

IALA Guideline 1012

For The Protection of Lighthouses and Aids to Navigation against Damage from Lightning

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Revisions to the IALA Document are to be noted in the table prior to the issue of a revised document.

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Guidelines For The Protection Of Lighthouses And Aids To Navigation Against Damage From Lightning

1 INTRODUCTION

Protection from lightning can be achieved with a reasonable amount of success. Successful protection can be expensive, therefore the decision to protect should be made considering the cost of the equipment to be protected or the critical need of the equipment/service.

A lightning protection system needs to be designed to ensure that the lightning discharge is diverted away from the equipment that is to be protected. To do this a path with a very low impedance to earth has to be provided such that the discharge occurs and the equipment remains in a protected zone similar to an umbrella and rain.

To protect equipment to the maximum possible, a rolling sphere technique should be employed. This method would provide the best protection for both direct and indirect lightning strikes. The rolling sphere technique, using a 10 KA (45 meter radius) sphere, is recommended for determining the location of air terminals at all except the most rudimentary navigational facilities. For simple structures not exceeding 20 meters in height, the 45 degree zone of protection is adequate.

2 SCOPE

Persons and equipment within buildings can be at risk from lightning currents and associated voltages which may be conducted into the building as a consequence of a lightning strike to the building or associated services. Some equipment (e.g. electronic equipment, including computers) is especially susceptible to damage from over voltages in the electricity supply caused by lightning and such damage may occur even when the lightning strike is remote from the building (e.g. from a surge conducted into the building via the electricity supply).

Measures should to be taken to protect persons and equipment within buildings from the effects of lightning.

These guidelines describe the practical design installation, inspection and testing of lightning protection systems for marine aids to navigation structures, equipment and systems. These guidelines are not intended as a rigorous treatise on lightning protection and the reader should refer to their national or an international standard for a more complete description of the protection methods.

3 NEEDS ANALYSIS

It must be emphasized at the outset that complete protection from the effects of lightning is not always practicable. It is an unfortunate fact that “solid state” elements (transistors, integrated circuits, microchips etc.) essential to complex modern electronics systems, are inherently much more susceptible to damage from excessive voltages than older types of equipment. There are several factors that have to be considered when evaluating the need for lightning protection. Is there enough of a threat from lightning to justify protection? Is the cost of replacement of the equipment sufficient to justify the cost of protection? Is the service critical enough to justify the cost of protection? The environment of the equipment must be considered because a

dry ground plane will require an extensive installation while a wet one will provide a ground path with a minimum installation.

A risk analysis based on British Standard 6651 : 1992, “The protection of structures against lightning” suggests a need for protection at most Marine Aids to Navigation facilities with few exceptions.

The decision to install protection is based mainly on the vulnerability of the equipment contained within the installation or the structure itself. If the structure is particularly resilient against lightning strike (such as a metallic day mark) or contains no equipment vulnerable to a strike, protection is not warranted by the specifications.

For most sites proper grounding installations for lighthouses and equipment accommodation are essential to minimise danger to personnel and damage to buildings. Simple and relatively inexpensive measures for the treatment of incoming telecommunication line circuits and electrical power supply circuits should give worthwhile additional protection, even to the modern types of communications and telemetry equipment.

4 TYPES OF LIGHTNING DAMAGE

There are two main categories of lightning strike. In the first category (direct strike) the building or structure is struck by lightning and very high currents flow to earth (ground potential) via the lightning protection system and, in some cases, also via the fabric of the structure. The second type (indirect strike) is where other buildings, structures, trees or the ground some distance from the structure are struck and the current flows to the remote site. The potential (voltage) can be just as high in an indirect strike.

4.1 Direct Strike

During a direct lightning strike on a building or structure, currents of up to 200,000 Amps flow to earth. The electrical potential of the earth in the immediate vicinity of the strike may rise to several hundred kilovolts above that of its surroundings. Side flashing will occur between lightning conductors and any conducting surface which is not electrically bonded by means of a low impedance path to the lightning protection earth system. Very high, damaging, currents will flow in these side flashes if the conducting surface has a separate earth path (e.g. incoming services, buried cables etc.).

4.2 Indirect Strike

Lightning does not have to strike an aid to navigation for damage to be caused to it or its contents. As with the direct strike, the electrical potential of the earth in the area of the strike will rise rapidly to many kilovolts above normal and this transient voltage will be induced or conducted into any services (which have conducting parts) passing through or near the area of the strike. If these services are connected to an aid to navigation then the transient voltages will appear on that Aid to Navigation and may, if the services are not bonded to the aids’ lightning protection earth system, cause side flashing within the aid, even if the strike is several kilometres away. This is probably the most common form of lightning damage.

5 DESIGN

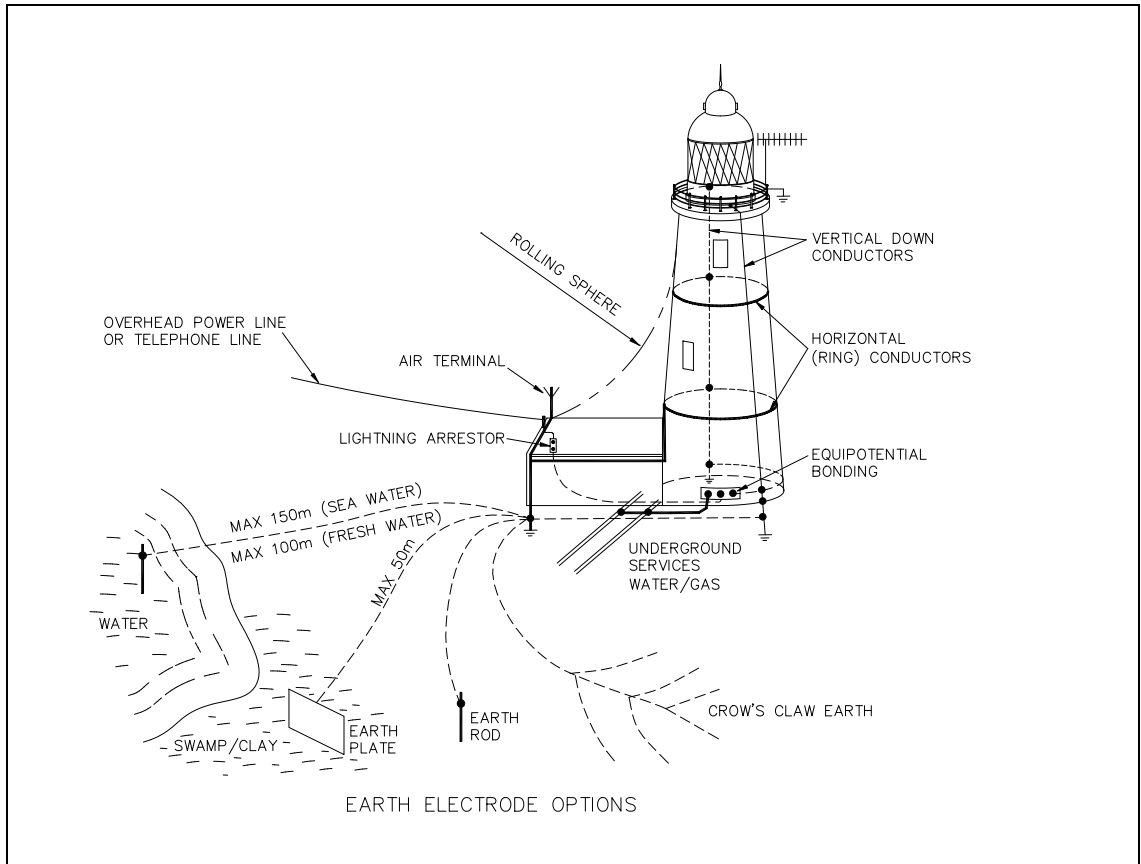
5.1 The Basics of Lightning Protection

The magnitude of a lightning discharge defies any attempt to block lightning current from damaging equipment. As a result, the basic philosophy of lightning protection is to divert the lightning current past personnel and vulnerable equipment along an efficient path to ground where it can safely dissipate.

The first stage in installing lightning protection is the location of suitable air terminations, down conductors and a ground termination network that will collect any lightning discharges and get them to earth with the minimum of disturbance. The design of the lightning termination network should be completed in accordance with appropriate national standards. The rolling sphere technique, using a 10 kA (45 metre radius) sphere, is recommended for determining the location of air terminations at all but the most rudimentary navigational facilities. For simple structures not exceeding 20 metre in height, the 45 degree zone of protection technique is adequate.

The second stage and an equally important one, is bonding, shielding and interface protection. The concept here is that even with an efficient termination network, lightning is such a violent phenomena that large voltages and electromagnetic fields will still be created at the site and can cause damage.

To illustrate this, Figure 1 shows a lighthouse and building powered by an overhead supply. The installation is remotely monitored though a telephone line. The lightning termination system in Figure 1 has been properly designed and an earth impedance of 2 ohms created to dissipate the lightning current. Bonding of the tower and building and the down conductor has resulted in very low down conductor resistance although the tower lighthouse may create a down conductor inductance of approximately 10 μH .



Sketch illustrating various bonding and earthing arrangements

FIGURE 1

Even though the lightning termination network has been properly designed and installed, significant voltages will still be generated at this site during even a moderate discharge. If this installation is hit by a moderate lightning strike with a $1\mu\text{s}$ rise time to 100 kA, 10kV will be generated across the inductance of the tower during the rising front of the strike. As the power supply cable for the light also runs up the tower and is connected to earth at each end, this voltage is impressed across this cable and more importantly across its terminations. Consequently these terminations (e.g. the lamp changer or the power supply output stage) will be damaged by over voltage if not correctly protected.

During the same strike, 20 kV is also generated across the earthing impedance at the peak current of the strike. As the site is connected through the Public Switched Telephone Network (PSTN) to a remote site not disturbed by the lightning strike, this voltage will be impressed across the interface to the PSTN line and the line itself. This will result in current flow from the site to the undisturbed remote earth, with resulting damage to the interface.

The response to this problem is to use bonding to create equipotential zones at the site and to ensure that connections between these equipotential zones are suitably protected. In the example, bonding should be used at the top of the tower (at the light) and within the power supply building. The aim of this bonding is to ensure that during a strike no significant voltages are generated between equipment within each equipotential zone. Bonding should then be used to connect these equipotential zones

efficiently and by the shortest path to the lightning protection system. If possible, only one connection should be made to the lightning protection down conductor from each equipotential zone in order to ensure that direct lightning current does not flow through the bonding network of the zone on its way to earth.

The lightning protection system needs to be designed to ensure that the absolute minimum of voltage is generated along the lightning discharge path. Otherwise unnecessary voltage will be generated between the equipotential zones complicating the protection of interfaces connecting the zones. Protection of the interfaces and cables which interconnect the zones including cables from remote areas, for example PSTN lines, need to be designed to prevent damage given the voltages which are expected and the lightning protection termination system installed.

5.2 Design Approach

The installation of full lightning protection in accordance with these guidelines may not be cost effective for all lighthouses and aids to navigation. However, there are some measures which are considered essential.

5.2.1 Mandatory Protection

The following measures should be undertaken:

- Building and structure protection in accordance Structure Protection below;
- Earthing in accordance with the section on earthing;
- Bonding of incoming and outgoing electricity, telephone, water and gas services;
- Installation of surge arrestors in all incoming and outgoing electrical and communications circuits.

5.2.2 Highly Desirable Protection

The following measures should be undertaken:

- Bonding of solar photo voltaic arrays, remote fog signals etc.;
- Installation of bonding conductor(s) on cable trays and trunking;
- Bonding of metal enclosures and backplanes in insulated enclosures;
- Bonding of radio communications and radiobeacon antenna feeder cable screens.

5.2.3 Recommended Additional Measures

The following measures will further reduce the risk of damage:

- Positioning control and monitoring equipment to reduce vertical cable runs;
- Installation of surge arrestors on long power, telemetry, control and sensor cables;
- Relocation of incoming services to allow short, direct bonding;
- Additional external down conductors will reduce the current in internal conductors;

- Use of distributed intelligence monitoring to reduce the number of sensor cables;
- Use of fibre optics on long sensor runs;
- Install surge arrestors in radio communications antenna feeder cables.
- Concentrate the sensitive Aids to Navigation in a restricted area and provide a zone of protection encompassing the restricted area by the provision of surge arrestors fitted to all cables entering and leaving the zone.

6 **INSTALLATION**

6.1 ***Protection of Structures***

6.1.1 General

Vertical down conductors of not less than 50mm² should be provided at evenly spaced horizontal intervals of not less than 20m (10m if the structure exceeds 20m in height) around the perimeter of the outside of the building (many structures have lightning conductors on the inside).

Each down conductor should run vertically, sharp bends are to be avoided wherever possible and re-entrant loops exceeding 8d are not permitted (Figure 2).

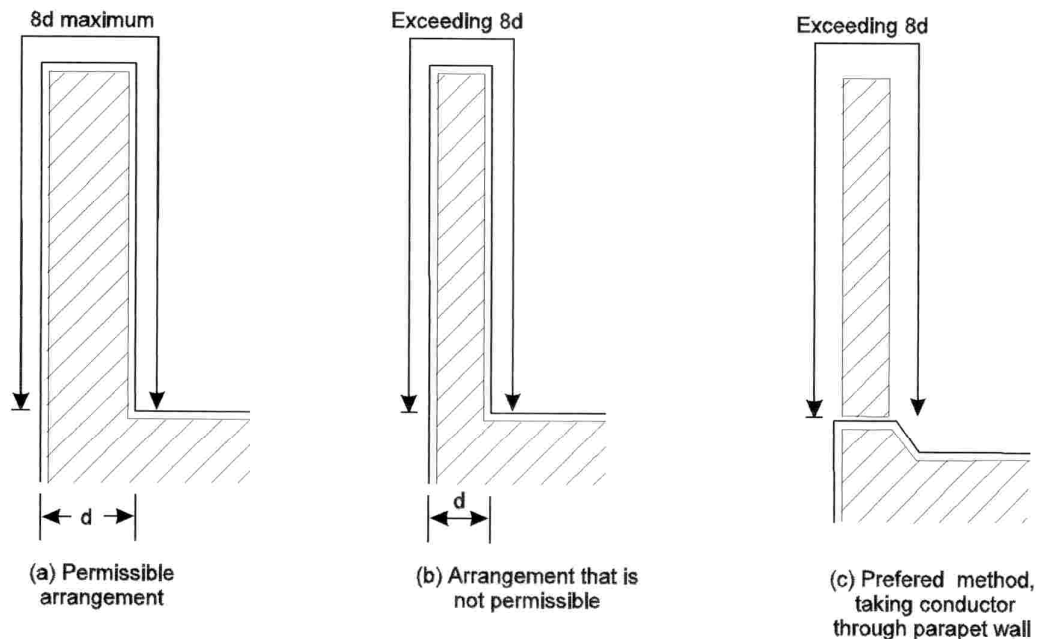


FIGURE 2

Each earth electrode should have a test joint at about 300mm above ground level

All down conductors should be connected together by a continuous horizontal (ring) conductor of not less than 50 mm². This band should be located at the lowest possible

point above the test joints. Where the structure exceeds 20m in height, additional ring conductors should be provided, spaced evenly throughout the height of the structure.

It is essential that each down conductor should have a separate earth electrode.

Existing down conductors should be inspected and tested. A test joint should be fitted if one does not already exist. The earth should be inspected and tested in accordance with Section 6.4 below.

Where the aid to navigation is a lantern and it has a metal murette, each down conductor should have its top bonded to the murette. Where the lantern or lantern roof is non conductive, an air terminal network should be provided at the highest point on the structure and all down conductors bonded to this network. The air termination should be in the form of a mesh of strip conductors set out so that no part of the roof is more than 5 metres from a conductor. Where vertical air termination finials are provided, these should be greater than 0.3m in height, located at intersections of the horizontal mesh and spaced not more than 10m apart. All metallic projections on or above the roof should be bonded to the air terminal. Where handrails are provided on the roof, these may form the air terminal provided that they are bonded at frequent intervals to a ring conductor which is bonded to the down conductors.

6.1.2 Independent Buildings and Structures

Where a station comprises two or more separate buildings e.g. lighthouse, generator building, fog signal house etc. each building should be provided with its own lightning protection system which should be interconnected to the main building lightning protection system by means of a conductor of not less than 50mm². Services (telephone, mains electricity etc.) to these buildings should be bonded to the outbuilding lightning protection system in the same manner as for the main building.

6.1.3 Steel Lattice Towers

Each leg of a steel lattice tower should be provided with a lightning protection earth. These separate earths should be interconnected between the tower leg and the earth test joint; the interconnection should be further bonded to the main building lightning protection system (See Figure 3).

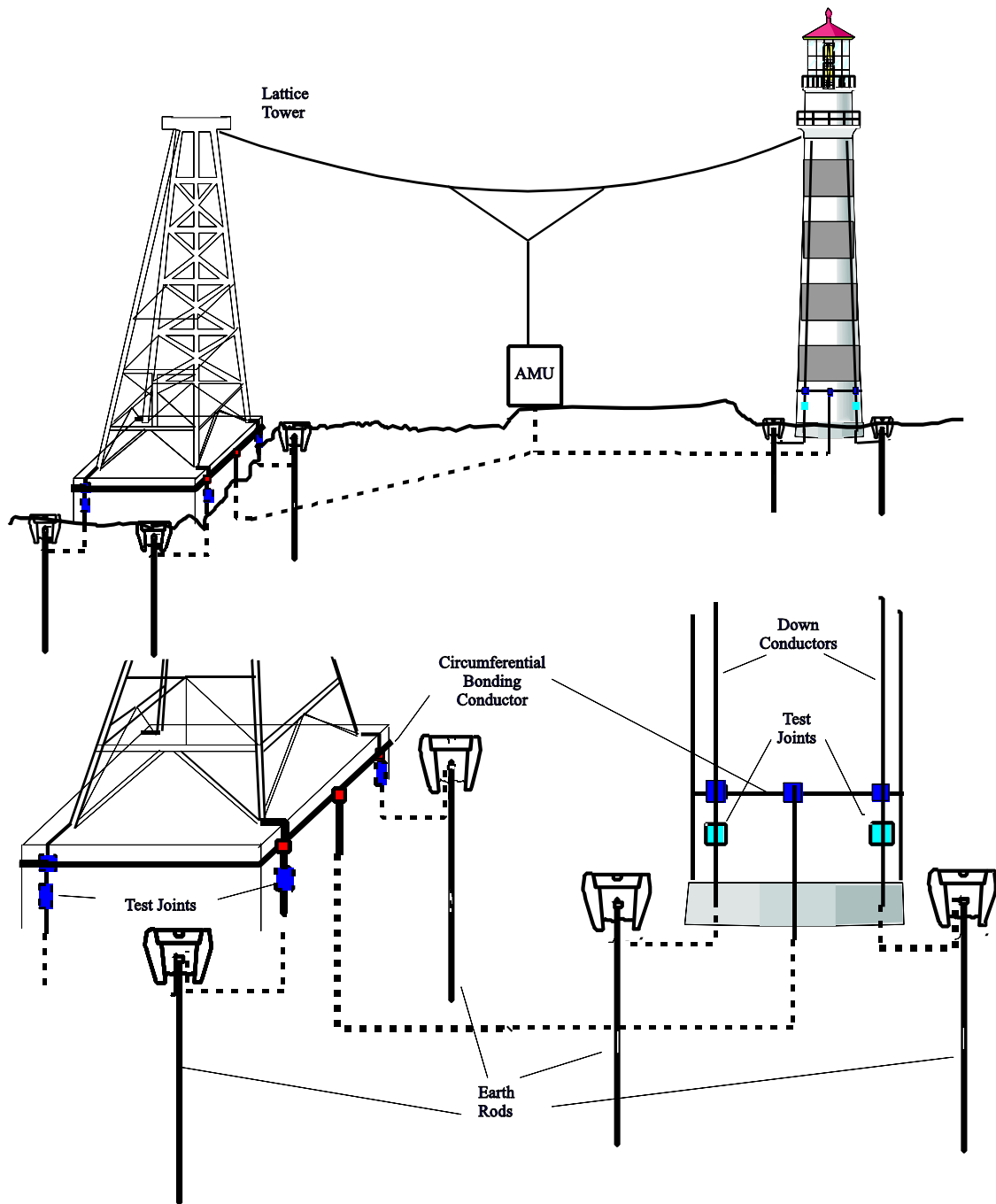


FIGURE 3

6.1.4 Floating Aids

The majority of floating aids such as light vessels, light floats, Lanbys and buoys are of metallic structure and form a Faraday cage effectively shielding sensitive electronic equipment mounted within the hull or superstructure. However, induced voltages are possible and can be avoided by ensuring that metallic enclosures are earthed to the metallic structure of the vessel. A discharge path to earth consisting of surge arrestors should be provided for radio and navigational equipment antennas.

Plastic or GRP hulled vessels including buoys should be fitted with an air termination with a low impedance path to earth to avoid structural damage to metallic superstructure. The metallic superstructure may act as the air termination. The earth terminal should consist of copper or other conducting material not less than 0.25 m² compatible with sea water and mounted such that it is permanently immersed below the water line.

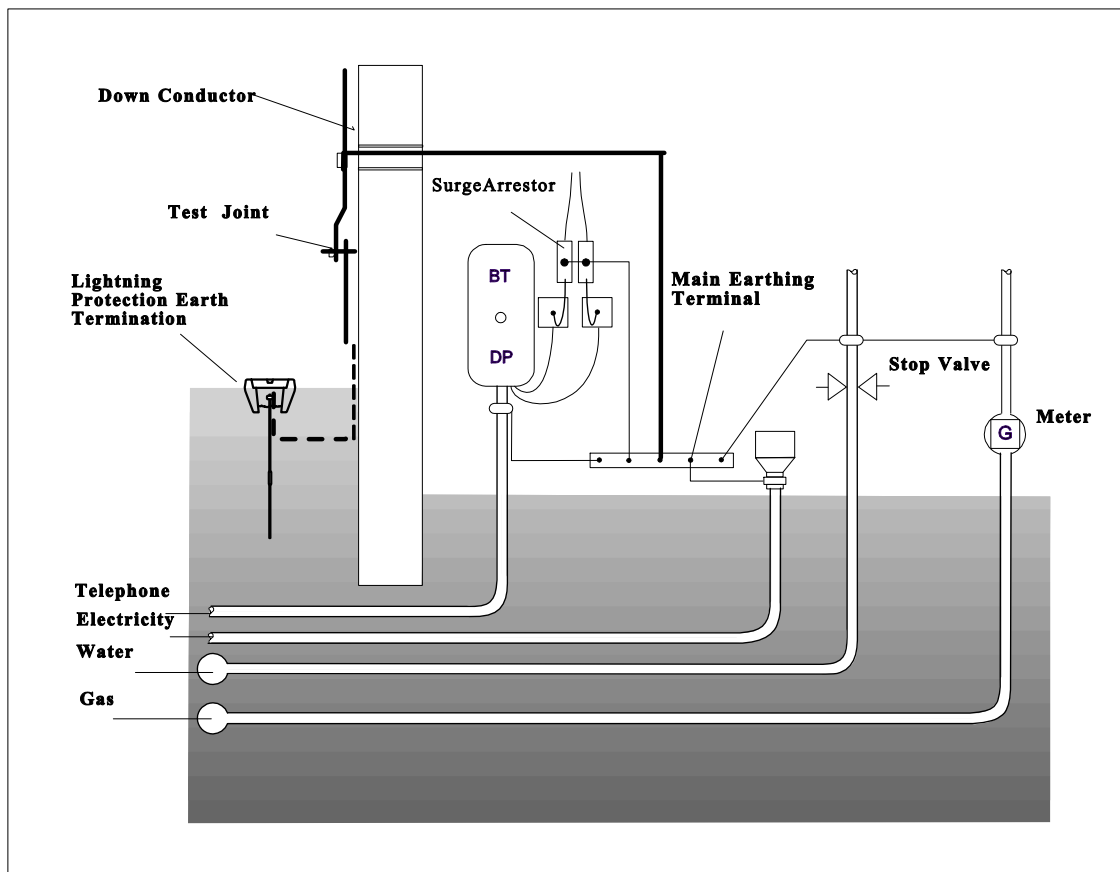


FIGURE 4

6.2 Bonding

6.2.1 Services

All incoming and outgoing services should be bonded to the lightning protection system at the point of entry into the building. These bonds should be as short and direct as possible, see Figure 4 above. The size of bonding conductor should be not less than 30mm². Conductors used for compliance with current national wiring regulations are not suitable for lightning protection purposes.

The appropriate utility provider may need to be consulted before this work is carried out. In some cases it may be necessary for the provider to relocate the point of entry into the building.

Conductors entering the building could be carrying lightning currents or voltage transients and are considered to be “dirty”. Internal conductors after the earth bonding point, and surge protection where appropriate (see Section 6.3), are considered “clean”. It is essential that clean conductors are not routed near or parallel to dirty conductors. Figure 5 below shows the arrangement for routing cables to and from surge protectors.

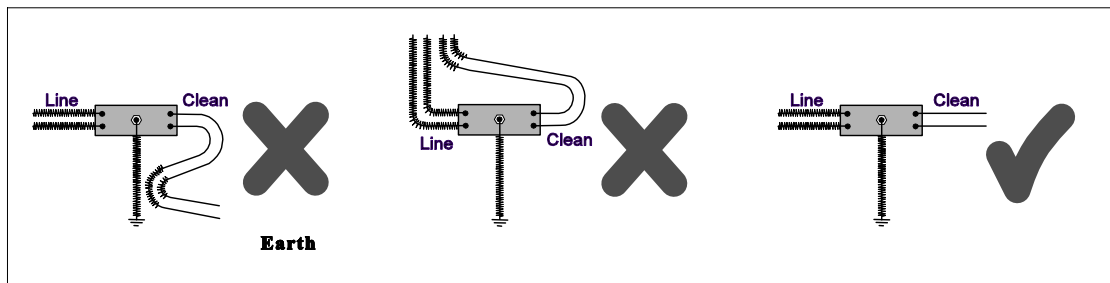


Figure 5

6.2.2 Electricity Supply

All electricity circuits including station and domestic supplies should be protected. The minimum requirement is for the armour of underground cables to be bonded by means of a short, direct connection to the lightning protection system (Figure 4). On particularly vulnerable stations, e.g. those stations where the low voltage transformer is off site, and/or those with a high earth resistivity may require additional protection in the form of surge suppression.

6.2.3 Telephone Circuits

All telephone circuits, including station and domestic circuits should be protected because, if only the telemetry circuit is protected, surges on the other circuits can induce high voltages into the protected circuits. The minimum requirement is for all telephone lines to be fitted with surge suppression at the point of entry/exit. Where the incoming telephone lines are in the form of an armoured underground cable, the local telephone company should be asked to allow bonding of the armour to the lightning protection system.

6.2.4 Water Supply

Incoming metal water pipes, (or internal metal water pipes where the incoming supply is in plastic), should be bonded to the lightning protection system.

6.2.5 Gas Supply

Incoming metal gas mains should be bonded to the lightning protection system on the consumer side of the meter.

6.3 Structural Metalwork

6.3.1 General

All isolated metalwork, e.g. sector light pedestals, metal windows, rainwater pipes and metal soil pipes, should be bonded to the lightning protection system. Vertical metal pipes should be bonded at the top and bottom. Voltage drops in conductors are due to inductance rather than resistance, it is therefore essential that the bonding conductors are kept as short and straight as possible.

6.3.2 Weight Tubes

The weight tube probably forms the best lightning protection system for the installation (where it is still intact) and should be bonded to the lightning protection system at its lowest point. Even where the weight tube has been removed, totally or partially, the foundations may still provide a very useful addition to the main building earth system and should be utilised for this purpose, see Figure 6 below

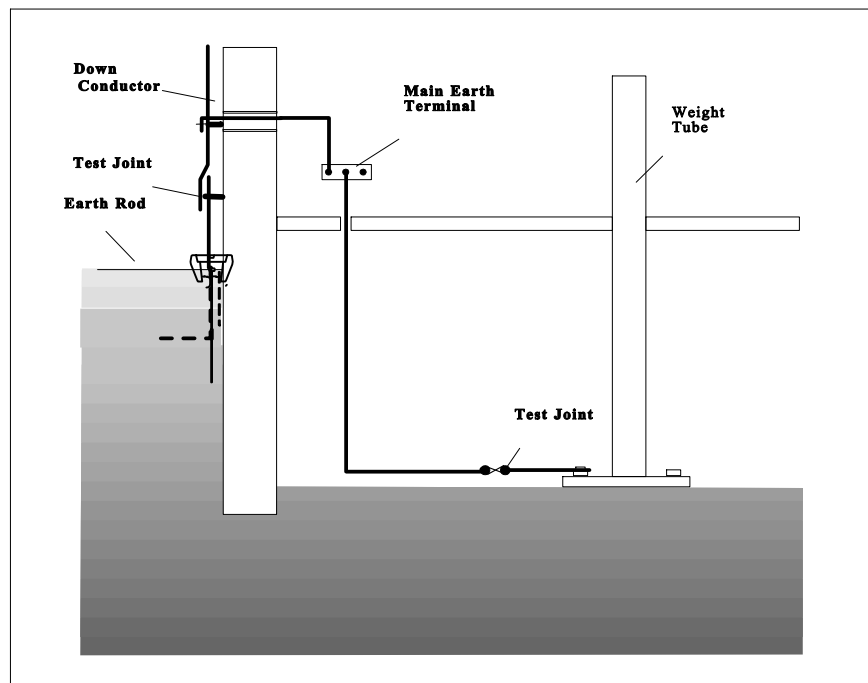


FIGURE 6

6.3.3 Stairway Handrails

All metal handrails should be bonded to the lightning protection system.

6.4 Cable distribution systems

6.4.1 Conduit

Galvanised steel conduit provides the best protection for cables against the effects of lightning, therefore this method is recommended for cables connecting vulnerable equipment. All joints should be screwed in to the full depth of the coupler.

6.4.2 Trunking

Metal trunking provides the second best form of protection provided that the removable covers are permanently bonded by means of a permanent, flexible connection at each end.

6.4.3 Cable Trays

Metal cable trays form the third best (and most common) protection, provided that the following are adhered to:

- Cable trays and trunking should not be used as the sole means of bonding. Because of the large number of joints and discontinuities in cable tray and trunking routes, there is a high risk of high resistance joints forming. It should be noted that stainless steel has a significantly higher resistivity per unit length than aluminium, mild steel or copper.

A continuous, insulated, copper conductor of at least 30mm² should be provided on the full length of the cable tray and should be bonded to the tray at all joints and discontinuities. Any joints in the copper conductor should be soft soldered and bolted using spring washers, or riveted; connections from cabinets and cable trays etc. should be tinned to reduce the risk of electrolytic action. This conductor should be bonded to the lightning protection earth system at its lowest point. The preferred method would be to provide two equal conductors with a total cross section of at least 30mm², one on each outer edge of the tray. Each conductor should be bonded as above.

6.4.4 Fire Detection Circuits

Because of the length of most of these cable runs, mineral insulated cables should be used, bonded to the lightning protection system at both ends.

Alternatively cables meeting the requirements of IEC 60332 for flame retardant cables may be used. These should be fitted with surge arrestors at their point of entry and exit from the equipotential zone.

6.4.5 Equipment Cabinets and Cubicles

Metal equipment cabinets and cubicles should be bonded to the earth conductor on the cable tray or trunking by means of a short, direct, flexible conductor of not less than 6mm² (16mm² preferred). The use of non-metallic equipment housings should be avoided wherever possible but where these are used, the metal back-plane should be bonded as for a metal housing.

6.4.6 Sensor, Control and Data Cables

All interconnecting sensor, control and data cables should use screened cable. The screen should be bonded to the lightning protection earth conductor at both ends. (A cable screen, bonded at one end only, is ineffective at screening against lightning

induced voltages). In the majority of cases, the effect of this on circulating currents is negligible.

Where single point earthing is essential due to induced noise onto signal conductors, additional surge arrestors may be used to provide the earth at the remote end. In addition the use of double screen cables may be considered with the outer sheath earthed at both ends for lightning protection purposes and the inner sheath earthed at one end to minimise induced noise.

Where external sensor, control or data cables are installed, e.g. fuel storage tanks, the cables should be fitted with a surge arrestor, earthed to the lightning protection system, at the point of entry to the building. Consideration should be given to implementing extended data cable runs for computers and distributed control systems using fibre optic cables which are inherently immune to damage by lightning discharge voltages. Fibre optic cables may have a metallic sheath which should be stripped well back (2m) from one end if electrical isolation is intended.

Where long sensor cable runs exist these should use MICC cable with the copper sheath bonded at each end to the lightning protection system or bonded metal enclosure. Alternatively, standard sensor cables may be run in conduit, or be fitted with surge arrestors at their point of entry and exit from each equipotential zone.

6.4.7 Radio Communication Antennas and Feeder Cables

The screens of all radio communication antenna feeder cables should be bonded to the lightning protection system at the antenna and again at the point of entry to the building. Where a surge arrestor is fitted, this should be at the point of entry to the building and should be bonded to the lightning protection system.

The radio equipment should also be bonded to the lightning protection system.

The mountings of single element antennas and the mounting pole of yagi antennas should be bonded by a short direct route to the building lightning protection system.

6.5 Radio Beacon Antennas

6.5.1 Earth Mat

The radio beacon earth mat often forms a much better earth conductor than the lightning protection earths. It is essential that this earth mat is bonded to the station lightning protection system, using 50 mm² copper tape or cable.

6.5.2 Antenna Feeder Cable

The screen of the radio beacon antenna feeder cable should be bonded to the earth mat at the antenna matching unit and to the station lightning protection earth at the point of entry to the building.

6.5.3 Antenna Support Structures

All antenna support structures should be connected to its own earth electrode and bonded to the radio beacon earth mat. If the earth resistance of the earth mat is greater than 10 ohms then additional earth rods may be required, depending upon ground conditions (e.g. rock).

If the antenna support structure is a steel lattice tower then the earthing arrangements for lattice towers will apply.

All ground anchors for guyed poles should be bonded to the earth mat.

All building anchors for ‘T’ antennas etc. should be bonded to the building lightning protection system.

6.6 Fog Detectors

Fog detectors and their mountings should be bonded to the lightning protection system and the interconnecting cables should be screened (bonded at both ends) or run in metal conduit and surge protection should be provided.

6.6.1 Fog Signals

The metalwork of a fog signal should be bonded to the lightning protection system. Where the fog signal is remote from the lighthouse an earth conductor of not less than 30mm² should be provided between the fog emitter and the building. This conductor should follow the same route as the emitter drive cables and should be bonded to the lightning earth at the point of entry into the building. Consideration may need to be given to providing a lightning protection earth at the fog emitter where this is at a considerable distance from the main building; if this is provided then the cross bonding conductor should not be less than 50 mm².

6.6.2 Emergency Lights

Where an emergency light is installed on the roof of the lantern, for example, it may be necessary to provide an air terminal above the emergency light (minimum height difference of 300mm), bonded to the building lightning protection system. In addition, surge protection should be provided at the point of entry into the building.

6.6.3 Solar Photo-Voltaic Arrays

Photo-voltaic (PV) arrays are vulnerable to lightning damage, particularly where they are located at a distance from the main building. A separate earth termination should be installed locally, connected to the array mounting frame. This should be bonded to the main lightning earth using a bonding conductor of not less than 50mm², which should follow closely the route of the DC cables between the photo-voltaic array and the main building. When assessing this requirement, the 20m rolling sphere technique should be used and account taken of the location of the photo-voltaic array.

All cables should be run either on cable tray, in conduit/trunking or tightly against earthed metalwork/conductor tapes.

6.6.4 Generators

The frame of the generator(s) should be bonded to the lightning protection system by means of a flexible conductor of not less than 30mm².

6.6.5 Fuel Storage Tanks

Service tanks should be bonded to the lightning protection system.

External storage tanks should be adequately earthed and cross bonded to the generator building lightning protection system.

6.6.6 Fuel Level Sensors

Level sensor connections etc. should be in screened cable, earthed at each end and ideally run in solid drawn metal conduit or MICC. The sensor wires should be fitted

with a surge arrestor, bonded to the lightning protection system at the point of entry into the building. In extreme conditions consideration could be given to the use of self-powered fibre optic sensors where the storage tank is remote from the main building.

6.6.7 Radar Antennas

Radar antennas consist of a rotating scanner mounted on a housing containing the drive motor and gearbox. This antenna assembly is connected to the transmitter via an electrically continuous, rectangular copper waveguide. Both the waveguide and the drive housing should be bonded to the vessel superstructure or in the case of a lighthouse to the lightning protection system, the latter at its point of entry into the lighthouse.

6.7 *Surge Protection*

6.7.1 General

All incoming and outgoing power, telephone, data communications, telemetry sensor and control cables, and radio antenna feeder cables should be fitted with surge protection at (or as near as practicable) the point of entry into the building.

All surge protectors should be installed in accordance with the manufacturers' instructions.

Owing to the nature of lighthouse installations, it is likely that there will be a significant number of vertical cable runs. This considerably increases the risk of both resistive coupled and induced transient over voltages being introduced into many of the internal power, control, monitoring and telecommunications circuits. It is, therefore, essential that each installation be assessed and appropriate surge suppression installed. Reference documents listed at the end of these guidelines should be used and, if necessary, the advice of consultants and manufacturers should be sought in making this assessment.

6.7.2 Electricity Supplies

- The type and rating of the protector should be appropriate for the supply voltage.
- The protector should have continuous indication of its protection status.
- The status indication should warn of protection failure between all combinations of conductors, including neutral to earth (otherwise a potentially dangerous neutral-earth short could go undetected).
- The protector should be rated for a peak discharge current of not less than 10kA, 8/20 microsecond waveform (8 μ s rise time/20 μ s 3dB pulse width).
- The protector should limit transient over voltage to less than the equipment damage level. The peak transient let-through voltage should not be exceeded for all combinations of conductors e.g.. P-N, N-E and P-E.
- The protector should not interfere with or restrict the system's normal operation; nor should it corrupt or shut down the power supply after operation.
- The protector should not have a high earth leakage current.

6.7.3 Uninterruptible Power Supplies (UPS)

Despite some manufacturers' claims to the contrary, most UPSs do not have surge protection suitable for lightning protection. It is essential that both the input and output (or input of each load) of each UPS is adequately protected.

6.7.4 Solar Photo-Voltaic Arrays

Photo-voltaic arrays, particularly those installed at a distance from the main building, should have surge protectors installed in the DC cables, at the point of entry into the building to protect the photo-voltaic voltage regulator.

Such devices for 12/24V DC systems should have minimal insertion loss and very small leakage current.

6.7.5 Telephone, Data, Control and Monitoring Circuits

Circuits between buildings should be protected at BOTH ends in order to protect both pieces of equipment.

The protective device should have the appropriate rating for the application e.g. a PSTN telephone surge protector is NOT suitable for telemetry I/O and vice versa;

The protector should be capable of being installed in groups or individually with appropriate mounting and earth commoning kits;

The protector should not interfere with the normal operation or affect the performance of the service being protected;

Where internal circuits are of significant length or the equipment being interconnected is of prime importance or especially vulnerable, then surge protection should be provided at both ends of each interconnecting circuit;

Protective devices for PSTN and Private wire use should be rated at 10kA (8/20 μ s).

6.7.6 Co-axial and Screened Circuits

Certain types of coaxial and screened circuits, e.g. Local Area Networks and some types of sensors, should only be earthed at one point. The use of an appropriate transient overvoltage protector will provide the additional bonding required by these guidelines whilst maintaining isolation of the screening.

6.8 Earthing

6.8.1 General

Earthing of a system involves the provision of a connection to the general mass of earth. This connection should have a resistance not greater than 10 ohms. In typical Aids to Navigation installations, it is often difficult to achieve this ideal. In such conditions the general philosophy of protection must be to provide an equipotential site so that damage due to voltage differences within the site are minimised.

Earth electrodes can be installed in a variety or combination of forms including deep driven spikes, plates, horizontal strips or conductors and sea terminations. The type(s) of electrode used depend on local conditions.

The resistance to earth of a given electrode depends upon the electrical resistivity of the soil in which it is installed. Measurement of soil resistivity and consequent length of earth electrode can be determined in the following manner.

Four equally spaced electrodes are driven into the soil to a depth not exceeding 5% of the spacing between any two electrodes. A current source is connected to the outer two electrodes and the voltage between the middle two electrodes is measured, see Figure 7. From the values of the voltage and current, a value for ‘R’ can be calculated (most resistively measuring equipment gives a direct reading).

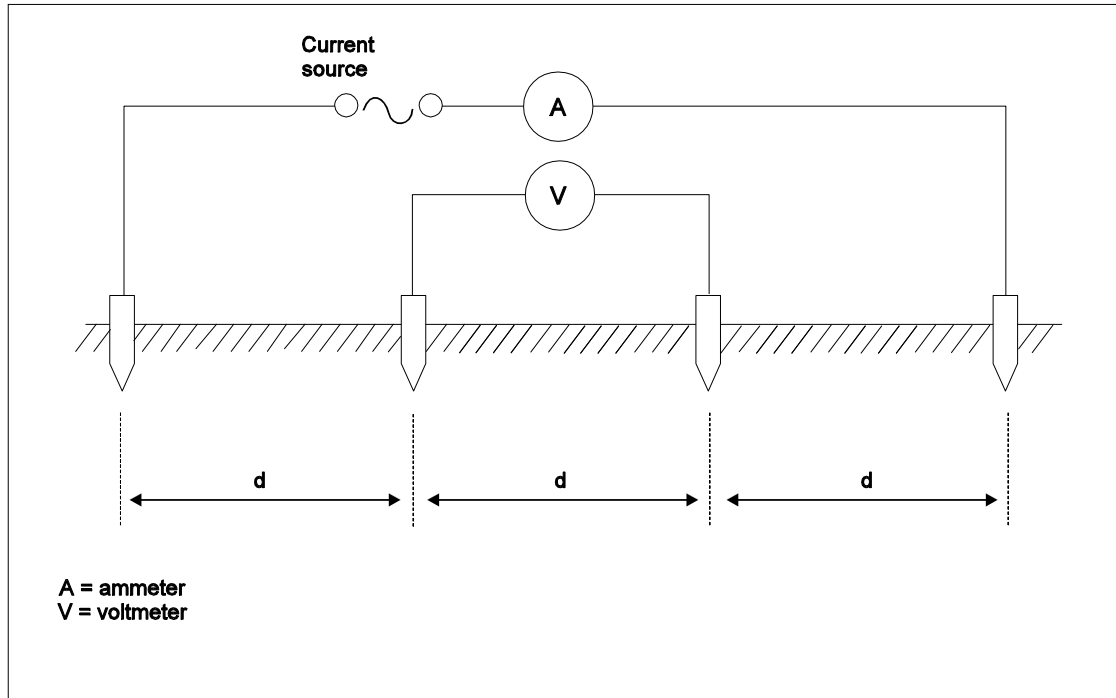


FIGURE 7

The soil resistivity can be calculated from the formula:

$$\rho = 200 d R \text{ ohms centimetres}$$

where:

d is the distance between electrodes

R is the resistance (in ohms) measured between the middle electrodes

This measurement gives the soil resistivity at a depth equal to the distance between the electrodes.

If the distance between the electrodes is varied, the measurement repeated and the results recorded, soil resistance at various depths will be obtained.

The length of earth electrode required, depending on the section used, can be determined using the following formulae:

Rectangular Section Horizontal Strips.

$$R = \frac{200 L^2}{275 L} \text{Log}_{10} \frac{200 L^2}{w D}$$

Circular Section Horizontal Strips

$$R = \frac{\rho}{275L} \text{Log}_{10} \frac{100L^2}{D}$$

Rectangular Sectional Vertical Strips

$$R = \frac{\rho}{275L} \text{Log}_{10} \frac{800L^2}{wD}$$

Circular Sectional Vertical Strips

$$R = \frac{\rho}{275L} \text{Log}_{10} \frac{400L^2}{ND}$$

Where:

R = apparent earth electrode resistance in ohms

ρ = soil resistivity in ohm centimetres

D = depth of electrode in metres

ϕ = diameter of electrode in centimetres

L = length of electrode in metres

w = width of electrode in centimetres

6.8.2 On Soil

Each down conductor should have an associated earth network. This may comprise a single earth electrode or a number of electrodes connected together to form a single network. The total earth resistance of each earth network should not exceed 10 ohms multiplied by the total number of down conductors.

6.8.3 On Rock

Where a structure is built on rock, it may not be possible to achieve the 10 ohm maximum value for earth resistance.

Where this is the case, no maximum value is stated and the following procedure should be adopted.

Each earth electrode should be formed by inserting a 2.4m earth rod into a 75mm diameter hole core drilled to a minimum depth of 2.4m and the hole back filled with cement mixed with a conductive carbonaceous aggregate, for example, Marconite. Bentonite may be used as a substitute for the cement mix but care will be needed to ensure that the Bentonite is not washed out of the hole or that it becomes dry.

It is important to note that in cases where a low resistance earth cannot be achieved, the local ground potential rise during a lightning event can be very extreme indeed. If suitable bonding arrangements have been put in place at the site, this alone may not cause significant damage to the installation, but extreme damage may occur to interfaces and wired connections between the site and remote earths (such as PSTN,

electric power and remote monitoring connections). As a consequence, careful attention needs to be put towards protecting such interfaces at sites where low resistance earths cannot be achieved.

6.8.4 On Thin Soil

Where the station is built on rock with a thin covering of soil, the earth may be formed by burying strip electrodes in trenches. The trench should be at least 1 metre deep and the system should be installed below the frost line and below the area which may be subject to seasonal changes.

6.8.5 Sea Earth Electrodes

On structures built on rock, a sea earth electrode can be used as an alternate or in addition to the earth rod system. The earth electrode comprises a mesh of 20 mm x 3 mm copper tape of at least 1 m x 1 m, attached to the rock below the low tide water line. Secure fixing is difficult as the electrode is in the wave area and consequently subject to severe conditions.

7 PERIODIC INSPECTION AND MAINTENANCE

7.1 Inspection

All lightning protection systems should be visually inspected by a competent person during installation, after completion and after alteration or extension, in order to verify that they are in accordance with the recommendations in these guidelines and with BS6651:1992 or the appropriate national or international standard. Visual inspections of the installation and of the lightning surge arrestors should be repeated at fixed intervals not exceeding 12 months.

In addition, the mechanical condition of all conductors, bonds, joints, terminations and earth electrodes (including reference electrodes) should be checked and the observations noted. If, for any reason, such as site works, it is temporarily not possible to inspect certain parts of the installation, this should also be noted.

During periodic inspection of the lightning protection system, the bonding of any recently added services should be checked to ensure that they are in accordance with these guidelines.

7.2 Testing

Only disconnect one earth electrode at a time for testing. If only one earth electrode exists then the installation **MUST** be disconnected from all sources of mains power (including generators) before the earth electrode is disconnected for testing. It is not sufficient to remove the mains earth bond for this test as other connections between the lightning protection system and mains earth will probably exist.

7.2.1 General

On completion of the installation or any modification to it, the following measurements and/or checks should be made and the results recorded in a lightning protection system logbook:

- a) The resistance to earth of the earth termination network and of each earth electrode;

- b) The results of a visual check on all conductors, bonds and joints or their measured electrical continuity.

Tests should be repeated at fixed intervals, preferably not exceeding 12 months.

7.2.2 Testing Earth Electrode Resistance

The resistance of each earth electrode should be measured with that electrode disconnected from the rest of the lightning protection system and the results recorded. The preferred method of measurement is illustrated in Figure 8. A known current is passed between the earth electrode (E) under test and the test electrode (TE1) and the voltage between E and a second test electrode (TE2) is measured. From these values the earth electrode resistance can be calculated. Measuring instruments are available that combine the above functions and indicate earth electrode resistance directly.

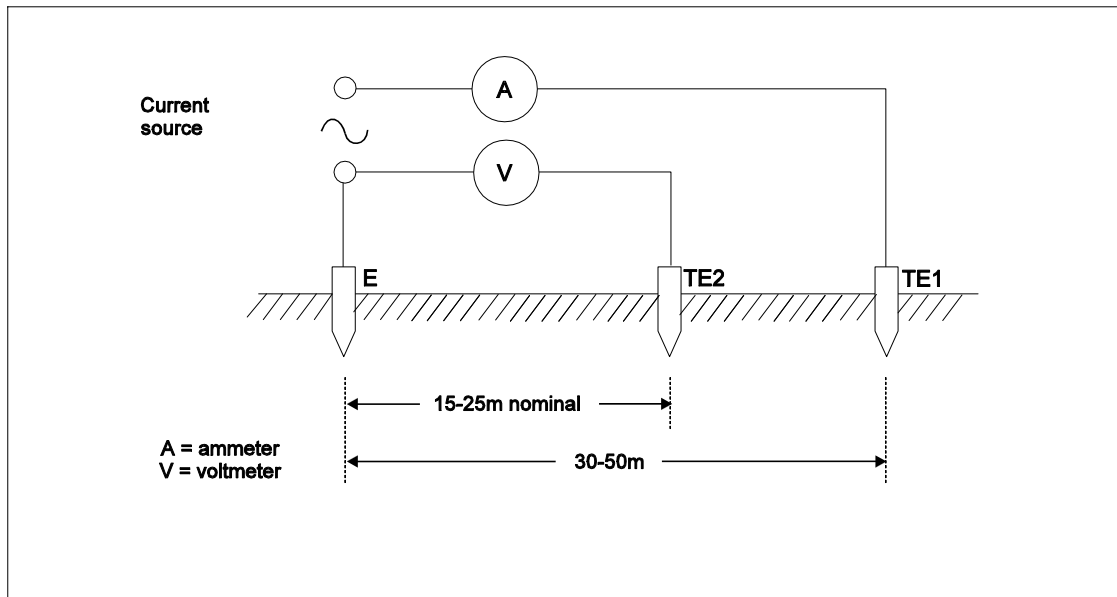


FIGURE 8

The current test electrode (TE1) should be inserted into the ground some 30 to 50 metres from the lightning earth electrode under test. Initially, the voltage electrode (TE2) should be inserted about midway between E and TE1. The earth electrode resistance should be measured and recorded. Two further readings should be taken and recorded with TE2 placed 7 metres closer to and then 7 metres further from E. If the three readings match within 5% then the position of TE1, the initial position of TE2 and the initial value obtained should be recorded for comparison with future tests. If the three results do not agree then the distance between E and TE1 should be increased and the three tests repeated. This process should be repeated until the three readings agree within the required accuracy.

If the resistance to earth of the lightning protection system exceeds 10 ohms except on rock (see 7.2.3 below), or if the resistance of an individual electrode exceeds 10 ohms multiplied by the total number of electrodes, the value should be reduced. If the resistance is less than 10 ohms but significantly higher than the previous reading, the cause should be investigated and any necessary remedial action taken.

7.2.3 Testing Earth Electrodes on Rock

Where possible, two permanent test electrodes should be provided, located in accordance with Figure 8. Earth electrode resistance measurements should be made and recorded using these test electrodes.

Where this is not possible (e.g. on a rock station) then each earth electrode should be disconnected in turn and the resistance between the isolated electrode and the rest of the system measured and recorded (see Note 1).

Note 1. It is emphasized that before disconnecting a lightning protection earth, it should be tested to ensure that it is not 'live', using a sensitive voltage testing device.

Note 2. It may be advantageous to choose a period slightly less than 12 months in order to vary the season in which the tests are made.

Note 3. The presence of buried conductors e.g. underground mains and telephone cables, gas and water pipes, radiobeacon earth mats etc. can considerably influence the results of earth electrode resistance measurements. Every effort should be made to locate these services and, wherever possible, select a measurement site away from these services.

7.3 Maintenance of Surge Arrestors

As a result of the many ways that protection devices can fail without causing a long term interruptions, many manufacturers build metal oxide varistor (MOV) protectors with failure indicators on the front which indicate which MOV has failed and which are still operational. Maintenance will be restricted to periodic visual inspection and checking of the earth connections to ensure that they have not deteriorated and that all other connections are secure.

"In circuit" resistance measurements could be carried out on other surge protectors to establish the integrity of surge arrestors but frequent checking is not advisable as faults in many instances are self revealing. There is a real chance that routine disconnection and reconnection can lead to errors with crossed wires because of the large number of surge arrestors that may be present in an installation.

7.4 Records

The following records should be kept on site or by the person responsible for the upkeep of the installation:

- i) Scale drawings showing the nature, dimensions, materials and positions of all component parts of the lightning protection system;
- ii) The nature of the soil and any special earthing arrangements;
- iii) The type and position of the earth electrodes, including reference electrodes;
- iv) The test conditions and the results obtained (see testing);
- v) Any alterations, additions or repairs to the system;
- vi) The name of the person responsible for the installation or its upkeep.

A label should be attached at the origin of the electrical installation, worded as follows:

“This installation is provided with a lightning protection system. The bonding to other services and the main equal potential bonding should be maintained accordingly.”

7.5 Maintenance

The periodic inspections and tests recommended above will show what maintenance, if any is needed. Particular attention should be given to the following:

- earthing;
- evidence of corrosion or conditions likely to lead to corrosion;
- alterations and additions to the structure which may affect the lightning protection system (e.g. changes in the use of the building, the erection of radio antennas etc.).

8 REFERENCE DOCUMENTS

Two publications of the British Standards Institution are particularly important in this context and reference will be made to them throughout the remainder of these guidelines. They are:

- British Standard 6651 : 1992, "The protection of structures against lightning";
- British Standard Code of Practice BS7430 : 1991, "Earthing".

Other documents considered:

- General Lighthouse Authorities; Development Department Report, "Guidelines for the Protection of Lighthouses and Aids to Navigation against Damage from Lightning", No. 20/RPD/1995, Trinity House Lighthouse Service, 1995
- "Lightning Protection", Australian Maritime Safety Authority (AMSA): AS-1768-1991
- "Lightning Protection", Norwegian Coastal Administration, 1997
- "Lightning Protection for Radio Transmitter Stations", Nautel Ltd., 1985
- "Lightning Protection Systems", USCG, 1995

Other relevant documents:

- IEC 61024 “Protection of Structures against Lightning”
- IEC 61312 “Protection against Lightning Electromagnetic Impulses – IT Systems”