Direct Lightning protection

Lightning conductors' range

HELITA
YOUR LIGHTNING PROTECTION
Member of ABB Group

contents

General 5

Material 37

LIGHTNING MECHANISM AND LOCATION

STORMS

The presence of unstable, moist and warm air masses gives rise to the formation of cumulo-nimbus storm clouds. This type of cloud is very extensive, both horizontally (about 10 km in diameter) and vertically (up to 15 km). Its highly characteristic shape is often compared with the profile of an anvil of which it displays the upper and lower horizontal planes. The existence of extreme temperature gradients in a cumulo-nimbus (the temperature can drop to - 65°C at the top) generates very rapid ascending air currents, and results in the electrical energisation of the water particles.

In a typical storm cloud, the upper part, consisting of ice crystals, is normally positively charged, whilst the lower part, consisting of water droplets, is negatively charged. Consequently, the lower part of the cloud causes the development of electrically opposite charges (i.e. positive over the part of the ground nearby).

Thus the cumulo-nimbus formation constitutes a sort of huge plate /ground capacitor whose median distance can often reach 1 to 2 km. The atmospheric electrical field on the ground, about 100 V/m in fine weather is reversed and can reach an absolute value of 15 to 20 kV/m when a ground discharge is imminent (the lightning stroke).

Before and during the appearance of the lightning stroke, discharges can be seen both within the cloud and between clouds.

LIGHTNING

According to the direction in which the electrical discharge develops (downward or upward), and the polarity of the charges it develops (negative or positive), four classes of cloud-to-ground lightning stroke can be distinguished. In practice, lightning strokes of the descending and negative type are by far the most frequent: it is estimated that on plains and in our temperate zones, they account for 96% of all cloud / ground discharges.

MECHANISM OF A LIGHTNING STROKE

It is impossible to discern the individual phases of the lightning stroke by simple visual observation. This can only be done with high-performance photographic equipment.
Most lightning bolts exhibit the following phenomena: a leader leaves a point in the cloud and travels about 50 m at a very high speed of around 50,000 km/s.

A second leader then leaves the same point, follows the previous path at comparable speed, goes beyond the final point of the first leader by an approximately identical distance, then disappears in turn.

There is a brief pause between the leaders, resulting in an average weighted speed (see fig. 1 page 6).

The process is repeated until the tip of the last leader reaches a point a few dozen metres, or even just a few metres above ground level.

The ascending jets then converge, producing a return stroke from the ground towards the cloud (the upward streamer) during which the electric current circulates: The convergence of these two phenomena produces the main discharge, which may be followed by a series of secondary discharges, passing unbroken along the channel ionised by the main discharge.

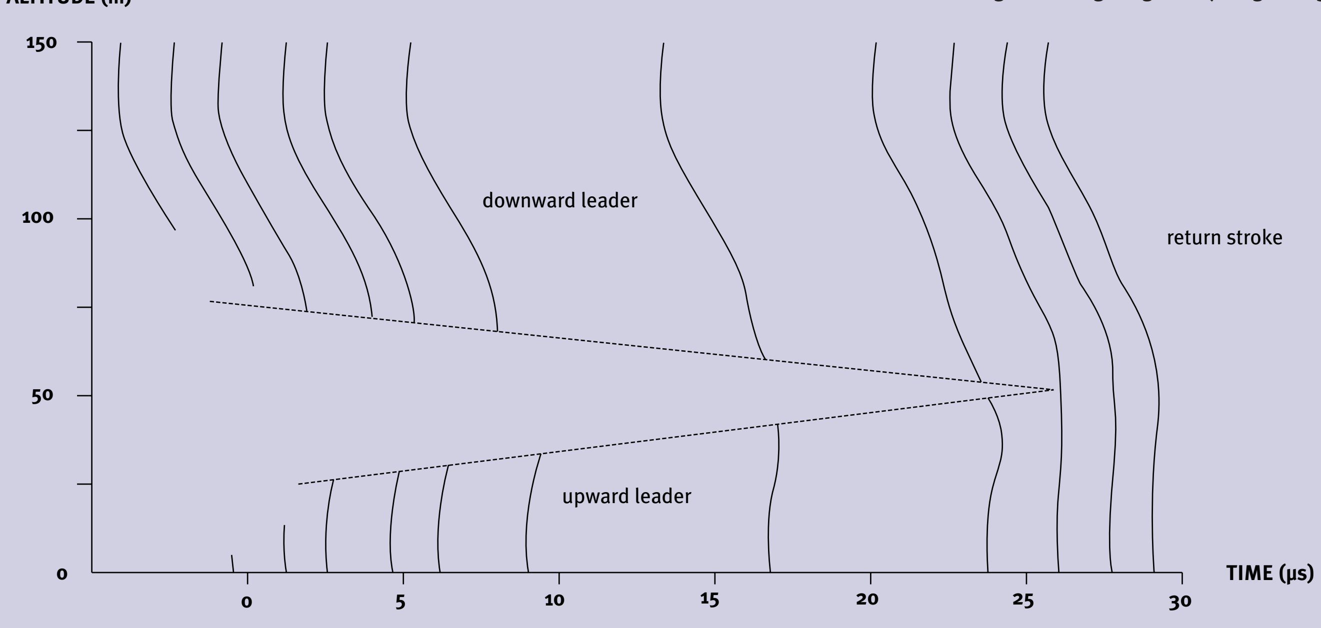
In an average negative lightning stroke, the maximum current is around 35,000 amperes.

THE EFFECTS OF LIGHTNING

The effects of lightning are those of a high-strength impulse current that propagates initially in a gaseous environment (the atmosphere), and then in a solid, more or less conductive medium (the ground):

- **visual effects (flash):** caused by the Townsend avalanche mechanism;
- **acoustic effects:** caused by the propagation of a shock wave (rise in pressure) originating in the discharge path; this effect is perceptible up to a range of around 10 kilometers;
- **thermal effect:** heat generated by the Joule effect in the ionised channel;
- **electrodynamic effects:** these are the mechanical forces applied to the conductors placed in a magnetic field created by the high voltage circulation. They may result in deformations;
- **electrochemical effects:** these relatively minor effects are conveyed in the form of electrolytic decomposition through the application of Faraday's law;
- **induction effects:** in a variable electromagnetic field, every conductor harnesses induced current;
- **effects on a living being (human or animal):** the passage of a transient current of a certain r.m.s value is sufficient to incur risks of electrocution by heart attack or respiratory failure, together with the risk of burns.

Fig. 1: Timing diagram of a lightning stroke



Lightning causes two major types of accidents:

- Accidents caused by a direct stroke when the lightning strikes a building or a specific zone. This can cause considerable damage, usually by fire. Protection against this danger is provided by lightning conductor systems.
- Accidents caused indirectly, as when the lightning strikes or causes power surges in power cables or transmission links. Hence the need to protect the equipment at risk against the surge voltage and indirect currents generated.

I- PROTECTION AGAINST DIRECT LIGHTNING STROKE

To protect a structure against direct lightning strokes, a preferred impact point is selected to protect the surrounding structure and conduct the flow of the electric current towards the ground, with minimal impedance on the path followed by the lightning.Four types of protection systems meet these requirements.

Protection systems	French standards
Early Streamer Emission lightning conductors	NF C 17-102
Simple rod lightning conductors	NF C 17-100
Meshed cages	NF C 17-100
Stretched wires	NF C 17-100

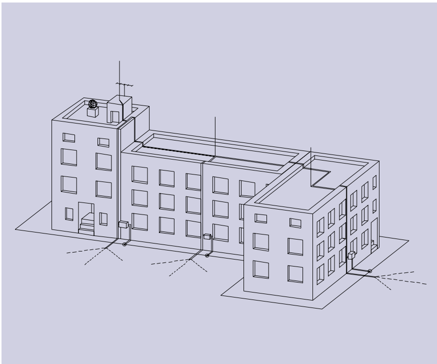
I-1 / Simple rod lightning conductors

By protruding upwards from the building, they are likely to trigger the release of ascending streamers and thus be selected as impact points by lightning strokes occurring within the vicinity of the structure.

This type of protection is especially recommended for radio stations and antenna masts when the area requiring protection is relatively small.

A simple rod lightning conductor is made up of:

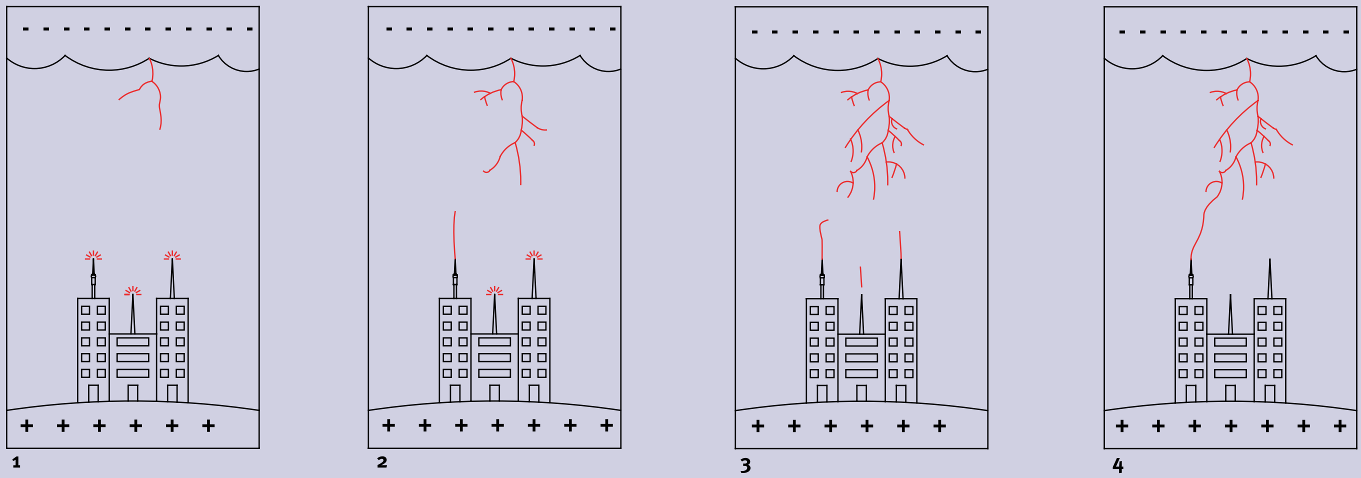
- a rod lightning conductor and its extension mast
- one or two down conductors,
- a connection link or test coupling on each down conductor to check the conductor earth resistance,
- a protecting flat to protect the down conductor for the last two meters above ground level,
- an equipotential bonding between each earth and the general earthing circuit of the structure; this can be disconnected.



I-2 / Early streamer emission (ESE) lightning conductors

These state-of-the-art technologies have been designed on the basis of a series of patents registered jointly by HELITA and the French National Scientific Research Centre (CNRS). The PULSAR is equipped with an electronic device which emits a high pulse voltage of known and controlled frequency and amplitude enabling the early formation of the upward leader which is then continuously propagated towards the downward leader.
The PULSAR draws its energy from the ambient electrical field during the storm. After capturing the lightning stroke, the PULSAR directs it towards the down conductor to the ground where it is dissipated.

Triggering time of an ESE lightning conductor



The early streamer emission concept

During a storm, when the propagation field conditions are favourable, the Pulsar first generates an upward leader. This leader from the Pulsar tip propagates towards the downward leader from the cloud at an average speed of 1m/µs.

The triggering time ΔT(µs) is defined as the mean gain at the sparkover instant (continuous propagation of the upward leader) obtained with an ESE lightning conductor compared with a simple rod lightning conductor exposed to the same conditions. ΔT is measured in the high-voltage laboratory conditions defined in Appendix C of the French standard NF C 17-102.

The triggering time instance gain ΔT is associated with a triggering time distance gain ΔL.
ΔL = v. ΔT, where:

ΔL (m): gain in lead distance or sparkover distance.

v (m/µs): average speed of the downward tracer (1m/µs).

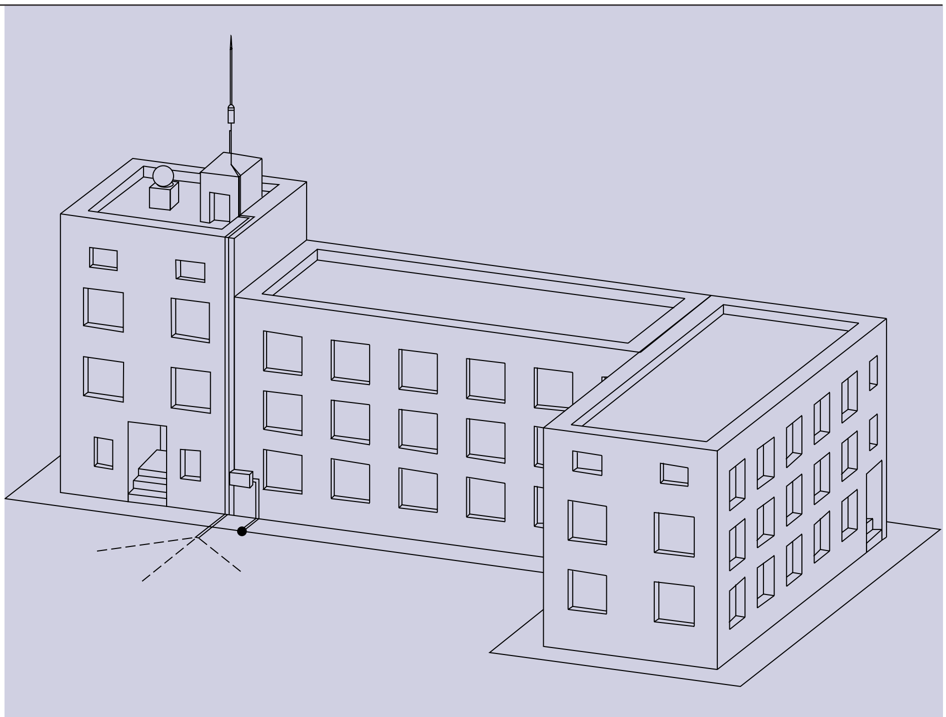
ΔT (µs): gain in sparkover time of the upward leader measured in laboratory conditions.

PULSAR conductors are especially effective for the protection of classified industrial sites, administrative or public buildings, historical monuments and open-air sites such as sports grounds.

Installation conditions

An ESE lightning conductor is made up of:

- an ESE lightning conductor and its extension mast
- one or two down conductors,
- a connecting link or test coupling for each down conductor to enabling the earth resistance to be verified,
- a protecting flat to protect the down conductor for the last two meters above ground level,
- an earth designed to dissipate the lightning currents at the bottom of each down conductor,
- an equipotential bonding between each earth and the general earthing circuit of the structure; this can be disconnected.



I-3 / Meshed cages

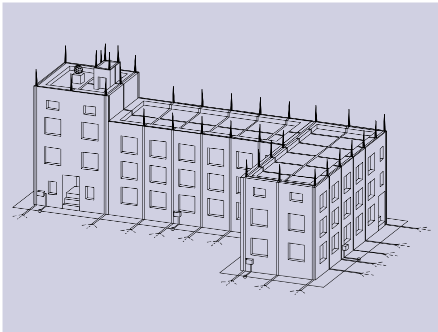
This principle consists of dividing up and more easily dissipating the lightning current by a network of conductors and earths.

A meshed cage installation has multiple down conductors and consequently provides very effective protection for buildings that house equipment sensitive to electromagnetic disturbance.

This is because the lightning current is divided among the down conductors and the low current circulating in the mesh creates very little disturbance by induction.

A meshed cage installation is made up of:

- devices to capture the atmospheric discharges consisting of strike points,
- roof ridge conductors,
- down conductors,
- earths,
- an equipotential bonding between each earth and the general earthing circuit of the structure; this can be disconnected.



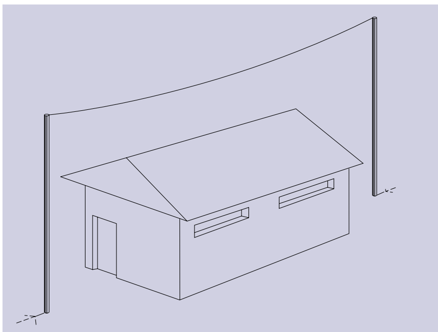
I-4 / Stretched wires

This system is composed of one or several conductor wires stretched above the protected installation. The protection area is determined by applying the electrogeometrical model.

The conductors must be earthed at each end.

A stretched wire installation requires a thorough preliminary study to consider issues such as mechanical strength, the type of installation, and the insulation distances.

This technology is used to protect ammunition depots and as a general rule in circumstances where the site cannot be protected by using a building structure to support the conductors that convey the lightning currents to the earth.



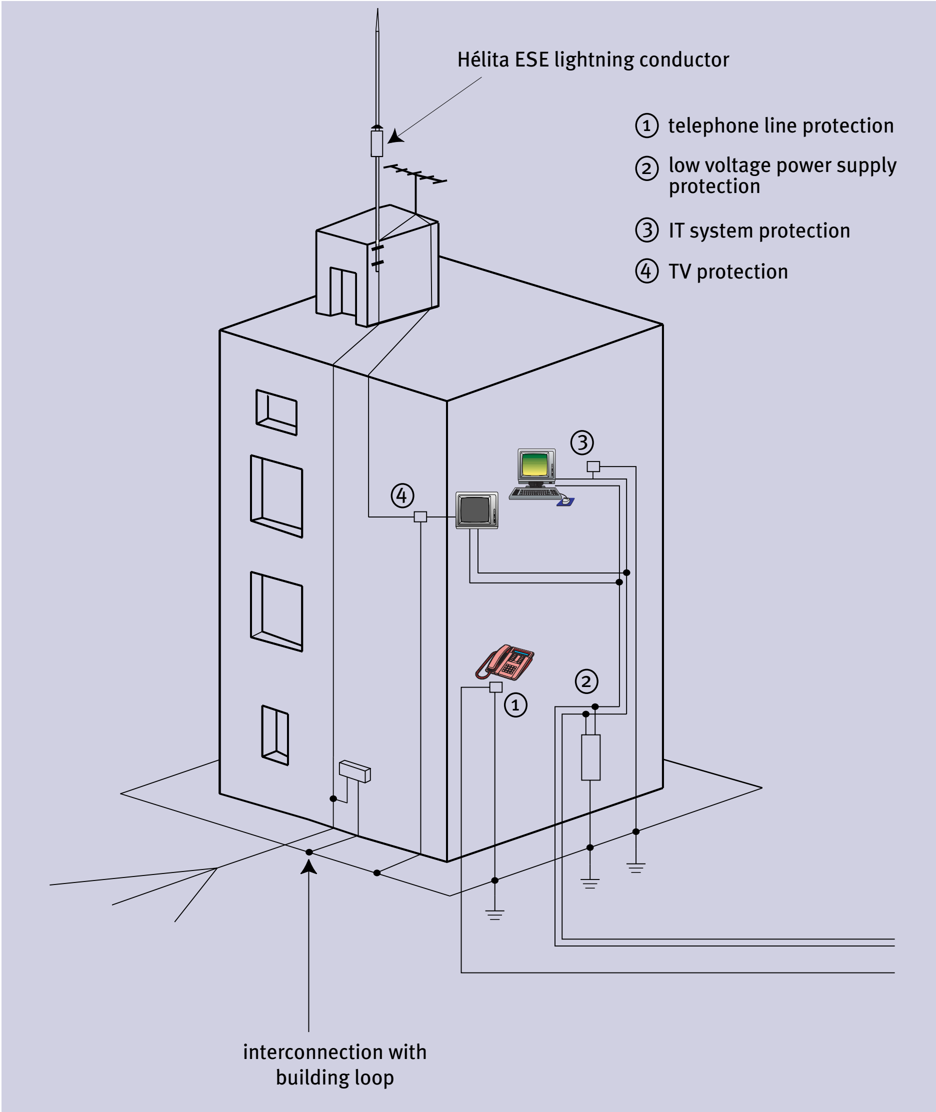
II- PROTECTION AGAINST INDIRECT LIGHTNING STROKE EFFECTS

When lightning strikes cables and transmission lines (H.F. coaxial cables, telecommunication lines, power cables), a voltage surge is propagated and may reach equipment in the surrounding. This voltage surge can also be generated by induction due to the electromagnetic radiation of the lightning flash.

This can have many consequences: premature component ageing, destruction of printed circuit boards or component plating, equipment failure, data loss, programs hanging, line damage, etc.

This is why you need to use surge arresters to protect equipment liable to be affected by lightning strikes.

The use of surge arresters is recommended when there is at least one lightning conductor on the building. 65 kA calibration is then recommended.



III- EQUIPOTENTIAL BONDING DEFECTS

During a lightning stroke or even as a result of indirect effects, equipotential bonding defects can, by differences in potential, generate sparkover causing particularly destructive interference currents.

This is why it is an essential part of effective lightning protection to ensure that a site's equipotential bonding is effective and in good condition.

The same applies to interconnections between metal earthing networks close to sensitive equipment (telephone exchanges or CPUs).

The French NF C 17-100 and NF C 17-102 standards recommend a preliminary study in three parts:

- lightning risk evaluation
- protection level selection,
- protection device definition.

LIGHTNING RISK EVALUATION

The following method is used for risk evaluation:

1 - Expected frequency Nd of direct lightning strikes on a structure

The yearly average frequency Nd of direct lightning to a structure is assessed by the following equation:

Nd = Ng max. Ae.C1 10-6/year where:

Ng max. = 2 Ng

Ng: mean annual lightning flash density in the region where the structure is located (number of lightning strikes/year/km2) which can be determined by:

- consulting the map overleaf (Ng),
- using the isokeraunic level Nk:
  Ng max =0.04 Nk 1.25, i.e. around Nk/10

Ae: is the equivalent collection area of the isolated structure (in m^2). It is defined as the ground area having the same annual direct lightning strike probability as the structure.

The calculation formulae are defined in Appendix B of the NFC 17-100 and NF C 17-102 standards.

C1: environmental coefficient (defined in table B2 of the NF C 17-102 standard).

2 - Tolerable frequency Nc of lightning strikes to the structure

The tolerable frequency is assessed using the following equation:

Nc = 5,5. 103 / C2 x C3 x C4 x C5

where C2 represents the construction type,
C3 represents the structure contents,
C4 represents the structure occupancy,
C5 represents the consequences of a lightning strike.

The coefficients are defined in tables B5 to B8 of the NF C 17-102 standard.

PROTECTION LEVEL SELECTION

The values Nc and Nd are compared.

If Nd ≤ Nc, the lightning protection system is not a mandatory requirement.

If Nd > Nc, a protection system offering E ≥ 1 -Nc /Nd level of efficiency should be installed.

Calculated efficiency	Corresponding level of protection NFC 17-100 December 1997	Corresponding level of protection NFC 17-102 July 1995
E < 0,98	Level 1 + additional measures	Level 1 + additional measures
0,95 < E < 0,98	Level 1	Level 1
0,90 < E < 0,95	Level 2	Level 2
0,80 < E < 0,90	Level 3	Level 2
0 < E < 0,80	Level 4	Level 3

The protection level determines the protection radius of the lightning conductor, the safety distance (earth interconnection) and the maintenance period.

If necessary, additional protection measures aimed at limiting the step voltage, fire propagation or induced surge voltage effect can be deployed.

PROTECTION DEVICE DEFINITION

It is advisable to take into account the technical and architectural constraints when configuring the different components of the protection device.

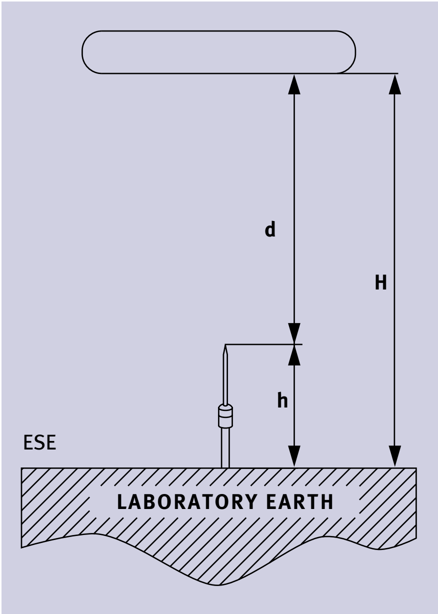
To facilitate your preliminary studies, Hélita will provide a questionnaire in which the minimum required information can be entered, and a calculation software package.

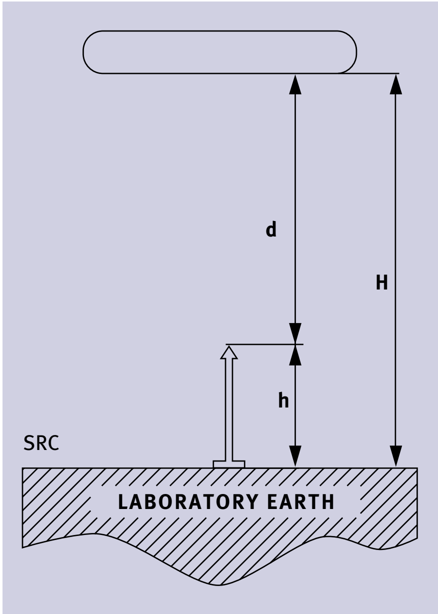
PROCEDURE FOR EVALUATING THE EFFICIENCY OF AN ESE LIGHTNING CONDUCTOR ACCORDING TO STANDARD NC F C 17-102 - APPENDIX C

This test procedure consists in evaluating the triggering time of an early streamer emission (ESE) lightning conductor compared with a simple rod lightning conductor (SRC) in high voltage laboratory conditions. 100 shocks are applied to the Pulsar in the first configuration, then to the simple rod conductor in the second configuration.

SIMULATION OF NATURAL CONDITIONS

Natural conditions can be simulated in a laboratory by superimposing a permanent field and an impulse field associated with a plate / ground platform area (H). The tested lightning conductor is placed on the ground, beneath the centre of this platform. In the experiment, the height H = 6 m, and the lightning conductor height h = 1.5 m.





ELECTRICAL CONDITIONS

The permanent field caused by the charge distribution in the cloud is represented by a DC voltage of 15 to 20 kv/m (simulating a field of around 15 to 20 kV/m) applied to the upper plate.

The impulse field caused by the approach of the downward leader is simulated with a negative polarity wave applied to the platform. The rise time of the wave Tm is 650 µs. The wave gradient, at the significant points is around 10^9 V/m/s.

IREQ Laboratory (Canada - 2000)

GEOMETRICAL CONDITIONS

The volume used for the experiment must be large enough to allow the ascending discharge to develop freely:

- distance d between upper platform and tip ≥ 2 m,
- upper plate diameter ≥ distance from upper plate to ground

The lightning conductors are tested in sequence in strictly identical geometrical conditions: same height, same location, same distance between tip and upper platform.

CHAPTER 4

PROCEDURE FOR EVALUATING THE EFFICIENCY OF AN ESE LIGHTNING CONDUCTOR ACCORDING TO STANDARD NC F C 17-102 - APPENDIX C

ESE LIGHTNING CONDUCTOR TRIGGERING TIME CALCULATION

General conditions

- Number of shocks: around 100 per configuration (sufficient for an accurate analysis of the leader /Leader transition).
- Interval between shocks: the same for each configuration.

Recording

- Triggering time (TB): obtained directly by reading the data from the diagnostic equipment. This data is not characteristic, but it does enable a simple reading to establish whether or not a shock can yield a valid result.
- Light emitted by the leader at the lightning conductor tip (photomultipliers): this data provides a very accurate detection of the leader continuous propagation instant.
- Pre-discharge current (coaxial shunt): the resulting curves confirm the previous diagnostic data.
- Space-time development of the discharge (image converter): the image converter pictures provide a further means of analysing the results.

Other recordings or measurements

- Short-circuit current (coaxial shunt).
- Time/voltage characteristics for several shocks.
- Rod to plate distance before and after each configuration.
- Climatic parameters: pressure, temperature, absolute humidity.

Triggering time of a simple rod lightning conductor

Triggering time of An ESE lightning conductor

ΔT CALCULATION

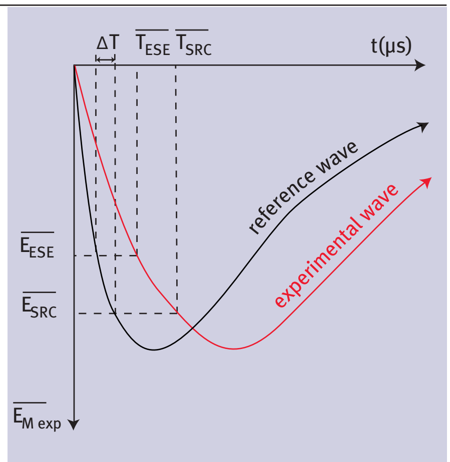
The triggering time instants, or continuous propagation instants of the upward leader are obtained by analysing the diagnostic data described above. The mean is then calculated for each lightning conductor tested, and the difference between the mean values is the ESE lightning conductor triggering time.

$$\Delta T = \overline{T}_{PTS} - \overline{T}_{PDA}$$

Hélita has unique know-how and experience in this field.

Hélita has generated more than 40,000 sparks using this test procedure in the following high voltage laboratories:

- Bazet VHV Laboratory - **SEDIVER** (France)
- Volta HV Laboratory - **MERLIN GERIN** (France)
- L.G.E.Les Renardières - **ELECTRICITE DE FRANCE**
- Bagnères de Bigorre HV Laboratory - **LEHTM** (France)
- Varennes **IREQ** Laboratory (Canada)
- **WHVI - WUHAN** (China)



IN SITU TESTS

OBJECTIVES

HELITA has been investing for many years in research into lightning conductor protection devices, and is constantly striving to enhance the performance of its products.

HELITA's ongoing in situ research in France and abroad has three main objectives:

- to enhance the protection models,
- to measure in situ the effectiveness of ESE conductors, already evaluated in laboratory conditions,
- to qualify the dimensioning of the equipment in real-life lightning strike conditions.

NATURAL LIGHTNING EXPERIMENTAL SITE

- **Located in the Hautes-Pyrénées department of France**
- **Keraunic level: 30 days of storms per annum**

Purpose of the experiments:

- to confirm the triggering time of ESE lightning conductors compared to simple rod conductors
- to direct the flow of the lightning currents captured by the lightning conductors to low-voltage surge arresters via an appro priate earthing network.
- to test the resistance of the equipment to lightning shocks and climatological constraints.

EXPERIMENTAL ARTIFICIAL LIGHTNING TRIGGERING SITES

Because lightning is a randomly occurring natural phenomenon, artificial triggering techniques have been developed to speed up the research process.

When lightning conditions are prevalent the triggering technique consists in sending a rocket with a trailing wire in the direction of the storm clouds to cause a lightning strike at the experimental site.

The wire may comprise an insulating section in order to generate the largest possible number of lightning strikes for experimental purposes.

- **Site located at Privat d'Allier in Auvergne, France**
- **Keraunic level: 30**

Purpose of the experiments:

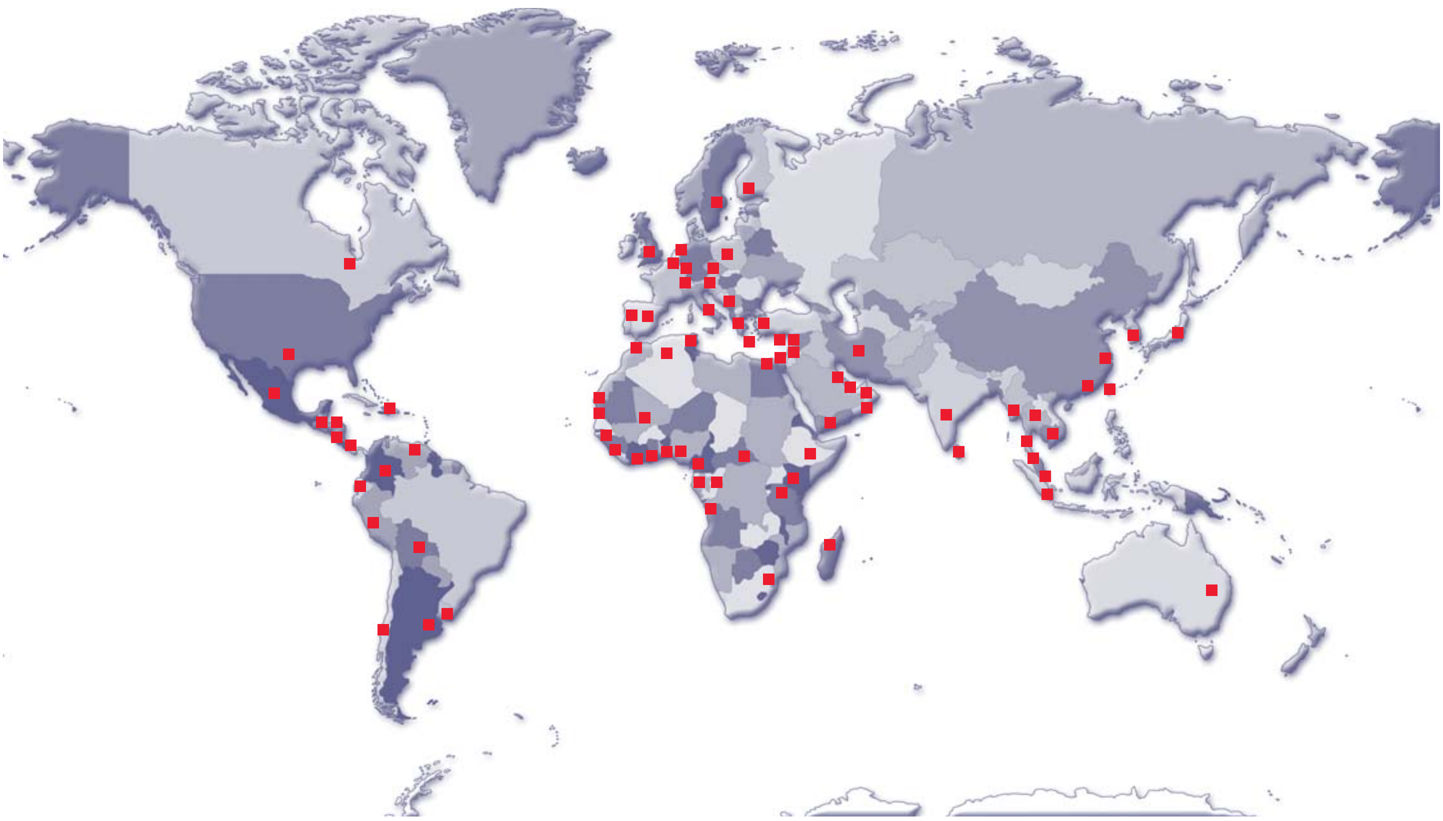
- to qualify the lightning strike counters and low-voltage arresters in situ,
- to qualify the resistance of the equipment to triggered lightning strikes.

- **Site located at Camp Blanding (Florida/USA)**
- **Keraunic level: 80**

Purpose of the experiments:

- to confirm the triggering time gain of the ESE lightning rods compared with single rod conductors,
- to collect data with a view to improving the protection models.

HÉLITA WORLDWIDE



TRAINING

Hélita provides training courses for its field technicians and for the employees of other companies.

The courses are designed to enable the evaluation of technical skills and service quality, and to develop the highest possible awareness and understanding of the range of available solutions for lightning protection.

Hélita also organises annual forums run by lightning specialists for our field technicians, and participates actively in seminars organised by our partners.

Our instructors have nationally and internationally recognised skills and experience and are also available to speak at conferences on lightning.

A SOFTWARE PACKAGE DEDICATED TO THE NF C 17-102 STANDARD

Hélita has developed a software package supplied on CD-ROM. The software runs in the PC WINDOWS 2000, 98 and 95 environments and can be used to:

- evaluate the lightning risk,
- select the appropriate protection level,
- select the protection device,
- calculate safety distances,
- compile technical descriptions and equipment parts lists: Hélita will be glad to provide this package free of charge.

A TECHNICAL SERVICE AT YOUR DISPOSAL

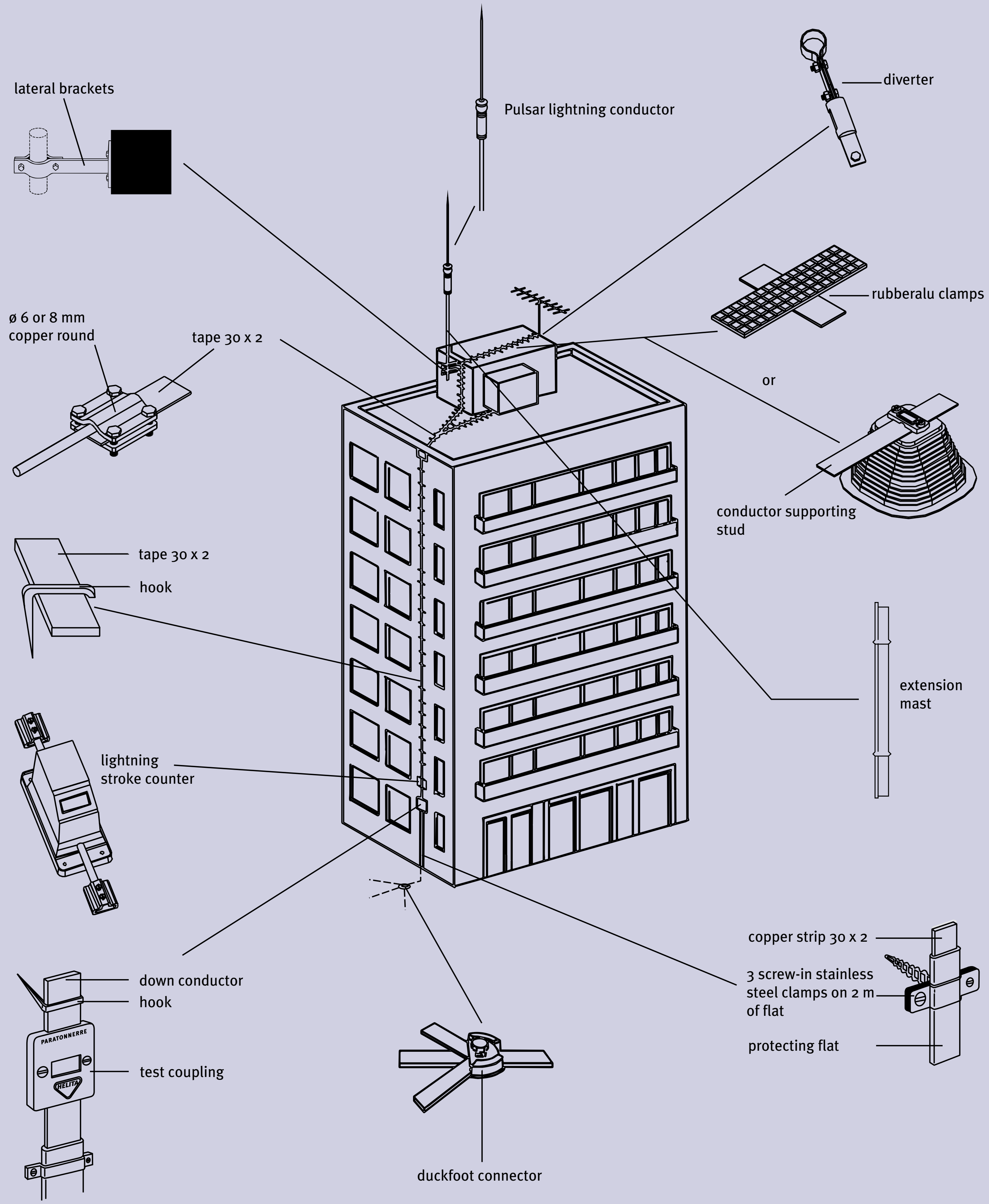
Hélita offers a free survey and design service for lightning protection. Simply send us the drawings of the structure you are seeking to protect (cutaway or side views and roof views) and we shall send you back a detailed estimate for the type of material required to protect the structure.

FIELD TECHNICIANS THROUGHOUT FRANCE AND A WORLDWIDE DEALER NETWORK

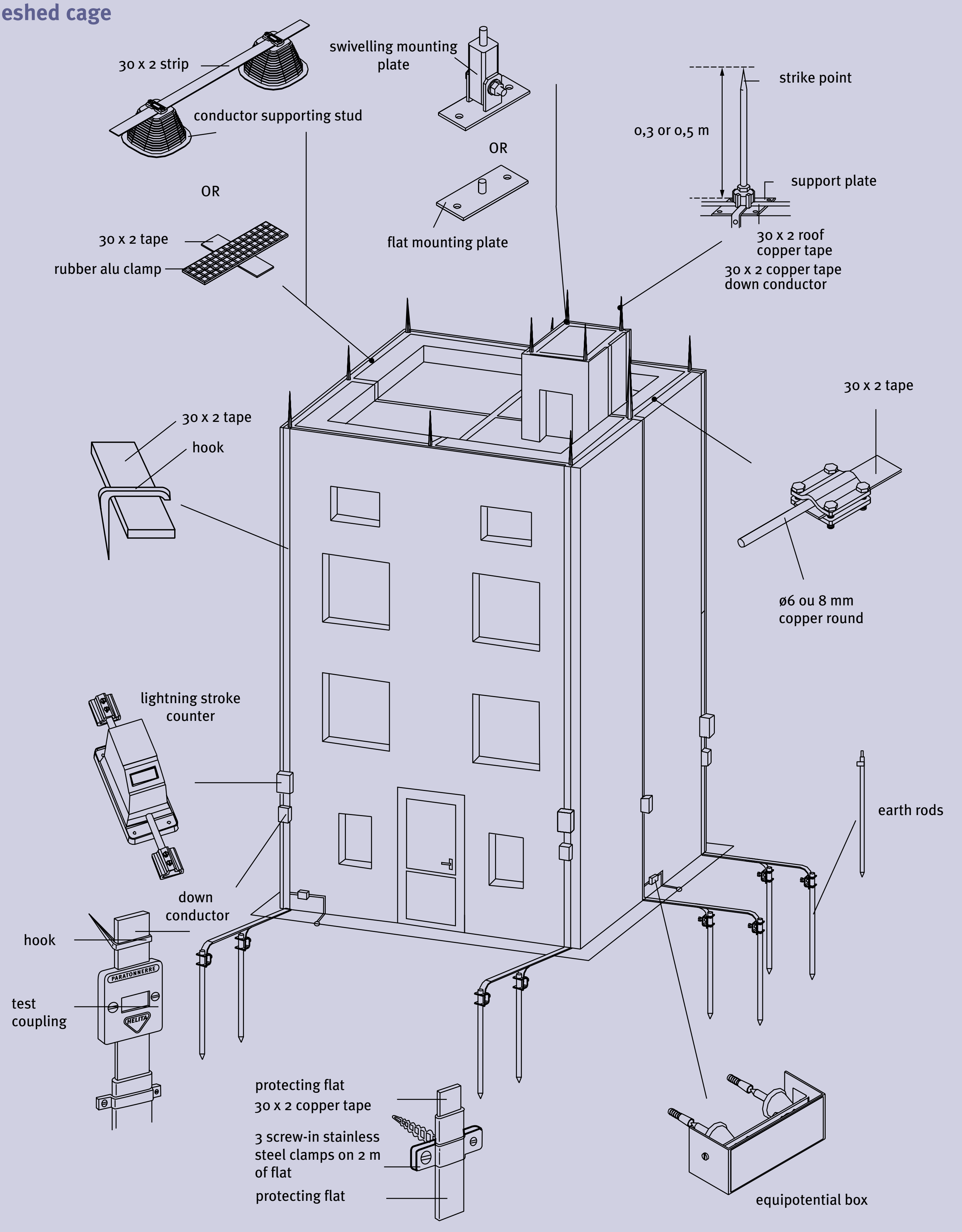
Our services are also available via our network of approved field technicians throughout France, and our sole agents in over 60 countries worldwide.

They have received full technical training and are at your service to draw up free quotations and offer you the full benefits of their experience in the field.

Early streamer emission lightning conductor



Meshed cage


30 x 2 strip
conductor supporting stud
OR
30 x 2 tape
rubber alu clamp
swivelling mounting plate
OR
flat mounting plate
strike point
0,3 or 0,5 m
support plate
30 x 2 roof copper tape
30 x 2 copper tape down conductor
30 x 2 tape
hook
30 x 2 tape
ø6 ou 8 mm copper round
lightning stroke counter
down conductor
hook
test coupling
PARATONNERRE
HELITA
earth rods
protecting flat
30 x 2 copper tape
3 screw-in stainless steel clamps on 2 m of flat
protecting flat
equipotential box

LIGHTNING CONDUCTORS

Early Streamer Emission (ESE) lightning conductors or simple rod lightning conductors (SRC)

As a general rule, the lightning conductor should culminate at least two metres above the highest points of the building(s) to be protected.

Its location should therefore be determined relative to building superstructures: chimneys, machine and equipment rooms, flagpoles, pylons or aerials. Ideally, these vulnerable points should be selected for lightning conductor installation.

The lightning conductor may be raised by an extension mast.

Hélita stainless steel interlocking extension masts can reach an overall height of 5.75 metres or 7.50 metres including the lightning conductor height. They have been specially designed to obviate the need for guying. However, if guying is essential (e.g. when the conductor is fixed with a flat support on the roof waterproofing, or is exposed to particularly strong winds), the guys should be made of Ø 5.6 fibre glass. When metal cables are used for guying, the lower anchoring points should be interconnected with the down conductor by a conductive material of the same type. Hélita offers a range of fixtures adapted to most requirements.

Installation specifications are detailed in the individual product data sheets.

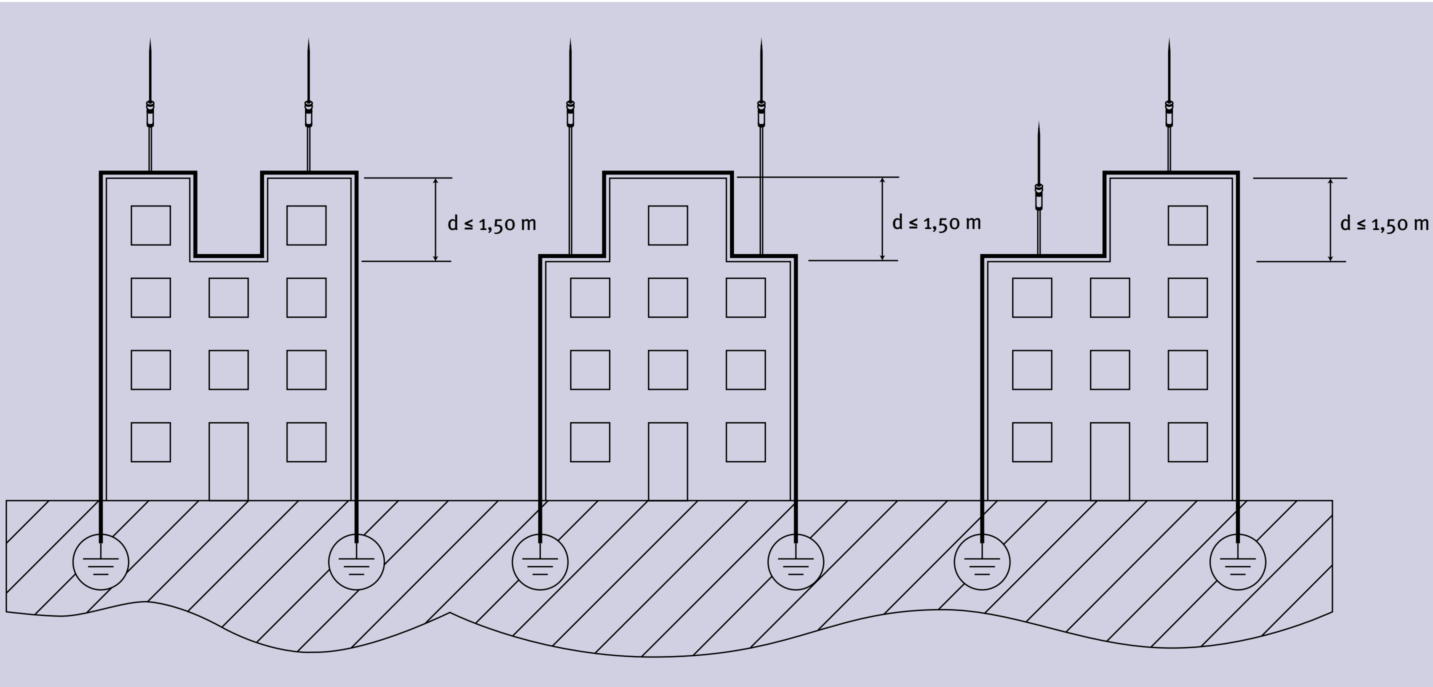
If several lightning conductors (ESE or SRC) are used in the outside installation on the same structure, they should be connected by a conductor, except when this has to pass an obstacle of more than 1.5 metres in height.

D ≤ 1.50 m : connect ESE lightning conductors

D ≥ 1.50 m : do not connect lightning conductors

When protecting open-air sites such as sports grounds, golf courses, swimming pools, and camping sites, ESE lightning conductors are installed on special supports such as lighting masts, pylons, or any other nearby structures from which the conductor can cover the area to be protected.

The software developed by Hélita can be used to produce a study with the calculated protection radius for ESE lightning conductors and evaluate the interconnection requirements.



SPECIAL CASES

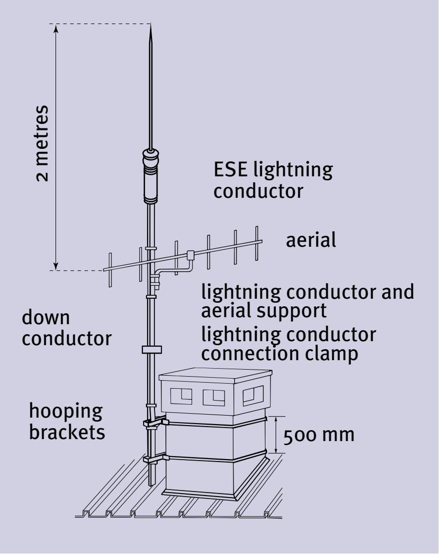
TV or transmission / reception aerials

By agreement with the user of the aerial, the device can be mounted on the aerial mast, provided that allowance is made for a number of factors notably:

- the lightning conductor tip must culminate at least 2 m above the aerial,
- the coaxial cable will be fed down through the lightning conductor mast and its supports,
- the common supporting mast will no need guying,
- the connection to the down conductor will be made using a clamp fixed to the foot of the mast.

This process, widely used today, offers three advantages:

- technical (it earths the aerial itself),
- visual (there is only one mast)
- cost.



Industrial chimney

ESE lightning conductor

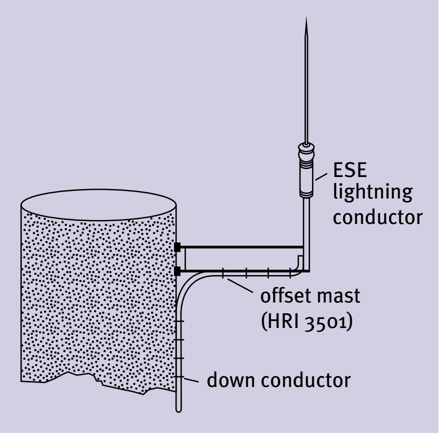
- The lightning conductor should be mounted on an HRI 3501 offset mast as far as possible from smoke and corrosive vapours.
- The mast should be fixed to 2 points as shown in the diagram.

Simple rod lightning conductor

The lightning conductors (HPF 1001 or 2001) should be mounted on HPS 2630 stainless steel supports to enable mounting at a 30° angle. They will be interconnected by a belt conductor positioned 50 cm from the summit of the chimney.

When using 1 metre strike points (HPF.1001) at least two points should be used and placed at intervals of no more than 2 m around the perimeter.

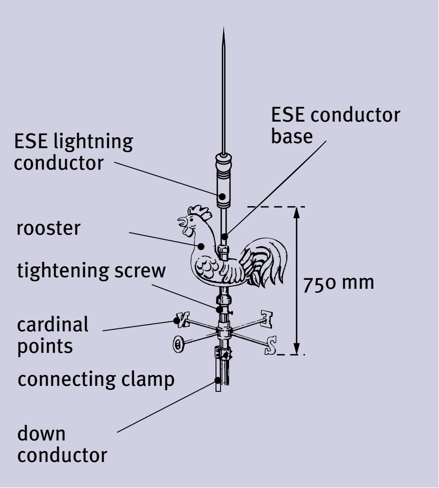
When using strike points of at least 2 meters in height, the number of points should be calculated to cover the protection radius.



Steeple

The lightning conductors have been designed to carry roof ornaments (rooster, weathervane, cardinal points, etc.) available from our catalogue.

The down conductor is then fixed below the ornaments.



MESHED CAGES

The width of roof meshes depends on the required protection level and should not exceed 15 m. The meshes should be made as follows:

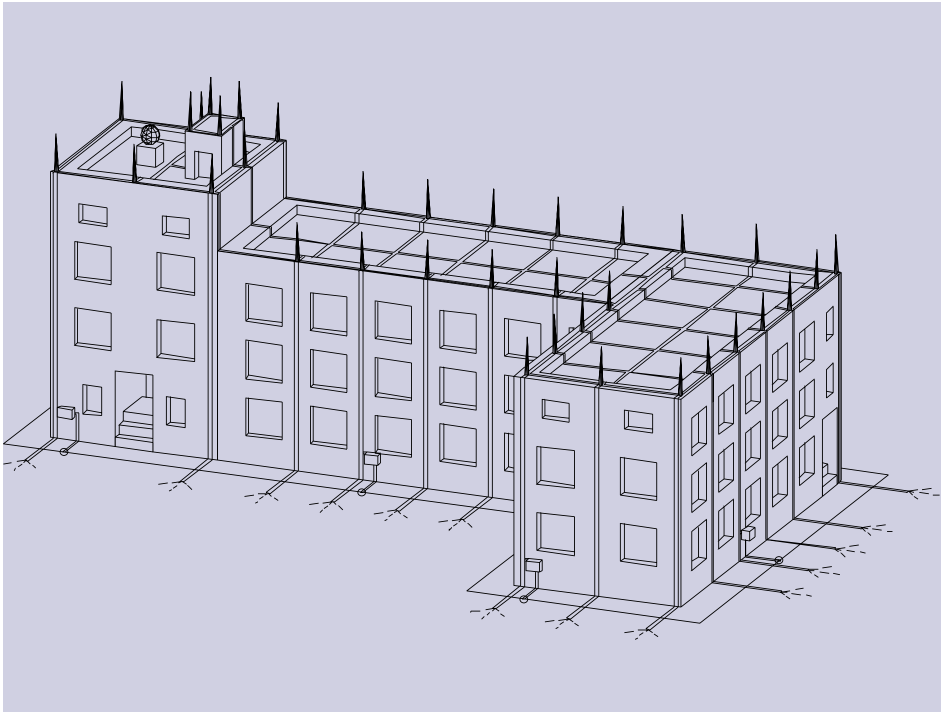
- firstly a closed polygon is formed with a perimeter close to the periphery of the roof,
- transverse sections are then added as required to achieve the required mesh density
- a conductor should be laid on any roof ridges

Air terminals are placed vertically at the highest and most vulnerable points on the buildings (roof ridges, salient points, edges, corners, etc.).

They are arranged at regular intervals around the periphery of the roof:

- the distance between two 30 cm air terminals should not exceed 10 m
- the distance between two 50 cm air terminals should not exceed 15 m
- strike air terminals not located on the outer polygon are connected to the polygon:
  - either by a conductor excluding any upturn if the air terminals is less than 5 m from the polygon
  - or by two conductors in opposite directions forming a transversal section if the air terminals is located more than 5 m from the polygon.

Protection level NF C 17-100	Mesh size
I	5 X 5
II	10 X 10
III	15 X 15
IV	20 X 20



CHAPTER 9

DOWN CONDUCTORS

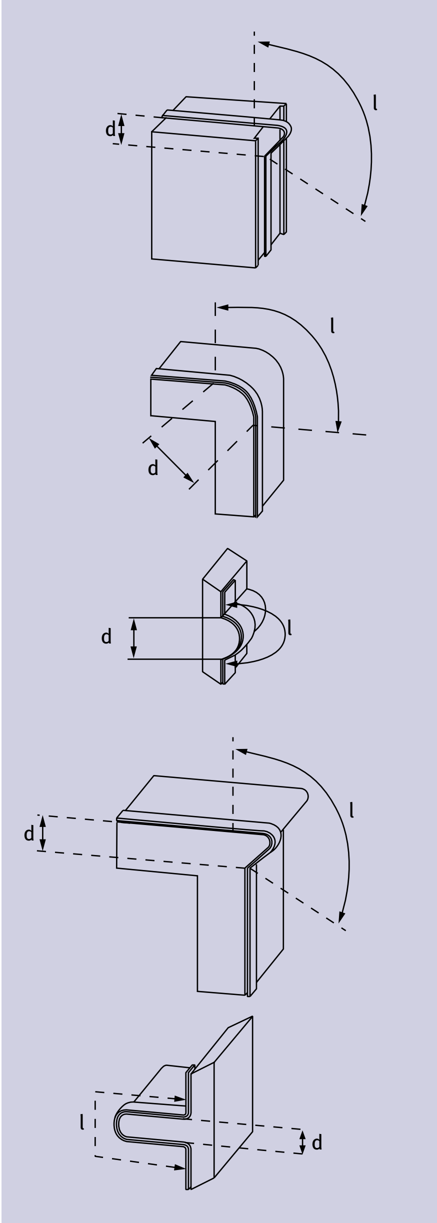
OVERVIEW

Down conductors should preferably be made with tin-plated red copper strips, 30 mm wide and 2 mm thick.

Lightning is a high frequency current that flows along the periphery of the conductors. For a like cross-section, a flat conductor has a greater periphery.

An exception to the above rule is buildings with aluminium cladding on which a copper down conductor might generate an electrolytic coupling phenomenon. Here a 30 x 3 mm aluminium strip should be used or bimetal connection.

In some cases where it is impossible to fix the copper strip, a round Ø 8 mm tin-plated copper conductor or a 30 x 3 mm flexible tin-plated copper braid should be used.



PATH

The path should be planned to take account of the location of the earth termination. The path should be as straight and short as possible avoiding any sharp bends or upturns. Curvature radii should be no less than 20 cm. To divert the down conductor laterally, 30 x 2 mm tin-plated red copper preformed bends should be used.

The down conductor path should be chosen to avoid electrical ducts and intersections. However when crossovers cannot be avoided, the conduit should be protected inside metal sheathing extending by 1 m on either side of the crossover. This sheathing should be connected to the down conductor.

However, in exceptional cases where an outside down conductor cannot be installed, the conductor may run down through a service duct, provided that this is used for no other purpose (and subject to agreement with the safety services and inspection organisations).

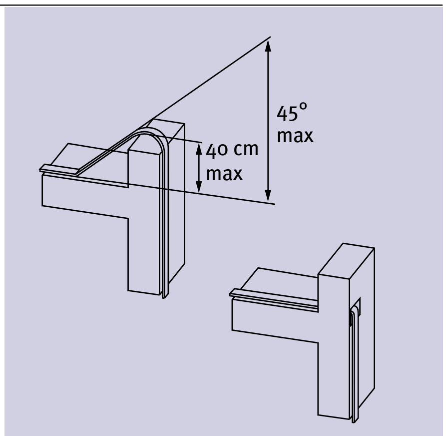
The down conductor can also be fixed on a main concrete wall located behind a curtain wall.

The conductor supports on the curtain walls should be connected to the down conductor.

PARAPET WALLS

When the face of the parapet wall is less than or equal to 40 cm, an upward section in the down conductor is allowed with a maximum slope of no more than 45°. For parapet walls with an upward section of more than 40 cm, space should be allowed or a hole drilled to accommodate a 50 mm minimum diameter sheath and thereby avoid bypassing.

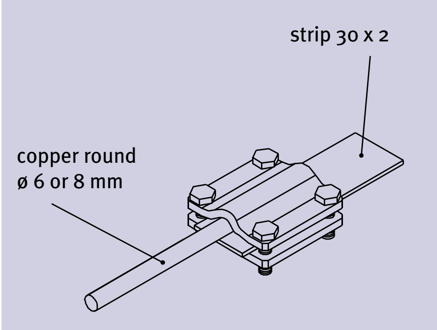
If this is not possible, supports of the same height as the wall should be installed to avoid an upturn.



CONNECTION

The lightning conductor is connected to the down conductor by a connecting clamp that must be tightly secured on to the mast.

The strip will be secured along the extension masts by stainless steel clamps. The conductors can be connected together by coupling strips.

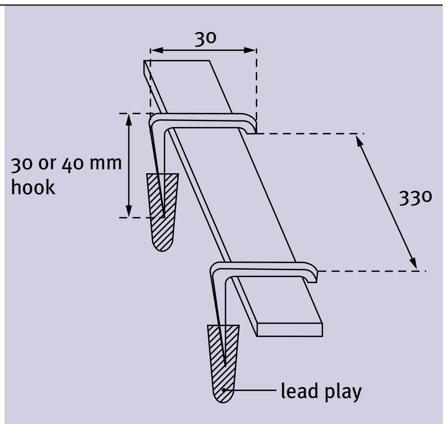


FASTENERS

Whatever the supporting medium the down conductor must be secured by at least 3 fasteners per linear metre.

Insulators are of no effect in dealing with lightning current. However, insulators are used to distance the conductors and prevent contact with easily flammable material (thatch or wood, for example).

The fastener must be appropriate for the supporting medium and installed so as not to impair watertightness and allow the conductor to expand.



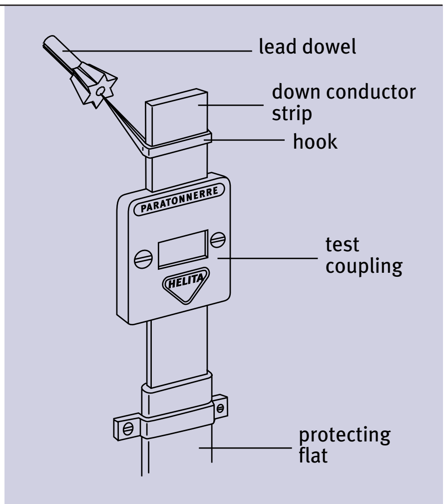
TEST COUPLING

Each down conductor must be fitted with a test coupling or connection link to enable measurement of the resistance of the earth and the electrical continuity of the down conductor.

The test coupling is usually placed about 2 m above ground level to make it accessible for inspection purposes only.

To be compliant with standards, the test coupling should be identified by the words “lightning conductor” and the “earth” symbol.

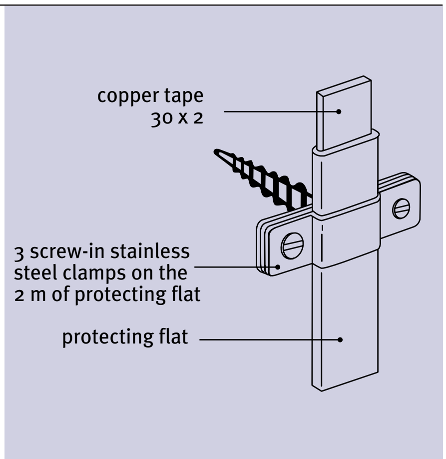
On metal pylons, framework or cladding, the test coupling should be placed on the ground in an inspection and earth pit about 1 metre from the foot of the metal wall to avoid distorting the resistance measurement of the earth connection by inevitably measuring the electrical resistance on the other metallic networks in the building.



PROTECTING FLAT

Between the test coupling and the ground, the strip is protected by a 2-meter galvanised sheet metal flat fixed by 3 clamps supplied with the flat.

It is not advisable to use steel protection flats because of the premature damage liable to be caused by the electrolytic coupling created by the steel-copper contact. The protecting flat can be bent to follow the profile of the building.

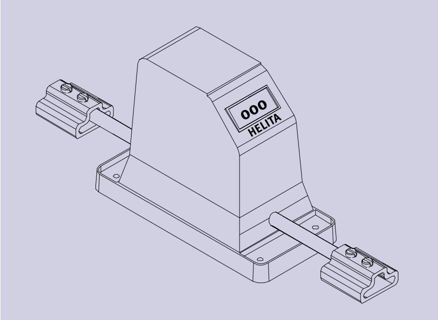


LIGHTNING STROKE COUNTER

When the regulations require the installation of a lightning stroke counter, one per lightning conductor should be installed for simple rod or ESE conductors, and 1 on every 4 down conductors in a meshed cage installation.

The lightning stroke counter should be installed above the test coupling around 2 meters above the ground.

The counter is connected as a standard fitting on the down conductor.

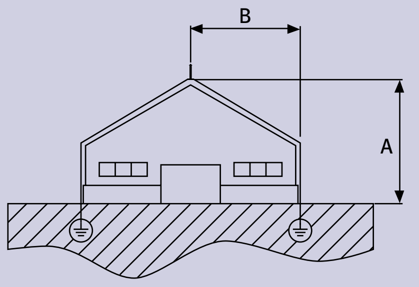


SPECIAL CONDITIONS

ESE lightning conductors

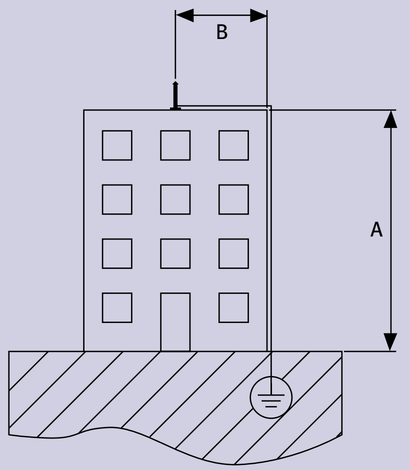
Each ESE lightning conductor is earthed by at least one down conductor. An additional down conductor located on another main wall is required in the following cases:

- when the horizontal path projection of the conductor is greater than the vertical path projection,
- when lightning protection is being installed on structures taller than 28 metres, or 40 metres in the case of industrial chimney stacks and churches.



A < B : 2 DOWN CONDUCTORS

A : vertical projection of the down conductor path
B : horizontal projection of the down conductor path



A < 28 m and A > B : 1 DOWN CONDUCTOR

Simple rod lightning conductors

Each simple rod lightning conductor is earthed by at least one down conductor.

When the down path exceeds 35 m a least two conductors are required for each simple rod conductor. These down conductors must be installed on two different main walls.

On churches, 2 down conductors are systematically installed, one of which follows the ridge of the nave.

Meshed cages

The down conductors are placed on the corners and salient features of the building in a layout that should be as symmetrical and regular as possible.

Protection level NF C 17-100	Distance between 2 down conductors
I	10 m
II	15 m
III	20 m
IV	25 m

The average distance between two adjacent down conductors depends on the required protection level.

If there is no buried interconnection between the earths, the down conductors must be interconnected at ground level.

OVERVIEW

When lightning current flows through a conductor, differences in potential appear between the conductor and nearby metallic networks (steel framework, pipes, etc.) inside or outside the building. Dangerous sparks may be produced between the two ends of the resulting open loop.

There are two ways to avoid this problem:

a) establish an interconnection providing an equipotential bond between the conductor and the metallic networks

b) allow a safety distance between the conductor and the metallic networks

The safety distance is the distance beyond which no dangerous sparks can be produced between the down conductor carrying the lightning current and nearby metallic networks.

Because it is often difficult to guarantee that the lightning protection system is sufficiently isolated during installation or will remain so in the event of structural changes, on-site work, etc., equipotential bonding is often preferred.

There are, however, some cases in which equipotential bonding is not used (e.g. when there are flammable or explosive piping networks). Here, the down conductors are routed beyond the safety distance "s".

Safety distance calculation

$$S\ (m) = \frac{n.ki.L}{km}$$

where:

"n" is a coefficient determined by the number of down conductors per ESE lightning conductor before the contact point considered:

n = 1 for one down conductor,
n = 0,6 for two down conductors,
n = 0,4 for three or more conductors

" ki " is determined by the required protection level:

ki = 0.1 for protection level 1 (high protection), for very exposed or strategic buildings

ki = 0.075 for protection level 2 (reinforced protection, exposed building)

ki = 0.05 for protection level 3 (standard protection)

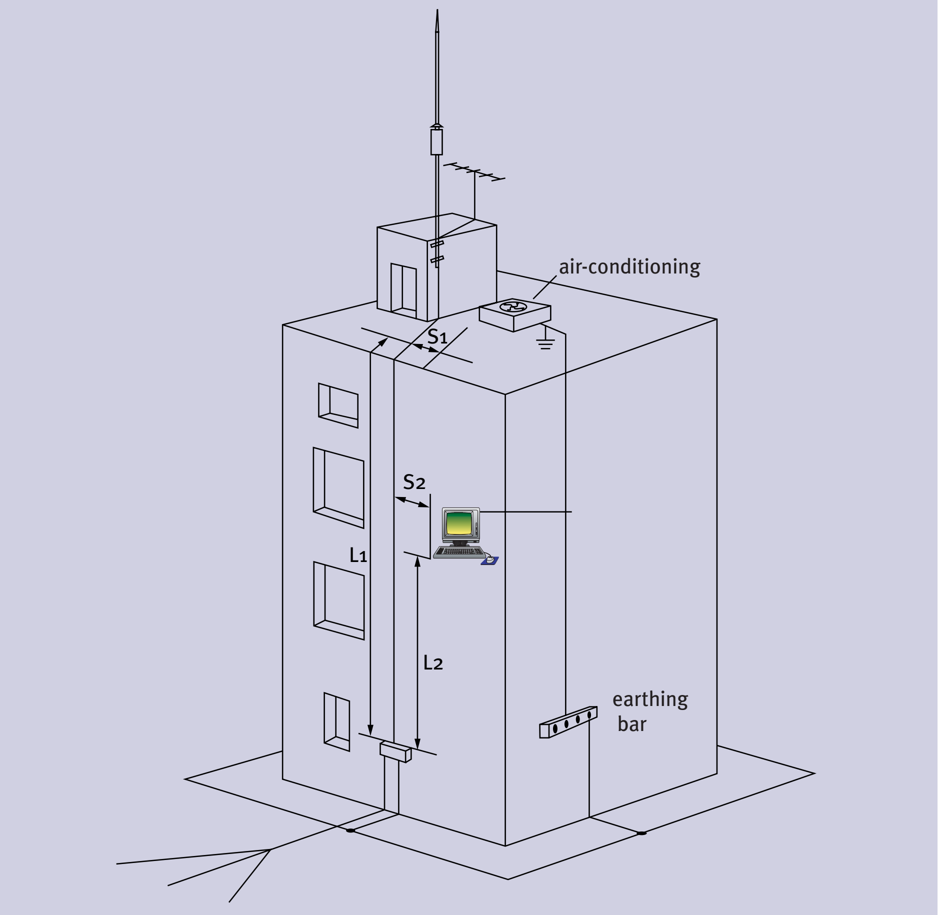
"km" is related to the material situated between the two loop ends:

km : 1 for air

km = 0.52 for a solid material other than metal

"L" is the vertical distance between the point at which proximity is measured and the point at which the metallic network is earthed or the nearest equipotential bonding point.

For gas service pipes S = 3 m.



Example: a lightning conductor with a down conductor protects a 20-meter high building with protection level I.

Question 1 : *should an air conditioning extractor located on the roof be interconnected 3 metres from the down conductor where L1 = 25 metres?*

Answer 1: $S1 = 1 \times \frac{0,1}{1} \times 25 = 2,5$ **m.**

Since the distance (3 metres) between the conductor and the air-conditioning system is greater than the safety distance (2.5 metres), there is no need to interconnect this extractor.

Question 2 : *Should the computer located in the building 3 metres from the down conductor be interconnected with the conductor, where L2 = 10 metres?*

Answer 2: $S2 = 1 \times \frac{0,1}{0,52} \times 10 = 1,92$ **m.**

Since the distance between the computer and the down conductor (3 metres) is greater than the safety distance (1.92 metres), there is no need to interconnect this computer.

The software developed by Hélita can be used to quickly calculate the safety distances.

EQUIPOTENTIAL BONDING OF EXTERNAL METALLIC NETWORKS

The equipotential bonding of external metallic networks is an integral part of the outdoor lightning protection installation just like the down conductors and their earths.

All conductive metallic networks located at a distance of less than s (safety distance) from a conductor should be connected to the conductor by a conductive material with a like cross-section.

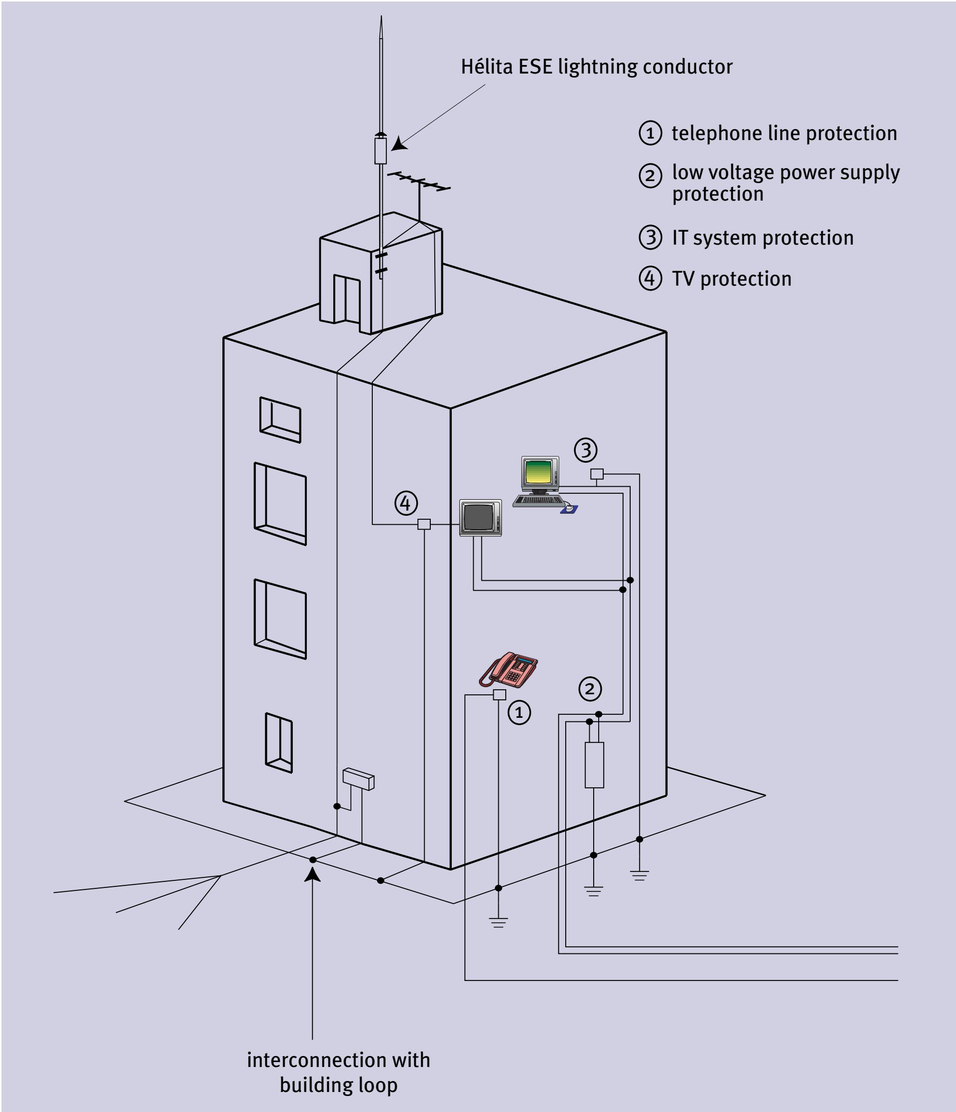
The aerial masts and small posts supporting electrical power lines should be connected to the conductor via a mast arrester. Earthing systems embedded in walls should be connected to the conductor if terminal connections have been provided.

EQUIPOTENTIAL BONDING OF INTERNAL METALLIC NETWORKS

The equipotential bonding of internal metallic networks is an integral part of the indoor lightning protection installation.

All conductive metallic networks in the structure (steel frameworks, ducts, sheathing, electrical raceways or telecommunication cable trays, etc.) should be connected to the conductor.
This is done by using a conductive material with a cross-section of at least 16 mm² for copper or 50 mm² for steel to connect to equipotential bonding bars installed inside the structure and connected in turn to the closest point of the earthing circuit.

Unscreened telecommunication or electrical conductors should be bonded to the lightning protection system via surge arresters.



EQUIPOTENTIAL BONDING OF EARTHS

See chapter on earth termination systems.

CHAPTER 11

EARTH TERMINATION SYSTEMS

OVERVIEW

Each down conductor in a lightning protection system must be connected to an earth termination system designed to carry away and disperse the lightning current.

The earth termination system must fulfil three inseparable conditions:

■ The earth termination resistance value

French and other international standards, as well as the technical requirements of a number of authorities stipulate an earth termination resistance value of less than 10 ohms.

This value should be measured on the earth connection isolated from any other conductive component.

If the resistance value of 10 ohms cannot be achieved, the earth termination is nonetheless considered compliant if it is made up of at least 100 m of conductors or electrodes, each section measuring no more than 20 m.

■ Current carrying capacity

This is an often overlooked but essential aspect of lightning conduction. To minimise the wave impedance value, a parallel configuration of three electrodes is strongly recommended instead of just one excessively long electrode.

■ Equipotential bonding

Standards require the equipotential bonding of lightning conductor earth termination systems with the existing earthing systems.

■ Inspection earth pit

The connection parts of an earth termination system (duck's foot connector, earth rod, test coupling) can be accessed in an inspection earth pit.

LIGHTNING CONDUCTORS

Duck's foot connector

The minimum earth termination system is made up of 25 meters of 30 x 2 mm tin-plated copper strip, split into 3 strands buried in 3 trenches at a depth of 60 to 80 cm dug in a fan shape like a duck's foot: one end of the longest strand is connected to the test coupling, the two other strands being linked to a special connection known as a duck foot's connector.

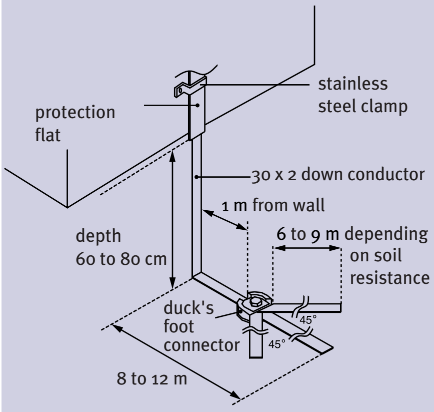
Earth rods

When the site topography does not lend itself to the installation of a duck's foot as described above, an earth termination system can be developed using at least 3 copper earth rods each with a minimum length of 2 m, buried vertically in the ground; the rods should be spaced at intervals of about 2m and at a mandatory distance of 1 m to 1.5 m from the foundations.

Combined

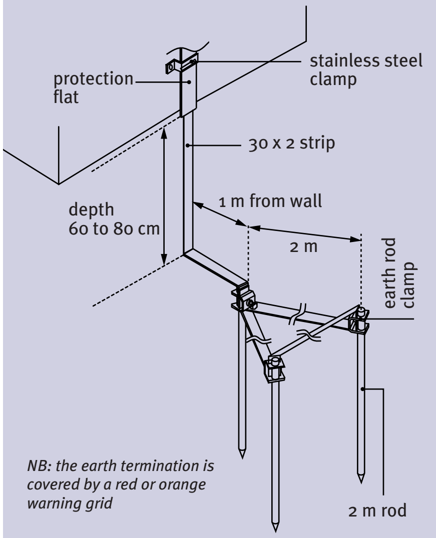
If the soil type is not altogether suitable for a duck's foot connector, a combination of duck's foot and earth rods will significantly enhance protection. In this case, the end of each duck foot connector strand is connected to an earth rod.

DUCK'S FOOT EARTH TERMINATION SYSTEM



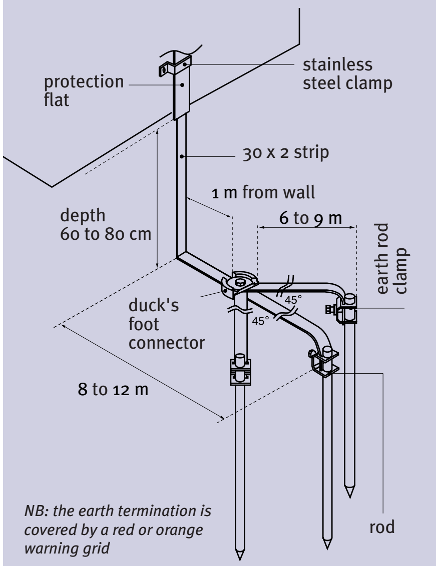
NB: the earth termination is covered by a red or orange warning grid

ROD TRIANGLE EARTH TERMINATION SYSTEM



NB: the earth termination is covered by a red or orange warning grid

DUCK'S FOOT EARTH TERMINATION SYSTEM WITH EARTH RODS



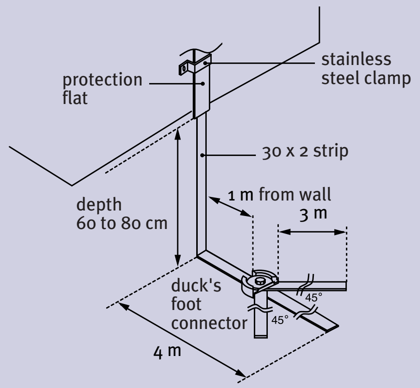
NB: the earth termination is covered by a red or orange warning grid

MESHED CAGES

Duck's foot connector

The earth connection is made up of 3 conductors each 3 m in length, buried horizontally at a depth of 60 to 80 cm. One of the strips is connected to one end of the test coupling; the other two splay out at an angle of 45° on either side of this central strand and are coupled to it with a special connector known as a duck's foot connector.

DUCK'S FOOT SYSTEM FOR A MESHED CAGE



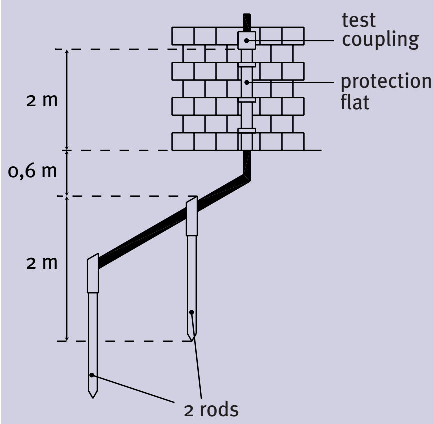
NB: the earth termination is covered by a red or orange warning grid

Earth rods

The earth connection is made up of 2 spiked vertical rods at least 2 m in length, connected to each other and to the down conductor, and at least 2 m from each other. The rods should be 1 m to 1.5 m from the foundations.

The earth termination systems in a building should be connected together with a conductor with the same cross-section and of the same type as the down conductors.

Where there is an existing entrenched earth loop in the foundations for the building's electrical installations, there is no need to create a new loop: the earth terminations can simply be interconnected by a tin-plated 30 x 2 mm copper strip.



EARTHING SYSTEM EQUIPOTENTIAL BONDING

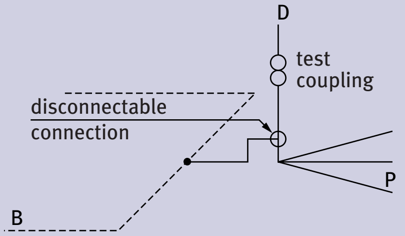
When the protected building or area has an existing earth termination system for the electrical installations, the lightning conductor earths should be connected to it.

This interconnection should be made to the earthing circuit at the closest point to the down conductor.

When this is impossible in an existing building, the interconnection should be made to the earth plate. In this case, the interconnecting conductor should be constructed such that no currents are induced in nearby equipment cables.

In all cases, the interconnection should include a device that can be disconnected to enable measurements of the resistance of the lightning conductor earth.

This device can be made up of either an equipotential connection case fixed to the main wall of the building, or an equipotential bonding bar located in an inspection earth pit.



D : down conductor of a lightning conductor
B : entrenched building loop
P : lightning conductor earth termination system

REQUIRED DISTANCE BETWEEN LIGHTNING CONDUCTOR AND BURIED UTILITIES

The NF C 17-102 and NF C 17-100 standards specify the minimum distances to be observed between the lightning conductor components and buried utilities.

Buried utilities	Minimum distances (m)	
	Ground resistivity ≤ 500 Ω.m	Ground resistivity ≥ 500 Ω.m
HV electrical conduit	0,5	0,5
Unearthed LV electrical conduit	2	5
Earth termination system / LV distribution	10	20
Metal gas pipes	2	5

These distances are applicable only to conduits that are not electrically connected to the building's main equipotential connection. There are no minimum distance requirements for non-metallic conduits.

CHAPTER

12 INSPECTION/MAINTENANCE

The current standards recommend regular, periodical inspections of the lightning protection system.

The following schedules are recommended:

	Normal periodicity	Reinforced periodicity
LEVEL I	2 YEARS	1 YEAR
LEVEL II	3 YEARS	2 YEARS
LEVEL III	3 YEARS	2 YEARS
LEVEL IV	4 YEARS	3 YEARS

In a corrosive atmosphere, the more reinforced periodicity is recommended.

A lightning protection system should also be inspected whenever the protection structure is modified, repaired or when the structure has been struck by lightning.

Lightning strikes can be recorded by a lightning strike counter installed on one of the down conductors.

ESE lightning conductor maintenance kit, a unique solution

With its experience of ESE lightning conductor development and special testing processes, Hélita offers a simple and complete solution: a telescopic 8 meter pole supplied with a portable test case to enable simple in situ inspections. The device can be used without dismantling the ESE lightning conductor.

The following aspects of the lightning conductor operation should be inspected (cf NF C 17-102 paragraph 7.2.2 & NFC 17-100 paragraph 4.2.2)

Visual inspection should be conducted to ensure that:

- no extension or modification of the protected structure necessitates the installation of additional lightning protection,
- the electrical continuity of visible conductors is good,
- all component fasteners and mechanical properties are in good condition,
- no parts have been weakened by corrosion,
- safety distances are complied with and there are sufficient equipotential bondings that are in satisfactory condition.

Measurements should be taken to verify the:

- electrical continuity of the hidden conductors,
- the earth termination system resistance values (any variation should be analysed)

The findings of each scheduled inspection should be recorded in a detailed report stating the required corrective measures.

Any faults identified in a scheduled inspection should be corrected as soon as possible in order to maintain optimal lightning protection.

An inspection of this kind should also be conducted on completion of a new lightning protection installation.

Material