CHURCH LIGHTNING PROTECTION

1. Introduction. This leaflet on church lightning protection has been produced primarily for the guidance of inspecting architects, parish architects and surveyors, churchwardens and other PCC members involved in maintenance of church buildings. It is being issued to inspecting architects and surveyors, and is available to others on the Diocesan website www.rochester.anglican.org (click 'Resourcing', then 'Forms, Publications and Guidance Notes' on the drop down menu. On the 'Forms, Publications and Guidance' page select 'Church Buildings') or on request from the DAC Secretary. This leaflet is based on BS EN 62305 'Protection against lightning' (refs 1 to 4), with some reference to its predecessor, BS 6651:1999 (ref 5), which has now been withdrawn. The leaflet incorporates guidance related to the 'Electricity at Work Regulations – 1989' (ref 6) (EWR:1989) and reference to the 'Construction (Design and Management) Regulations 2007'.

NEED FOR PROTECTION

2. Aspects. There are three aspects of protection namely:

a. Protection of the structure of the building.
b. Protection of people in the building and in the vicinity of the building.
c. Protection of electrical, especially electronic, equipment in the building or connected to the building's supplies.

3. Requirement to Protect. There is no formal requirement to install lightning protection. However a Church Council or other body could be held to blame for not having considered the need for protection. In the same way it could be held to blame if, having considered the need, of not then installing protection where it was shown to be necessary, especially for the protection of people. One particular aspect of this is the requirement of EWR:1989. Regulation 6 of the EWR:1989 requires that "Electrical equipment which may reasonably foreseeably be exposed to….. the effects of the weather, natural hazards….. shall be of such construction or as necessary protected so as to prevent, as far as is reasonably practicable, danger arising from such exposure." A lightning strike to an unprotected building could damage the electrical system leaving it in a state where a person could receive an injurious or fatal shock. Although it has not, as far as is known, been tested, a court might hold that a Church Council, in not installing an LPS (lightning protection system) was failing in its duty under the EWR:1989. The risk of such an accident is remote, nonetheless PCCs would do well to take account of the requirements of the EWR:1989 in deciding whether or not to install or upgrade an LPS, paying particular attention to the need for surge protection at the incoming service position. Ecclesiastical Insurance strongly recommends the installation of lightning protection but it is not usually a condition of the policy. Whilst most insurance claims are for damage to electronic equipment, on average one church in the UK is seriously damaged every year or so, often with the loss of irreplaceable cultural heritage and the loss of use of all or part of the church for a year or more.

4. Risk Assessment. The need for protection is determined by risk assessments using the procedures of BS EN 62305-2 'Protection against lightning – Part 2: Risk management'. The risks may be calculated in one or more of four categories and then compared with what is determined

as a tolerable figure. If a calculated risk exceeds the tolerable figure, then lightning protection should be installed in such a way as to reduce that risk to the tolerable figure or less. Relevant typical tolerable risks related to three of the four categories are given in the Edition 2.0 UK National Annex N F, as set out below:

Table N F.1 – Typical values of tolerable risk R_T

Types of Loss	R_T (y^{-1})
Loss of human life or permanent injuries	10^{-5}
Loss of service to the public	10^{-4}
Loss of cultural heritage	10^{-4}

It would need strong justification to allow a building to have a higher risk than that recommended for loss of human life or permanent injuries. This figure derives from a comparison with the risks of everyday living, as set out for example in BS 6651:1999. The fourth category of loss is economic loss and it is left entirely to the responsible authority to decide upon the need for lightning protection based on the economic viability but also related to other relevant categories of risk/loss. For churches, the first and third categories of loss are the more important, although it may be prudent to calculate the risk of economic loss where there is a variety of electronic equipment, since the majority of claims are for damage to electronic equipment. Because the risk calculation procedure is somewhat complex, a software programme is normally used.

DESIGN OF PROTECTION

5. Protection Levels. A lightning protection system (LPS) is designed according to one of four levels of protection such as is necessary to reduce each risk to no more than the tolerable risk. A church will generally require only a level IV protection although for larger buildings, in a high risk situation, level III may sometimes be required.

6. Air Termination Systems. Air terminations are those parts of an LPS, which are intended to act as capture points for a lightning strike. They will generally be placed on the high points of the building e.g. spires, pinnacles, flag poles and roof ridges and on high corners of a building, including tower corners. They may take the form of a separate rod or tape connected to a down conductor, a section of the down conductor brought up above the surrounding stonework or a weathervane. Bare conductors are to be preferred for all air terminations although roof ridge conductors may be PVC covered or placed under ridge tiles. Radioactive air terminals are not allowed (BS EN 62305-3 clause 5.2.1). The advice of the Diocesan Consultant should be obtained before installing other air terminals, such as early emission streamer devices, claiming to have qualities superior to conventional (Franklin) rods. Although lightning strikes are more likely to attach to the highest point of the building this is by no means invariably the case. In 2005 a Church in Rochester Diocese having an air termination on the tower was struck at the East end of the chancel with serious fire damage to the chancel.

7. Down Conductors. Down conductors are designed to take the current from the air terminations to ground level, where they will be connected to earth points. Older LPS commonly had a single down conductor on a church tower or spire. There have been a number of instances of lightning damage to churches with such installations, including one church in our own Diocese in 1989 and a church in Oxford Diocese in 2004. A system designed to Level IV requires an LPS with one down conductor for every 20 m taut string perimeter and to Level III, one every 15 m. It is a requirement of the Standard that an LPS shall include at least 2 down conductors. It is strongly recommended that, a church tower or spire should have at least two down conductors. One advantage of several down conductors is the splitting of the current into several channels; this reduces the high voltage that builds up during a strike. This voltage may cause 'side flashes', whereby the lightning seeks other metallic paths e.g. bell frames and mains wiring. Side flashing may, in passing over combustible material, cause a fire and also may cause severe damage to

electrical installations. Test breaks are inserted into down conductors to enable earth resistance testing of individual earth points. Whilst it is good practice to link tower down conductors, spire down conductors and tower corner conductors with a horizontal ring at tower roof level, subsequent continuity testing can be made easier if isolating spark gaps are inserted in the ring.

8. Earth Points. The lower end of the down conductors must be well connected to earth via an earth point for each conductor. The overall earth network resistance should be no more than 10 ohms. The earth resistance of an individual earth point should be no more than about 10 ohms times the number of down conductors. Thus for an installation with two down conductors, the earth resistance of each earth point may be up to about 20 ohms – easier to achieve than 10 ohms for a single earth point, especially in soils of high resistivity. Regardless of resistance, a minimum rod depth of 2.4 m should be used to minimise seasonal and long-term variation of resistance. Exceptionally in rocky conditions the 10 ohm limit may be discounted but a ring earth electrode around the base of the church, connected to all down conductors and to the mains earth is required. An earth point may consist of more than one earth rod, separated horizontally by a distance of at least the depth of the deepest rod. Each earth rod should be provided with an inspection pit.

9. Bonding - General. Bonding is the term used for connection of the LPS to any sizeable metallic structure that is considered to be in range of side flashing (as a rough guide one metre at ground level plus one metre per 10m of height). Bonding will often include metal bell frames, clock faces and mechanisms and invariably include the mains electrical installation, which will itself be connected to other services. BS EN 62305–3 states in clause 5.4.1 "Earth termination systems shall be bonded in accordance with the requirements of 6.2". Also The IEE Wiring Regulations, (ref 7) state in Regulation 411.3.1.2 "Connection of a lightning protection system to the protective equipotential bonding system shall be made in accordance with BS EN 62305". Bonding should not therefore be regarded as an optional extra, but as an integral part of an LPS. The value of such bonding is that during a lightning strike it reduces the voltage difference between the LPS and services or other metalwork and hence reduces the risk of flashover to the services or metalwork. In particular, bonding to the mains electrical system increases the contact with the earth and is beneficial to both the lightning protection system and to the mains electrical system and is a wise precaution under the EWR:1989 Regulations 6 and 8. Visually non-intrusive PVC-covered conductors (e.g. not green and yellow coverings) must be used, at least externally. The minimum cross-sectional areas for bonding conductors are given in Tables 8 and 9 of BS EN 62305-3:2011 under clause 6.2.2, including 16 mm^2 for copper and 25 mm^2 for aluminium for bonding conductors to the main earth terminal. Although these minima are much less than the typical 50 mm^2 of the main conductors, it is quite permissible to use lightning protection conductors. Any underground bonding must be in non-corroding material, i.e. copper, copper-clad steel, but not aluminium, and great care must be taken to protect joints against corrosion. Any bond taken through a wall would most conveniently be in circular section rather than tape and, even if PVC-covered, should be in copper, unless a separate sleeve is used, because of the likelihood of damage to the PVC during installation and the corrosive effect of limestone and lime mortar and concrete on aluminium. Although bonding of the LPS and the mains earth/neutral is advantageous and an important part of an LPS, it does bring part of the lightning current to the mains earth and therefore raise the voltage between the earth/neutral conductor and the live conductors. The fitting of Type 1 surge protection devices (SPDs) at the mains intake is an integral part of the external lightning protection system. Any other electrical service such as a telephone line should be fitted with Type 1 SPDs at the point of entry. The fitting of SPDs will normally require an electrician or telecoms technician.

10. Bonding - Routeing. Because the rate of rise of current in a lightning strike is very high, the bond should have not only a low resistance but also a low inductance. The inductance is largely determined by the length of the bonding cable, which should be taken by a fairly direct route, ideally no more than 1½ times the direct distance, from the nearest point at or above a test break of the nearest down conductor of the LPS, to the incoming service or metalwork. Its total

length should be ideally no more than 10 m and at the most 15 m. If a bonding lead is taken round a buttress or inside the building care should be taken to avoid long loops. Detailed guidance is given in clause 5.3.4 of BS EN 62305-3. As a rough guide the length of the loop must not exceed eight times the open end of the loop. Generally, services such as gas and water will already be bonded to the mains electrical system. Further bonding would be necessary only where the services pass fairly close to part of the LPS. Guidance is given on this in clause 6.3 of BS EN 62305-3. As a rough guide, 'close' might be considered to be 1m at ground level increasing to 3m at a height of 20m. Bonding to metal oil tanks and their feed pipes, again at the nearest point, is important even if the oil system is disused. Lightning side flashing may occur underground and it may be necessary to bond to an underground pipe if this is the nearest point (but the connection must still be above the test break on the nearest down conductor). It may be possible to avoid drilling through thick walling by bonding to the electrical system earth outside the building at the system earth point for separate earth systems (with overhead cables) but not to the sheath of the underground supply cable.

11. Electronic Equipment. Electronic equipment can be damaged by direct strikes to service cables or more commonly by voltage transients (surges) appearing in power lines or telephone lines as a result of a strike at a distance. The risk of damage to electronic equipment through transient voltages (surges) on mains supplies and telephone lines or induced voltages in system cabling is much higher than the risk of a strike to the building – of the order of 1 in 10 to 1 in 50 per year - albeit the consequences are far less, rarely extending beyond damage to the equipment itself. MICC cable is also susceptible to lightning transient damage. Damage due to transients can be minimised by installing surge protection devices, e.g. between each phase of the mains supply and earth where the supply enters the building, and at the equipment itself. Churches with computers or with a variety of electronic equipment, such as some of the following: smoke detection, intruder alarms, electronic boiler controls, sound systems, electronic lighting controls, electronic organs, would be advised to install Type 2 surge protection devices at the mains intake, to minimize the risk of damage. Overhead lines increase the risk. Combined Type 1 and 2 SPDs are available. Good design of an installation paying attention to routeing of cables and location of equipment can also help to reduce damage particularly by induced voltages from a direct strike to the LPS. BS EN 62305-4 gives comprehensive guidance on the protection of electronic equipment.

12. Theft precautions

a. Vulnerability. Parishes will be aware of the extensive theft of metals, including lightning conductors, from churches. The spate of thefts continues, albeit recent legislation is reducing it. Copper is more attractive than aluminium to thieves because of the higher price per weight and the greater weight in a given length of lightning conductor. Usually the section between about 2.5 m above ground and ground level is cut out, although sometimes, especially with older conductors having infirm fixtures, a longer section is pulled away. Occasionally the short link (earthing conductor) between the test break and the top of the earth rod is stolen. Sometimes aluminium conductors are stolen or cut and discarded.

b. Protection. Parishes are recommended to protect their church lightning conductors and if they are unfortunate in having conductors stolen, to replace any section of conductors above ground with aluminium. It is advisable to remove the PVC from the bottom inch or so of an aluminium down conductor so that the type of metal is more evident to thieves. The lower 3 m of copper down conductors should be covered with guards (see para. 13). For electrical safety a guard is also recommended for protective multiple earthing installations (see para 15). There should be adequate access to test joints. Vulnerable earthing conductors (connecting the test break to the earth rod) may be concreted into the ground.

13. Materials.

a. General. To avoid corrosion, bare aluminium must not be used below ground or where it is in contact with concrete, limestone or lime mortar.

b. Air terminations. Air terminations preferably should be in bare metal – copper or aluminium.

c. Down conductors and guards. Down conductors may be in either copper or aluminium, in either tape (flat strip) or round section and aesthetically will generally be better with a suitably coloured PVC coating. It is advisable to fit guards to the bottom 3 m of down conductors especially copper conductors, whilst leaving test breaks accessible. Guards for down conductors may be purpose-made in hard wood, in a tough PVC or in metal. The PVC and metal guards are available commercially from Furse of Nottingham. The PVC guards are moulded to fit snugly on both rod and tape conductors, are much better aesthetically and about half the price of the metal guards.

d. Joints. To avoid inter-metallic corrosion, leading to high resistance joints, purpose made bi-metallic joints must be used when joining dissimilar metals e. g. copper and aluminium.

e. Bonds. Aesthetically it is not acceptable to trail green-and-yellow PVC-covered bonding cables around the outside of the building. Bonds should be made using appropriately coloured (e.g. stone) or non-invasive colour, such as black, covered conductors and, in the case of bonds to the electricity supply main earth terminal, identified at each end.

f. Earthing. Earth inspection pits are available in either concrete or high performance polymer at similar prices. The concrete pits can be concreted in the ground to reduce movement or disturbance by thieves. The latter have lockable lids and are much lighter. Earth points usually use hardened steel copper-coated rods driven into the ground. It is possible to use horizontal tape in a trench where soil conditions make the driving of rods difficult or impossible. The trench must be at least 0.6 m deep to avoid problems of drying out. In ancient churchyards archaeological supervision of trenching will be required.

GENERAL

14. Requirements. The Diocese has prepared a requirements document to assist architects and other professionals in drawing up a specification for contractors (ref 8). Copies are available on the Diocesan website or from the DAC Secretary.

15. Permission. PCCs are advised to submit all proposals for repair and upgrading of lightning protection systems to the DAC for consideration. Routine inspection and testing requires no permission. Repairs including upgrading of defective earthing, the addition of a single down conductor, bonding and the installation of surge protection are considered minor matters not requiring a faculty provided the work is carried out in accordance with this guidance leaflet and relevant standards. Upgrading involving more than one additional down conductor will require a faculty. Reference should be made to the current Minor Matters guidance note.

Planning consent could be required for external work, if it constitutes a material alteration. The advice of relevant local authority planning officer may be sought.

EDF does not require consumers to seek the Company's permission to bond the lightning protection system to the Company's earth, provided that the bonding arrangements comply with BS EN 62305, the network earth is no more than 10 ohms and the LPS is regularly inspected and tested in accordance with BS EN 62305.

In addition it is recommended that in the case of protective multiple earthing installations, i.e. installations using the supply neutral conductor as the protective conductor, (normally appropriately labelled at the company's supply terminals) the first three metres of the lightning conductors above ground should be protected from direct contact. This gives protection from shock to anyone touching the down conductors, in the rare situation of a break in the Company's neutral conductor. Such protection is achieved in the case of PVC-covered conductors by making sure any joints are covered. Nonetheless full guards as paragraph 12 above may be advisable.

British Gas does not require churches to obtain individual permission for bonding provided that the requirements of the regulations are observed.

16. Additions. Advice should be sought about lightning protection implications when additions are made to the building including external electrical installations in the vicinity of down conductors and earth points, such as floodlighting, photovoltaic installations, external sensors, cameras and alarms, and also oil tanks near the building, or new equipment installed, such as electronic equipment, within the building.

17. Radio Equipment. Any firm installing radio equipment in a church tower or spire, will wish to protect its equipment from damage by lightning and may be willing to contribute to overall protection of the building and its equipment where a new installation or improvement of an old installation is required. Agreement should be reached on subsequent maintenance and responsibilities. Firms installing broadband equipment are not always aware of overall requirements for a building having an external LPS.

18. Regulations. Nothing in this guidance leaflet should be construed in a contrary manner to relevant British Standards and other regulations.

19. VAT. Advice should be sought at an early stage from the DAC Secretary and H M Customs and Revenue concerning current rates and applicability for new installations, upgrading (improvements) and repairs.

20. Health and safety. The Construction (Design and Management) Regulations 2007 may well apply both to the installation, maintenance and testing of lightning protection systems and also to other work, considering lightning as a hazard which should be guarded against. For example the designer of an LPS has a responsibility for providing a design that has considered safety in its installation and subsequent maintenance, regardless of whether the project size 'triggers in' the CDM Regulations. Also, in a general works project involving major scaffolding, the need to bond the scaffolding to the LPS and mains earth and provide its own earthing should be considered as a safety issue. Anyone in doubt about the application of the CDM Regulations should seek advice from a health and safety consultant.

MAINTENANCE

21. Visual Inspection. At least once a year a Churchwarden or other designated person should carry out a visual inspection of the LPS from ground level and other easily accessible areas such as a tower roof to see that all parts are securely connected together, fixed to the building and with no evident corrosion. A record should be made using the form attached to this leaflet. After a known or suspected lightning strike the system should be inspected for obvious damage. In conjunction with the four-yearly testing, the contractor should carry out a close visual inspection involving all conductors at tower roof level and any part of the system where faults are revealed by testing.

22. Testing. Although BS 6651 has now been 'withdrawn', it is permissible to continue testing a system designed to this standard. The requirements of the two standards are similar apart from

the testing periodicity. The individual earth points and the earth network as a whole should be tested at least every four years (BS EN 62305, but annually by BS 6651), using the procedures stated in BS 7430 (ref 9) It is advisable to test a new installation within 12 months. Testing involves the following:

- Earth resistance of each earth point (test break open). BS 6651:1999 specifies a maximum of 10 ohms times the number of down conductors. BS EN 62305-3:2006 does not specify a maximum but a figure not exceeding the BS 6651 figure by 20% should be considered acceptable. Large changes even below these limits are cause for concern and should be investigated or watched by more frequent testing.
- Earth network resistance from each earth point (test break closed). This is done at the same time as the test above. It is not an accurate test but will reveal high resistance connections of that particular down conductor to the rest of the system.
- Earth network resistance. This involves placing the test probes at a considerably greater distance than for the two tests above and in such a manner that the measurement is related to the electrical centre of the network.
- Continuity testing. In a church with a spire having two down conductors, it is good practice, due to the inaccessibility of the connections to the weathervane or other air termination, to carry out an electrical test of continuity from the ground having temporarily broken any other paths, e.g. through a metal bell frame or at tower roof level, unless these are already broken by the insertion of isolating spark gaps. Also a test from one end of the system to the other, typically from the tower to the East end of the chancel is useful. More extensive systems should have a continuity test between each pair of adjacent conductors.

Earth testing requires specialist equipment and knowledge possessed by lightning protection engineering firms but not generally by electrical contractors.

23. Records. A plan of the installation together with additions and modifications and results of periodic inspections, including annual visual inspections, and tests should be kept in the Church Log Book.

24. EWR 1989. The Church Council as the 'duty holder' under the Electricity at Work Regulations 1989 has a responsibility for determining adequate maintenance periodicities, i.e. for both visual inspection and testing and under EWR Regulations 13 & 14 and that testing is carried out in a safe manner.

25. Firms. The Association of Technical Lightning, and Access Specialists (ATLAS), 6 - 8 Bonhill Street, London EC2A 4BX, tel. 0844 249 0026, fax 0844 249 0027, E mail info@atlas.org.uk provides general guidance and, on its website www.atlas.org.uk a list of member firms and their specialities. Note the change of all ATLAS contact details. A list of installers in the South East of England, who work in Kent, is available from the DAC Secretary.

INSPECTING ARCHITECTS AND SURVEYORS

26. The Diocese recommends that inspecting architects and surveyors, in their quinquennial reports, should:

a) advise PCCs having unprotected churches to consider installing a LPS. A formal risk assessment is the appropriate basis for this consideration.

b) advise PCCs having a church with a single down conductor to consider upgrading the installation to include at least two down conductors with bonding to extensive metalwork in the tower, the main earth terminal of the electricity supply and the installation of a Type 1 SPD.

c) advise PCCs having an LPS, which is not bonded to the mains electrical installation, to

have a bond and Type 1 SPD installed. (Such a recommendation may come from the electrical inspector). Bonding may require an extension to the LPS to provide a down conductor in proximity (say 10 m) to the main earth terminal of the electrical installation.

SUMMARY

27. All but the smallest churches in our Diocese ought to have a lightning protection system for the protection of both the building and also probably for people in the building and in the vicinity of the building. An LPS with two down conductors and appropriate bonding with Type 1 SPDs should be considered a basic minimum standard. Such a partial system may in some cases provide adequate protection. Additionally churches with computer or extensive electronic equipment are advised to have Type 2 SPDs at the mains intake as well as at the equipment, to protect the equipment. Specialist firms should be used for all lightning protection work and appropriate tradesmen and contractors for installation of SPDs. **The Ecclesiastical Insurance strongly recommends the installation of lightning protection but it is not usually a condition of the policy.**

28. Advice. This leaflet has been prepared for the Diocesan Advisory Committee for the Care of Churches by The Rev. Christopher Miles C Eng, FIET who will be pleased to give further advice.

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REFERENCES

1. BS EN 62305-1:2011 Protection against lightning – Part 1: General principles.
2. BS EN 62305-2:2012 Protection against lightning – Part 2: Risk Management
3. BS EN 62305-3:2011 Protection against lightning – Part 3: Physical damage to structures and life hazard.
4. BS EN 62305-4:2011 Protection against lightning – Part 4: Electrical and electronic systems within structures.
5. BS 6651:1999 Code of practice for protection of structures against lightning
6. Memorandum of Guidance on the Electricity at Work Regulations 1989. HMSO HS(R)25 ISBN 07176 160 29.
7. BS 7671:2008 - Requirements for Electrical Installations IEE Wiring Regulations Seventeenth Edition.
8. 'Requirements for Lightning Protection for Parish Churches', May 2007, prepared by Eur Ing P C Palles-Clark, C Eng, FIET and Rev G C M Miles MA, MSc, C Eng, MIET.
9. BS 7430:2012 Code of practice for Earthing.

June 2014 Para. 1 (website access), Paras. 12b, 13c (guards) and ref. 2 updated and ref 5 inserted.

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LIGHTNING PROTECTION SYSTEM VISUAL INSPECTION REPORT [1]

1. Brief Description of System Church:

Item	Location
Air Terminations	e.g. 3 corners of tower roof, nave roof ridge
Down conductors	e.g. Tower N, Nave S
Earth points (with inspection pits?)	e.g. Tower N (no pit), Tower S (pit)
Bonds	e.g. Bellframe, tower roof, main earth terminal
Surge protection devices	e.g. Main switchboard

2. Inspection

Inspection item	Date [1]		
From ground level and tower roof (if accessible) check (with binoculars) that the ridge tape/s and down conductor/s are intact and firmly fixed to the structure.			
Check where possible that all joints and bonds are firmly tight and not showing signs of corrosion.			
At ground level check that the tape is not corroded away.			
If there are earth rod inspection pits, lift the lid and check the condition of the joint between the tape/rod and earth rod. Report more than slight corrosion.			
Check for signs of any other mechanical damage. Report any damage found.			
Signature			

Notes
1. This form is designed for use by a churchwarden or other PCC authorized person in Canterbury and Rochester Dioceses in accordance with the Diocesan leaflet on lightning protection.
2. This form is designed for the 3 intervening years between a full inspection and test by a lightning protection specialist.

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