper tape should be carried down on opposite sides of the shaft to earth from the ring; and these conductors should be connected at the base, a test clamp being added to enable the continuity of the conductors and the state of the earth connections to be ascertained when necessary.

Joints in conductors.

XXVII. Metallic continuity should be ensured at the joints of all conductors. Solder should never be used where this can be done by closely-fitting rivetted or screwed joints. The solder is seldom properly sweated through the joint, and often consists of an imperfectly adhering mass of metal hiding up badly-fitting and dirty surfaces. Solder tends to set up galvanic action, which after a time will destroy the connection; and, in the case of copper conductors, its use is objectionable, because it interposes an alloy of high resistance and low melting point in the joint. Soldering conductors in the vicinity of magazines and powder factories is attended with so many restrictions and precautions, that it is practically unsuited for War Department requirements.

For these reasons it is considered preferable to ensure a perfect metallic contact between copper tapes, by drawing the surfaces together by close rivetting or by screw clamps, and to exclude damp from the joint by paint or other means.

In rivetting copper tapes, five rivets should be used, and the holes should be bored, not punched. The "arris" being removed, and the surfaces brightened with emery, the joint should be brought together with a hollow punch before rivetting.

Joint between lightning rod and conductors.

XXVIII. The connection between the lightning rod and the conductor is made by means of a slotted clamp similar in design to those employed for test or other joints. The lightning rod terminates at its lower extremity in a ⅜-inch bolt, which is screwed into the clamp, thereby making firm contact with one or more tapes inside it. This joint admits of visual inspection.

Repair of old conductors.

XXIX. For the repair of old lightning conductors, however, it is sometimes necessary to use solder. For copper the solder usually employed consists of equal parts of tin and lead, which has a resistance nearly ten times that of copper. The surface of the joint should, therefore, be not less than 1½ square inches.

Molten zinc should be used for soldering iron conductors. Being nearly twice as conductive as iron, the surface of the joint need not necessarily exceed that of the cross section of the conductor.

In both cases the joint should be put together previously by screws or rivets, and the soldered joint, especially in underground work, should be carefully protected from galvanic action by tarred tape.

Connecting wire rope to copper tape.

XXX. Existing iron wire rope conductors may be connected to copper tapes in the following manner. Take a piece of sheet copper 4½" × 3" × ⅛", and cut it down at one end to the size of the tape for a length of 14", and rivet the tape to the sheet at this part; then bend the remainder of the sheet round the end of the rope, which has been previously frapped with fine wire, thus forming a tube which should be previously tinned inside. Sweat up the joint with zinc solder, and protect it by tarred tape bound tightly over it.

Connection to mains.

XXXI. Copper tape conductors may be connected to iron water mains by filing about a foot of the top of the pipe bright, binding the tape on to it by wire, and soldering with zinc; or a short length of iron bar, 2" × ½", may be rivetted and soldered to the copper tape, and then ½" screws studded together both through the bar and a flange of the pipe.

It is a good plan to coil several turns of the copper tape round the main, keeping it from actual contact by battens previous to fastening the end, so as to increase the earth connection should the joint ultimately fail.

The greatest care must in all cases be taken to protect the joint from galvanic action by layers of tarred rope, or by imbedding the main at the joint in cement.

Expansion of conductors.

XXXII. Metal surfaces on which the rays of the sun fall are exposed to a maximum range of temperature of about 144° Fahr. This range of temperature produces an expansion and contraction in copper conductors of about 1 inch in 60 feet, which should be provided for by forming small loops near the base of the lightning rods, and by allowing the conductor free play through the holdfast employed to fix it on the building. Conductors should never be screwed or nailed down. Vertical conductors on shafts, flagstaffs, and high walls should have small loops above every second or third holdfast, to take the weight of the conductor while still allowing for expansion and contraction. The holdfasts should in this case be about 4 feet apart.

Conductors not to be tampered with.

XXXIII. Artisans, and especially painters employed on War Department Works, should be cautioned never on any pretence to disconnect, move, or tamper with any portion of a lightning conductor without first obtaining the written authority of the Royal Engineer Officer in charge.

Record plans.

XXXIV. Lightning conductor records should be kept in the office of the Commanding Royal Engineer of each district. In addition to the usual small scale plan, showing the details of the conductors, the position of the buildings protected and the earth connections should be marked on the lithographed plan. Copper conductors should be shown by red, and iron by blue lines. The lightning rods numbered 1, 2, 3, &c., conductors *a*, *b*, *c*, and earths E_1, E_2, E_3, &c., to correspond with a descriptive record containing as many of the following particulars as possible:—

(1.) Date of erection or reconstruction of lightning rods.

(2.) Character of soil and substrata, and depth of permanent water level or wet soil.

(3.) Full particulars of lightning rods, conductors, and earth connections, nature of joints and connections, &c.

(4.) Details of all external or internal masses of metal entering into construction of building, and how connected to conductors.

(5.) Position of test joints, if any. Nearest earth available for testing, &c.

(6.) Quantity of powder, &c., kept in store.

(7.) Date of last inspection and *précis* of former tests, suggestions, &c., of Inspecting Officer.

(8.) To whom notice of inspection should be sent, so that ladders may be ready for getting on the roofs, &c.

Periodical inspection.

XXXV. Lightning conductors should be periodically inspected, once a year, and the Inspector should forward, on the accompanying form, a report to the Inspector-General of Fortifications, through the Commanding Royal Engineer of the district

The Commanding Royal Engineer should take steps to have every portion of the system of lightning conductors visually examined by a competent mechanic, in order that all defects may be remedied, so far as the means at his disposal will admit, before the periodical inspection.

Annual Inspection of Lightning Conductors.

District

Name of fort, battery, magazine, &c. ...

State of soil when inspected.

Date of inspection.

Lightning rod.		Conductor.		Earths.		
Number.	State of points and connections.	Letter.	Condition.	Letter.	Condition.	Tests.
1						
2		*a*		E_1		
3		*b*		E_2		
&c.		*c*		E_3		
		&c.		&c.		

Repairs or reconstruction.

XXXVI. In the case of lightning rods which require repair or reconstruction, the Inspector should submit, in addition, a special report, accompanied by tracings or hand sketches, foolscap size, of the existing system of conductors, detailing fully the various defects either in design or construction, and his suggestions and proposals for their improvement.

Govt. of 1883

Electrical tests.

XXXVII. The object of electrical tests of lightning conductors is to determine the resistance of the earth connections, and to localize the position of any defective joints or connections in the conductors. The resistance of the conductor itself is quite inappreciable (less than $\frac{1}{4}$ ohm per 1,000 yards for copper tapes $1'' \times \frac{1}{8}''$), and could not be detected by the portable testing apparatus employed. The resistance of the earths depends on the nature of the soil, and its state of moisture at the time of the test. As a rough guide, however, it may be mentioned that the joint resistance of two earths, such as those described in paragraph XIII., 30 yards apart in damp soil, will not exceed 2 ohms.

System of testing.

XXXVIII. The best system of testing lightning conductors is to balance the resistance of each of the earths of the building against the remainder of the system, from which the state of the earths may be inferred with sufficient accuracy for all practical purposes. With this object test joints should be added to all magazines and shafts.

When the system of conductors is permanently rivetted up, the resistance of two small test earths, placed not less than 20 yards apart in water or moist soil, or of any two convenient earths unconnected with the system of lightning rods, such as a gas and a water-pipe, is first ascertained. Then the sum of the resistance of each test earth in succession, and the earths of the lightning conductor system is ascertained, and the joint resistance of the latter calculated from the resulting three equations. Thus:—

Let L = conductivity resistance of the leads,

Then the resistance of leads and test-earths .... $= L + e_1 + e_2 = A$

Resistance of leads, one test-earth, and the earths of lightning conductors .... $= L + e_1 + E = B$

Resistance of leads, other test-earth and earths of lightning conductors .... $= L + e_2 + E = C$

$$\text{Then } E = \tfrac{1}{2}(B + C - A - L) \quad (1)$$

$$e_1 = \tfrac{1}{2}(A + B - C - L) \quad (2)$$

$$e_2 = \tfrac{1}{2}(A + C - B - L). \quad (3)$$

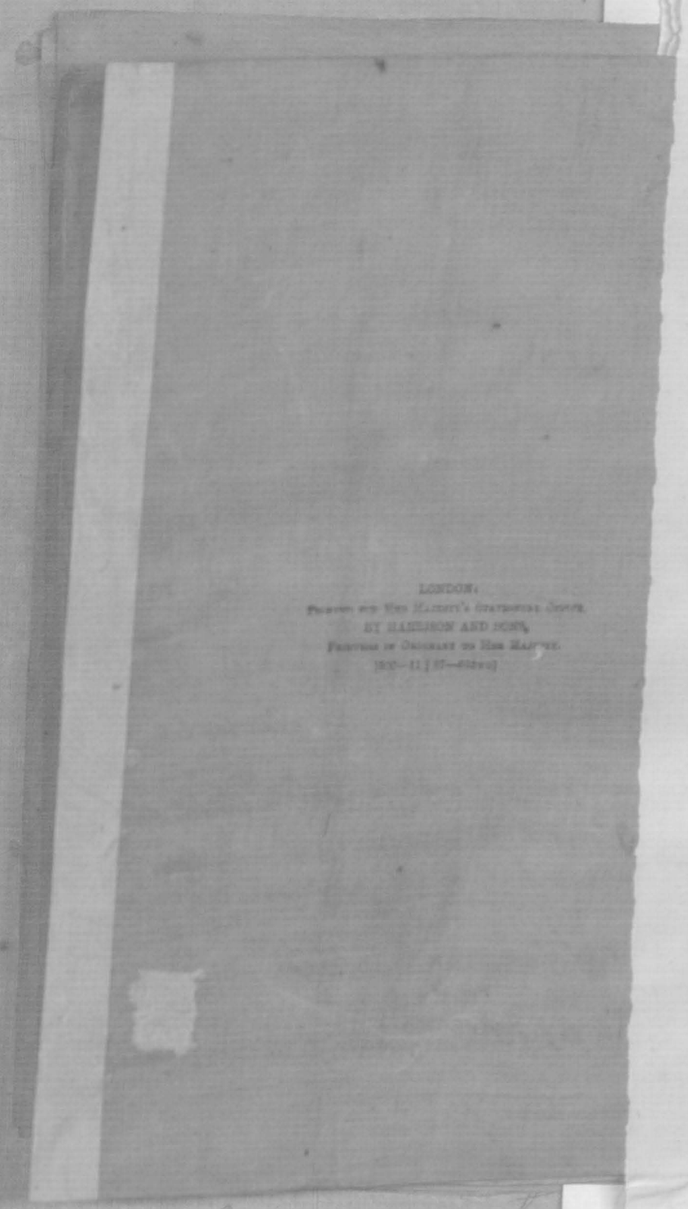
Very short contacts should be made in order to avoid polarisation of the test plates. If the resistances be very unequal, the results obtained from these equations may not be very accurate.

Defective joints localized.

XXXIX. The resistance of the conductors from each lightning rod point to that part of the conductor from which the resistance of the earth connections was ascertained, is then found. As the resistance of the conductor should be practically *nil*, any resistance in excess of that of the leads must be due to defective joints, and the faults should be localized and marked for repair.

XL. Conductors made in short lengths and connected by joints, the metallic continuity of which has not been ensured by soldering, or by a good system of rivetting, if tested electrically, give results of little value.

Underground joints and earths, the nature of which are not known, should be dug up and examined when practicable.



M. D. 18.

HEADING. Buildings

21/845

No. 318 M. W.

GOVERNMENT OF INDIA,

MILITARY DEPARTMENT.

It is requested that the above heading, with number and date of this communication, may be quoted in any subsequent correspondence on the subject.

Fort William, the 7 February 1888.

To

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

SIR,

In continuation of Military Department No. 2496 M. W. dated the 14th December 1887, I am directed to forward 10 additional copies of Instructions as to "the application of Lightning Conductors "for the protection of Powder Magazines "and other buildings".

I am,
Sir,
your most Obedient Servt.

J. E. Mowbray Lieut. Major
Asst Secretary to the Govt of India

No. 766 c dy 22 Feby 1888

P W C No 161

To

The Secretary to the Govt.
of India
Military Dept.

Sir

I am directed to
request that you will
be good enough to furnish
a copy of your No 2496 M. W.
dated 14th December 1887, quoted
in your letter No 318 M. W. of
15th February 1888 the original
not having been received.

No. 766 c dy 22 Feby 1888

M. D. 18.

3 to

HEADING. Buildings

No. 573 M. W. 22/845

GOVERNMENT OF INDIA,

MILITARY DEPARTMENT.

It is requested that the above heading, with number and date of this communication, may be quoted in any subsequent correspondence on the subject.

Fort William, the 7 March 1888.

To

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

SIR,

In reply to your letter No 766 c dated the 22nd February 1888, I am directed to state for the information of the Governor in Council, that Military Department No 2496 M. W. dated 14th December 1887, a copy of which is asked for, is merely a docket forwarding two copies of the Instructions for the application of Lightning conductors.

I am,
Sir,
Your most obedient servant.

J. S. Broadbent Major
for Secy. to the Govt of India.

No. 845 W & 14 - March 1883.

W.C. No. 2458

B & R

Communicated to Colonial Governments & Officers of the Public Works Department for information and guidance in continuation of G.O. 3187 W dated 12th November 1883.

13.3.83

13/3/83

Dy 14

Supdg Engineers
Engr Archt to Govt
Engineer for Burma

with Copies of letter of instructions

Print the instructions

845
23.

23
845

Govt. of Madras.

PUBLIC WORKS.



G.O. 4 Mch 8 845 W.

Lightning Conductors

Letter from the Govt of India stating that their Military Department have issued instructions for the application of — for the protection of powder magazines & other buildings, communicated to officers of the P.W. Department.

190/12

845/23.