London Diocesan Advisory Committee

LIGHTNING PROTECTION

1. SUMMARY GUIDANCE: BASIC REQUIREMENTS FOR TESTING OF LIGHTNING PROTECTION SYSTEMS
2. DETAILED GUIDANCE: INTRODUCTION
3. THE NEED FOR PROTECTION
4. DESIGN OF PROTECTION
   - 4.1 Protection Levels
   - 4.2 Air Termination Systems
   - 4.3 Down Conductors
   - 4.4 Earth Points
   - 4.5 Bonding – General
   - 4.6 Bonding – Routeing
   - 4.7 Electronic Equipment
   - 4.8 Materials
5. PERMISSIONS
   - 5.1 The DAC and the Faculty Process
   - 5.2 Planning Permission
   - 5.3 Electricity Suppliers
   - 5.4 Gas Suppliers
6. ADDITIONS TO EXISTING SYSTEMS
   - 6.5 Additions in General
   - 6.6 Radio Aerials
7. REGULATIONS AND LEGISLATION
   - 7.1 VAT
   - 7.2 Regulations and Standards Generally
   - 7.3 Health and Safety
   - 7.4 Electricity at Work Regulations 1989
8. MAINTENANCE
   - 8.1 Visual Inspection
   - 8.2 Testing
   - 8.3 Records
9. THE ROLE OF INSPECTING ARCHITECTS / SURVEYORS
10. SUMMARY
11. MAINTENANCE AND INSTALLATION COMPANIES
12. REFERENCES AND FURTHER READING
13. ACKNOWLEDGEMENTS

1. SUMMARY GUIDANCE: BASIC REQUIREMENTS FOR TESTING OF LIGHTNING PROTECTION SYSTEMS

1.1 It is a requirement of the *Code of Practice for Protection of Structures Against Lightning (BS EN 62305: 2006)* that all lightning protection systems are inspected and tested annually. This is because earth resistance readings do not simply increase annually, they will invariably rise in summer months, as the sub-strata (earth) dries-out. For this reason the code of practice states that tests should be repeated at fixed intervals, preferably not exceeding 12 months, although it may be advantageous to choose a period slightly shorter than 12 months in order to vary the seasons in which tests are made. It is also important that a fully qualified and registered engineer checks that all joints and bonds are not corroded and still have electrical continuity.

1.2 It is worth remembering that most places of worship have lightning protection systems that would not meet the standards set out in the code of practice so maintaining these 'partial' systems effectively becomes even more important. Lightning strikes are no longer a rarity - as a result of climate change associated with global warming we now have lightning strikes in the winter as well as in the summer months.

1.3 Some people argue that it may be appropriate to reduce the frequency of testing to once every two and a half years or perhaps every five years to coincide with the quinquennial inspection report, but this is not advisable as the results of lightning strikes and static discharge can be devastating. Testing is important as the air termination rod is a 'capture mechanism' which attracts the lightning.

1.4 Therefore if a building with a poorly maintained system or a defective earth installation is struck by lightning or static electricity this can result in 'flash-over' to other metals within or on the structure. This can take place even without a direct strike, as all lightning conductors pick up static even if the storm is 4 miles distant. For this reason, all metal bellframes and other metal within or on the structure should be bonded to the lightning conductor system to prevent this 'flash-over' taking place.

1.5 In order to ensure that the person carrying out the test is suitably qualified it is a good idea to ask to see the engineer's Construction Skills Certification Scheme (CSCS) card as proof of qualification. The card will contain the engineer's photograph and their Construction Industry Training Board (CITB) registration number.

1.6 The method of testing must be in accordance with the relevant section of the code of practice. Testing, inspection and certification for one earth installation and one down conductor can cost less than

£100 and should therefore be incorporated into the yearly maintenance budget. A certificate of compliance with the code of practice is effective for a 12 month period (much like an MOT on a motor vehicle) and can assist in proving that the building is well maintained in the event of a claim made to your insurance company.

1.7 In addition, where surge protection is fitted to the electrical system this must be independently inspected as part of the periodic fixed electrical inspection by a qualified electrician or electrical contractor.

2: DETAILED GUIDANCE: INTRODUCTION

This guidance has been produced to inform inspecting architects, parish architects, churchwardens and other PCC members involved in maintenance of church buildings. It is based on BS EN 62305:2006 'Protection against lightning' (refs 1 to 4), with some reference to its predecessor, BS 6651:1999 (ref 5), which remained a valid standard until 31st August 2008. 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 1994'.

3: THE NEED FOR PROTECTION

3.1 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.

3.2 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 or having considered the need, nonetheless not having installed 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 as to prevent, so 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.

3.3 Although it has not, as far as is known, been tested, a court might hold that a Church Council, in not installing an LPS 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. The Ecclesiastical Insurance Group strongly recommends the installation of lightning protection but does not insist on it. 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.

3.4 The need for protection is determined by risk assessments using the procedures of BS EN 62305-2:2006 '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.

3.5 Relevant typical tolerable risks related to three of the four categories are given in the UK National Annex NK, as set out below:

Table NK.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 should be noted that BSI has assigned a UK recommended tolerable risk of loss of cultural heritage which it believes is more appropriate to the UK environment Further, it is stated in the Standard "It is the responsibility of the authority having jurisdiction to identify the value of tolerable risk" (Clause 5.4) and therefore other values may be used provided they can be justified. 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 a tolerable risk. 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.

4: DESIGN OF PROTECTION

4.1 Protection Levels. A lightning protection system (LPS) is designed according to one of four levels of protection such as is necessary to reduce the risks 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.

4.2 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. On a large roof area, requiring an air termination network, the mesh size differs for different levels of protection (20 m x 20 m for level IV and 15 m x 15 m for level III).

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 DAC 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 E end of the chancel with serious fire damage to the chancel.

4.3. 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 has been a number of instances of lightning damage to churches with such installations, including a church in Rochester 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, as in BS 6651 and to Level III, one every 15 m. It is strongly recommended that, as in BS 6651, 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 'sideflashing', whereby the lightning seeks other metallic paths e.g. bellframes and mains wiring. Sideflashing may, in passing over combustible material, cause a fire and also may cause severe damage to electrical installations.

EIG and English Heritage in their joint booklet (ref 3) suggest that in most cases good protection of a church tower or spire, including two down conductors, will give a satisfactory level of protection to the whole building. This however depends on the geometry of the building, that is, the height of the tower or spire in relation to the length of the nave and chancel in a traditional church layout, and the ability to bond to the mains earth (see paras. 9, 10 below). 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.

4.4 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. Each earth rod should be provided with an inspection pit.

4.5. 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 sideflashing (as a rough guide one metre at ground level plus one metre per 10m of height). Bonding should generally include metal bellframes, clock faces and mechanisms and 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 413-02-02 "Main equipotential bonding conductors are required to

connect the following metallic parts to the main earthing terminal … (vi) lightning protection systems".

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. Non-invasive PVC-covered conductors (e.g. not green and yellow coverings) should be used, at least externally. The minimum cross-sectional areas for bonding conductors are given in Tables 8 and 9 of BS EN 62305-3:2006 under clause 6.2.2, including 14 mm^2 for copper and 22 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 lime mortar on aluminium.

4.6. 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 a point at or above a test break on the nearest point 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 oil tanks and their feed pipes, again at the nearest point, is important even if the oil system is disused. Lightning sideflashing 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 either at the system earth point for separate earth systems (with overhead cables) but not to the sheath of the underground supply cable. The layout of a typical bonding arrangement is shown on page 172 of the I.E.E. On Site Guide to BS7671:2001(2004) (ref 8).

4.7. Electronic Equipment. Electronic equipment can be damaged by direct strikes 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. M.I.C.C. 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 lightning controls, electronic organs, would be advised to install surge protection devices at the mains intake, to minimize the risk of damage. Overhead lines increase the risk. 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. Guidance is also provided in the EIG/EH booklet 'Surge Protection Equipment' (ref 10).

4.8. Materials. Air terminations should preferably be in bare metal – copper or aluminium. 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. Bare aluminium must not be used where it is in contact with limestone or lime mortar because of corrosion. Because of the high cost of copper there have been a number of thefts of copper

down conductors, also a case of cutting and discarding of aluminium conductors. Therefore there is an advantage in using aluminium but the bottom two inches should be left bare to show that it is aluminium.

Copper down conductors may be protected by a hardwood cover provided the test break is accessible. Such cover is also recommended for protective multiple earthing installations (see para 14). Joints between dissimilar metals should be made using bi-metallic connectors. 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 0.5m deep to avoid problems of drying out. In ancient churchyards archaeological supervision of trenching will be required. 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 main earth terminal, identified at each end.

5. PERMISSIONS

5.1 The DAC and the Faculty Process. PCCs are advised to submit all proposals for repair and upgrading of lightning protection systems to the DAC for consideration in advance of making an application for a Faculty. 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 may be considered minor matters not requiring a faculty provided the work is carried out in accordance with this guidance leaflet and relevant standards. Reference should be made to the current minor works list available at the following link: http://www.london.anglican.org/DACMinorWorks.

5.2 Planning Permission. Planning Permission is usually required for external work. The advice of the relevant local planning authority should be sought. Please also consult the London DAC's forthcoming advice note entitled "Church Buildings and the Planning System" which will be available on the "In Depth Advice by Topic" area of the Diocese's website: http://www.london.anglican.org/DACInDepthAdvice

5.3 Electricity Suppliers. EDF does not require consumers to seek the Company's permission to bond the lightning protection system to the Company's earth provided that:

(1) The bonding arrangements comply with BS EN 62305:2006.

(2) The network earth is no more than 10 ohms

(3) The LPS is regularly inspected and tested in accordance with BS EN 62305:2006

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.

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

6. ADDITIONS TO EXISTING SYSTEMS

6.5. Additions in General. Suitable professional advice should be sought about lightning protection implications when additions are made to the building including external installations, such as floodlighting and oil tanks in the vicinity of down conductors and earth points or new equipment installed, such as electronic equipment, within the building.

6.6. Radio Aerials. Any firm installing radio equipment in a church tower or spire (using it as an aerial mast), will wish to protect its equipment from damage by lightning and is likely to be willing to contribute significantly 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.

7. REGULATIONS AND LEGISLATION

7.1. VAT. On listed buildings, new installations are zero-rated for VAT. Repairs and maintenance may be eligible for a partial refund of VAT under the Listed Places of Worship Grants Scheme. Please see the Scheme's website below for further details:
http://www.lpwscheme.org.uk/

7.2. Regulations and standards generally. Nothing in this guidance should be construed in a contrary manner to the most recent relevant British Standards and other statutory regulations.

7.3. Health and safety. The Construction (Design and Management) Regulations 1994 may well have applicability 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 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.

7.4. Electricity at Work Regulations 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.

8. MAINTENANCE

8.1. Visual Inspection. At least once a year a Churchwarden or other designated person should carry out a visual inspection from ground level of the LPS to see that all parts are securely connected together and fixed to the building. 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.

8.2. Testing. The individual earth points and the earth network as a whole should be tested at least every four years, using the procedures stated in BS 7430:1998 (ref 12). 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 bellframe 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 E end of the chancel.

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

8.3. 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.

9. THE ROLE OF INSPECTING ARCHITECTS / SURVEYORS

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.

c) advise PCCs having an LPS, which is not bonded to the mains electrical installation, to have a bond 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 point of the electrical installation.

10. SUMMARY

All but the smallest churches 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 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 surge suppressors at the mains intake as well as at the equipment, to protect the equipment. Specialist firms should be used for all lightning protection work. The Ecclesiastical Insurance Group strongly recommends the installation of lightning protection but does not insist on it.

11. MAINTENANCE & INSTALLATION COMPANIES

The Association of Technical, Lightning and Access Specialists (ATLAS) (formerly National Federation of Master Steeplejacks and Lightning Conductor Engineers), provides general guidance and a list of member firms and their specialities.

ATLAS, 6-8 Bonhill Street, London EC2A 4BX
Phone: 0844 249 0026
Email: info@atlas.org.uk
Website: www.atlas.org.uk

12. REFERENCES AND FURTHER READING

1. BS EN 62305-1:2006 Protection against lightning – Part 1: General principles
2. BS EN 62305-2:2006 Protection against lightning – Part 2: Risk Management
3. BS EN 62305-3:2006 Protection against lightning – Part 3: Physical damage to structures and life hazard.
4. BS EN 62305-4:2006 Protection against lightning – Part 4: Electrical and electronic systems within structures.
5. BS 665l:1999(2005) - Code of practice for the protection of structures against lightning.
   This Standard ceases to be valid on 1st September 2008.
6. Memorandum of Guidance on the Electricity at Work Regulations 1989. HMSO HS(R)25
   ISBN 07176 160 29
7. BS 7671:2001(2004) - Requirements for Electrical Installations - IEE Wiring Regulations - Sixteenth Edition. *This Standard will be replaced by BS 7671:2008 17th Edition*.
8. IEE On-site Guide to BS 7671:2001(2004). *A new guide based on the new edition of the Standard will be published.*
9. 'Lightning Protection for Churches – A guide to design and installation' (2000), available free from EIG, Beaufort House, Brunswick Road, Gloucester GL1 1JZ or English Heritage, 23 Savile

Row, London, W1X 1AB. *Note: this publication and the one below were prepared before the introduction of BS 62305*

10. 'Surge Protection of Equipment – A guide to selection and installation in historic buildings' October 2004 available free from EIG or EH.
11. 'General Advice for Architects and Surveyors on the Requirements for Lightning Protection for Parish Churches', Sep 2007, prepared by Eur Ing P C Palles-Clark, C Eng, FIET and
    The Rev G C M Miles MA, MSc, C Eng, MIET.
12. BS 7430:1998 Code of practice for Earthing. A new edition of this Standard is in course of preparation.

13. ACKNOWLEDGEMENTS

This advice draws substantially upon a document drawn up for the Diocese of Canterbury by The Rev. Christopher Miles C Eng, MIET, Diocesan Consultant on Lightning Protection, and also upon the Society for the Protection of Ancient Buildings' advice on its "Faith in Maintenance" website, www.spabfim.org.uk, by kind permission of Ms Sara Crofts.

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