
**SPECIFICATION FOR LIGHTNING
PROTECTION SYSTEM FOR
STRUCTURES**



Cawangan Kejuruteraan Elektrik
Jabatan Kerja Raya Malaysia

	SPECIFICATION FOR LIGHTNING PROTECTION SYSTEM FOR STRUCTURES (L-S9)	CKE.LS.01.09.(01).2011
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Table 5: LPS Material and conditions of use

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1.1 SCOPE

This section of the specification describes and specifies requirements for the supply, delivery, installation, testing, commissioning, handing over in approved working order and maintenance thereof during the Defects Liability Period (DLP) of the whole lightning protection system (LPS) in accordance with the Specification, Supplementary Notes, Bills of Quantities, Conditions of Contracts, Drawing etc.

The lightning protection system shall include air termination system, down conductor system, joints and bonds, testing joints, lightning flash counter, earth termination system, and other accessories incidental to the completion of the whole system as specified in the Drawings and/or Bills of Quantities.

1.2 STANDARDS

Generally, methods and materials used for the construction and installation of the LPS shall comply in accordance with MS IEC 62305:2007 and IEC 62561.

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2.1 CLASS OF LIGHTNING PROTECTION SYSTEM

Four classes of LPS (I to IV) are defined in MS IEC 62305-1 corresponding to lightning protection levels as shown in Table 1 (see Appendix A: Table 1) and the class of required LPS shall be selected on the basis of a risk assessment.

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3.1 GENERAL

Air termination components installed on a structure shall be located at corners, exposed points and edges (especially on the upper level of any facades) in accordance with one or any combination of the following methods:

- the protection angle method;
- the rolling sphere method;
- the mesh method.

The values for the protection angle, rolling sphere radius and mesh size for each class of LPS shall be as per Table 2 of MS IEC 62305-3 (see Appendix A : Table 2).

For the determination of the volume protected only the real physical dimensions of the metal air termination system shall be considered.

3.2 AIR TERMINATION SYSTEM

Air termination system shall consist of a network of vertical and horizontal conductors generally as shown in the Drawings. All salient points of the structure shall be incorporated in the air termination system. All metallic projections, chimneys, ducts, gutters, vent pipes, guard rails, aerial masts, etc. on or above the main surface of the roof of the structure whether shown in the Drawings or not shall be bonded to and form part of the air termination system. Air terminals or vertical finials shall be provided if specified in the Drawings and/or Bills of Quantities.

For structures taller than 60m, a lateral air termination system shall be installed on the upper part typically the topmost 20% of the height of the structure for protection against flashes to the side of the structure. If there is metal façade, it must be bonded and form part of the air termination system.

In addition, for structures taller than 120m, all parts which may be endangered above 120m shall be protected.

Unless otherwise specified, air termination system other than the air terminals or vertical finials shall be of 25mm x 3mm annealed copper tape. Should other materials be specified, it shall conform to Table 5 and 6 of MS IEC 62305-3 (see Appendix A : Table 5 & Table 6).

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The method and nature of the fixing shall be simple, solid and permanent. The air termination system shall be secured to the structure by means of purpose made conductive fixtures at the intervals not exceeding 500mm. Purpose made supports for securing the air termination system onto the roof tiles and ridge tiles shall be used. Conductive fixtures shall be of same material as the air termination system.

In the case of metal cladding roof where it cannot be considered as air termination components, the air termination system shall be secured to the metal roof structures by means of non-metallic purpose made. Intervals between fixings shall not exceed 500mm.

In the case of metal cladding roof to be used as air termination components, the minimum thickness of metal sheets shall conform to Table 3 of MS IEC 62305-3 (see Appendix A : Table 3).

Air termination rods shall be of rounded or tapered pointed end and made of copper. Unless specified otherwise in the Drawings and/or Bills of Quantities, they shall be minimum of 300mm in length and 16mm diameter with lock nut. The base for supporting the air termination rods on the flat surface or ridges shall be of same material as the air termination system.

If portions of the structure vary considerably in heights, any necessary air termination system of the lower portions shall, in addition to their own down conductors, be bonded to the down conductors of the taller portions.

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4.1 DOWN CONDUCTOR SYSTEM

Unless otherwise specified, down conductor system shall be 25mm x 3mm annealed copper tapes installed around the outside walls of the structure. Should other materials be used, it shall conform to Table 5 and 6 of MS IEC 62305-3. (see Appendix A: Table 5 & Table 6).

Down conductors shall not be installed in gutters or down-spouts even if they are covered by insulating material. No down conductors shall be routed inside the service ducts. A down conductor should be installed at each exposed corner of the structure, where it is possible.

The down conductor shall be installed in such a way that its path is as direct as possible between air termination system and earth termination system. It shall be as straight as possible along the shortest path without sharp bends or upward sections. They shall be securely fixed at intervals not exceeding 500 mm by means of conductive fixtures same material as the down conductor systems

The bend radii shall not be less than 200mm. Deep re-entrant loops, routing round parapet or cornices shall be avoided. However, a maximum height increase of 400mm is permissible for passing over a parapet wall with a slope of maximum 45°. Where this is not possible, the installation shall conform to Clause 6.3 MS IEC 62305. All wall or other building penetrations shall be made in a manner to prevent the ingress of water/water moisture and PVC sleeves shall be provided.

The number of down conductor shall not be less than two and should be distributed around the parameter of the structure to be protected subject to architectural and practical constraint. Typical values of the distance between down conductors with the relevant class of LPS shall be as per Table 4 of MS IEC 62305-3 (see Appendix A : Table 4).

All exposed down conductors may be painted with the decorative colour paint of the same colour for the wall finishes.

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4.2 NATURAL DOWN CONDUCTOR SYSTEM

If specified in the drawing and/or Bill of Quantities natural conductors such as reinforcing bars and structural steelwork may be used as a down conductor system provided that they are electrically continuous and adequately earthed.

When using a particular rod of the reinforcement steel as the down conductor, care should be taken in the route to earth to ensure that the rod that is located in the same position will be used all the way down, thereby providing direct electrical continuity.

Steelwork within reinforced concrete structures is considered to be electrically continuous provided that the major part of interconnections of vertical and horizontal bars are welded or otherwise securely connected. Connections of vertical bars shall be welded over a length not less than 30mm or properly clamped.

The electrical continuity of the reinforcing bars shall be determined by electrical testing between the uppermost part and ground level. An additional conductor may be used to enhance the natural down conductor system if the overall electrical resistance is greater than 0.2 Ohms. The additional conductor shall be bonded to the reinforcement bars by means of purpose made clamps conforming to IEC 62561 at 1 meter intervals.

The type and size of the conductor used shall conform to Table 5 and 6 of MS IEC 62305-3 (see Appendix A: Table 5 & Table 6).

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5.1 JOINTS AND BONDS

The lightning protection system should have as few joints as possible.

Joints and bonds shall be made mechanically and electrically effective by means of purpose made copper clamps or by exothermic welding or brazing. Contact surfaces shall first be cleaned then inhibited from oxidation with a suitable non-corrosive compound. With overlapping joints, the length of the overlap shall not be less than 20mm.

All metal works, including water pipes, gas pipes, handrails, air conditioning units, metal cladding, metal roof etc in the vicinity of the LPS shall be bonded to it, to avoid the danger of side flashing.

Where it is necessary to bond the copper conductor to any other metallic surface, this must be done by bolting or riveting. Care should be taken when attaching copper to a dissimilar metal to prevent electrolytic corrosion in that the joints are to be thoroughly cleaned and subsequently sealed. Proprietary bi-metallic connectors shall be used. LPS earth shall be bonded to the Main Earthing Bar, as well as any other earthing system present in the structure.

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6.1 TESTING JOINTS

Each down conductor shall be provided with a testing joint along the route of the down conductor except in the case of natural down-conductors combined with foundation earth electrodes. The testing joints shall be of purpose made copper clamps or of the same material of the down conductor. Unless otherwise specified, each testing joint shall be installed at 2500mm above the ground level.

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7.1 FIXING, CLAMPS AND SUPPORTS

All fixings, clamps and supports for the air termination system and down conductors of the lightning protection system shall be purpose made for use in the installation. Unless otherwise specified elsewhere, they shall be of copper alloy, naval brass or gunmetal.

The Electrical Contractor is required to submit installation methods and samples for fixings, clamps and supports for the approval of the S.O.'s Representative before installation.

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8.1 EARTH TERMINATION SYSTEM

An earth termination system shall be connected to each down conductor. Earth termination system shall be by 25mm x 3mm annealed copper tapes connecting the down conductor at the testing joint to the earth electrodes or reinforcing bars. The connection of the down conductor to the earth electrode of the earth termination system shall be soundly made by exothermic welding or brazing. The portion of the earth termination system between testing joint and ground may be enclosed in PVC casing of suitable size.

The earth termination system shall be of Type B arrangement in accordance with Clause 5.4.2.2 of MS IEC 62305-3. This type of arrangement comprises either a ring conductor external to the structure to be protected, in contact with the soil for at least 80% of its total length or a foundation earth electrode. Such earth electrodes may also be meshed.

The earth electrode of the type B arrangement shall be inter-connected by ring conductor 25mm x 3mm annealed copper tapes to form earth termination system and preferably be buried at a depth of at least 500mm and at a distance of about 1m around the external walls. The copper tapes shall be identified by permanent labels legibly marked with words "Lightning Protection Earth – Do Not Remove" permanently fixed at 1000mm intervals. The connection of two copper tapes shall be soundly made by exothermic welding or brazing.

Each earth termination connected to the down conductor shall have a resistance to earth not exceeding 10 Ohms. The entire of the LPS shall have a combined resistance to earth not exceeding 10 Ohms.

Bonding conductor of 25mm x 3mm annealed copper tapes shall be provided for connection between the earth termination for the lightning protection system at the testing joint and the Main Earthing Bar for the electrical installation.

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9.1 EARTH ELECTRODES

Earth electrode shall be of copper-jacketed steel core rods with 16mm diameter and supplied in 1500mm length and shall have provision for screw coupling with another standard length. The copper jacket of 99.9 % purity electrolytic copper shall be of minimum radial thickness 0.25mm and shall be molecularly bonded to the steel core to ensure that the copper jacket and steel core are not separable. Each earth electrodes shall be driven 3000mm in depth.

Where the desired earth resistance value cannot be achieved after the first earth electrode have been driven, sufficient number of earth electrodes in parallel shall be installed outside the resistance area until required value is reached. Mutual separation between two earth electrodes shall be more than the driven depth of the earth electrode but less than twice the driven depth. Interconnection between different earth electrodes shall be by means of 25mm x 3mm annealed copper tape.

The connection of the annealed copper tape to the earth electrode shall be soundly made by exothermic welding or brazing.

Each earth electrode shall be provided with heavy-duty type inspection chamber with removable cover. The compressive strength of the inspection chamber and cover shall be minimum 6 N/mm². Lifting hook shall be provided on the cover.

Each earth electrode shall be identified by permanent label legibly marked with words "Lightning Protection Earth – Do Not Remove" permanently fixed at the point of connection of every down conductor to an earth termination system.

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10.1 LIGHTNING FLASH COUNTERS

Where lightning flash counter is specified in the Drawing and/or Bills of Quantities, the counter shall be of outdoor weather proof type and shall be triggered whenever it encounters a 1.5 kA impulse current in 1.5 microseconds duration. The counter shall record up to minimum 9,999 lightning strikes. The counter shall be installed on the most direct down conductor above the testing joint or any location indicated in the Drawing and, in any case, at the height of about 2500mm above ground level.

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SECTION: 11.0	TEST, TEST INSTRUMENTS AND TEST CERTIFICATES	Revision: 1
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11.1 TEST AND CALIBRATION OF MEASURING AND TEST INSTRUMENTS

All measuring and test instruments used for testing of the LPS installations shall be regularly tested and calibrated by the manufacturers or test and calibration laboratories for their functionality and accuracy. Basic measurement accuracy for these instruments shall be within 5 %. In the case of analogue instruments, a basis accuracy of 2 % of full-scale deflection shall be provided. Test and Calibration Reports or Certificates for the measuring and test instruments issued by the test and calibration laboratory shall be valid for two years from the date of issuance. The instruments and their Test and Calibration Reports or Certificates shall be submitted to S.O.'s Representative for verification two weeks before testing of the electrical installation being carried out. No test on the electrical installation shall be carried out without prior approval of the S.O.'s Representative.

Notwithstanding the validity of the aforesaid Reports or Certificates the measuring and test instruments shall be re-calibrated if so required by the S.O.'s Representative after any mechanical or electrical mishandling. Fee required for the testing and calibrating of the measuring and test instruments is deemed to be included in the Contract.

11.2 TEST AND TEST CERTIFICATES

After the installation work has been completed and before Certificate of Practical Completion is issued, the whole LPS for electrical installation covered under this part of the Contract shall be tested in accordance with MS IEC 62305 and any other tests deem necessary by the S.O.'s Representative. In the event the installation fails to pass any of these tests, the Electrical Contractor shall take such measures as are necessary to remedy the defects and the installation shall not be considered as completed until all such tests have been passed.

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The tests to be carried out by the Electrical Contractor shall consist of the following tests as a minimum requirement: -

- a) Continuity of air termination system.
- b) Continuity of air termination system and the down conductors.
- c) Continuity of the down conductor and earth termination.
- d) Continuity of earth termination system.
- e) Continuity of earth termination and the main earthing bar for the electrical installation
- f) Earth electrode resistance.
- g) Earth termination resistance.

Fee required for the tests as described above is deemed to be included in the Contract.

The S.O.'s Representative reserves the right to be present at all tests and the Electrical Contractor shall give at least one-week notice in writing to the S.O.'s Representative for this purpose. In any case, no test shall be carried out without prior approval of the S.O.'s Representative. Copies of all the test certificates together with as-installed Drawings properly bound and titled shall be submitted to the S.O.'s Representative within one week after the completion of the testing.

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12.1 SERVICE AND MAINTENANCE

During the DLP, the Electrical Contractor shall be responsible for the service and maintenance work for the complete installation. All works shall be carried out by the competent person. All labour, material, tools and parts necessary to rectify the defect due to manufacturing/installation faults shall be supplied/executed at the Electrical Contractor's cost.

The service and maintenance to be performed and defects to be rectified and making good shall include but not limited to the following: -

- (a) Replacing or making good all lightning flash counters that do not meet the manufacturer's guarantees and warranties.
- (b) Replacing and making good all loose joints and terminations, all mechanical support linkage, earth electrode chambers and covers, etc.
- (c) Making good any damage to roads, buildings, drains, cables, pipes, concrete areas, paved areas etc. which had not been properly made good arising out of his work.
- (d) All other works as deemed necessary by the S.O.'s Representative.

All works shall be carried out as soon as the Electrical Contractor is being informed by the S.O.'s Representative or the occupant and shall be completed within a reasonable time except under emergency situation as stipulated in the Supplementary Conditions for Electrical Work. If the Electrical Contractor fails to comply with the above requirements, the S.O.'s Representative reserves the right to engage another party to carry out the work, in which case, the Electrical Contractor shall be responsible for all the expenses incurred.

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13.1 SHOP DRAWINGS

Two sets of prints of shop drawings for construction and/or installation shall be submitted to the S.O.'s Representative for approval. The Electrical Contractor shall prepare and submit shop drawings for the whole work or parts of the work at least two weeks before the work begins. If the shop drawings submitted are not acceptable by the S.O.'s Representative, the Electrical Contractor shall amend and re-submit the shop drawings within two weeks from the date of return of the shop drawings. No work shall be carried out without the shop drawings being approved by the S.O.'s Representative. The shop drawings shall include and show the following:

- a) The dimensioned general arrangements, layouts, positions and routes of air termination system, down conductors, earth terminations and all others necessary for the complete LPS installation as specified in the Drawings and/or Bills of Quantities;
- b) Elevations views of the LPS;
- c) The dimensioned general arrangements, layouts, positions and routes of bonding conductors;
- d) The dimensioned general arrangements, layouts, positions and routes of earth terminations and their earth electrodes.
- e) All other drawings as deemed necessary by the S.O.'s Representative.

The cost of all these shop drawings, whether or not provided in the Bills of Quantities, is deemed to be included in the Contract.

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13.2 AS-BUILT DOCUMENT AND TOOLS

As-Built document shall consist of but not limited to the As-Installed drawings, manual, certificates, catalogues, inventories and parts lists.

The As- Installed drawings shall comprise of:-

- (a) Site plan;
- (b) Layout Plans;
- (c) Elevations views of the LPS;
- (d) Layout plans of conductor routes and earthing points with reference to easily recognisable buildings and structures.
- (e) All other drawings as deemed necessary by the S.O.'s Representative.

These drawings shall be labelled at the lower right hand corner with the Electrical Contractor's name and address, date of commissioning, scale, drawing number (the drawing number to be obtained from the S.O.'s Representative), title and following particulars: -

JABATAN KERJA RAYA
CAWANGAN KEJURUTERAAN ELEKTRIK
CONTRACT NO.:

If the drawings submitted are not according to the actual installation at site and/or not acceptable by the S.O.'s Representative, the Electrical Contractor shall amend and re-submit the drawings within two weeks from the date of return of the drawings to the satisfaction of the S.O's Representatives.

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Manuals and documents for lightning flash counters and other important equipment shall be supplied.

It shall comprise of:-

- (a) Brief description of the installation/system
- (b) Installation manual
- (c) Operation manual;
- (d) Service And Maintenance Manual;
- (e) Parts List;
- (f) Product Data And Catalogue;
- (g) Product Test Certificates;

Certificates shall comprise of:-

All Testing Certificates (as per section 11.2)

Catalogues, parts lists, inventories, shall be as per project requirements.

Each of the As- Built documents shall be bound together with hard cover and submitted in minimum four (4) sets upon issuance of Certificate of Practical Completion (CPC) of the project.

In addition, one set of the As-Installed drawing shall be submitted in the form of tracing/original document and two sets in CD ROM.

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Special tools required for the operation, service and maintenance of lightning flash counters and other equipment shall also be provided.

The cost of all these prints, manuals, tools etc. is deemed to be included in the Contract.

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LPL	Class of LPS
I	I
II	II
III	III
IV	IV

TABLE 1 – Relation between lightning protection levels (LPL) and class of LPS (see MS IEC 62305-1)

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Class of LPS	Protection Method		
	Rolling sphere radius r m	Mesh size W M	Protection angle α°
I	20	5 x 5	See figure below
II	30	10 x 10	
III	45	15 x 15	
IV	60	20 x 20	

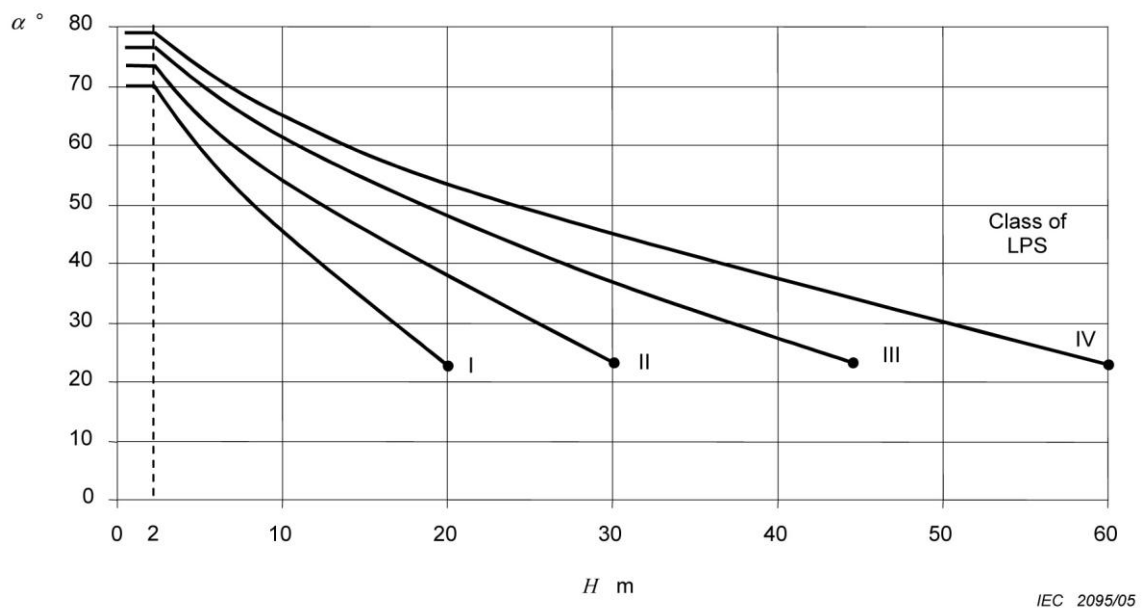


TABLE 2 – Maximum values of rolling sphere radius, mesh size and protection angle corresponding to the class of LPS

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Class of LPS	Material	Thickness ^a t mm	Thickness ^b t' mm
I to IV	Lead	-	2,0
	Steel (stainless, galvanized)	4	0,5
	Titanium	4	0,5
	Copper	5	0,5
	Aluminium	7	0,65
	Zinc	-	0,7
^a t prevents puncture, hot spot or ignition ^b t' only for metal sheet if it is not important to prevent puncture, hotspot or ignition problems.			

The metal cladding can be considered as natural air termination components and part of an LPS in accordance with Clause 5.1.3 of MS IEC 62305-3, provided that:

- the electrical continuity between the various parts is made durable (e.g. by means of brazing, welding, crimping, seaming, screwing or bolting);
- the thickness of the metal sheet is not less than the value t' given in Table 3 of MS IEC 62305-3 if it is not important to prevent puncture of the sheeting or to consider ignition of any readily combustible materials underneath (see Appendix : Table 3);
- the thickness of the metal sheet is not less than the value t given in Table 3 if it is necessary to take precautions against puncture or to consider hot spot problems;
- they are not clad with insulating material.

TABLE 3 – Minimum thickness of metal sheets or metal pipes in air-termination systems

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Class of LPS	Typical Distance m
I	10
II	10
III	15
IV	20

TABLE 4 – Typical values of the distance between down-conductors and between ring conductors according to class of LPS

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Material	Use			Corrosion		
	In open air	In earth	In concrete	Resistance	Increased by	May be destroyed by galvanic coupling with
Copper	Solid Stranded	Solid Stranded As coating	Solid Stranded As coating	Good in many environments	Sulphur compounds Organic materials	-
Hot galvanized steel	Solid	Solid	Solid	Acceptable in air, in concrete and in benign soil	High chlorides content	Copper
Stainless Steel	Solid Stranded	Solid Stranded	Solid Stranded	Good in many environments	High chlorides content	-
Aluminium	Solid Stranded	Unsuitable	Unsuitable	Good in atmospheres containing low concentrations of sulphur and chloride	Alkaline solutions	Copper
Lead	Solid As coating	Solid As coating	Unsuitable	Good in atmospheres with high concentration of sulphates	Acid soils	Copper Stainless Steel

NOTE 1 This table gives general guidance only. In special circumstances more careful corrosion immunity considerations are required (see Annex E).

NOTE 2 Stranded conductors are more vulnerable to corrosion than solid conductors. Stranded conductors are also vulnerable where they enter or exit earth/concrete positions. This is the reason why stranded galvanized steel is not recommended in earth.

NOTE 3 Galvanized steel may be corroded in clay soil or moist soil.

NOTE 4 Galvanized steel in concrete should not extend into the soil due to possible corrosion of the steel just outside the concrete.

NOTE 5 Galvanized steel in contact with reinforcement steel in concrete may, under certain circumstances, cause damage to the concrete.

NOTE 6 Use of lead in the earth is often banned or restricted due to environmental concerns.

TABLE 5 – LPS Material and conditions of use

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Material	Configuration	Minimum cross-sectional areas mm ²	Comments ¹⁰⁾
Copper	Solid tape Solid round ⁷⁾ Stranded Solid round ^{3), 4)}	50 ⁸⁾ 50 ⁸⁾ 50 ⁸⁾ 200 ⁸⁾	2 mm min. thickness 8 mm diameter 1.7 mm min. diameter of each strand 16 mm diameter
Tin plated copper ¹⁾	Solid tape Solid round ⁷⁾ Stranded	50 ⁸⁾ 50 ⁸⁾ 50 ⁸⁾	2 mm min. thickness 8 mm diameter 1.7 mm min. diameter of each strand
Aluminium	Solid tape Solid round Stranded	70 50 ⁸⁾ 50 ⁸⁾	3 mm min. thickness 8 mm diameter 1.7 mm min. diameter of each strand
Aluminium alloy	Solid tape Solid round Stranded Solid round ³⁾	50 ⁸⁾ 50 50 ⁸⁾ 200 ⁸⁾	2.5 mm min. thickness 8 mm diameter 1.7 mm min. diameter of each strand 16 mm diameter
Hot dipped galvanized steel ²⁾	Solid tape Solid round ⁹⁾ Stranded Solid round ^{3), 4), 9)}	50 ⁸⁾ 50 50 ⁸⁾ 200 ⁸⁾	2.5 mm min. thickness 8 mm diameter 1.7 mm min. diameter of each strand 16 mm diameter
Stainless steel ⁵⁾	Solid tape ⁶⁾ Solid round ⁶⁾ Stranded Solid round ^{3), 4)}	50 ⁸⁾ 50 70 ⁸⁾ 200 ⁸⁾	2 mm min. thickness 8 mm diameter 1.7 mm min. diameter of each strand 16 mm diameter
1) Hot dipped or electroplated minimum thickness coating of 1 µm. 2) The coating should be smooth, continuous and free from flux stains with a minimum thickness coating of 50 µm. 3) Applicable for air-termination rods only. For applications where mechanical stress such as wind loading is not critical, a 10 mm diameter, 1 m long maximum air-termination rod with an additional fixing may be used.			

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- 4) Applicable to earth lead-in rods only.
- 5) Chromium $\geq 16\%$, nickel $\geq 8\%$, carbon $\leq 0.07\%$.
- 6) For stainless steel embedded in concrete, and/or in direct contact with flammable material, the minimum sizes should be increased to 78mm^2 (10 mm diameter) for solid round and 75mm^2 (3 mm minimum thickness) for solid tape.
- 7) 50mm^2 (8 mm diameter) may be reduced to 28mm^2 (6 mm diameter) in certain applications where mechanical strength is not an essential requirement. Consideration should, in this case, be given to reducing the spacing of the fasteners.
- 8) If thermal and mechanical considerations are important, these dimensions can be increased to 60mm^2 for solid tape and to 78mm^2 for solid round.
- 9) The minimum cross-section to avoid melting is 16mm^2 (copper), 25mm^2 (aluminium), 50mm^2 (steel) and 50mm^2 (stainless steel) for a specific energy of 10 000 kJ/Ω. For further information see Annex E.
- 10) Thickness, width and diameter are defined at $\pm 10\%$.

TABLE 6 – Material, configuration and minimum cross-sectional area of air-termination conductors, air-termination rods and down conductors