LIGHTNING PROTECTION INTERNATIONAL PTY LTD

GUARDIAN PLUS Installation Manual

Comprehensive Lightning, Surge Protection & Earthing Solutions

www.lpi.com.au

GUARDIAN PLUS

System Owner: _____

Date Installed: _____

Installation Contractor: _____

Supplied by: _____

Location of Installation: _____

Lightning Protection International Pty Ltd
ABN 11 099 190 897

PO Box 379 Kingston, Tasmania, Australia 7051
Phone: +61 3 62271955
Fax: +61 3 62291900
Email: info@lpi.com.au
Web: www.lpi.com.au

Market - Leading Advantages

LPI's award-winning families of enhanced air terminals have the following key characteristics:

- First company to introduce corona minimising terminals with optimised blunt design and four independent panels;
- Extensive field experience with more than 50,000 installations over 15+ years in more than 75 countries around the world;
- Air terminal families designed to meet direct-strike placement methodologies in compliance with various international standards; and
- Proven technology based on international research findings, modelling and field testing.

AUSTRALIAN MADE

Lightning Protection International Pty Ltd

Contents

Placement Methodology (Software)

The placement of the G+ air terminal range on structures and within facilities is achieved via the Standards-compliant "leader inception theory" published in IEEE Std. 998 and other international codes. In brief, the steps required to obtain capture areas and volumes according to this method involve the computation of:

(a) Geometric factor R (induced voltage component due to the physical geometry of the problem being solved);

(b) Leader inception proximity factor (which quantifies the "suppressing influence" of the structure on which a protective air termination is installed);

(c) Space potential proximity factor (ratio of space potential at the air terminal tip position to that which would have existed in the absence of the structure); and

(d) Critical ambient electric field required to initiate and sustain the continuous upward leader.

LPI's in-house software (LITCALC) has been developed using a world-first three-stage approach to identifying areas around the structure or facility where the strike probability exceeds a minimum level and treating those areas appropriately. The computational stages implemented are:

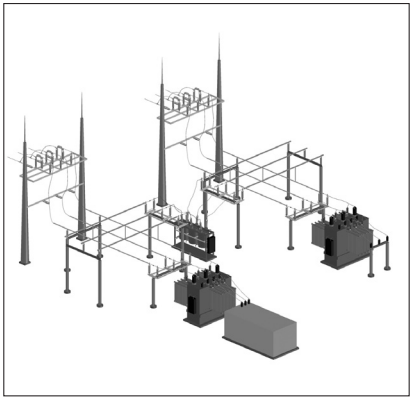
(a) Identification of likely strike points on a structure using the rolling sphere method per IEC 62305-3 for a range of stroke currents per lightning statistics as published in IEC 62305-1;

(b) Computation of the capture areas and volumes of those likely strike points on a structure in accordance with the leader inception theory published in IEEE Std. 998; and

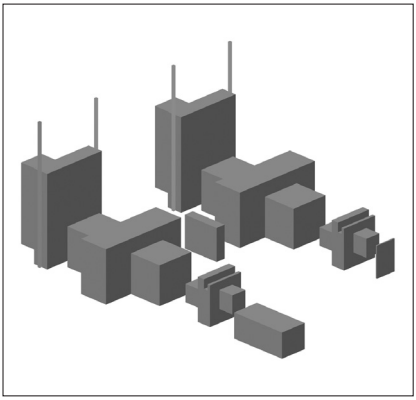
(c) Placement of air terminals on the structure at those locations and computations of the capture areas and volumes of the air terminals in accordance with the leader inception theory published in IEEE Std. 998.

(Refer to diagrams on Page 4.)

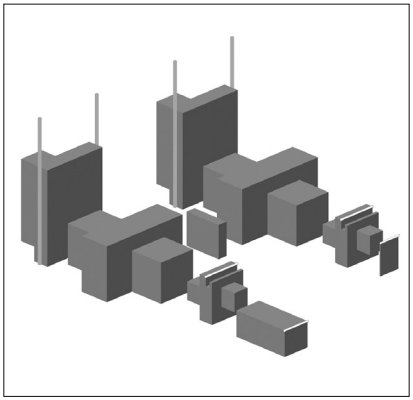
Substation Placement Methodology



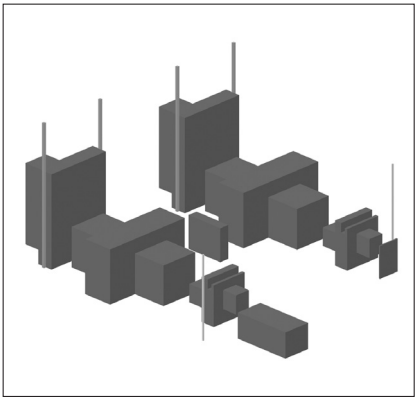
Case Study: 69 kV substation in IEEE Std. 998.



Step 1: Simplify the equipment and buses.



Step 2: Perform strike probability analysis (SPA) utilising a dynamic EGM and published lightning stroke statistics.



Step 3: Position air terminals in optimum locations based on the SPA and attractive radius calculations in accordance with LIT.

Air Terminal (Hardware)

The new Guardian Plus™ (G+) air terminal range has been developed after taking into account the latest international research into the effect of space charge and air terminal geometry, characteristics of long sparks, lightning characteristics and statistics, and the lightning attachment process itself.

The design of the G+ air terminals was based on detailed modelling and calculations geared towards achieving optimum corona performance in the quasi-static phase of a thunderstorm. Some of the key technical factors considered in the optimised design included the:

- Dome size (there are three sizes to cater for all practical installation scenarios);
- Tip radius of curvature and tip protrusion (optimised to minimise corona discharge);
- Materials (robust, long-lasting yet cost-effective options).

Furthermore, under the dynamic phase of lightning, i.e., during the descent of the downward leader, the response of the air terminal to the rapidly-escalating electric field is achieved via capacitive coupling to four independent panels on the air terminal, leading to a triggering spark that changes the spatial electric field as part of the leader initiation process.

Final optimisation of the G+ corona performance and upward leader initiation under dynamic electric fields was achieved via extensive testing at a state-of-the-art high-voltage test laboratory, namely the National Engineering Laboratory for Ultra High Voltage Technology (NELUHVT) located near Kunming in China. The NELUHVT is an outdoor facility and hence the air terminals were not only tested under different electrical conditions but also a range of environmental effects.

WARRANTY

LPI's Guardian Plus terminals (including all accessories) are guaranteed against defects in materials or workmanship for a period of 5 years from the original sales date when it was purchased from LPI or one of its authorised distributors.

The warranty is limited to the ex-factory cost of replacement of equipment providing it has been installed and/or certified by LPI or its distributor. All other costs such as freight, re-installation, loss of profit, or insurance premiums are not included.

Responsibility for other direct or indirect damages or death is also specifically excluded from the warranty.

DISCLAIMER

The LPI Guardian Plus design software LITCalc provides the end-user with a customised lightning protection design in compliance with the Leader Inception Theory included in IEEE Std. 998 and other standards.

LPI has a policy of continuing research and product improvement and hence retains the right without notice to alter future design methods or specifications in accordance with revisions of applicable standards or other validated research programs.

The range of Guardian Plus air terminals or, to our knowledge, any other lightning protection system cannot provide 100% protection and it is not inferred.

Safety Guidelines for Installation

The LPI Guardian Plus terminals should only be installed when there is no threat of a thunderstorm and lightning.

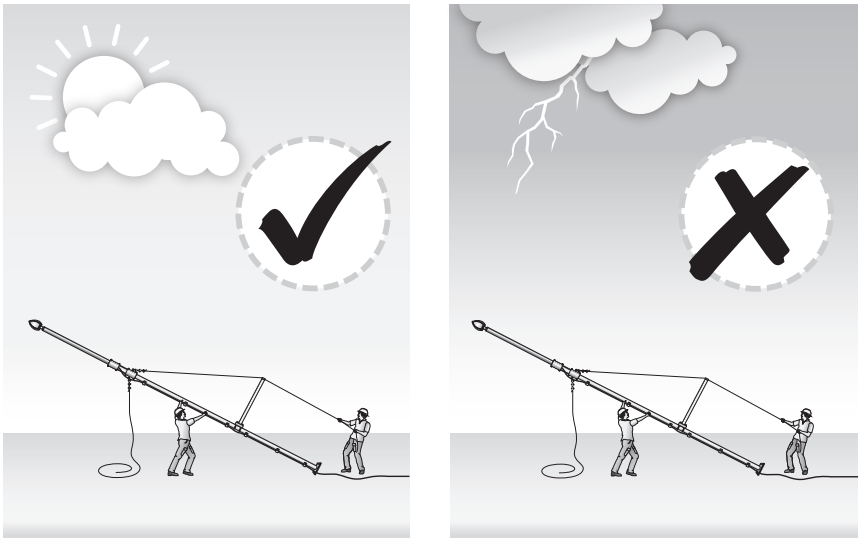


Figure 1.

Other Recommendations:

- Ensure safe working environments and practices to local codes
- Use personal protective equipment during installation
- Use mechanical methods of raising and installing masts over 6 m
- Cordon off the area below the installation point
- Check for overhead powerlines, live conductors and any other obstructions before lifting or raising
- Ensure enough personnel are used to safely conduct all aspects of the installation

Checking Lightning Protection Components Supplied

The LPI Guardian Plus components received should be checked against the "bill of materials" for loss during shipping and for damage.

Check the following:

- Air terminals have not been dented or damaged in any way during transit
- Instructions, warning labels, warranty, test certificate and relevant mast base components are supplied
- HVSC Plus cable drum (if supplied) is not damaged
- Correct HVSC Plus length(s) have been supplied
- There is no obvious damage to the HVSC Plus cable
- If a factory completed upper termination is supplied, check to see that it is not damaged and confirm inside or outside termination(s)
- Order of lengths and quantities of HVSC Plus (if multiple lengths on one drum), will be shown on the side of the cable drum(s)

LPI Guardian Plus Installation

All site and safety requirements must be followed during the installation of the LPI Guardian Plus System. The correct order of installation is as follows:

1. Installation of the lightning earth.
2. Installation of the HVSC Plus downconductor.
3. Preparation of the lower termination of the HVSC Plus downconductor and connection to the lightning earth.
4. Preparation of the upper termination of the HVSC Plus downconductor and connection to the Guardian Plus terminal.
5. Preparation and raising of the mast into position.

Notes:

- The installation must comply with all of the relevant local standards and regulations
- If the Guardian Plus terminal needs to be raised prior to connection to the lightning earth or immediate connection is not possible, then connect the lower end of the downconductor to structural steel reinforcing or another suitable earth point

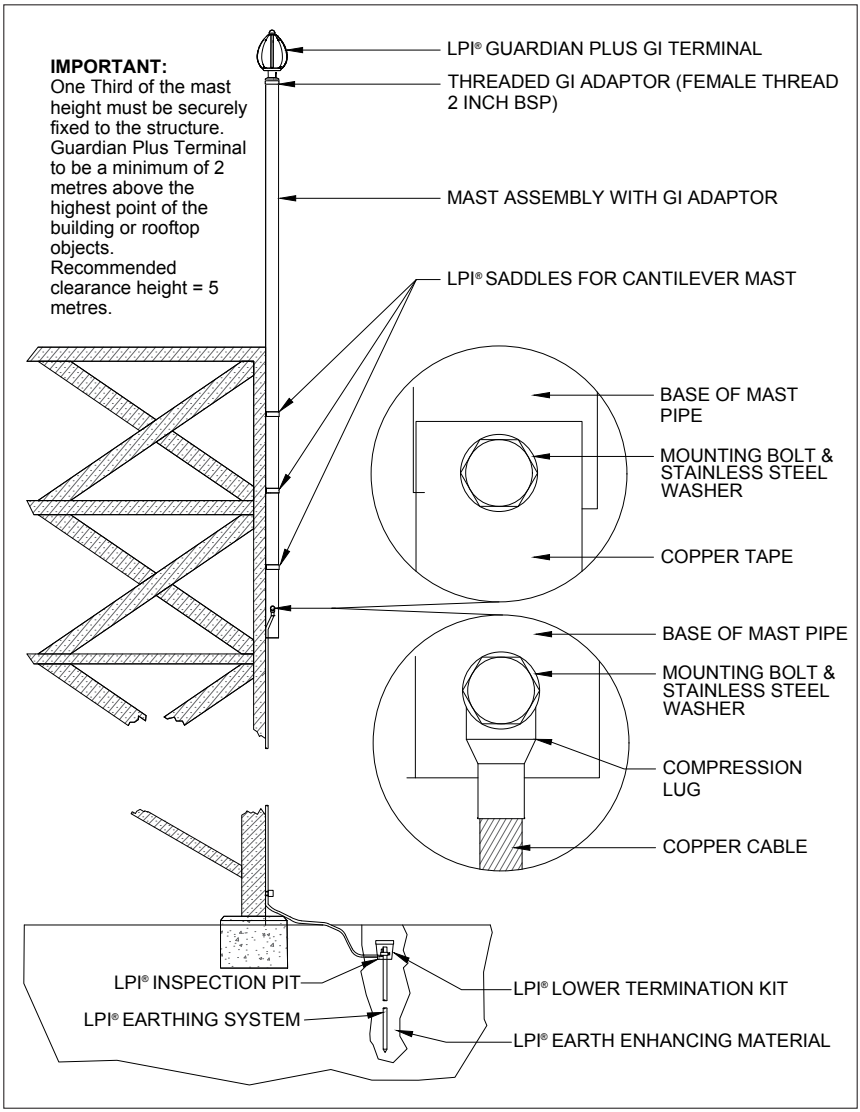

IMPORTANT:
One Third of the mast height must be securely fixed to the structure. Guardian Plus Terminal to be a minimum of 2 metres above the highest point of the building or rooftop objects. Recommended clearance height = 5 metres.
LPI® GUARDIAN PLUS GI TERMINAL
THREADED GI ADAPTOR (FEMALE THREAD 2 INCH BSP)
MAST ASSEMBLY WITH GI ADAPTOR
LPI® SADDLES FOR CANTILEVER MAST
BASE OF MAST PIPE
MOUNTING BOLT & STAINLESS STEEL WASHER
COPPER TAPE
BASE OF MAST PIPE
MOUNTING BOLT & STAINLESS STEEL WASHER
COMPRESSION LUG
COPPER CABLE
LPI® INSPECTION PIT
LPI® EARTHING SYSTEM
LPI® LOWER TERMINATION KIT
LPI® EARTH ENHANCING MATERIAL

Figure 2.

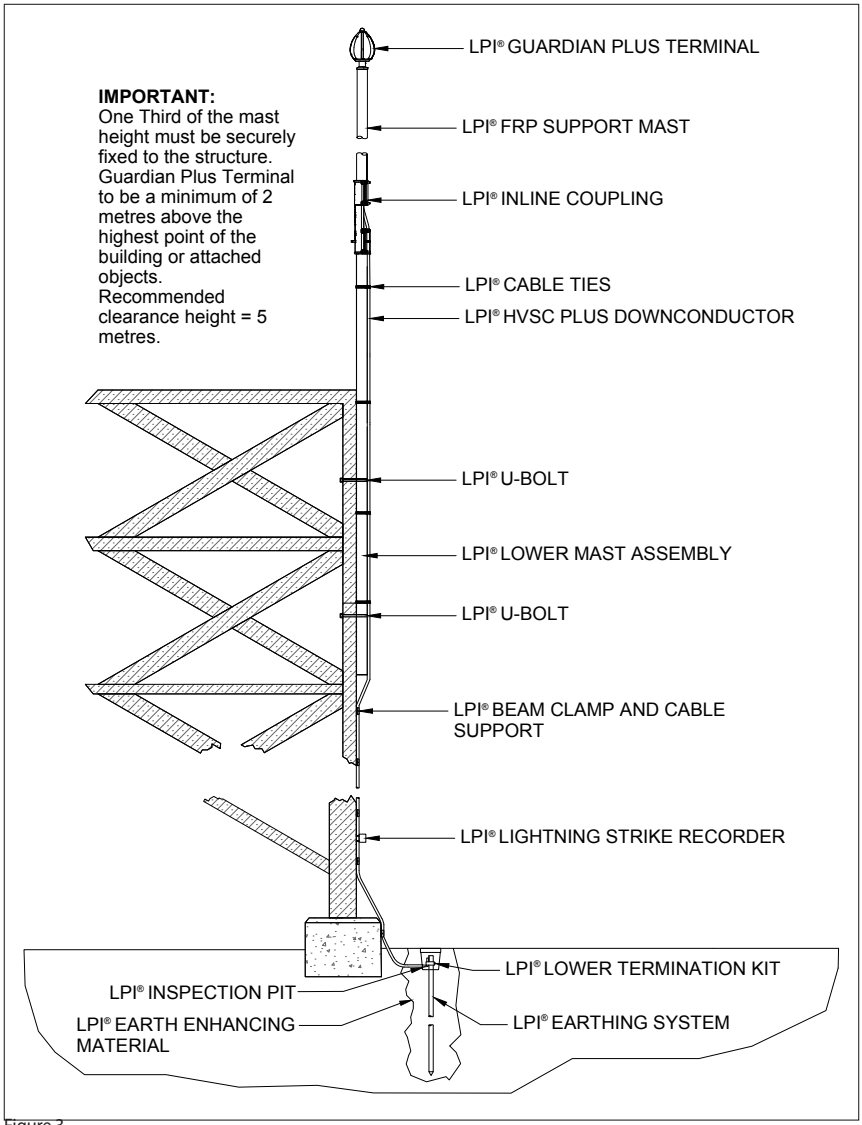

LPI® GUARDIAN PLUS TERMINAL
IMPORTANT:
One Third of the mast height must be securely fixed to the structure. Guardian Plus Terminal to be a minimum of 2 metres above the highest point of the building or attached objects. Recommended clearance height = 5 metres.
LPI® FRP SUPPORT MAST
LPI® INLINE COUPLING
LPI® CABLE TIES
LPI® HVSC PLUS DOWNCONDUCTOR
LPI® U-BOLT
LPI® LOWER MAST ASSEMBLY
LPI® U-BOLT
LPI® BEAM CLAMP AND CABLE SUPPORT
LPI® LIGHTNING STRIKE RECORDER
LPI® LOWER TERMINATION KIT
LPI® INSPECTION PIT
LPI® EARTH ENHANCING MATERIAL
LPI® EARTHING SYSTEM

Figure 3.

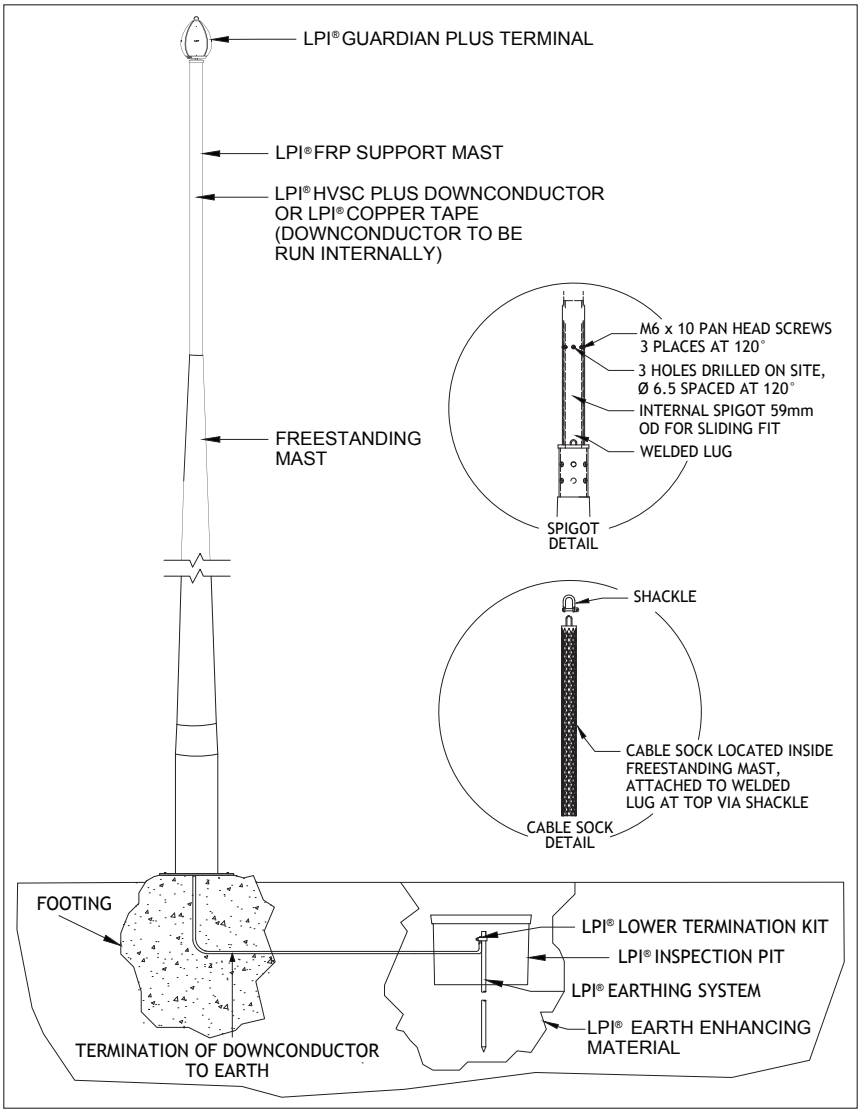

LPI® GUARDIAN PLUS TERMINAL
LPI® FRP SUPPORT MAST
LPI® HVSC PLUS DOWNCONDUCTOR OR LPI® COPPER TAPE (DOWNCONDUCTOR TO BE RUN INTERNALLY)
FREESTANDING MAST
M6 x 10 PAN HEAD SCREWS 3 PLACES AT 120°
3 HOLES DRILLED ON SITE, Ø 6.5 SPACED AT 120°
INTERNAL SPIGOT 59mm OD FOR SLIDING FIT
WELDED LUG
SPIGOT DETAIL
SHACKLE
CABLE SOCK LOCATED INSIDE FREESTANDING MAST, ATTACHED TO WELDED LUG AT TOP VIA SHACKLE
CABLE SOCK DETAIL
FOOTING
LPI® LOWER TERMINATION KIT
LPI® INSPECTION PIT
LPI® EARTHING SYSTEM
LPI® EARTH ENHANCING MATERIAL
TERMINATION OF DOWNCONDUCTOR TO EARTH

Figure 4.

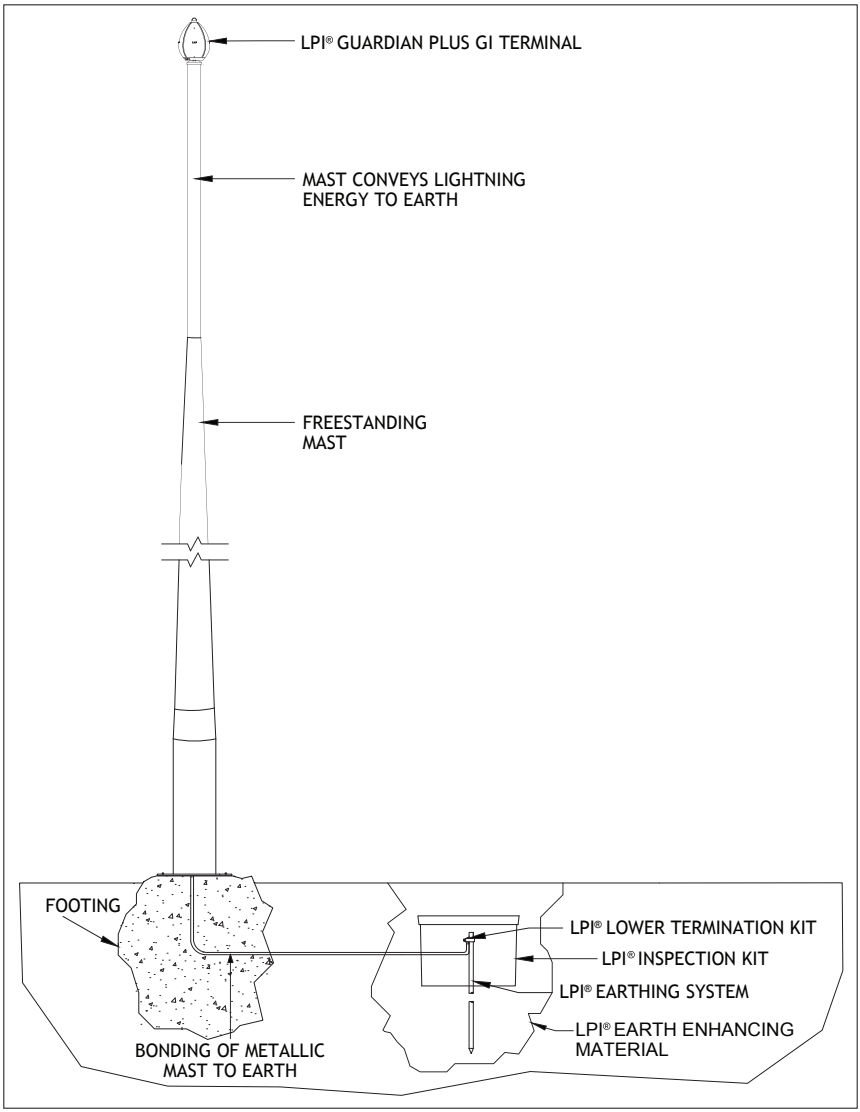

LPI® GUARDIAN PLUS GI TERMINAL
MAST CONVEYS LIGHTNING ENERGY TO EARTH
FREESTANDING MAST
FOOTING
BONDING OF METALLIC MAST TO EARTH
LPI® LOWER TERMINATION KIT
LPI® INSPECTION KIT
LPI® EARTHING SYSTEM
LPI® EARTH ENHANCING MATERIAL

Figure 5.

Installation of the Lightning Earth

Before installation of the lightning protection earth, consult site drawings of underground services so that these are not damaged during installation of the earthing system.

An earth of ≤ 10 Ω is generally required for the successful operation of LPI Guardian Plus terminal.

For standalone Guardian Plus installations, LPI recommends the installation of a radial lightning earth, as shown in Figure 6.

- The minimum earthing system comprises 3 x 10 metre radials, typically utilising 25 x 3 mm copper tape
- Each radial must be installed in a trench with approximate dimensions 500 mm (depth) x 200 mm (width)
- An earth rod should be driven at the end of each radial. The depth of the earth rod length should be tailored to the soil resistivity profile of the installation location
- The earth rod material should also be matched with the local conditions, i.e., typically copper-bonded steel, but stainless steel may be required in more aggressive soils
- The use of earth rod clamps to fix the tape to rods is recommended

Note: If space constraints do not permit the installation of a radial earth system per above, consult with LPI or an authorised distributor for further advice.

If the Guardian Plus is installed within an earth grid, e.g., in a substation, then the earth grid can substitute the radials. However, an earth rod of suitable depth must be installed at the base of the mast supporting the Guardian Plus air terminal.

Some of the practical aspects of the lightning earth installation are as follows:

- Waterproofing mastic tape should be used on all mechanical connections
- The use of earth enhancing compounds is recommended around all earth electrodes installed, e.g., LPI RESLO, LPI SRIM or LPI GRIP, especially in areas where soil resistivity is moderate to high
- An earth pit should be installed where the end of the downconductor terminates to the lightning earth (see Figure 6). The earth pit provides an access point for disconnection and future testing of the earthing system
- When installing the earth rods, use driving heads to prevent mushrooming of the top of the rod and when using coupled rods. Use a post or picket driver

Note: do not connect the lower termination of the downconductor to the earthing system at this point in time.

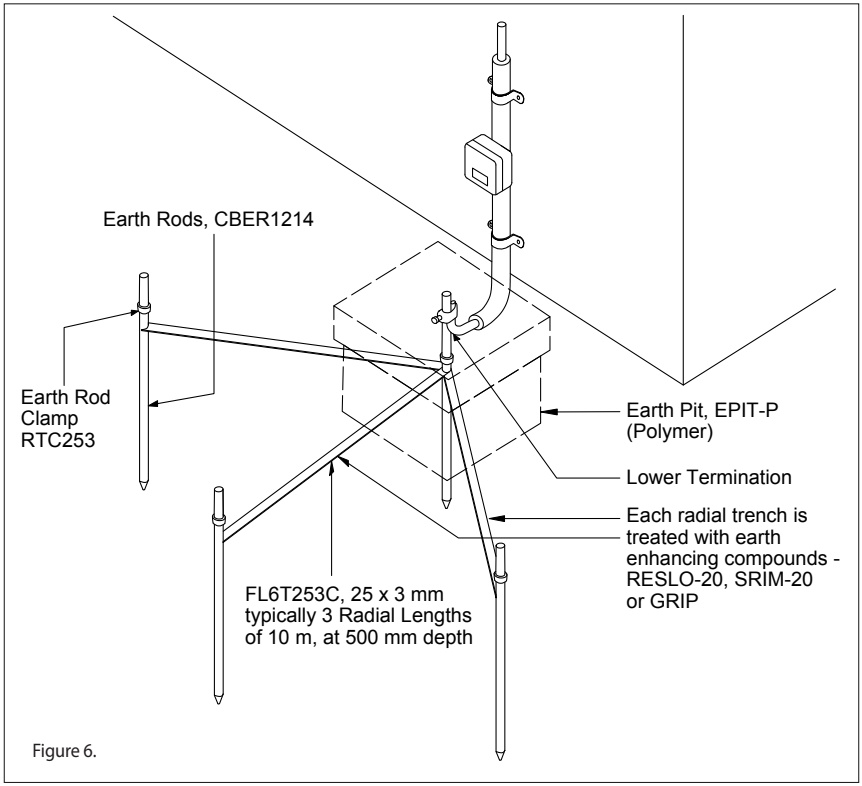


Figure 6.

Earth Enhancing Compounds

- Earth enhancing compounds such as LPI RESLO, LPI SRIM or LPI GRIP are supplied when soil resistivity is moderate to high
- The use of such compounds significantly lowers the overall earth resistance/impedance, typically by at least 50%
- These compounds will require water and a mixing container
- When applying the compounds, follow all installation and safety instructions

Bonding the Lightning Earth

Where separate earths exist, e.g., structure, power, communications and lightning protection, they need to be bonded to form an equipotential earth reference. The action ensures potential differences arising under transient conditions are minimised.

Before bonding the various earths together, ensure the appropriate authorisation has been obtained.

The bonding conductor used is typically 70 mm^2 (2/0 AWG), but its size may depend on local standards.

It is acceptable to use a Transient Earth Clamp, e.g., LPI TEC100-2L, to achieve bonding of some earths only under transient conditions, if local authorities disallow direct bonding between those earths.

Reference should also be made to local standards that apply, e.g., IEC 62305-3, AS/NZS 1768, NFPA 780, CSA C22.1, NEC etc.

Labelling

It is the responsibility of the customer/installer to label earth pits or earthing systems to local requirements.

Installation of the HVSC Plus Downconductor

If installing LPI HVSC Plus downconductor(s), the upper termination(s) at a pre-specified end of the cable may have already been prepared by the LPI factory before being shipped.

When removing HVSC Plus downconductor packaging, do not use a knife or sharp implement, as this can damage the outer layer of the termination and render it useless.

The LPI HVSC Plus has an outer layer which is approximately 2 mm (1/16 in.) thick. Be careful not to damage this layer.

Hauling the HVSC Plus Downconductor

- Check that the correct length of HVSC Plus downconductor has been supplied. The length of HVSC Plus will be marked on the drum
- Make sure that the cable drum is in a serviceable condition
- Place the HVSC Plus downconductor cable drum close to where it is to be installed (Figure 7)

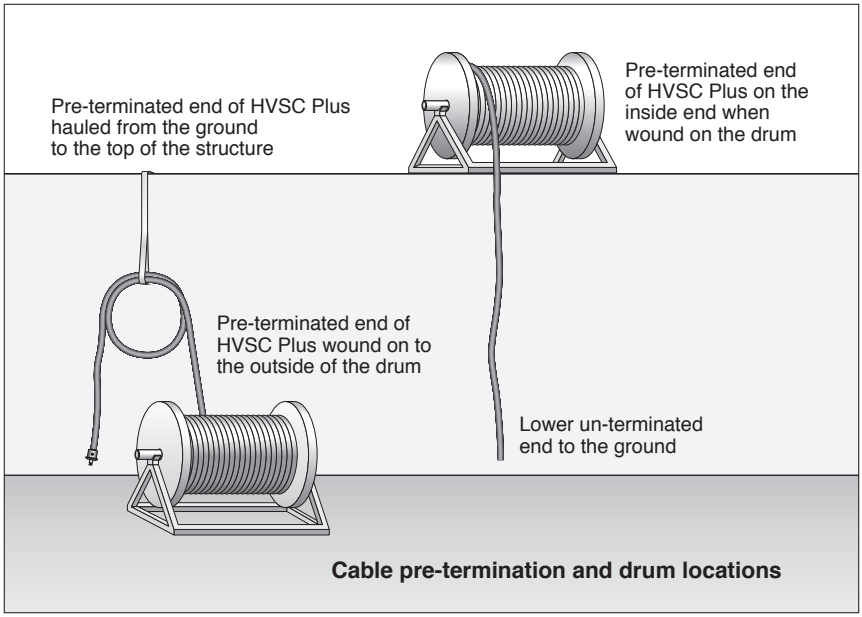


Figure 7.

- If the HVSC Plus downconductor has an upper termination on the outside of the drum, it will need to be hauled up the structure with the drum staying on the ground
- If the HVSC Plus downconductor has an upper termination on the inside of the drum, then the drum has to be positioned at the top or near the top of the structure. Then the HVSC Plus downconductor can be hauled downwards from the drum to the ground

Additional points:

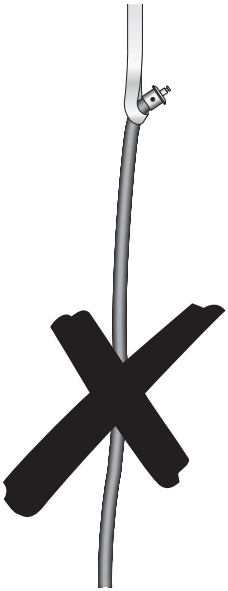
- Any lifting slings or ropes must be securely attached
- DO NOT haul the HVSC Plus downconductor from the termination. See Figure 8
- Protect the HVSC Plus downconductor at all times when it is being moved

HVSC Plus Downconductor Clearance Holes

Before running the HVSC Plus downconductor through any clearance holes, ensure that:

Figure 8.

Correct method of hoisting HVSC Plus



Incorrect method of hoisting HVSC Plus

- A minimum hole diameter of 60 mm (2 3/8") is used
- Enough protection is provided so that the HVSC Plus downconductor is not damaged during or after installation
- A waterproofing sealant or sealing gland should be used if the hole needs to be weatherproof

Routing

The routing of the HVSC Plus downconductor needs to follow these guidelines:

- The route of the HVSC Plus downconductor should follow the guidelines of the original design. Ensure no structural changes, such as new antenna or mast installations, air conditioning towers or ducting, has been installed in the interim

- Minimise strain on the HVSC Plus downconductor
- The HVSC Plus downconductor may be installed internally or externally on the structure
- The HVSC Plus downconductor should be installed as close (flush) as possible to the structure
- Minimise the number of bends and use the most direct route to ground
- Re-entrant loops ("doubling back") of the HVSC Plus downconductor MUST be avoided
- Ensure minimum bend radius is not surpassed, i.e., smallest bend radius allowed is 430 mm (20")
- Parallel routing with other services should be avoided. If unavoidable, the minimum separation distance is 2 metres (Figure 9)
- If the HVSC Plus downconductor has to cross other services, ensure it crosses at right angles. Use a conduit that extends at least 1 m beyond either side of the existing service

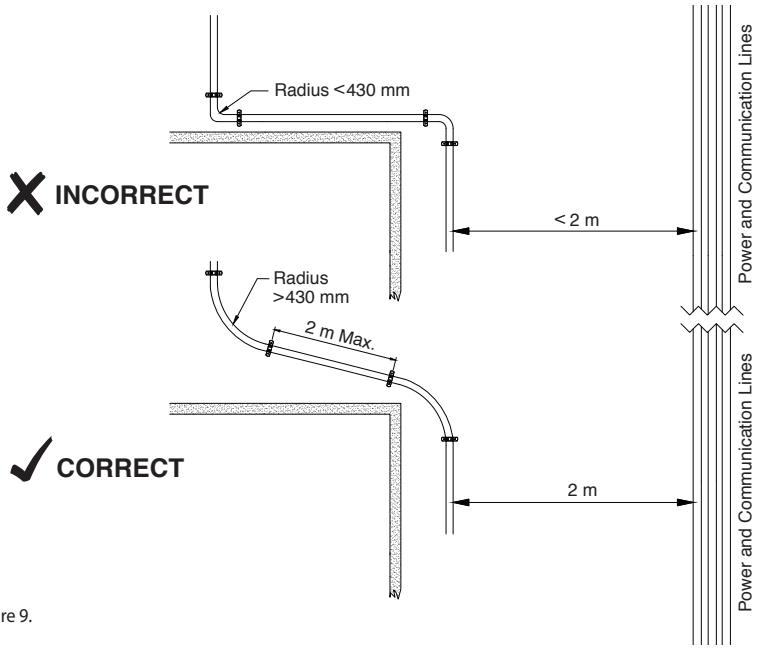


Figure 9.

- The lower end of the HVSC Plus downconductor must terminate close to the initial injection point of the lightning earth
- Be sure to allow for enough slack in the HVSC Plus at the top end for connection to the Guardian Plus terminal and the raising of the mast
- If it is necessary to isolate the HVSC Plus downconductor from the structure, run the cable in an insulating conduit with a minimum wall thickness of 3 mm (1/8"). The maximum length isolated from the structure should be 2.5 m (9 ft). The entire length of the HVSC Plus downconductor cannot be run in insulated conduit
- The HVSC Plus downconductor should be protected from damage at the lower end by installing a "Top Hat" surface mount cover of no more than 2 m from ground level
- The HVSC Plus downconductor must be checked by an LPI representative if it is damaged during installation to see if the damage will affect performance

Fixing the HVSC Plus Downconductor

Using non-LPI fastening saddles can damage the downconductor outer sheath. Always use LPI-supplied or recommended saddles, fixing and cable ties.

- The HVSC Plus downconductor should be fixed to the structure every 2 m for the entire length of the run
- For masonry walls or roofs, use the LPI saddles provided. These can be used with masonry anchors, suitable fastenings for wood, fibreglass and metallic surfaces, or self-tapping screws
- The most direct path to ground is recommended. Avoid sharp bends (see Figure 9)
- Use cable ties when fixing to round sections, such as pipes, tower legs, masts, etc.
- If the HVSC Plus downconductor is to be routed above a false ceiling, ensure that it is fixed to the underside of the concrete floor slab
- Do not use explosive fastening methods on LPI saddles or HVSC Plus downconductors

Installation of Conventional Downconductors

In some installations, the use of copper tape or insulated stranded copper conductor may be installed as the downconductor. In such cases, it may be necessary to install multiple downconductors in compliance with local and/or international standards, such as NF C 17-102, AS 1768, NFPA 780 and IEC 62305. The following dot points provide further information.

- The Guardian Plus terminal provides a bolt for the lug connection to the lower finial

connector of the mast butt adaptor. All conventional downconductors should be lugged and fixed to the terminal per Figure 10

- For structures made of combustible materials, downconductors must be separated from the structure by a distance of at least 0.1 m and they must have a cross-sectional area of 100 mm^2

Installation on structures:

- Minimum of two downconductors are required, preferably on opposite sides of the structure
- If natural components of the structure are used, electrical continuity to ground must be checked
- For installations where multiple Guardian Plus terminals are installed, the requirement for two downconductors per terminal is waived

Standalone / isolated / freestanding mast installation:

- Only one downconductor is required
- Natural components, e.g., steel mast, may be used if it complies with the requirements for downconductors (in general, a minimum cross-sectional area of 50 mm^2)

Routing and installation:

- Install externally wherever possible. Internal installation requires routing inside a non-flammable insulating pipe
- Keep the path as direct and straight as possible
- Avoid sharp bends. Bend radius must not be smaller than 20 cm
- Avoid routing along or across electrical conduits
- Use three fasteners per metre
- Protect against the risk of mechanical impact damage with guard tubes up to a height of at least 2 m above the ground level

Natural components:

- External interconnected steel frames (metal structures) may be used in place of dedicated downconductors if it is shown that the electrical continuity / resistance is ≤ 0.1 Ω
- Internal metallic structures, concrete reinforcements, metal structures inside walls, metal sheets and pipes at least 2 mm thick may be used to supplement dedicated downconductors(s)

Equipotential bonding:

Dangerous sparking may occur between the external Guardian Plus system and components such as metal installations, internal systems, external conductive parts and lines connected to the structure.

The dangerous sparking can be avoided by means of equipotential bonding, using conductors and/or SPDs or electrical insulation between the parts (which must comply with separation distance requirements per IEC 62305-3).

Installation of Guardian Plus GI Terminal to Threaded Pipe

LPI offers within its range of Guardian Plus terminals a "CM version" which is designed for a threaded connection to a 2 inch BSP Galvanised Iron (GI) pipe. Please refer to Figure 11 for further details.

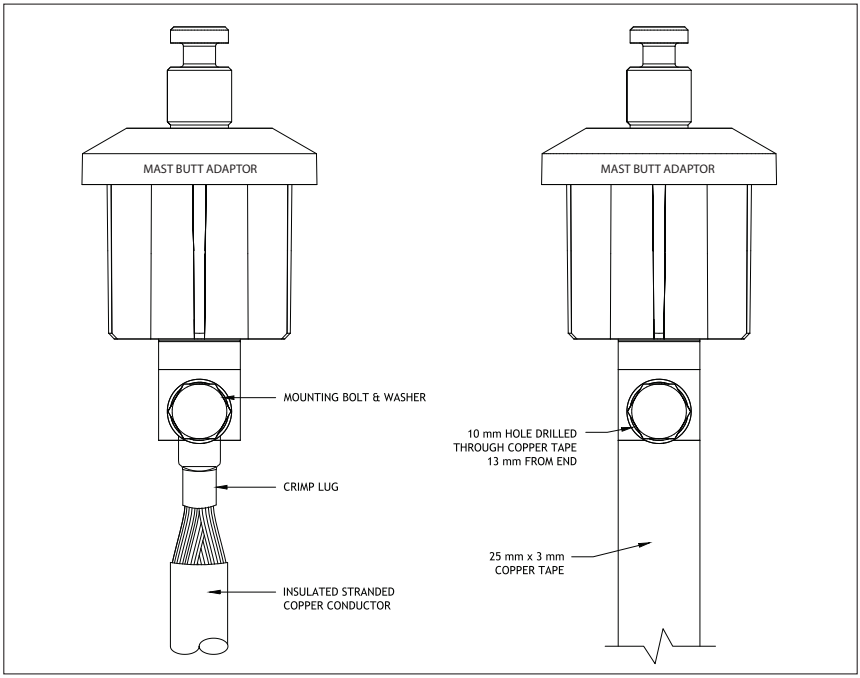


Figure 10.

The Guardian Plus CM terminal is supplied with a threaded coupler (female thread) fixed to the terminal and designed for connection to a the 2-inch GI pipe (male thread).

After installation of the Guardian Plus CM terminal to the threaded pipe as per Figure 11, it is necessary to connect the metallic pipe to a conventional downconductor in order to convey the lightning energy to the earthing system.

Ideally, the connection between the metallic pipe and the conventional downconductor should be completed by lugging the downconductor at a practical point somewhere along the length of the pipe.

Particular care should be taken to ensure that compatible metals are used when connecting the downconductor to the metallic pipe.

For installation details of the conventional downconductor, please follow the instructions on "Installation of Conventional Downconductors".

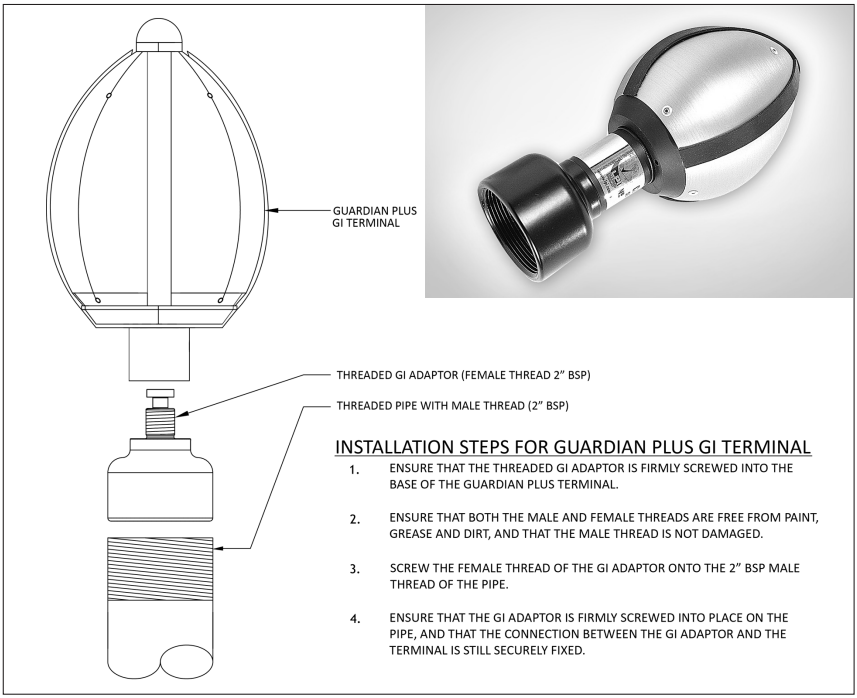


Figure 11.

Termination of the HVSC Plus Lower End

Note: *This Document is to be used in conjunction with the LTERMKIT-MK3 on HVSC Plus cable only. Using the following guide, check the cable first prior to performing the termination to ensure the use of the correct lower termination kit.*

HVSC Plus cable has an outer diameter of approximately 35 mm and has an aluminium stranded centre conductor and copper tape screen (which can be easily seen from the end of the cable).

This termination kit will not work with any other cable.

Tools and parts required for the completion of HVSC Plus lower termination include:

- Compression or mechanical crimping tool (for 70 mm² crimp lug)
- Sharp knife
- Shifting spanner (or 17 mm A.F. spanner/socket)
- Rubber gloves
- Tape measure (metric)

Lower Termination Kit consists of:

- Instructions
- 1 x Roll of waterproofing mastic tape
- 1 x 70 mm² crimp lug
- 2 x Warning labels
- U-Bolt earth clamp
- 1 x Tube of conductive paste

The following steps outline the termination of the lower end of the HVSC Plus to the lightning earth.

The diagram below shows the different layers of the HVSC Plus cable and indicates their names as referred to in the following instructions:

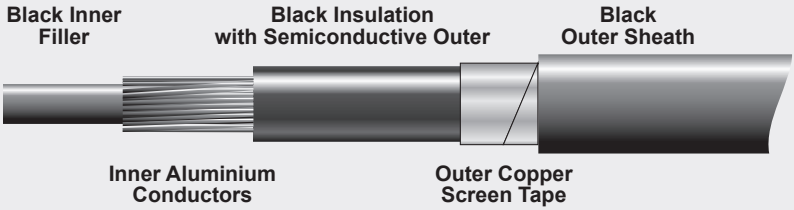


Figure 12.

1. First, remove the black outer sheath for a length of 15 cm by cutting radially round the HVSC Plus cable with a sharp knife. The lengthwise cut can also be completed with a knife, but take great care not to score or damage the copper tape. Cut and remove the material lining over the copper tape (Figure 13).

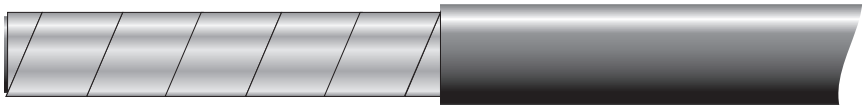


Figure 13.

2. Carefully unwind the copper tape to expose about 7 cm of the sheath underneath. Again, be careful not to damage the copper tape during this process. Measure 5 cm from the end of the cable and remove the black insulation section of the sheath over the aluminium conductors (Figure 14). Note: There are many valid ways of removing this layer, but it is very important that the aluminium conductor strands are not scored or damaged in any way as this will decrease their strength and may lead to breakage when bending them for insertion into the crimp lug.

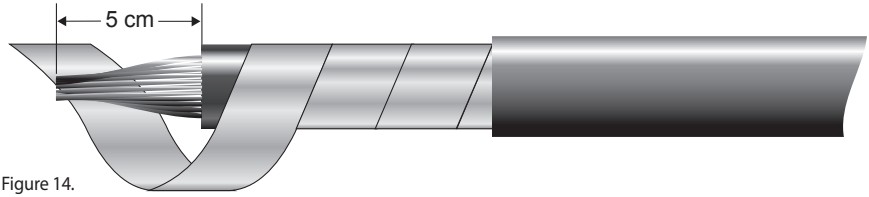


Figure 14.

3. Cut and remove the black binding tape from over the aluminium strands. Remove at least 3 cm of the black Inner filler core under the inner aluminium conductors by carefully bending back the conductor strands to expose the filler core then cut and remove the core with a knife. Carefully bend the conductors back to allow them to be fed into the lug.

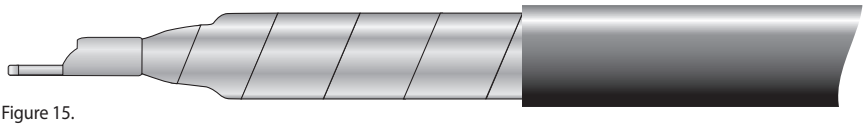


Figure 15.

4. Using a rubber glove, apply all conductive paste evenly over the 5 cm length of aluminium strands prior to re-wrapping the copper tape.
5. Re-wrap the copper tape back into its original position neatly over the aluminium conductors. Wrap the tape as tight as possible over the aluminium strands and place both the tape and strands into the supplied 70 mm² crimp lug and crimp securely using a suitable compression or mechanical crimping tool (Figure 15). Note, this will require crimping at 70 mm² to obtain a secure compression.
6. If terminating the lower end of the HVSC Plus to a bus bar, connect to the bus bar as per Figure 16.
7. Connect the crimp lug to the earthing system using the supplied U-Bolt earth clamp if necessary (Figure 17). Ensure the connection is aligned correctly and tightly secured using a 17 mm spanner, socket or shifting spanner.
8. Use the waterproofing mastic tape to completely cover all exposed conductive areas of the lower termination and to seal the termination from moisture ingress where it connects to the earthing system (Figure 17).
9. Place the warning labels on or next to the HVSC Plus cable where they can be easily seen and read by anyone with access to that area.

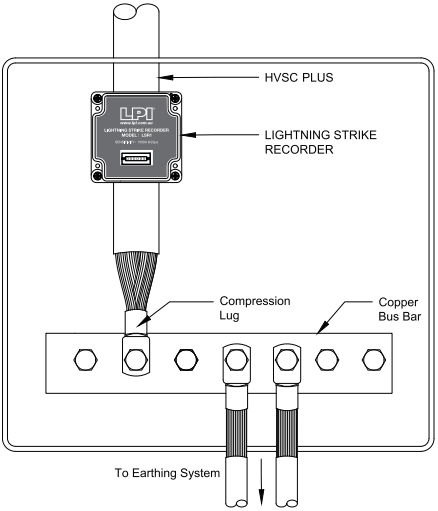


Figure 16.

Lower Termination of Conventional Downconductor to the Lightning Earth

- If installing stranded copper cable as a downconductor then the lower end should be connected to the lightning earth through the use of an earth rod clamp and then wrapped with waterproofing tape to avoid oxidisation
- If installing copper tape (25 x 3 mm) as a downconductor then the lower end should be directly connected to the lightning earth through the use of a suitable earth rod clamp and then wrapped with waterproofing tape to avoid oxidisation

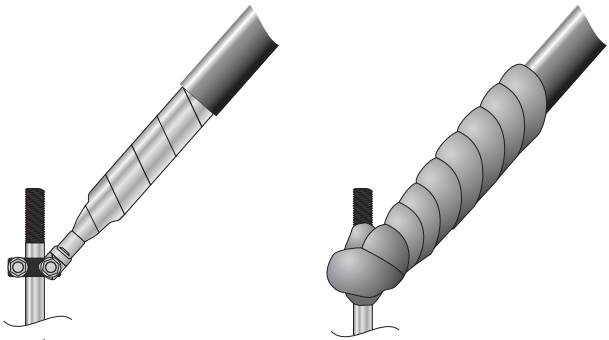


Figure 17.

Termination of the HVSC Plus Upper End

Note: This Document is to be used in conjunction with the UTERMKIT-MK3 on HVSC Plus cable only. Using the following guide, check the cable first prior to performing the termination to ensure the use of the correct upper termination kit.

HVSC Plus cable has an outer diameter of approximately 35 mm and has an aluminium stranded centre conductor and copper tape screen (which can be easily seen from the end of the cable).

This Termination Kit will not work with any other cable.

Tools and parts required for the completion of the HVSC Plus Upper Termination include:

- Compression or mechanical crimping tool (for 50 mm² crimp lug)
- Sharp knife
- Scissors
- #2 Phillips head screwdriver
- Shifting spanner (or 17 mm spanner/socket)
- Heat gun or gas torch (LPG)
- Tape measure (metric)
- Combination pliers/cutters
- Mast base assembly (supplied with the Guardian Plus Terminal)

Upper Termination Kit consists of:

- Instructions
- 1 x Roll of semi-conductive tape
- 1 x 50 mm² crimp lug
- 2 Heatshrink tubes (1 x 1200 mm & 1 x 600 mm length)

Upper Termination Instructions for UTERMKIT-MK3 (Heatshrink)

The diagram below (Figure 18) shows the different layers of the HVSC Plus cable and indicates their names as referred to in the following instructions:

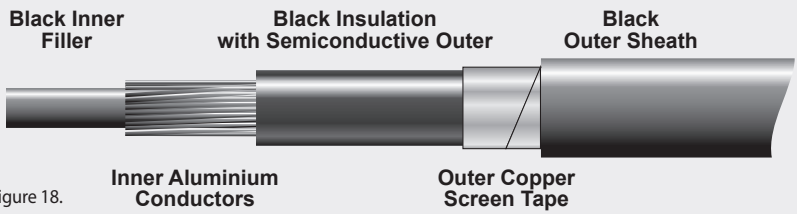


Figure 18.

1. First, remove the black outer sheath for a length of 160 cm by cutting radially round the HVSC Plus cable with a sharp knife. The lengthwise cut is also performed with a knife, but take great care not to score the black insulation under the copper tape as well as the 1st 3 cm of copper tape against the outer sheath. Cut and remove the material lining over the copper tape (Figure 19).
2. With a knife, cut and remove the fabric tape material over the copper tape up to the outer sheath. Measure and mark with a pen the outer copper screen tape at 3 cm along from the end of the outer sheath (Figure 19). With a knife or scissors, carefully cut and remove the copper tape, again without damaging the black insulation below. If using a knife, carefully score the tape without cutting through it and use this score line to tear the tape along the line.

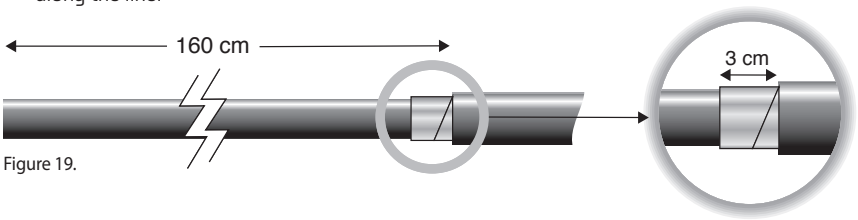


Figure 19.

3. Using a sharp knife, remove the black insulation to expose the inner aluminium conductors for a length of 5 cm from the top end of the HVSC Plus (Figure 20). Also remove the black fabric material lining over the aluminium conductors. Be careful not to damage the conductor strands during this process. Note: There are many valid ways of removing this layer, but it is very important that the aluminium conductor strands are not scored or damaged in any way as this will decrease their strength and may lead to breakage when bending them for insertion into the crimp lug.

4. Remove at least 3 cm of the black inner filler core under the inner aluminium conductors by carefully bending back the conductors to expose the filler core then cut and remove the core with a knife. Carefully bend the conductors back to allow them to be fed into the lug.

Figure 20.

5. Straighten the cable back to the black outer sheath as much as possible then crimp the inner aluminium conductors into the supplied 50 mm² crimp lug using a suitable compression or mechanical crimping tool (Figure 21).

Figure 21.

6. Connect the crimp lug to the Stormaster mast base assembly using the bolt and washers as supplied with the assembly. Ensure the connection is aligned correctly and tightly secured using a 17 mm spanner, socket or shifting spanner. Note orientation of lug on lower finial connector (Figure 22).

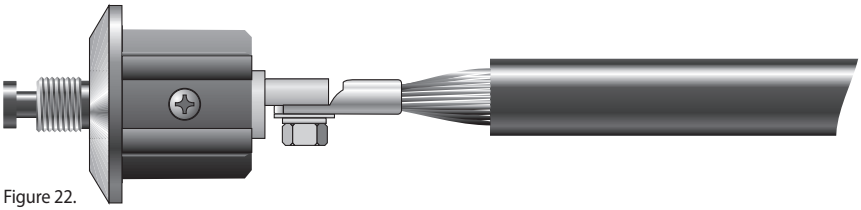


Figure 22.

7. Using the semi-conductive tape provided, starting 2 cm in front of the end of the outer copper screen tape (or 5 cm in front of the black outer sheath), stretch and wrap the tape back over the tape and 3 cm over the black with 50 % overlap, securing the outer copper screen tape in place. This should use approximately 50 cm of the tape (Figure 23).

   Note: DO NOT cut the tape at this stage.

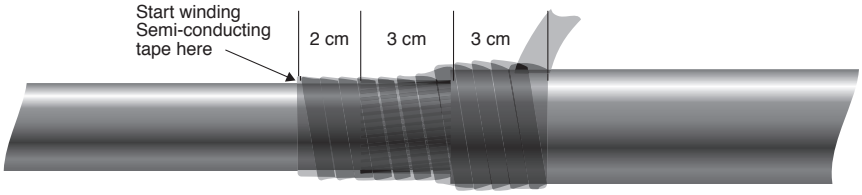


Figure 23.

8. Over wrap back towards the crimp end of the cable, again stretching the tape and with 50 % overlap, leaving 5 cm covering the outer copper screen tape and black insulation and 3 cm covering the black outer sheath. This should use approximately another 50 cm of the tape. Wrap another 2 layers, again stretched with 50 % overlap back up to where the black outer sheath ends, to build up the cable diameter and to smooth out transitions in diameter Figure 24. Cut the tape and press down firmly to ensure it amalgamates with the tape below it.

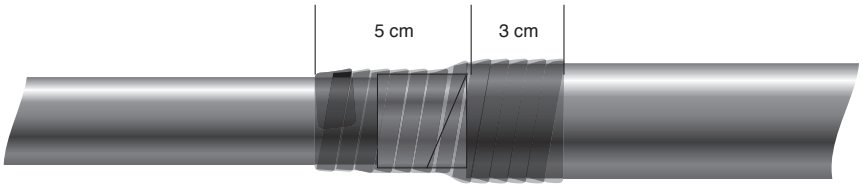


Figure 24.

9. Again using the semi-conductive tape, start stretching and wrapping over the aluminium conductor strands and connection to the lower finial connector to start building up in multiple layers. Continue wrapping the tape over the area shown to cover the last 3 cm of the black insulation, over the lower finial connector and up to the black plastic section of the mast base assembly in multiple layers, completely covering the crimp and achieving as smooth and level a surface as possible, removing all sharp edges (Figure 25).

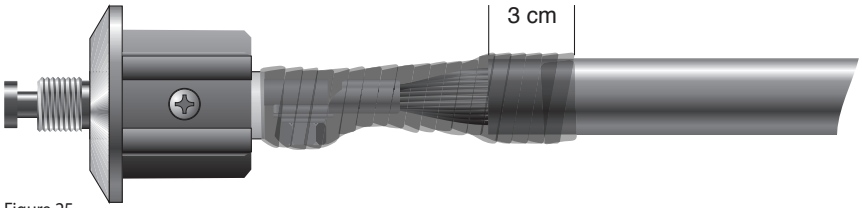


Figure 25.

10. Remove the plastic mast butt adaptor section of the mast base assembly (if fitted) by unscrewing the M6 Phillips head screw on the side. Straighten the cable as much as possible then carefully slip the first 1.2 m length of heatshrink over the cable until the end of the heatshrink tube covers and overlaps the semi-conductive tape (over the black outer sheath) by at least 3 cm (Figure 26). Ensure that the semi-conducting tape is not damaged or lifted during this process. Using a gas torch or heat gun, carefully shrink the lower end of the heatshrink into the correct position and gradually work up towards the top of the heatshrink ensuring there are no pockets of air trapped under the heatshrink.

Note: Ensure that the heat gun or gas torch is not pointed in the same area for too long as this will burn the heatshrink. Also be careful around the ends of the tube as too much heat will damage the black outer sheath, semi-conductive tape and black insulation.

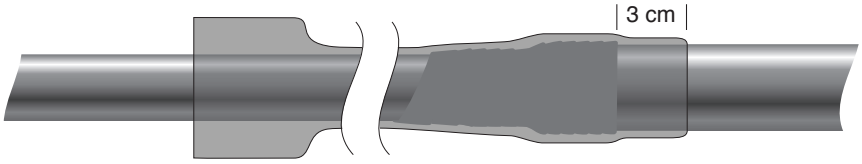


Figure 26.

11. Place the 2nd 600 mm heatshrink tube into place over the cable, again ensuring that the semi-conductive tape is not damaged, overlapping the previous heatshrink tube by approximately 6 cm. Shrink about 7 cm of the upper end of the heatshrink into place so that it will sit flush with the base of the plastic mast butt adaptor when fitted back into place. Note: That there is a mark on the lower finial connector indicating where the heat-shrink needs to be fitted to. Shrink the rest of the heatshrink from the top down, ensuring that it overlaps the previous piece of heatshrink by at least 6 cm Figure 27. Ensure the rest of the heatshrink has a smooth overall finish. Note: Do not bend the cable while the heat shrink is still hot.

Note: If required, feed the cable through the mast sections & guying ring prior to refitting the mast butt adaptor. Replace the plastic mast butt adaptor section of the mast base assembly back onto the lower finial connector and ensure that the M6 Phillips head screw is tight and secure.

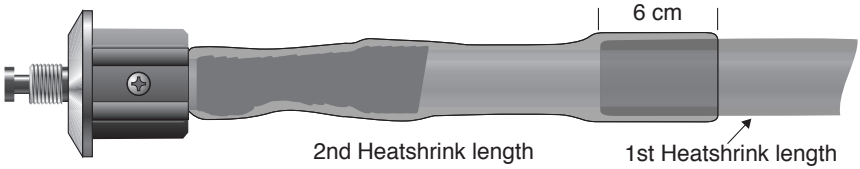


Figure 27.

12. The lugged HVSC Plus is now ready to be connected to the base of the Guardian Plus terminal. Screw the terminal onto the completed terminal base assembly and secure with the supplied M6 locking grub screw.

Termination of the HVSC Plus Lower End

Please refer to LTERMKIT-MK3 supplied with the HVSC Plus cable.

Check the cable first prior to performing the termination to ensure the use of the correct lower termination kit.

Connection of Factory Pre-Terminated HVSC Plus (Upper End) to Guardian Plus

The tools required for the installation of the factory completed upper termination include:

- Sharp knife
- PH2 Phillips head screw driver
- 3 mm Hex/Allen Key

Proceed as follows:

1. Remove the protective packaging from the cable and upper terminated end section, taking care not to cut the cable or associated upper termination.
2. Using a Phillips Head screwdriver, remove the M6 Phillips Head screw holding the mast butt adaptor (if fitted) to the lower connector and retain both the screw and the mast butt adaptor.
3. Feed the HVSC Plus cable through the FRP support mast.
4. Slide the black plastic mast butt adaptor back onto the lower finial connector, line up holes and screw the Phillips Head screw into position tightly. Next, screw the mast butt adaptor into the Guardian Plus terminal and tighten the M6 Grub screw at the base of the terminal to lock the assembly.

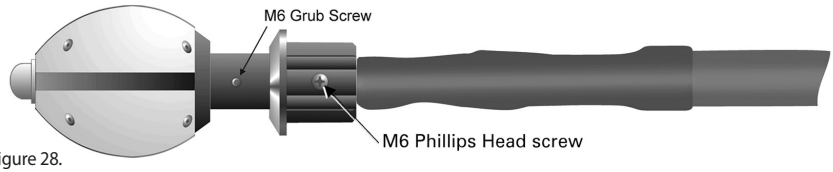


Figure 28.

Labelling

Warning labels are supplied with all Guardian Plus terminals and should be installed per the following guidelines:

- In locations where personnel may be in close proximity to the HVSC Plus downconductor
- Where the HVSC Plus downconductor connects to the earthing system
- At the base of the support mast

There are two warning labels supplied with the product, and also two supplied in the lower termination kit. If more labels are required, contact your nearest LPI supplier or distributor.

Masts

The mast chosen for the application must:

- Raise the terminal to a height of at least 2 metres higher than any competing points on the structure
- Have an FRP mast section of at least 2 metres below the air terminal if using LPI HVSC Plus
- Be suitable for local weather conditions. Seek guidance from a local civil engineer
- Be guyed and securely attached to the dedicated mounting points (if required)

Types of Mast Configurations

When mounting a Guardian Plus terminal, there are generally three types of mast configurations that can be used.

1. Cantilevered

Typically used for mounting to a tower or the side wall of a plant room when a mast and base are not suitable. See drawing figure 29.

- One third the overall mast height must be fixed to the structure for adequate mechanical strength
- Cantilevered masts can be guyed for additional strength. If guying, the use of a guy ring and/or the eyelets provided on the inline coupling can be utilised

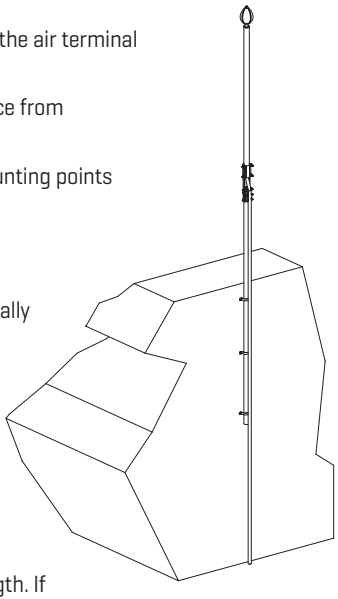


Figure 29. Cantilevered Mast

2. Guyed

Figure 30 shows the details for mounting the Guardian Plus terminal when guying is required. Typical configurations comprise:

- Two sections of mast (aluminium mast & FRP mast coupled together with an "inline coupling". Securing of guy wires is completed at the eyelets, as provided on the inline coupling

Figure 30. Guyed Mast

- Alternatively, or in addition, a guy ring can be supplied which is installed at the neck of the mast in between the Guardian Plus terminal and the top section of the FRP mast. The guy ring provides eyelets for connection of the guy wires

Further details regarding guying can be found below in the major section entitled "Guying".

3. Freestanding

A freestanding mast configuration is typically used in situations where "protection by isolation" is required. For example, a Guardian Plus terminal is installed 5 metres or more away from a fuel storage tank, or some distance form a HV transformer or buswork.

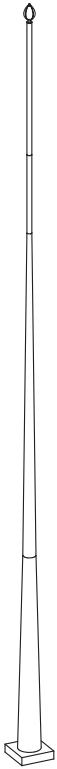


Figure 31. Freestanding Mast

Prior to installing the freestanding mast, ensure that:

- A spigot has been supplied with the freestanding mast which allows for external or internal mounting of the FRP mast, if installing HVSC Plus
- The downconductor can exit through the base of the freestanding mast if run internally
- Adequate information is provided for mast foundation requirements

Contact LPI or an authorised dealer for further details if required.

Mast Bases

LPI supplies a mast base welded directly onto the required length of aluminium mast.

Mast Couplings and Guying Points

There are two methods of coupling two sections of mast:

(i) The U-Bolt set uses two stainless steel U-Bolts to clamp the two masts together (Figure 32).

(ii) The inline coupling fixes the upper and lower mast sections together and provides guying points and an exit point for the HVSC Plus downconductor.

U-Bolts and inline couplings nuts must be tightened to no more than 55 kg/cm (45 in/lb).

A guying ring is supplied for guy points for any two piece masts that require double guying. This fits on the mast butt adaptor between the Guardian Plus terminal and the top of the mast. See Figure 33.

Guying

LPI offers a standard 4 m (LPI GUYKIT-4M) and 7 m (GUYKIT-7M) guy kit made up of light weight synthetic, non-conductive cable. They are designed to be installed with the use of a guy ring at the top section of the FRP mast, as illustrated in Figure 37. When guying from the LPI inline coupling, the use of stainless steel guy wire kits (GUYKIT-4M-SS, GUYKIT-7M-SS) is recommended.

Important Recommendations:

- The guying angle must be no greater than 60° from horizontal
- The inline coupling couples the upper and lower mast sections and provides guying points and an exit point for the HVSC Plus downconductor
- Minimum of 3 guying grips per guy end
- Guying grips spaced at a minimum of 25 mm
- Grips are correctly orientated. Saddle on the longer length side of the guy and U-bolt over the tail side of the guy
- Tighten grips to no more than 60 cN.m (5 lbf.in) of torque
- Protect guying from abrasion
- Customised guy kits can be supplied upon request

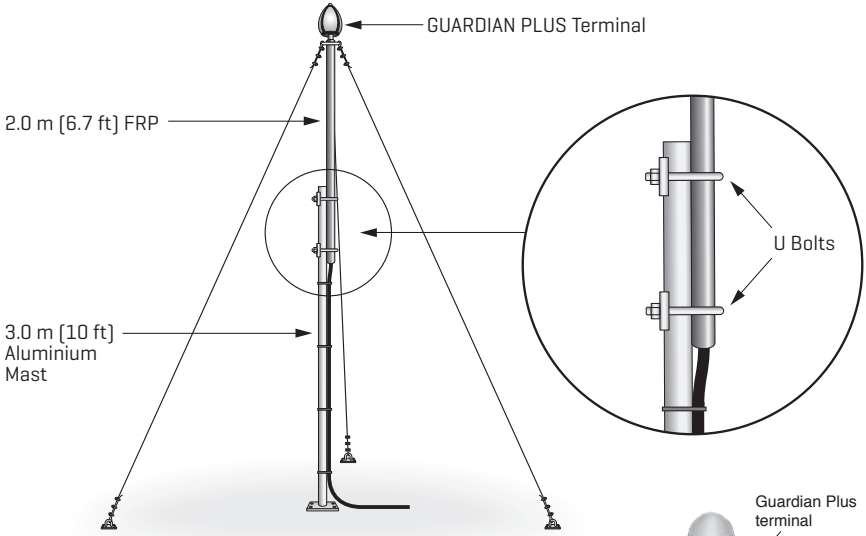


Figure 32.

Preparation for Raising the Mast into Position

With the upper termination of the HVSC Plus completed and the FRP mast in position it is now time to finalise the mounting arrangement so that the mast can be raised and secured into position.

- If using the recommended installation methods shown earlier, fit the inline coupling to the lower mast material.
- If required, fit the HVSC Plus down-conductor through the side entry of the inline coupling and through the FRP mast. Refer to Figure 34.
- Feed the upper termination through the guying ring if required.

Figure 33.

- Carefully fit the mast adaptor of the Guardian Plus terminal into the top of the FRP
- It may be necessary to pull back any slack of HVSC Plus downconductor through the FRP support mast to achieve a tight fit for the Guardian Plus terminal. This should be completed carefully so as to not damage the upper termination
- Fix the FRP support mast firmly into the inline coupling and tighten the coupling so that the FRP mast and lower mast material are secured firmly into position with no more than 55 kg/cm (45 in/lb)
- If a guy kit is to be installed, the guys should be securely fixed to the eyelets as provided on the inline coupling and or the guy ring. See "Guying" section for more information

Raising of the Mast

When raising the mast, ensure:

- Guys to inline coupling and/or guy ring are properly secured
- Guys are not twisted, kinked or damaged
- Guys are able to be easily secured at the lower guy anchoring points when the mast has been raised

Turnbuckles or rigging screws are recommended at the base anchor points of the guys.

Other guying methods such as conductive stainless steel can be used only on aluminium masts or inline couplings below an FRP section.

Using a crane is recommended (or other suitable equipment) for anything over 6 metres in height, or for hazardous areas or high areas.

It is very important to keep the mast straight during the lift to avoid damaging the mast.

- The Guardian Plus terminal must NOT be used as a slinging point. See Figure 35.
- When lifting the mast, ensure that the slings or ropes cannot damage the Guardian Plus terminal. See Figure 35.
- When lifting the mast, the HVSC Plus downconductor must be tied off to the mast to eliminate straining the HVSC Plus downconductor termination to the Guardian Plus terminal
- Protect the HVSC Plus downconductor at the base of the mast when lifting by ensuring the bending radius is not smaller than 430 mm and ensuring it does not drag over rough or sharp surfaces

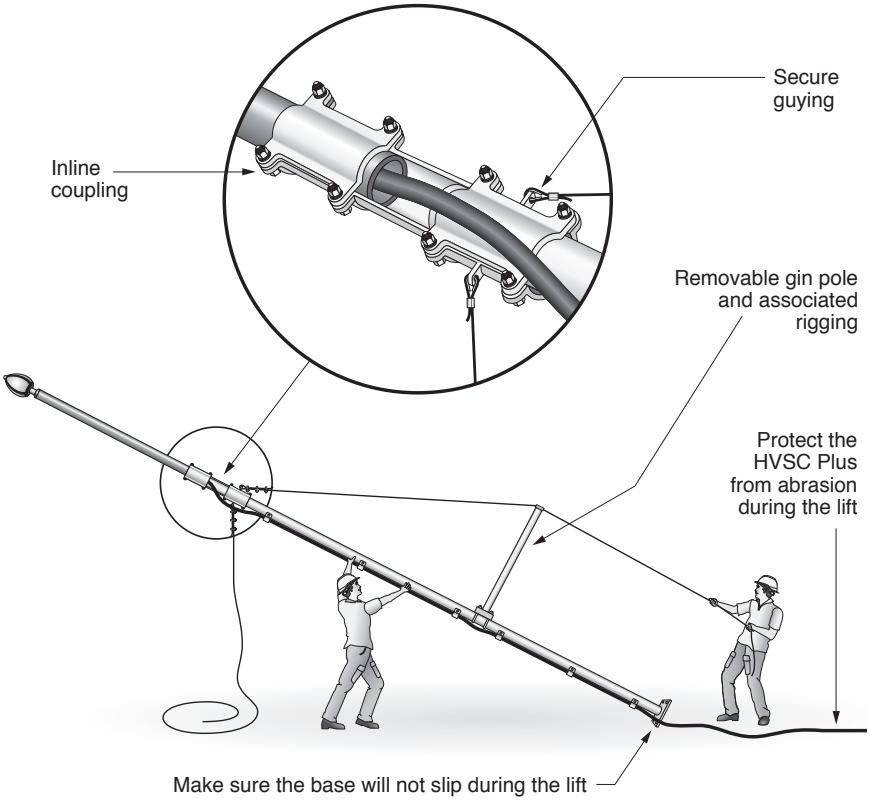

Secure guying
Inline coupling
Removable gin pole and associated rigging
Protect the HVSC Plus from abrasion during the lift
Make sure the base will not slip during the lift

Figure 34.

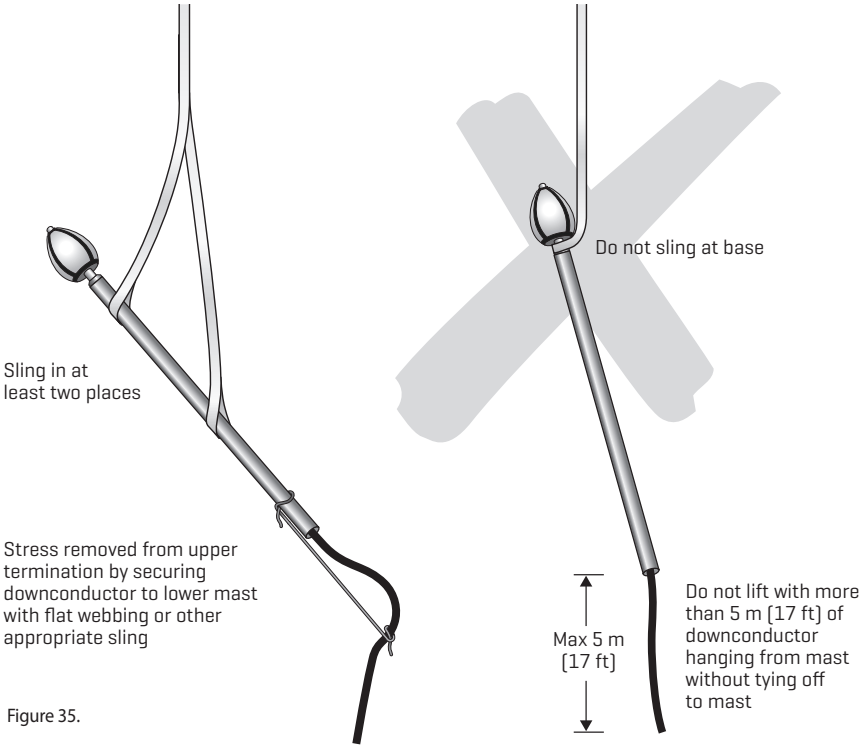


Figure 35.

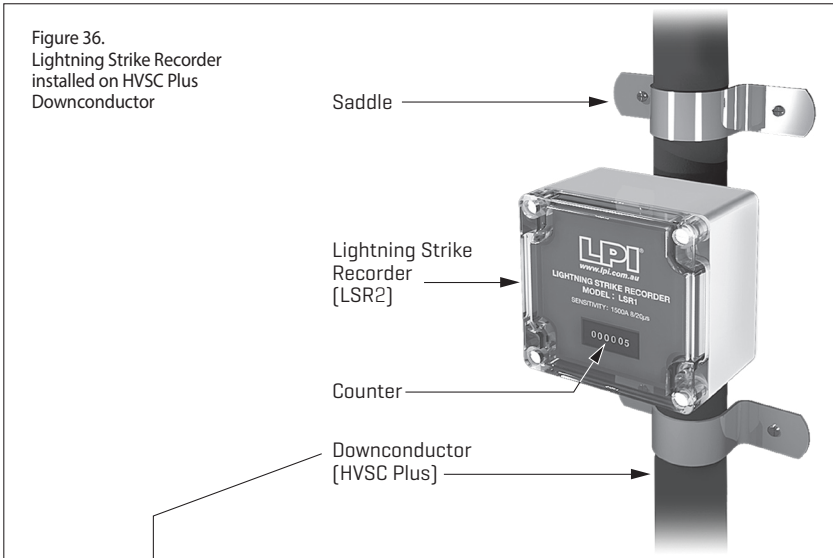
Lightning Strike Recorder (LSR2)

The Lightning Strike Recorder (LPI LSR2) should be installed at a position along the downconductor length where it can be accessed easily for inspection. Typically, the LSR2 should be installed approximately 1.5 m from ground level or alternatively within the earth pit at the lower termination point of the HVSC Plus. See Figure 36.

When installing the LSR2, the following points should be considered:

- The LSR2 should be mounted away from areas where damage may occur due to vandalism or nearby operations, or in locations where it could be stolen
- The LSR2 can be enclosed in a security enclosure but the display should be kept visible to allow for the checking of recorded strikes

Figure 36.
Lightning Strike Recorder installed on HVSC Plus Downconductor



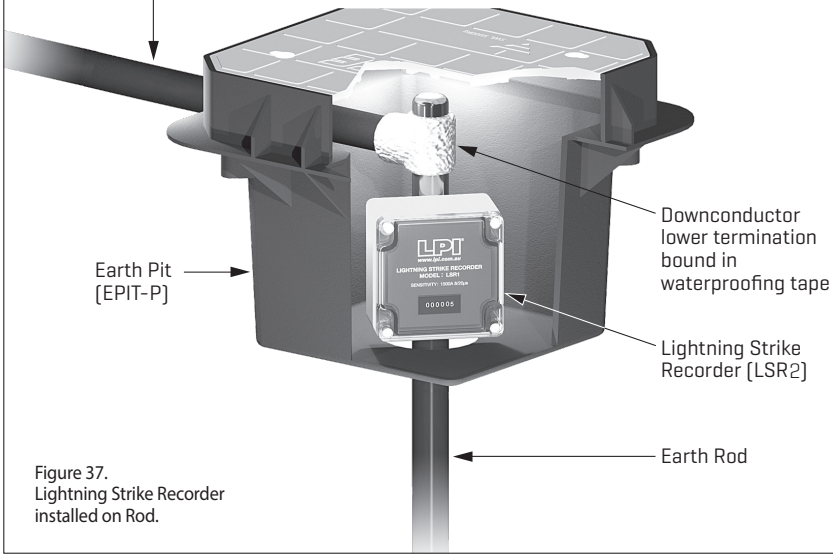


Figure 37.
Lightning Strike Recorder installed on Rod.

Certification

The certification of the LPI Guardian Plus installation should be performed by an authorised LPI representative.

A certificate of compliance and warranty registration is provided with the product. This certificate should be completed in full following the successful inspection and certification of the installation.

The following should be checked for quality of workmanship and compliance to recommended installation instructions.

Certification checklist:

- Correct mast and any associated brackets and fastenings have been used for installation
- Guying, anchor points and fastenings
- HVSC Plus downconductor routing, fixing and weatherproofing
- Lower termination of HVSC Plus downconductor
- Earthing system
- Labelling

Operation and Maintenance

The LPI Guardian Plus lightning protection system is designed to react to the rise in electric field which is present in approaching thunder storms. The Guardian Plus terminal becomes active only during storm activity.

- The system operates without the need for external power supply or spare parts for standard operation
- To keep the LPI Guardian Plus lightning protection system operating at optimum levels it needs to be regularly checked

Maintenance checks must be done:

- After each known lightning strike to the terminal
- Once every twelve months
- If changes have been made to the structure

Checks to be conducted in standard maintenance inspection:

- Is there any damage to Guardian Plus system?
- Has the structure to be protected been modified since the last maintenance check?

- Check finial tip for excessive pitting
- Check all rigging, mast mounts, saddles and conductor fixings are secure and tight
- Ensure that no dirt or other matter is sitting in the air gap between the finial tip and the surrounding panel edges
- If conventional downconductors are used, check that all conductors are securely fixed and not damaged
- Check for damage to the LPI HVSC Plus. The downconductor should not be able to be accessed by non authorised people or machinery
- All warning labels must still be in place
- Check LSR1 for secure installation and record number of strikes

Testing the Guardian Plus Terminal

LPI manufactures and supplies a terminal spark-over tester suitable for testing the Guardian Plus range of terminals. Contact your local distributor for further details.

Testing the HVSC Plus Downconductor

The HVSC Plus downconductor can be tested at various stages of its preparation for service. These stages and the tests that can be performed are summarised below.

1. Before upper or lower terminations are made (raw cable):

- Use a digital multimeter or, preferably, a Megger to measure the continuity between the inner and outer conductors of the HVSC Plus downconductor. The measurement should be "open circuit" (exceeding 1 MΩ)

2. After the upper termination is made but before the lower termination is made:

- Use a digital multimeter or, preferably, a Megger to measure the continuity between the inner conductor at the top (upper termination) and the shield (outer copper tape conductor) at the bottom of the cable. The measurement should give a resistance greater than about 3 kΩ and no more than about 15 kΩ

3. After the upper termination and lower termination are first made:

- Use a digital multimeter or, preferably, a Megger to measure the continuity between the inner conductor at the top (upper termination) and the shield (outer copper tape conductor) at the bottom of the cable. The measurement should be a "short circuit" (less than 1 Ω, excluding the resistance of the leads, the exact value depending on the length of HVSC Plus)

4. After installation of the HVSC Plus downconductor:

- Remove the waterproofing tape from the lower termination
- Disconnect the HVSC Plus downconductor from the lightning earth
- Use a digital multimeter or, preferably, a Megger to measure the continuity between the inner conductor at the top (upper termination) and the shield (outer copper tape conductor) at the bottom of the cable. The measurement should be a "short circuit" (less than 1 Ω, excluding the resistance of the leads, the exact value depending on the length of HVSC Plus).
- Reconnect the HVSC Plus lower termination to the lightning earth and re-seal the termination using waterproofing tape to ensure that it is waterproof

5. Report any problems arising from the above tests to your local LPI distributor for further advice

Testing the Lightning Earth

The procedure for obtaining the resistance of the lightning earth is described below. The method that is used is called the "fall-of-potential" (FOP) or "three-point" method. It relies on the use of a suitable 3-point or 4-point earth tester. As testing is carried out, please record all values per the table on page 45.

1. Disconnect the bonding cable from the structure to the lightning earth, as shown in Figure 38.
2. A "standard" LPI lightning earth will comprise radials of length 10 m. Assuming a 10 x 10 m earthing system, the current injection point for the FOP test should be at least 50 m, but preferably 100 m away from the lightning earth, with no intervening buried conductors. For a larger earthing system, this distance should be increased. Install a remote current injection electrode (RCIE) at a suitable location at about the above distance. This electrode may be a simple driven rod of sufficient depth to get a low resistance. (Note: if the resistance of this rod is too high, the instrument may be incapable of injecting a current to make the test).
3. Now install a rod at about 62 % of the distance between the RCIE and the lightning earth. The depth of this "potential rod" is not important (it can be less than 100 mm). Make a 3-point resistance measurement and note the value.
4. Shift the potential rod 1 m closer to the lightning earth, measure and note the value.
5. Shift the potential rod 1 m further away from the original test point, measure and note the value.
6. If the RCIE is sufficiently far away and there are no buried conductors affecting the results, the three values recorded should all be within 5 % of each other. If this is the case, then the resistance value measured is a true indication of the resistance of the lightning earth.

Record the value in the table on page 45 (lightning earth resistance).

7. The same procedure can be used to measure the resistance of the structure earth, bearing in mind that the RCIE distance needs to be 5-10 times the size of the earth grid. Record the resistance in the table on page 45 (structure earth resistance).
8. Reconnect the structure earth bonding cable to the lightning earth and measure and record resistance in the table on page 45 (overall earth resistance).
9. Record the lightning strike recorder (LSR) reading in the table on page 45.
10. Report any problems arising from the above tests to your local LPI distributor for further advice.

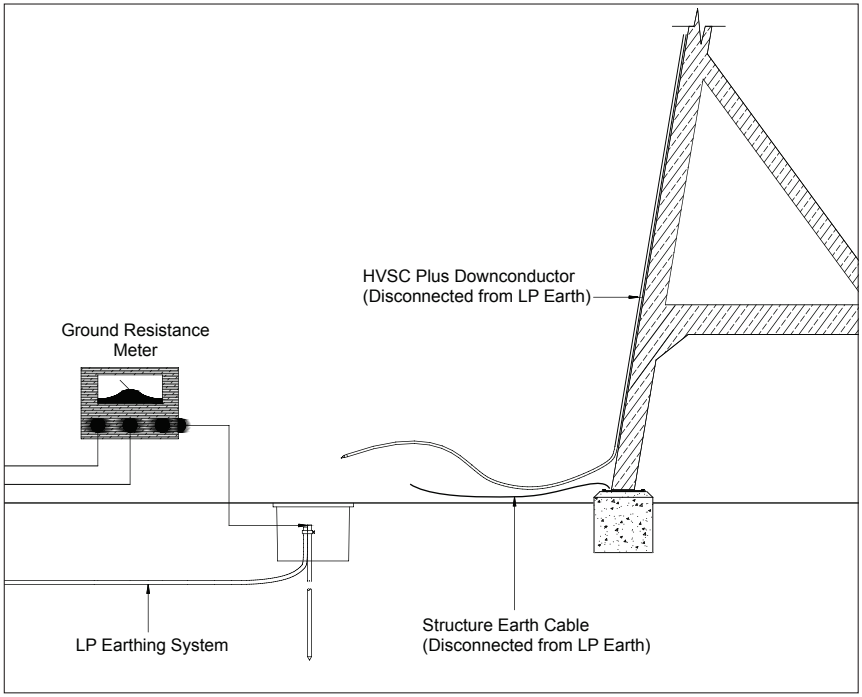


Figure 38.

Record of Earth Resistance Readings Table

Date	Inspected by	Lightning earth resistance [Ω]	Structure earth resistance [Ω]	Overall earth resistance [Ω]	LSR reading	Note (see below)

Notes:

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LIGHTNING PROTECTION INTERNATIONAL PTY LTD

ABN 11 099 190 897

- PO Box 379 Kingston, Tasmania, Australia 7051
- 9 Patriarch Drive, Huntingfield, Tasmania, Australia 7055

- Phone: *Australia:* 03 6281 2477
  International: +61 3 6281 2480
- Fax: +61 3 6229 1900
- Email: info@lpi.com.au
- Web: ***www.lpi.com.au***

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