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# REGULATIONS IN MEDICAL LOCATIONS

## The importance of Section 710

IET
Electrical excellence

**HERITAGE BUILDINGS PAGE 6** SENSITIVE RENOVATION | **FLOOR & CEILING PAGE 17** INSTALLING ELECTRIC FLOOR AND CEILING HEATING | **LEDS PAGE 22** EVOLUTION & INNOVATION | **PME SUPPLIES PAGE 32** PRINCIPLES AND ISSUES


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# **Wiring**Contents #45

**YOUR LETTERS**
From the Wiring Matters inbox. **P4**

**HISTORIC BUILDINGS AND MONUMENTS**
The work of English Heritage's Building services Engineering and Safety Team. **P6**

**EV CHARGING**
Voltimum's expert panel reveals the road ahead. **P9**

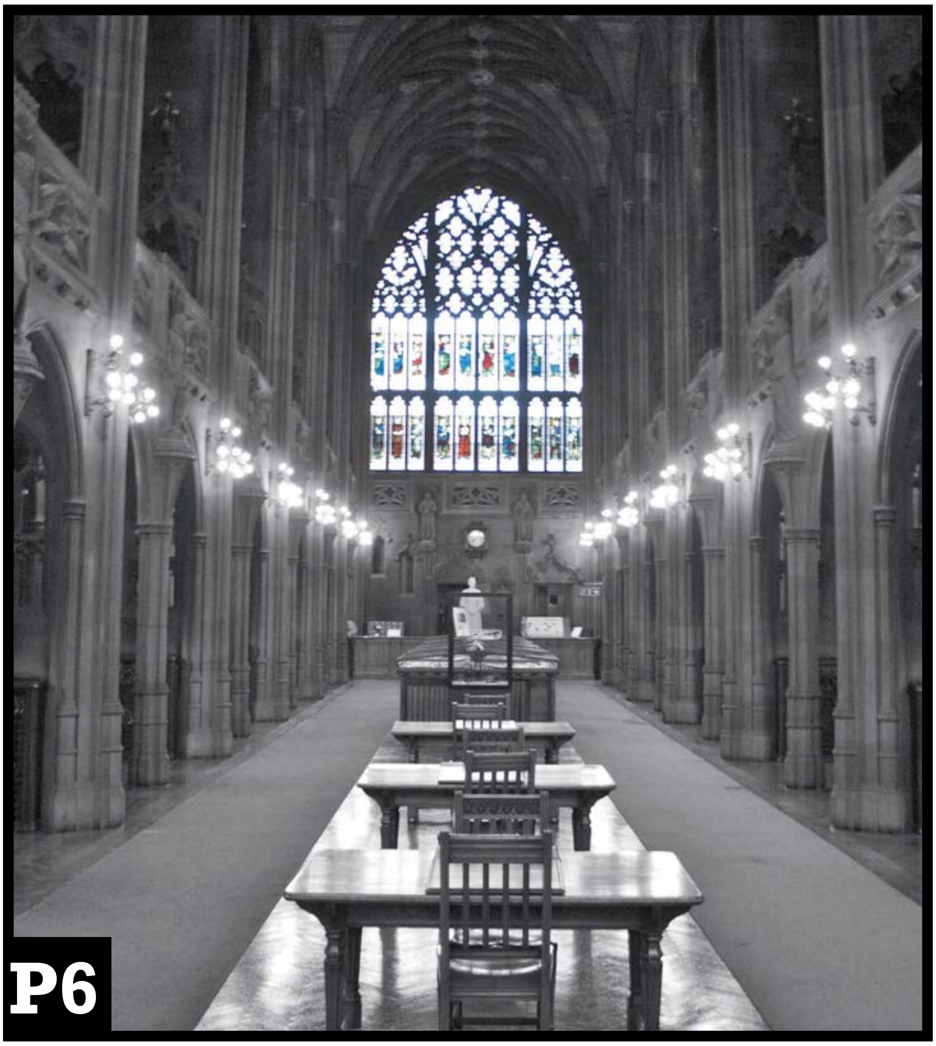
**SECTION 710**
Design culture within the Medical Locations sector needs to change. **P12**

**FLOOR AND CEILING HEATING SYSTEMS**
Current requirements and future developments. **P17**

**LED ADVANCES**
Rare earths are enabling flicker-free ac LEDs. **P22**

**MARINAS AND JETTIES**
Special requirements for electrical installations and European-level developments affecting inland navigation vessels. **P29**

**PME SUPPLIES**
Protective multiple earthing can pose issues when electrical supplies are used outdoors or to supply external buildings. **P32**



**P6**

**P12**

**P32**

IET Electrical excellence

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# YOUR**LETTERS**

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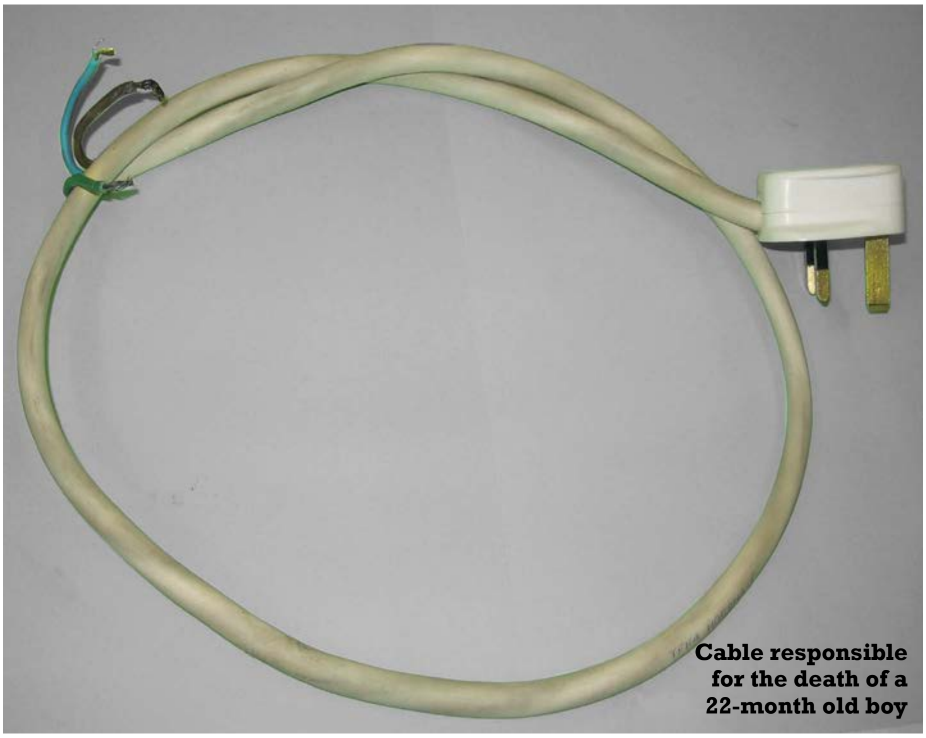


**Cable responsible for the death of a 22-month old boy**

## SOCKET PROTECTORS

The article on socket protectors in the latest edition of *Wiring Matters* caught my attention. There were two main reasons for this: first, as a grandfather of two young boys I use socket protectors in my house whenever my grandsons visit; and, secondly, because last year I gave evidence on socket protectors at a Fatal Accident Inquiry (the equivalent in Scotland of an inquest in England and Wales) concerning the tragic electrocution of a 22-month old boy in his home.

I had investigated this fatal accident in my capacity as the Health & Safety Executive's Principal Specialist Inspector (Electrical Engineering) in Scotland.

The young boy died when he picked up a short length of flexible cable, plugged it into a socket-outlet in his bedroom, and took hold of the exposed live conductor. The cable had been left in the property by some workmen who had removed it from an oven they were installing.

I gave evidence on the hazards and risks associated with not disposing of unterminated cables, on relevant legal duties, and on the matter of whether an RCD in the installation would have prevented the death.

However, as I was giving my evidence I was asked by the Procurator Fiscal if the death would have been prevented if a socket protector had been plugged into the socket-outlet. Having advised the court that domestic electrical safety is not a matter within HSE's remit, I did express the professional opinion that a socket protector would have prevented the accident. I maintain this view; I see this function of preventing inquisitive and playful youngsters from plugging appliances into socket-outlets as being the main advantage of socket protectors.

I agree with Mark Coles about the effectiveness of the shutter mechanism on BS 1363 socket-outlets preventing things being poked into the sockets. But I also agree with the sentiment in the second sentence of the government's advice about socket protectors stopping young children plugging in appliances.

On that basis, in the context of Mark's valid observations about the deficiencies of, and dangers associated with, some socket protectors currently on the market, I would suggest that the best solution is for interested parties, including the IET, to press for a British Standard on socket protectors to set standards on matters such as the size of the pins and the materials of construction.

On a lighter note, I would like to offer my congratulations on the new layout and style – it's very good.

***John Madden***
***HM Principal Specialist Inspector***
***(Electrical Engineering)***
***Health and Safety Executive***

## LOOP STITCHING

Please abandon the loop stitching (silly wire staples), they do not make filing easier; ring binders do not hold them in place and they will pull out of the magazine when hung in a binder for any length of time. I know this from other catalogues that use this method.

In any case, I have a perfectly good hole punch with which I am very happy. Why is it that big organisations always change things that work well? Now I have to remove the staples and re-staple it properly so that it fits in the hole punch and will stay in one piece when filed. So much for progress.

Changing the subject, I was pleased to see that you have finally caught up with the stupidity of socket covers. If only it was now possible to tell social services that electricians know best, and that playgroups, schools and village halls do not need them in order to have permission to operate.

***Paul Brown***
***PA Brown Electrical***

## PAT TESTING

The September issue of *Wiring Matters* was useful and informative as always. However I'm dismayed by the feature starting on page 11 which frequently refers to 'PAT testing'. Written long-hand this is 'Portable Appliance Tester testing' which implies testing of the PAT itself. Surely it would be much better to refer to 'testing using a PAT'?

I appreciate that 'PAT testing' is a colloquialism used in the trade, but it's wrong and there's no need to perpetuate it in writing.

***Colin Clarke MIET***
***Technical Manager***

*Point taken – Ed*

## LEDs

May I suggest an addendum to 'Leading lights?' – page 21 of issue 44. The ability to dim luminaires can be important. Some can be, some can't, and I suspect that the lumens per watt decrease at different rates between different technologies. It's possible that a fitting that is optimal when fully on may no longer be so when dimmed.

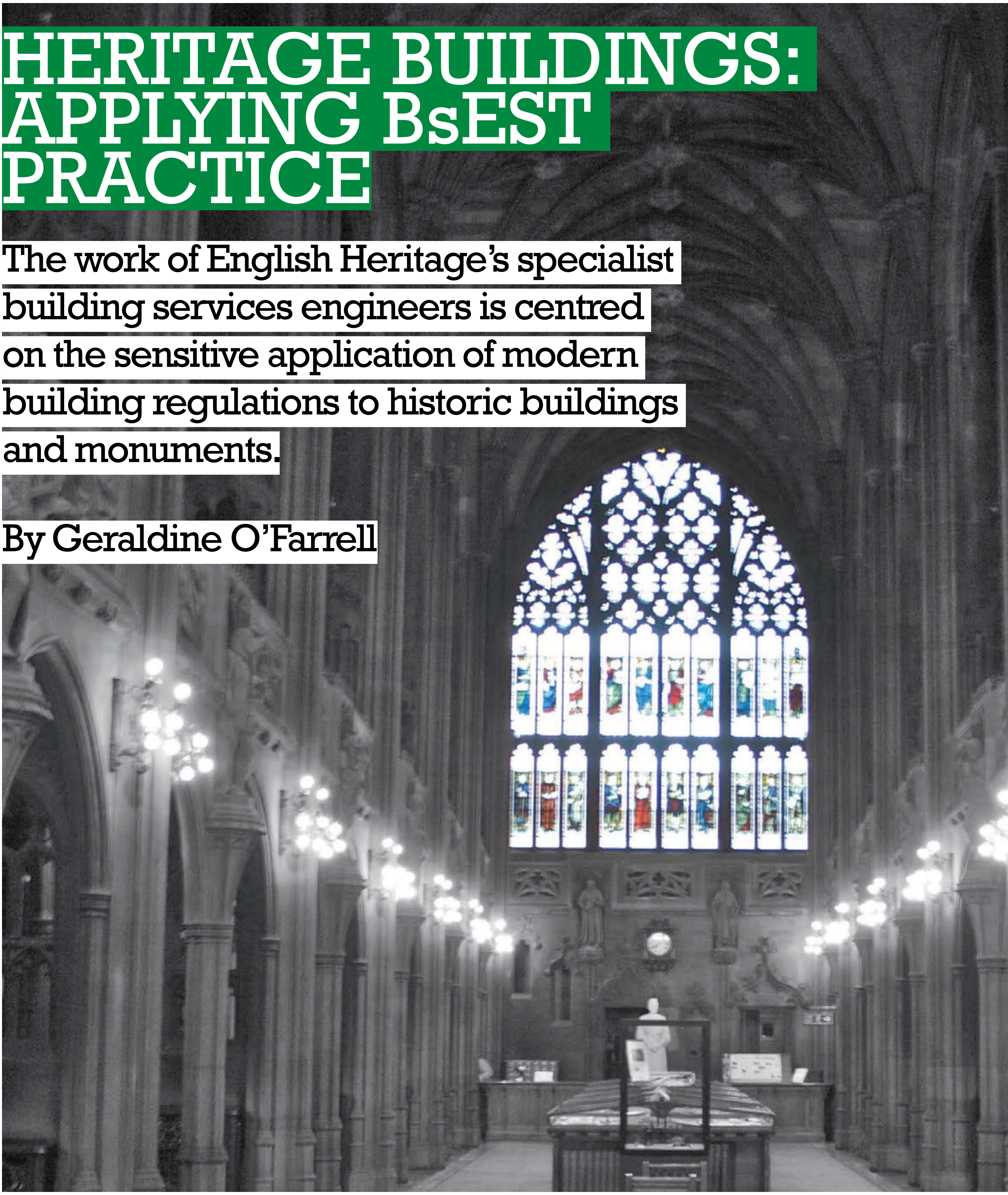
Full marks for the issue.

***Tom Jacobs MIET***

# HERITAGE BUILDINGS: APPLYING BsEST PRACTICE

The work of English Heritage's specialist building services engineers is centred on the sensitive application of modern building regulations to historic buildings and monuments.

By Geraldine O'Farrell



**Original multi-gang switch plate for lighting at the John Rylands library**

**Sensitive retention of original lighting fixtures in Manchester's John Rylands Library**

WHEN LISTED historic buildings and scheduled monuments are mentioned, the IET Wiring Regulations (BS 7671:2008 (2011)), or indeed any aspect of electrical services are unlikely to be among the first things on anyone's mind. However, for the members of the BsEST (Building services Engineering and Safety Team) the association of historical buildings with building regulations is an integral part of every working day.

This small team of chartered engineers works within English Heritage, the government's advisory body on England's historic places. It includes, among other specialists, a small group of electrical and mechanical building services engineers with decades of experience in design both within and outside the heritage field. The team handles a varied portfolio of work, mostly advising on and overseeing building-services work within third-party heritage buildings and English Heritage's own national properties.

As well as interpreting the many codes of practice and British Standards linked to building services, the team's role is to ensure that the unnecessarily rigid application of the same guidelines and standards does not destroy or permanently disfigure buildings of huge historic importance.

### Guidance

To this end, BsEST members have written English Heritage's own guidance on a variety of topics to assist heritage property owners and guardians in applying British Standards and adhering to other safety and standards issues. These are available both from the HELM (Historic Environment – Local Management) and the English Heritage websites.

The guidance offered covers general services, internal and external lighting, surge protection and lightning protection. In addition to the more traditional services the BsEST team members have also written guidance on photovoltaic and solar thermal installations, and their impact on heritage buildings, energy conservation, and micro wind generation; a short-form document on heat pumps will be released shortly.

These guidance notes are written in an accessible way and without too much technical language, enabling the widest audience possible to gain understanding from reading them.

In addition to all the new services work that the engineers are involved with, one group member is also working on the energy-monitoring of the entire English Heritage estate. The BsEST team is also actively incorporating smart-metering and green-champion schemes across the organisation.

English Heritage also actively encourages the preservation of early examples of building services which are often destroyed in the misguided belief that they have no historic value of their own: they are deemed reusble and part of England's industrial archaeology.

### John Rylands Library

One good example of how BsEST engineers promote the retention and possible reuse of existing early building-services systems can be found in the form of an early electrical system in the John Rylands Library, part of Manchester University since 1972. The striking Victorian Neogothic building, located in Manchester's Deansgate and designed by the architect Basil Champneys, is one of only five National Research Libraries and now houses the third-largest academic library in the United Kingdom.

It took ten years to build, and was inaugurated on 6 October 1899 with the first day of opening to the public being the 1 January 1900. It was erected as a permanent memorial to entrepreneur and philanthropist John Rylands by his third wife Enriqueta, who purchased some of the finest private book collections of the day including the famous Althorp Library from the 5th Earl Spencer in 1892, comprising 43,000 books, including some 4,000 printed before 1501.

All this valuable paperwork was deemed too great a fire risk to install gas lighting, so electrical lighting was installed throughout, in addition to a sophisticated ventilation and heating system. The same wonderful light fittings and accessories are still employed today, along with the brass wiring trunkings and original multi-gang light switches (although the latter are for display purposes only, the lighting controls being provided by modern units hidden 'back of house').

In 2003 a major refurbishment and new entrance wing project was started, funded by the Heritage Lottery Fund and other partnership donations. It was decided then that the original systems should be re-employed as much as possible, and the appointed consultants worked closely with English Heritage to ensure that original systems were brought back into use wherever possible. >

St Alban the Martyr interior, with hanging luminaires

In instances where lighting had to be supplemented because of a change of use, there was no attempt to blindly copy or attempt a 'faux' version of the original luminaires; instead modern contemporary light fittings were employed that were sympathetic to the original, or so understated as to make little visual impact. The rhythm of the building layout was used to help blend the old with the new, following locations already used by the existing installation.

The brass trunkings bear a close resemblance to the cable containment systems found at the National Trust's property Craigside in Northumberland, built by Lord Armstrong in 1863, which were manufactured using wood.

Craigside was the first house to be lit using hydroelectric power and the first 'proper installation' of electric lighting according to Joseph Swan. These cable ways had a ridged surface to indicate where the wiring ran beneath so that nails or screws would not damage the cables beneath when the lids were fixed down.

In addition to this trunking, features such as wooden handrails on some of Craigside's staircases were employed as cable routes – hardly adhering to the 17th edition, but it worked.

REV CANON GARY PHILBRICK

In both buildings early fuse-boards still survive. As to how much discrimination between boards was achieved is another matter, but both buildings are still here, many years later, so standards must have been satisfactory at the very least.

## St Alban the Martyr

Churches form a high proportion of an English Heritage engineer's work, mainly because so many are buildings of great significance and they will often throw up rare survivors of relatively early lighting. One such church is the grade 2 St Alban the Martyr in Swaythling, Southampton, built in 1933 and designed by the famous architects Welch, Cachemaille-Day and Lauder.

It contains hanging luminaires that were also designed by the architectural company and arranged in such a way as to show off the GLS lamps they employed. The fitting was made up of two highly decorated and gilded armatures which provided the cable route down to the individual lamps.

They are very decorative but, given the lumen output of early lamps, it is doubtful they would have produced much light. One question presented to the BsEST team was whether the fittings ever had shades fitted. This question was probably prompted by the fact that bare GLS lamps are now rarely used. The team advised that the use of shades was doubtful, as lamps from that period were not very efficient and any shade would have cut down an already inadequate light output.

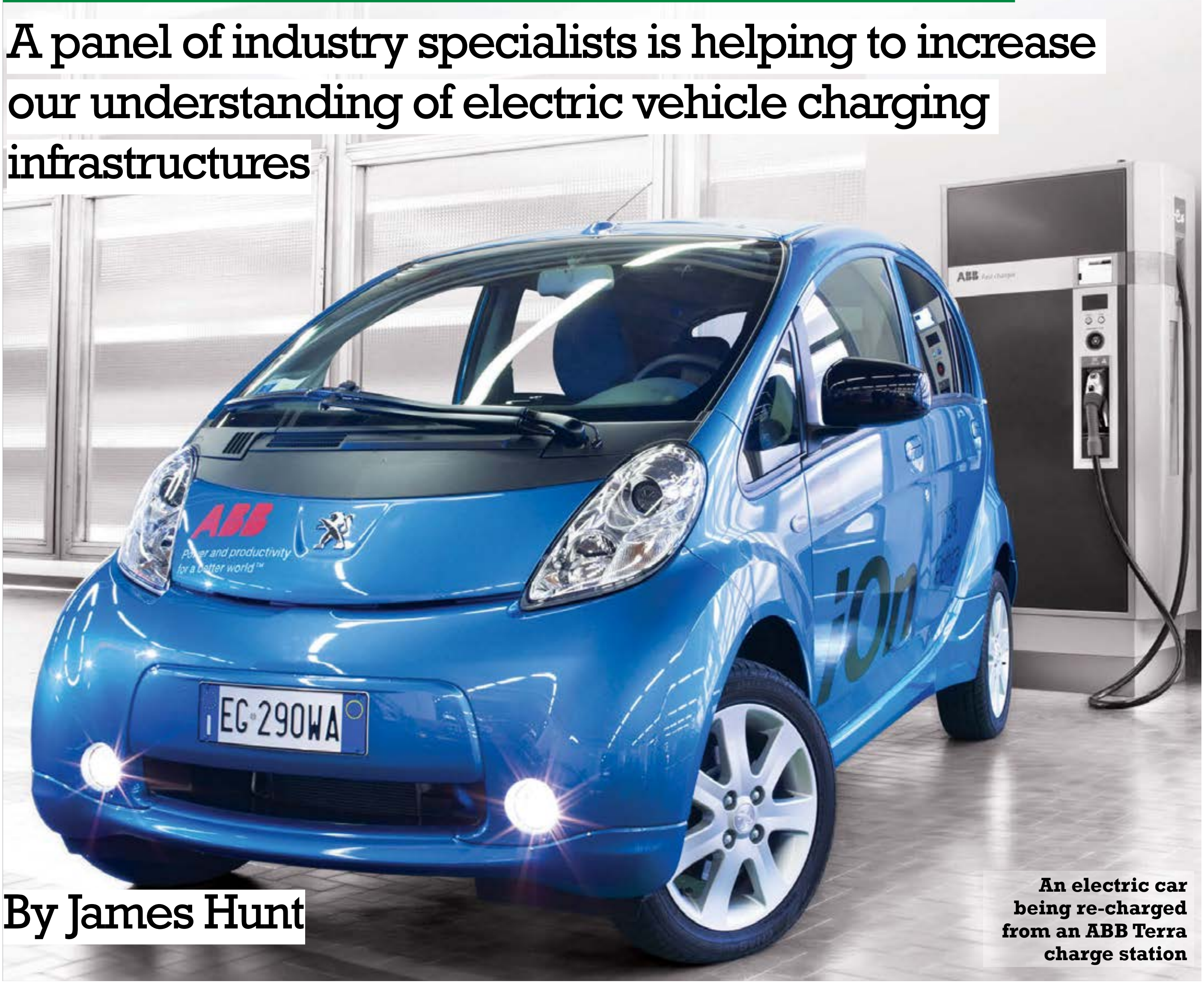
## Never humdrum

There are many more instances of the weird and wonderful that could be cited in this article, but it would then run to many pages. The intention has been to provide just a flavour of the exciting, ingenious, rare and extraordinary early engineering artefacts that BsEST engineers to work with and around. It is a job that is never humdrum or monotonous. Every visit to a new site will, nine times out of ten, throw up a new and unusual engineering problem or find, and that is what makes it so enjoyable.

**English Heritage: www.english-heritage.org.uk**
**Historic Environment – Local Management: www.helm.org.uk**
**Geraldine O'Farrell is senior building services engineer within BsEST**

# EXPERTS HIGHLIGHT EV CHARGING ROADMAP

## A panel of industry specialists is helping to increase our understanding of electric vehicle charging infrastructures




By James Hunt

**An electric car being re-charged from an ABB Terra charge station**

COME 2015, EU regulations require passenger vehicles to meet a $CO_2$ emissions target of 130g/km – averaged over all new vehicles. With a fine of €95/vehicle/gm $CO_2$ for breaches of the limit, there is a clear incentive to reduce average emissions. One important way of achieving this is through the gradual replacement of IC-engined vehicles with electric vehicles (EVs). When this new sector reaches a certain critical mass in terms of EV sales, a substantial and fast-growing residential, commercial and public infrastructure will be required – together with the adoption of smart grids, grid control, charging equipment maintenance, remote diagnostics and status visibility for users.

In response to the fast-growing importance of EVs, the Web portal Voltimum (see p11 for details) has formed an EV Infrastructure expert panel made up of industry specialists. The panel publishes the latest regulatory and technical information, and answers queries. Members of the panel comprise representatives from Siemens, ABB, BEAMA, Schneider Electric, ECA, Legrand, Eaton and the IET. This article is based on content provided for *VoltiTECH*, Voltimum's e-newsletter, by the EV Infrastructure panel. The Siemens white paper 'Demand Response' illustrates the calibre of article contributed to the *VoltiTECH* EV issue entitled: 'Electric vehicle (EV) infrastructures – how to understand them'.

The white paper argues that in 'smart' cities of the future all grids will be monitored and controlled by one integrated system, minimising overall energy requirements and incorporating renewables efficiently. EV battery storage capacity will be integrated into the power grid, which will allow >


**Plugging in to a charge - Schneider Electric recommends using the Type 3 socket, because it is the only one with safety shutters**

< surplus wind-generated electrical energy to be transmitted to EV batteries when the grid load is low. The batteries will then feed and stabilise the grid during peak-load periods.

## The charging infrastructure

Important variables include EV type, charging speed, long-term interoperability, UK wiring regulations, and charging modes, which are:

**Mode 1** – Using a non-dedicated circuit and standard socket-outlet. This charges without cable-incorporated RCD protection over 10-12 hours. This mode is not advised since RCD protection cannot be guaranteed at all outlets.

**Mode 2** – The EV is grid connected via household socket-outlets. Recharging is carried out via a single- or three-phase network and an earthing cable. Mode 2 is suitable for places having no dedicated charging installation, and for use by legacy vehicles. Cables have an integral control box with RCD set to a specific charging power and to guarantee protection. The household's existing electrical installation must be checked by a competent person and should be compliant with current industry regulations. EV manufacturers' guidelines must be followed.

**Mode 3** – Suitable for domestic and public installations, this is preferred long-term. Chargers come either with a tethered cable or a dedicated socket-outlet, and they allow load-shedding so that electrical appliances can be run during EV charging (or to optimise charging times). Communications functions will be essential because of the smart meter roll-out. Off-peak charging and energy management is built into Mode 3 chargers, future-proofing them.

**Mode 4** – This dedicated d.c. supply operates at 500V, 125A for rapid and service station charging, but the high current means it's unsuitable for domestic use. Integral control and protection functions are incorporated, and smart metering supports billing/ pay-as-you-go transactions based on energy consumption.

Siemens points out that smart grid real-time monitoring and control will use an energy automation communication infrastructure to collect dynamic status data about the grid and energy flows. Vast grid sizes mean distributed data aggregation to reduce the data volume to be processed by control centres. EV charging and billing will be a part of this; to avoid a still bigger grid load, coordination will be necessary to avoid peak-load increases – especially with fast charging, which will necessitate a decentralised energy buffer with careful demand response management.

## Domestic charging

Most EV charging will probably be at home, and BEAMA's new guide 'BEAMA Electric Vehicle Infrastructure Project – Guide to Electric Vehicle Infrastructure' states that it will be crucial for consumers to charge their EVs responsibly, limiting the effect on the local electricity networks while maximising the potential for carbon reduction and energy management. Off-peak charging minimises local network demand, while consumers will use less energy and benefit from cheaper tariffs.

From a safety perspective, BEAMA points out that as domestic appliances rarely exceed 2kW, householders may be unaware of the dangers involved in handling electrical equipment – such as chargers – that could pose just such a risk, so each installation must meet BS 7671 requirements.

As the IET's new 'Code of Practice for EV Charging Equipment Installation' shows, BS 7671:2008(2011) does not specifically cover installing EV charging equipment, but it does allow full compliance with the Wiring Regulations. It provides recommendations on charge-point physical layouts, such as avoiding trip hazards, and providing labelling of BS 1363 sockets, which must be on dedicated circuits.

Domestic installations should be risk-assessed, noting that separate earthing system conductive parts should not be simultaneously accessible. Moreover, if an EV cannot be charged inside the building, then the building's PME earth should not be used; the charging equipment should be on an external TT earth. Alternatively, use equipment to disconnect the supply, or provide electrical separation via an isolating transformer.

The Code of Practice says that roadside and commercial chargers must not be connected to an unmetered supply, nor to a PME earth, nor loop wired. For purely commercial installations, charge points can be connected to the building earth externally (if part of a guaranteed TN-S system), or if the building has a steel structure, or has reinforced foundations.

## Plugs and sockets

EV charging plug and socket-outlets are Types 1, 2 and 3 IEC 62196-2, BS EN 60309 industrial, and the BS 1363 domestic type. IEC 62196-2 defines a panel of sockets for Mode 3 charging. Schneider Electric recommends using the Type 3 socket, because it is the only one having safety shutters (mandatory in the UK) to minimise electric shock risk.

For fast-charging user safety, plugs and sockets feature extra pins ('pilot wires'), says Schneider Electric in its white paper entitled 'Connection Method for Charging Systems – a Key Element for Electric Vehicles'. The main control wire connects to the equipment earth through the EV's control circuitry and verifies that the EV is present and connected. It also allows supply energisation / de-energisation and transmits the supply equipment current rating to the vehicle while monitoring the earth presence.

For example, Eaton's Pow-R-Station DC Quick charger runs safety checks to verify that there is no chance of injury to users or damage to equipment. Until the EV has confirmed connection, the pins have no DC power – any disruption causes the power flow to stop immediately.

Key advice that Legrand gives to electrical installers regarding fitting an exterior socket, is to find out whether it will be used for EV charging. If so, there should be a dedicated circuit from the distribution board. This future-proofs the installation, should the customer subsequently install a proper charge point. It also reduces unwanted tripping of unrelated household power outlets.

## Billing

'Smart' (automated) billing systems will be crucial for success. For example, ABB's Authorisation and Transaction Support allows EV charging infrastructure operators to efficiently manage access to their web-connected charging equipment. Charge session transactional data provides essential user level information, and charging operations are integrated into an existing central back office system using Open Standard Protocol Support (OCPP).

Designed for EV infrastructure and fleet operators, features include user ID white list management, remote authorisation, session start and stop, and session statistics (kWh, time, ID etc). Subscriber management can be via RFiD smartcards, text, smart-phone apps or online payment.

## Standards

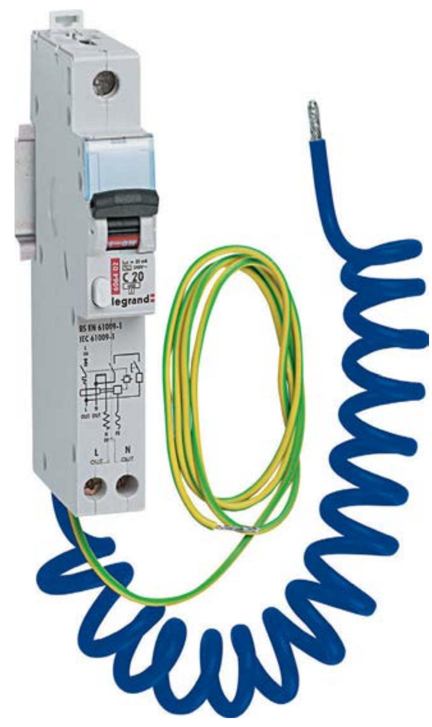
Electro-mobility growth means the development of new standards and a regulatory framework. The EC/EFTA issued mandate M/468 to CEN and CENELEC on European electro-mobility standardisation in 2010 to ensure interoperability and connectivity between the electricity supply point and EV chargers. It also considers EV smart charging issues and looks at safety risks and charger electromagnetic compatibility in terms of Directives 2006/95/EC (LV) and 2004/108/EC (EMC). National, European and international standards committees include the IEC, ISO, ITU-T, CEN, CENELEC, ETSI and BSI.

FACT BOX
## VOLTIMUM

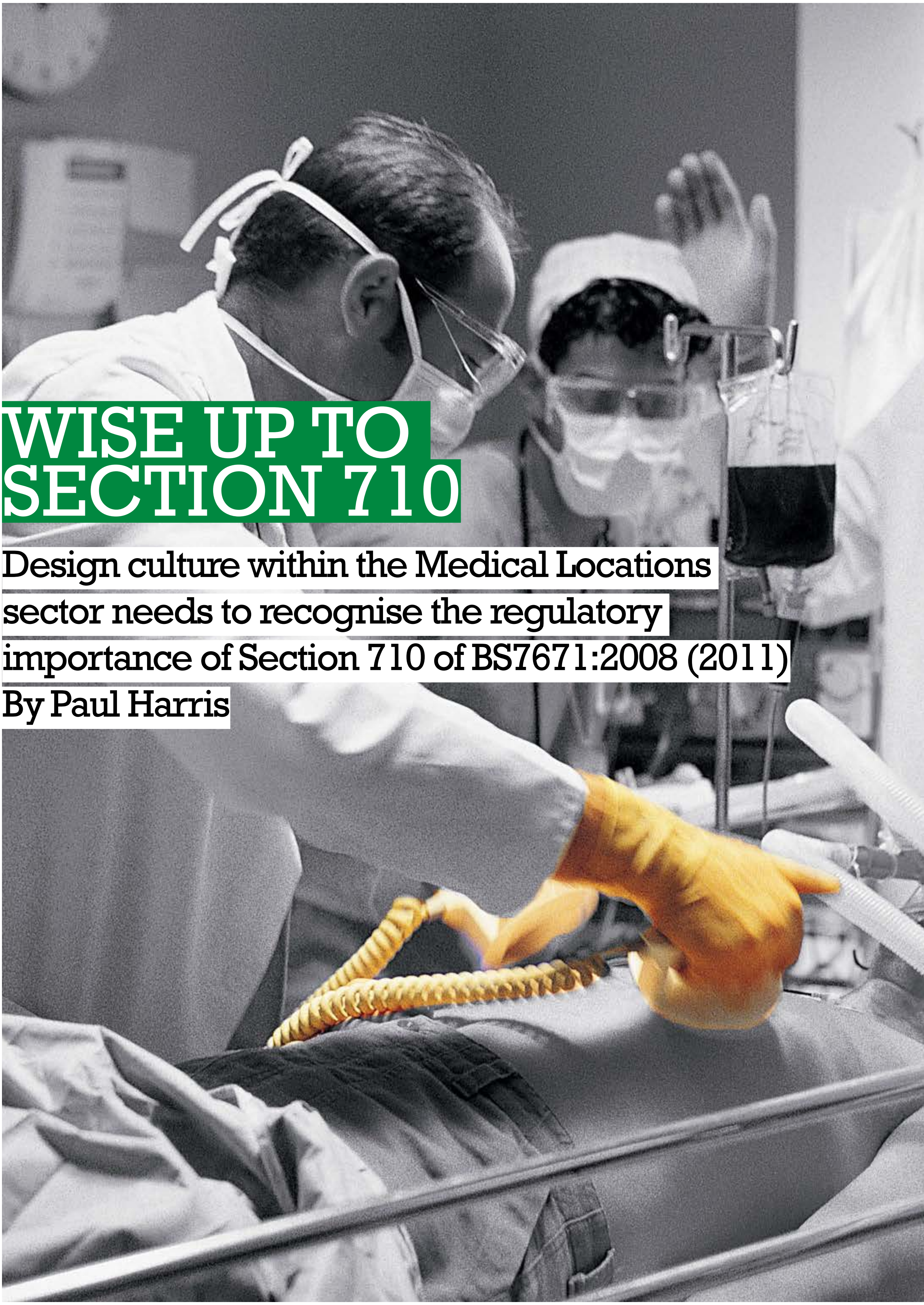
Voltimum is an electrical Web portal, which operates in a number of countries worldwide. This is a central source of information for electrical contractors and installers, panel builders, specifiers, consultants, manufacturers, trade associations and industry bodies (including the IET), and wholesale distributors. Voltimum is not a trading portal, but provides round-the-clock access to the latest industry news and events, training courses, technical information, and updates to legislation and regulations. Much rich content is provided by important industry partners, and then woven together by specialist journalists and editors. Search-engine optimisation expertise ensures high visibility in Web searches, while online video news reports present information in an enjoyable way.

Voltimum's award-winning monthly e-newletter, *VoltiTECH*, started publication in June 2003, and has now run to nearly 120 editions, covering a very broad spectrum of topics including regulations and standards, lighting technological advances such as LEDs, BS7671:2008 (2011) first amendment, surge protection, Building Regulations, circuit protection issues, electrical testing, building sustainability, and much more.

**James Hunt in the managing editor of the UK arm of the Voltimum electrical Web portal. Further articles, based on key issues from *VoltiTECH* are planned for future issues of *Wiring Matters*.**




**An RCBO by Legrand - Mode 1 charging is not advised since RCD (or RCBO) protection cannot be guaranteed at all outlets**



# WISE UP TO SECTION 710

## Design culture within the Medical Locations sector needs to recognise the regulatory importance of Section 710 of BS7671:2008 (2011)

By Paul Harris

IN JUNE 2005, the Medicines and Healthcare products Regulatory Agency (MHRA) published a guidance document, MEIGaN (Medical Electrical Installation Guidance Notes), to improve the quality and standard of workmanship in electrical imaging installations. This was followed by MEIGaN version 2 in 2007. The 2005 guidance document and its 2007 revision were designed specifically to deal with medical imaging installations.

Annex 1 to the 2005 guidance document, published later in 2005, was developed by the estates and facilities division of the Department of Health. This annex extended the scope of MEIGaN beyond imaging locations, and reflected the requirements of IEC 60364-7-710 2002, at the time the internationally agreed document for Medical Locations.

Available as a free download from the MHRA website, MEIGaN with its Annex 1, was considered 'best practice'. This best-practice status was reflected in the title of Annex 1: 'Healthcare interpretation of IEE Guidance Note 7 (Chapter 10) and IEC 60364-7-710 for Electrical Installations in Medical locations'. The publication of Section 710 within BS7671 2008 (2011), Guidance Note 7 (4th edition) and HD 60364-7-710 2012 overturned the best-practice status of MEIGaN and its Annex 1.

## Dated guidance

The use of MEIGaN as a standard, as opposed to a guidance note, helped create a perception of approval, i.e. that of 'MEIGaN compliance', and gave the various stakeholders involved – clients, designers and installers – a label on which to place an expectancy of a certain level of skill, expertise and understanding.

Although MEIGaN has undoubtedly had a positive impact on electrical standards in medical locations, it has become apparent that certain requirements have become custom and practice, which appear to be different from the requirements of BS7671 (2011). In addition, as with all technical documents, a considerable level of upkeep and maintenance is required to prevent them becoming outdated as technologies and methods change. A review of MEIGaN indicates that its references and practice requirements have become outdated.

In addition to the MEIGaN documentation, BSEN 60601-1:2006: 'Medical electrical equipment Part 1: General requirements for basic safety and essential performance'; is available for designers, and covers the basic safety requirements for medical electrical equipment. This standard is an internationally agreed harmonised document and, as with other British and European normative information, is regularly reviewed to ensure the maintenance and upkeep of the standard.

Annex 1 was withdrawn by the MHRA in October and it is understood by the UK technical group working on Section 710 that MEiGaN (currently suspended) will eventually be superseded by Section 710 of BS7671 – a natural outcome given that CENELEC Document HD 60364-7-710, which forms the basis of Section 710, has been developed by technical experts in both the UK and across Europe.

## HD 60364-7-710

The UK is a signatory to the Treaty of Rome for electro-technical matters and, as such, CENELEC Harmonised Documents have to be incorporated into our National Standard (BS7671) in terms of technical content, with very little room for manoeuvre in terms of the overall content. In the light of this requirement, the technical working group and JPEL 64 (the committee responsible for the production of BS7671) opted to incorporate the content of the draft standard, prHD 60364-7-710, into BS7671 2008 (2011). This act of foresight meant the wiring regulations (BS7671 2008 (2011)) incorporated the requirements later published as HD 60364-7-710:2012.

The resulting Section 710 divides all patient environments into three defined categories. These categories are defined in both Section 710 and HD 60364-7-710. Section 710 has empowered clients, healthcare providers and designers to make decisions based on internationally agreed regulatory requirements. However, what the regulations do not do, and are not intended to do, is to prescribe how particular performance criteria are to be achieved – this approach is in line with the general ethos of BS7671.

## Current Industry Practice

A survey of the websites of manufacturers supplying medical equipment for medical locations I conducted in August 2012 exposed a widespread misunderstanding of the importance of Section 710. Different sectors of the industry, manufacturers, designers and installers, all seemed to be unaware that BS7671 2008 (2011) Section 710 Medical Locations applies, and continue to refer solely to MEIGaN, or its annexes. This apparent ignorance of Section 710 could have have significant consequences for those concerned in electrical installation work, in particular anyone who has to correctly certify electrical installations within Group 0, 1 or 2 Medical Location.

## The document hierarchy

Most contracts and appointments will have as part of their requirements compliance with Health Technical Memoranda (HTMs), Health Building Notes (HBNs) and related healthcare guidance. The difficulty for the stakeholders and the client is to understand which documentation is applicable and, more importantly, the order of precedence within the hierarchy of documents. The diagram on p14 illustrates how precedence among documents operates: at a given level within the pyramid, a document has precedence over all documents lower down the pyramid.

For electrical installations the relevant documents, in order of decreasing precedence, are:

- Statute - Electricity at Work Regulations 1989
- Approved Code of Practice (ACOP) - HSR 25 Memorandum of Guidance on Electricity at Work Regulations 1989 published by the HSE
- British Standard/BSEN- BS76712008 (2011) Requirements for Electrical Installations
- Guidance Documentation- IET Guidance Notes, MEIGaN, HTM 06-01 etc.

In healthcare design, with the exception of the Firecode suite of documents, the HTMs and HBNs are deemed guidance and, as such, as with all informative documentation, a degree of interpretation is perfectly reasonable. Their guidance can be interpreted differently by different designers/ stakeholders, or even ignored completely. In contrast, British Standards and BS ENS are deemed to be generally best-practice and, in the case of BS7671, form the regulatory framework on which the wiring regulations for the UK are formed.

The other issue facing stakeholders is the age and clarity of the guidance. Whilst the principles of physics remain unchanged with the passage of time, any field of engineering will be subject >

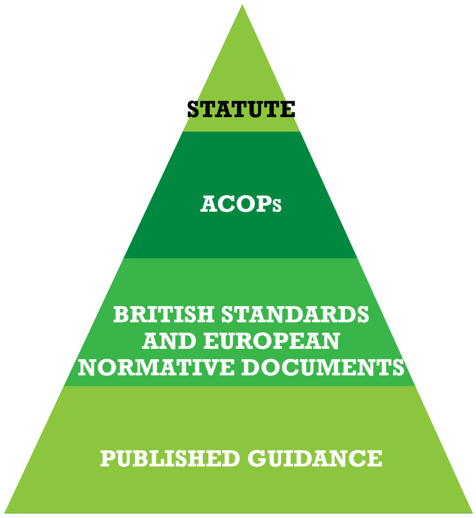



**Fig 1: Document hierarchy**

< to advances in equipment/products and changes in practice, with important ramifications for different industry sectors, such as Medical Locations. HTM 06-01 illustrates the relatively infrequent revision programme within HTMs. It was last issued in 2006, having previously been issued in 1995. Given that the refresh rate of HTMs is far lower than is the case for the Wiring Regulations or supporting guidance, it is likely that HTMs are likely to be out of date when compared to BS767, or any of the supporting Guidance Notes.

### A case in point

The potential for discrepancies between guidance and regulations can be illustrated by the example of a specific contradiction between BS7671 and HTM 0601. The contradiction arises from the difference in guidance offered by the HTM and the regulatory requirement stipulated by BS7671 (and HD 60364-7-710) in terms of UPS autonomy.

HTM 06-01 states in 10.9:

"….Where the UPS battery provides TPS to non operating-theatre low-power applications, the battery autonomy should provide clinical staff with enough time to start "hand bagging" or connecting supplementary equipment battery packs. Consequently, battery autonomy of 15–30 minutes may be appropriate…."

In contrast, Section 710, 710.560.6.1.1 Power supply sources with a changeover period less than or equal to 0.5s requires:

"In the event of a voltage failure on one or more line conductors at the distribution board, a safety power supply source shall be used and be capable of providing power for a period of at least 3h for the following:

i. Luminaires of operating theatre tables
ii. Medical electrical equipment containing light sources being essential for the application of the equipment, e.g. endoscopes, including associated essential equipment, e.g. monitors
iii. Life-supporting medical electrical equipment. The normal power supply shall be restored within a changeover period not exceeding 0.5s.

NOTE: The duration of 3h may be reduced to 1h if a power source meeting the requirements of Regulation 710.560.6.1.2 is installed.

There is an obvious discrepancy between Section 710 (which is HD 60364-7-710 2012 compliant) and the current HTM, written in 2006. If a contractor or consultant were to design to the HTM then there would be shortfall in autonomy of the UPS. This will have significant effects on the ability of the contractor and consultant to be able to sign compliance with BS7671.

**Paul Harris is an independent consultant and a member of the UK Technical Working Group responsible for Section 710. He is planning to publish additional Section 710 technical articles, along with guidance documentation, during 2013**

GROUPS

## THREE-WAY CLASSIFICATION

BS7671 2008 (2011) categorises medical locations into three Groups (0, 1 and 2).

Group 0. Medical location where no applied parts are intended to be used and where discontinuity (failure) of the supply cannot cause danger to life.

Group 1. Medical location where discontinuity of the electrical supply does not represent a threat to the safety of the patient and applied parts are intended to be used: externally; invasively to any part of the body except where Group 2 applies.

Group 2. Medical location where applied parts are intended to be used, and where discontinuity (failure) of the supply can cause danger to life, in applications such as: intracardiac procedures; vital treatments and surgical operations.

In order to determine the classification and Group number of a medical location, it is necessary that the relevant medical staff indicate which medical procedures will take place within the patient environment. Guidance for the designer is provided by a list of typical medical locations and associated measures are indicated in Annex A710 of BS7671 2008 (2011). However, as the list is not exhaustive, in order to correctly determine the classification of a location, it is essential to understand if medical electrical equipment is connected to a patient, or if there can be contact between a patient and other persons touching parts of the medical electrical equipment/system and does failure of the mains supply have a detrimental effect on the medical procedure or patient's well-being.

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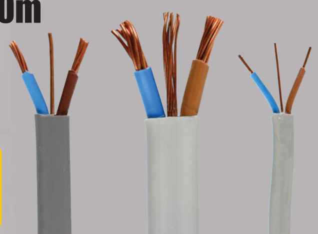

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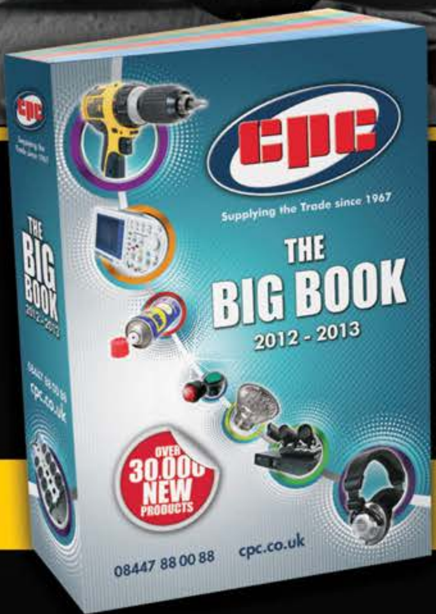


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# FLOOR AND CEILING HEATING SYSTEMS

## A look at the requirements for the installation of electric floor and ceiling heating systems, together with the associated risks.

By Geoff Cronshaw

THE 17TH Edition of the Wiring Regulations (BS 7671:2008) introduced additional sections on special locations in 2008 that were not previously included in the 16th Edition. Among the special locations introduced were requirements for floor and ceiling heating systems contained in section 753 of BS 7671:2008.

### Risks

The obvious risks associated with floor and ceiling heating systems are penetration of the heating element by nails, drawing pins, screws, etc., pushed through the ceiling surface.

Similarly, there are concerns that underfloor heating installations can be damaged by carpet gripper nails, etc. To protect the building structure and provide precautions against fire, there are requirements to avoid overheating of the floor or ceiling heating system.

### Protection against electric shock

As you would expect the protective measures of obstacles, placing out of reach, non-conducting location and protection by earth-free local equipotential bonding are not permitted. These measures are contained in Sections 417 and 418 of BS 7671:2008 and are not for general application. The protective measures of section 417 provide basic protection only, and are for application in installations controlled or supervised by skilled or instructed persons. The fault protective provisions of Section 418 are special and, again, subject to control and effective supervision by skilled or instructed persons. In addition the protective measure of electrical separation (section 413) is not permitted.

### Regulation 753.411.3.2

Where the protective measure is automatic disconnection of supply, >

heating units without exposed-conductive-parts, must have a metallic grid, with a spacing of not more than 30mm, (as an exposed conductive part) installed above the floor heating elements or under the ceiling heating elements. The grid must be connected to the protective conductor of the electrical installation and the heating system protected by an RCD with a rated residual operating current not exceeding 30mA for fault protection. A note below regulation 753.411.3.2 limits the rated heating power to avoid unwanted tripping of the RCD.

### Regulation 753.415.1

A circuit supplying heating equipment of Class II construction or equivalent insulation must be provided with additional protection by use of an RCD with a rated residual operating current not exceeding 30mA.

### RCDs

An RCD is a protective device used to automatically disconnect the electrical supply when an imbalance is detected between live conductors. In the case of a single-phase circuit, the device monitors the difference in currents between the line and neutral conductors. If a line-to-earth fault develops, a portion of the line conductor current will not return through the neutral conductor. The device monitors this difference, operates and disconnects the circuit when the residual current reaches a preset limit, the residual operating current ($I_{\Delta n}$). An RCD on its own does not provide protection against overcurrents. Overcurrent protection is provided by a fuse or a circuit-breaker. However, combined RCD and circuit breakers are available and are designated RCBOs.

### Special locations

There are special requirements where electric floor-heating systems are installed

| First characteristic numeral | Second characteristic numeral |
|---|---|
| (a) Protection of persons against access to hazardous parts inside enclosures<br>(b) Protection of equipment against ingress of solid foreign objects | Protection of equipment against ingress of water |

| No. | Degree of protection | No. | Degree of protection |
|---|---|---|---|
| 0 | (a) Not protected<br>(b) Not protected | 0 | Not protected |
| 1 | (a) Protection against access to hazardous parts with the back of the hand<br>(b) Protection against foreign solid objects of 50 mm diameter and greater | 1 | Protection against vertically falling water drops |
| 2 | (a) Protection against access to hazardous parts with a finger<br>(b) Protection against solid foreign objects of 12.5 mm diameter and greater | 2 | Protected against vertically falling water drops when enclosure tilted up to 15°. Vertically falling water drops shall have no harmful effect when the enclosure is tilted at any angle up to 15° from the vertical |
| 3 | (a) Protection against contact with tools, wires or such like more than 2.5 mm thick<br>(b) Protection against solid foreign objects of 2.5 mm diameter and greater | 3 | Protected against water spraying at an angle up to 60° on either side of the vertical |
| 4 | (a) As 3 above but against contact with a wire or strips more than 1.0 mm thick<br>(b) Protection against solid foreign objects of 1.0 mm diameter and greater | 4 | Protected against water splashing from any direction |
| 5 | (a) As 4 above<br>(b) Dust-protected (dust may enter but not in amount sufficient to interfere with satisfactory operation or impair safety) | 5 | Protected against water jets from any direction |
| 6 | (a) As 4 above<br>(b) Dust-tight (no ingress of dust) | 6 | Protected against powerful water jets from any direction |
| | No code7 | | Protection against the effects of temporary immersion in water. Ingress of water in quantitites causing harmful effects is not possible when enclosure is temporarily immersed in water under standardized conditiions |
| | No code8 | | Protection against the effects of continuous immersion in water under conditions agreed with a manufacturer |

**Table 1: IP characteristic numerals**

in special locations such as locations containing a bath or shower – specified in the following extract from 701.753:

"For electric floor-heating systems, only heating cables according to relevant product standards or thin sheet flexible heating elements according to the relevant equipment standard shall be erected provided that they have either a metal sheath or a metal enclosure or a fine mesh metallic grid. The fine mesh metallic grid, metal sheath or metal enclosure shall be connected to the protective conductor of the supply circuit. Compliance with the latter requirement is not required if the protective measure SELV is provided for the floor heating system.

"For electric floor heating systems the protective measure 'protection by electrical separation' is not permitted."

### Protection against burns and overheating

In floor areas where contact with skin or footwear is possible, the surface temperature of the floor shall be limited (for example, 35°C).

To avoid overheating of floor or ceiling heating systems in buildings, at least one of the following measures shall be applied to limit the temperature and the heating zone to a maximum of 80°C:

- Appropriate design of the heating system;
- Appropriate installation of the heating system;
- Use of protective devices.

Heating units shall be connected to the electrical installation via cold tails or suitable terminal fittings.

Heating units shall be inseparably connected to the cold tails, e.g. by welding, brazing or by compression jointing techniques.

Heating units must not cross expansion joints.

As the heating unit may cause higher temperatures or arcs under fault conditions, special measures to meet the requirements of Chapter 42 should be taken when the heating unit is installed close to easily ignitable building structures, such as placing on a metal sheet, in metal conduit or at a distance of at least 10mm in air from the ignitable structure.

### Standards

Flexible sheet heating elements should comply with BS EN 60335-2-96 and heating cables should comply with IEC 60800.

### External influences

Any wiring system or equipment selected and installed must be suitable for its location and able to operate satisfactorily without deterioration during its working life.

Heating units for installation in ceilings shall be at least IPX1 and heating units for installation in floors of concrete or similar material shall be not less than IPX7 with appropriate mechanical properties.

The IP classification code BS EN 60529:2004 describes a system for classifying the degrees of protection provided by the enclosures of electrical equipment. The degree of protection provided by an enclosure is indicated by two numerals. The first numeral indicates protection of persons against access to hazardous parts inside enclosures or protection of equipment against ingress of solid foreign objects. The second numeral indicates protection of equipment against ingress of water (see Table 1, facing). More information on the IP classification code is given in IET Guidance Note 1 – Selection and Erection.

### Operational conditions

Precautions shall be taken not to stress the heating unit mechanically; for example, the material by which it is to be protected in the finished installation shall cover the heating unit as soon as possible.

### Identification

The designer of the installation/heating system or installer shall provide a plan for each heating system, containing the following details:

1. Manufacturer and type of heating units;
2. number of heating units installed;
3. length/area of heating units;
4. rated power;
5. surface power density;
6. layout of the heating units in the form of a sketch, a drawing or a picture;
7. position/depth of heating units;
8. position of junction boxes;
9. conductors, shields and the like;
10. heated area;
11. rated voltage;
12. rated resistance (cold) of the heating units;
13. rated current of overcurrent protective devices;
14. rated residual operating current of RCD;
15. the insulation resistance of the heating installation and the test voltage used;
16. the leakage current.

The plan shall be fixed to, or adjacent to, the distribution board of the heating system.

### Heating-free areas

Where heating units are installed, there shall be heating-free areas where drilling and fixing by screws, nails and the like are permitted. The installer shall inform other contractors that no penetrating means, such as screws for door stoppers, shall be used in the area where floor or ceiling heating units are installed.

It may be necessary to provide areas of floor or ceiling that are unheated, e.g. where fixtures to the floor or ceiling would prevent the

There are concerns that underfloor heating installations can be damaged by carpet gripper nails and suchlike

proper emission of heat.

Account shall be taken of the increase in ambient temperature and of its effect upon the cables, including cold tails (circuit wiring) and control wiring installed in heated zones.

**Information from the contractor for the user of the installation**

A description of the heating system shall be provided by the installer/contractor of the heating system to the owner of the building or his or her agent upon completion of the installation. The description shall contain at least the following information:

- **A.** Description of the construction of the heating system, which must include the installation depth of the heating units;
- **B.** location diagram with information concerning the distribution of the heating circuits and their rated power; the position of the heating units in each room; conditions which have been taken into account when installing the heating units,e.g. heating-free areas, complementary heating zones, unheated areas for fixing means penetrating into the floor covering;
- **C.** data on the control equipment used, with relevant circuit diagrams and thedimensioned position of floor temperature and weather conditions sensors, if any;
- **D.** data on the type of heating units and their maximum operating temperature.

The installer/contractor shall inform the owner that the description of the heating system includes all necessary information, e.g. for repair work.

The designer/installer/contractor of the heating system shall hand over an appropriate number of instructions for use to the owner or his or her agent upon completion. One copy of the instructions for use shall be permanently fixed in or near each relevant distribution board.

The instructions for use shall include at least the following information:

- **A.** Description of the heating system and its function;
- **B.** operation of the heating installation in the first heating period in the case of a new building, e.g. regarding drying out;
- **C.** operation of the control equipment for the heating system in the dwelling area and the complementary heating zones as well, if any;
- **D.** information on restrictions on placing of furniture or similar. Information provided to the owner shall cover the restrictions, if any, including: whether additional floor coverings are permitted, for example, carpets with a thickness of >10mm may lead to higher floor temperatures which can adversely affect the performance of the heating system where pieces of furniture solidly covering the floor and/or built-in cupboards may be placed on heating-free areas where furniture, such as carpets, seating and rest furniture with pelmets, which in part do not solidly cover the floor,

may not be placed in complementary heating zones, if any;

**E.** information on restrictions on placing of furniture or similar;

**F.** in the case of ceiling heating systems, restrictions regarding the height of furniture. Cupboards of room height may be placed only below the area of ceiling where no heating elements are installed;

**G.** dimensioned position of complementary heating zones and placing areas;

**H.** statement that, in the case of thermal floor and ceiling heating systems, no fixing shall be made into the floor and ceiling respectively. Excluded from this requirement are unheated areas.

Alternatives shall be given, where applicable.

## Future developments at international level

The Wiring Regulations (BS 7671) are based on international standards. Work is ongoing at present at international level to extend the scope of Section 753. These proposals would apply to embedded electric heating systems for surface heating. They would also apply to electric heating systems for de-icing or frost prevention or similar applications, and would cover both indoor and outdoor systems.

This would include heating systems for: walls, ceilings, floors, roofs, drainpipes, gutters, pipes, stairs, roadways, non-hardened compacted areas (e.g. football fields and lawns). Heating systems for industrial and commercial applications complying with IEC 60519 and IEC 62395 would not be covered.

The draft covers issues such as surface temperatures and refers the reader to the appropriate IEC guide. Documentation is also covered and requires the designer to provide appropriate documentation about approved substances in the surroundings of the heating units.

For wall heating systems the draft contains additional requirements to protect against the effects of overheating caused by a short circuit between live conductors due to penetration of an embedded heating unit. In addition, the draft requires that electric heating systems shall be selected and erected so as to avoid any harmful influence between the heating system and any electrical or non-electrical installations envisaged.

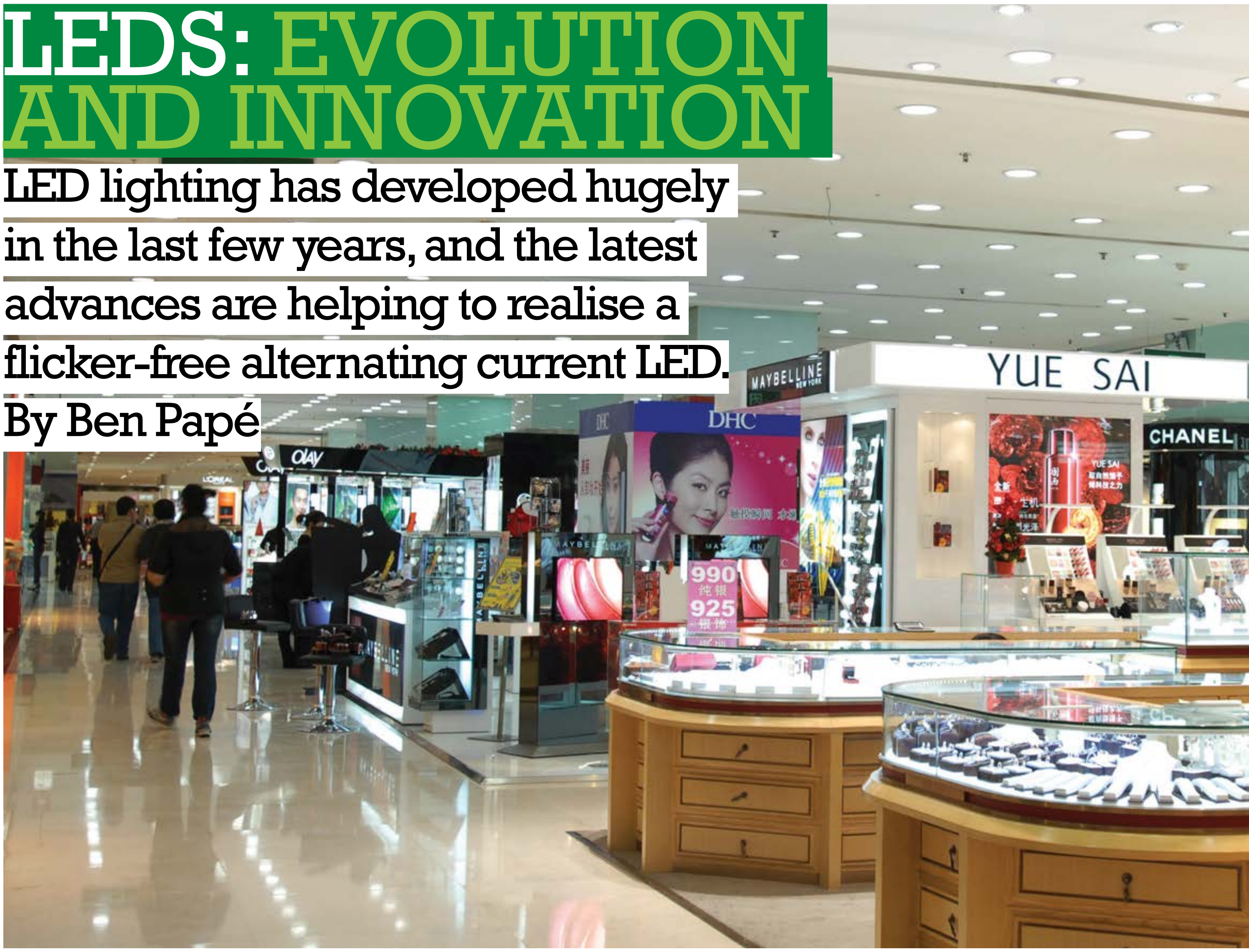
## Conclusion

It is important to be aware that this article only gives an overview of the installation of electric floor and ceiling heating systems. For more information refer to Section 753 of BS 7671:2008 incorporating Amendment 1. Also, it is important to point out that this future development work is still at a very early stage of development in IEC and therefore may not become an international standard.

ALAMY

# LEDS: EVOLUTION AND INNOVATION

**LED lighting has developed hugely in the last few years, and the latest advances are helping to realise a flicker-free alternating current LED. By Ben Papé**




THE LIGHT-EMITTING diode (LED) has been with us since its release in 1962. Early examples of this semiconductor light source emitted low-intensity red light, but modern versions are available across the visible, infrared and ultraviolet wavelengths with high brightness.

They have typically been used as indicator lamps, but developments in the latter half of the technology's lifetime have enabled LEDs to be used in applications as diverse as aviation lighting, automotive lighting, advertising, general lighting and traffic signals.

New text, video displays and sensors have also hit the market, while the LED's high switching-rate is also useful in advanced communications technology. Infrared LEDs are used in the remote control units of many commercial products including TVs, DVD players and other domestic appliances. However, it is in the illumination of space that the humble LED is arguably making the most progress.

The development of LED technology has resulted in steadily falling costs and ever increasing light outputs. Since the 1960, costs per lumen have fallen by a factor of 10 every decade and the amount of light generated per LED package has increased by a factor of 20. The exponential rise in light output, mirroring Moore's Law for electronic devices, is called Haitz's Law after Dr Roland Haitz.

Typical indicator LEDs are designed to operate with no more than 30-60mW of electric power. In 1999, Philips Lumileds introduced power LEDs capable of continuous use at 1W. These LEDs use much larger semiconductor dies to handle the larger power output and are also mounted on metal slugs to facilitate heat removal from the die.

High luminous efficacy is an important attribute of LED light sources. In 2002, Lumileds made 5W LEDs with a luminous efficacy of 18-22lm/W (lumens per watt), which compared with standard incandescent at around 15lm/W and fluorescent at 80lm/W. Unfortunately, LED luminous efficiency falls sharply with increasing current – a real problem when it comes to trying to improve efficacy.

### Luminous efficacy

In late 2003, a new type of blue LED was demonstrated by Cree of USA to provide 24lm/W at 20mA. This produced commercially packaged white light giving 65lm/W at 20mA, some four times more efficient than standard incandescent lamps. In 2006 Cree demonstrated a prototype

**Maoye department store in Shenzhen, Guangdong, lit by ACRE LEDs**

with a record white light luminous efficacy of 131lm/W and this was followed by a Nichia white LED with a luminous efficacy of 150lm/W. Cree then responded in 2011 with a commercially available white LED producing 100lm/W at full 10W power input and 160lm/W at 2W power input. Cree has also just reported achieving 200lm/W and Osram has more recently claimed 250lm/W in a laboratory prototype, so greater output efficiacies in white LEDs seem not too far away.

It should be noted that these luminous efficacies are for the LED chip alone and in a controlled low-temperature laboratory environment. Commercial lighting works at higher temperatures and with drive circuit losses which will cause lower efficiencies. The US DOE (Department of Energy) testing of commercial LED lamps designed to replace incandescent lamps or CFLs (compact fluorescent lamps) showed that average efficacy was still around 46lm/W in 2009 with a range of 17lm/W to 79lm/W from lowest to highest.

## Durability

There are reportedly over 10,000 LED manufacturers in China alone, with many others elsewhere. Their products are of varying quality, with many focusing on undercutting their competitors on cost. No wonder then that some pioneer customers are complaining of lower light-outputs and higher failure rates than were promised and expected. This plethora of cheap LED products from a mass of low-quality LED manufacturers has somewhat tarnished the reputation of the LED product. Even so, many of the LEDs made in the 1970s and 1980s are still in service today.

Temperature is the enemy of durability and LED performance is temperature-dependent. Most manufacturers' published ratings of LEDs are for an operating temperature of 25°C, for which a lifetime of 25,000 hours (seven years at 10hrs/day) can be expected. This compares with typical lifetimes of incandescent lamps at 1,200 hours and CFLs at 8,000 hours. The latest LEDs are now being quoted with lifetimes of 40,000 hours and with 100,000 hours achievable in the near future.

Actual lifespans are a subject of some dispute. There are two issues: first, the failure of the device; and, second, the decline in light output with time. Outright failure of the LED is rare, although poor thermal management can expose LEDs to unnecessary heat, leading to a dramatic reduction in lifespan. It is said that bad LEDs don't die they just fade away and sometimes rather quickly. Even good LEDs suffer some fall-off in light output over time but the lifespans quoted from reputable manufacturers guarantee that the luminous output will be at least 70 per cent of original value over 40,000 hours (11 years at 10hrs/day), which is significantly better than any competitive product in the market.

The luminaire design will also have an effect on the lifespan of the LED, along with the lux levels of the space to be lit. Not only is there a transmission loss but the fitting can also increase heating, contributing to a reduction in lifespan.

In terms of physical robustness, the LED can survive some jarring and on-site rough handling, in contrast to the glass-encased, relatively fragile, incandescent and fluorescent lamps.

## Domestic acceptability

Most homeowners liked the incandescent lamp. They were used to the warm light which could be switched on/off immediately and could also be dimmed to create the desired ambience. When the government prohibited these much-loved and affordable incandescent lamps in varying shapes, sizes, colours and hues, the alternative was a CFL which was over-bright, did not light immediately, flickered, generally could not be dimmed, was relatively >

HISTORY

## DEVELOPMENT OF THE LED

The discovery of electroluminescence and LED phenomena dates back to 1907 in the Marconi Labs in UK, followed by further research in Russia and USA. In 1961, American researchers at Texas Instruments found that the simple gallium arsenide (GaAs) diode emitted infrared radiation when electric current was applied across the p-n junction. This discovery formed the basis for the subsequent patent for the infrared LED.

The first practical visible-spectrum (red) LED was developed in 1962 at General Electric Co of USA, followed by a brighter red-orange. However, these devices were still too costly and insufficiently bright for commercial use. In 1968, Hewlett Packard produced the first brighter red LED (as a replacement for neon indicator lamps) for use initially in instrumentation such as laboratory and electronic test equipment, but later in consumer appliances such as TVs, radios, telephones, calculators and digital watches. At that point in the early 1970s, LEDs were discovered by the general public.

These first red LEDs were bright enough for use as indicators on instruments or appliances but insufficiently bright for space lighting. What was needed was a white light. With developing material technology, other colours steadily became available in ever improving output and reliability. However, it wasn't until 1995 when the first high-brightness blue LED was demonstrated by Shuji Nakumura of Nichia Corporation, augmented by further developments in Nagoya and Cardiff. The invention of these high-brightness high-efficiency blue LEDs led to the development of an LED which employed a yellow phosphor coating to produce a white light. This was the birth of white LEDs.

ugly and limited in design and cost much more. Hardly the basis for encouraging a wholesale changeover; no wonder many homeowners have been stockpiling incandescent lamps before they disappear completely from the marketplace.

The other option was extra-low-voltage halogen spotlights (another incandescent version to the traditional tungsten variety), which could be dimmed and were compact and unobtrusive but were better suited to a bathroom or kitchen environment. They were also rather costly and suffered from a relatively short lifespan. There were also inherent fire risks when recessed into ceilings.

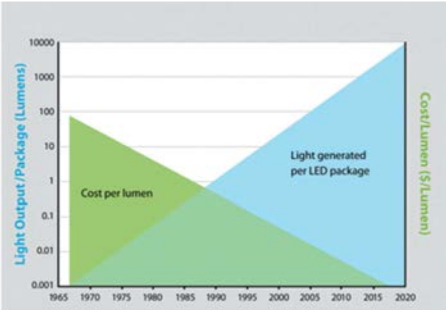
So the CFL can only be an intermediate and temporary replacement for the household incandescent lamp until a better option comes along. That selection is likely to be the LED with all its advantages of on/off immediacy, colour variability, dimmable intensity and compactness. The one remaining obstacle is affordability, and that should be overcome very shortly.

## DC issues

The basic LED is an inherently DC device – emitting light only when forward-biased. This DC characteristic has two major drawbacks. First, there is the requirement to incorporate electronic components within the luminaire to convert AC to DC, so that the LED can work off mains electricity. This need for rectification increases component/packaging costs and reduces efficiency. Second, these additional electronic components generate heat, which is difficult to dissipate in a compact lamp design required for internal and domestic applications. As a consequence, DC LED lamps are significantly de-rated (up to 50 per cent) and therefore need additional dies and components to achieve the desired luminous output.

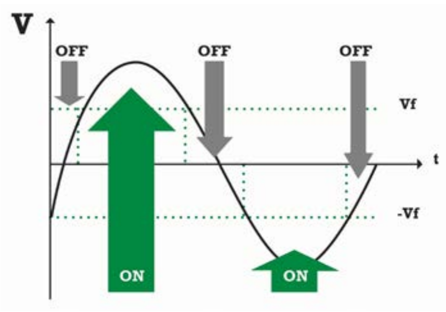
All this makes compact domestic internal LED lamps relatively unaffordable. Any visitor to a local supermarket will see that 100W equivalent (1,200lm output) domestic LED lamps retail at £20 to £30, compared with CLFs at £5 to £15, and incandescent lamps at 50p to £1 (although increasingly unavailable). No homeowner will replace all the lights in their home at such a cost penalty until there is a significant price reduction.

Costs of DC-LEDs will undoubtedly reduce in time as production quantities

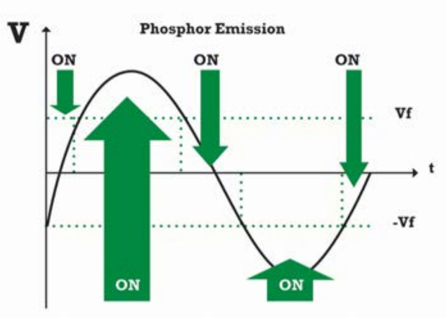



HAITZ'S LAW: Cost per lumen falls by a factor of 10 every decade and the amount of light generated per LED package increases by a factor of 20.

Source: DOE SSL Multiyear Program Plan




**AC LEDs will turn off (flicker) when the applied voltage falls below Vf**




**The ACRE LED uses photoluminescence to eliminate flicker**

**A greatly reduced component count is one major advantage of the ACRE LED (left)**

**DC LED street lighting, Binghe Road, Meizhou**

increase. However, there seems to be an intrinsic cost disadvantage in a design which adds unnecessary components and thereby de-rates luminous output. So what is the alternative?

## AC LEDs

A logical option would be to use AC power drivers rather than the DC used to date. This solution does not come without its own problems as the LED semiconductor will switch off when the drive voltage falls below the turn-on voltage for a period in each cycle, resulting in flicker.

AC LED lamps have been introduced, which, cleverly, use LEDs to form the diode bridge and so use both half-cycles of the AC input power. The downside is that, without the output-smoothing capacitor, the drive voltage will still fall below the turn-on voltage for a period in each cycle, resulting in some flicker although less severe than in the unregulated AC input. So there is significant, but only partial, reduction in electronic components and in concomitant de-rating.

## ACRE LEDs

White light is most widely produced by coating LEDs of one colour (mostly blue) with phosphors of different colours (mainly yellow) to form the emitted light (desired

**Links**

**UK_China Eco-Cities Group:**
**www.ukchinagroup.org**
**The China Greentech Report May 2012:**
**www.china-greentech.com/node/3242**
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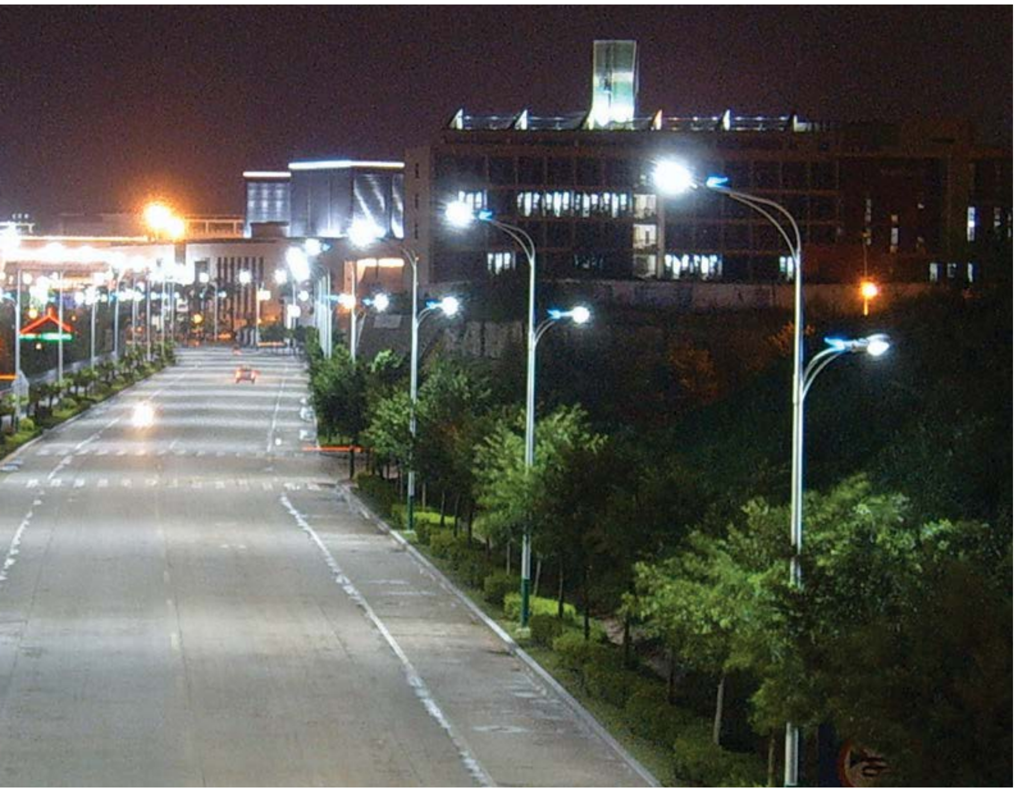

**DC LED tunnel lighting, Dongchenggen Tunnel, Chengdu**

white), and the resultant LEDs are called phosphor-based LEDs. The latest innovation in LED technology uses rare earth phosphors to overcome the flicker in AC LEDs. The use of these rare earth phosphors makes the diode coating photoluminescent, i.e. it will absorb and then, almost immediately, emit photons (particles of light).

By careful selection of the rare earth phosphors, the time between absorption and emission in a ACRE (alternating current rare earth) LED can be tailored to ensure that the LED continues to emit light during the period when the AC drive voltage is below the turn-on voltage of the LED, producing a continuous light. There is still some residual flicker, but its amplitude and frequency are beyond the range discernible by humans in normal life.

The invention of the ACRE LED offers an AC-LED design without any unnecessary electronic components. Voltage regulators and resistors are eliminated at the circuit board level within the lamp modules, component costs are reduced, heat management issues are overcome and power efficiency is increased. The ACRE LED technology addresses the heat, component cost, reliability and power efficiency issues faced by LEDs in an innovative way that is now commercially tested and proven to be robust for outdoor and indoor industrial and general lighting.

## AC versus DC

For the present, the DC LED remains the dominant technology. DC LEDs already offer significant energy savings, and are the conventional choice for exterior lighting applications, such street lights. The AC LED is still somewhat experimental, with various manufacturers offering complex circuitry to overcome the inherent flicker problem.

The ACRE-LED resolves the flicker issue in a simple, elegant way using the photo-luminescence of rare earth coatings to prolong the luminance of the lamp during the AC voltage cycle. Such products are now available initially for interior lighting applications, and it would appear that the ACRE-LED offers the best prospect to become the replacement of choice for incandescent and fluorescent lamps in the foreseeable future.

The DC-LED celebrated its 50th anniversary in October 2012, as narrated by it inventor Professor Nick Holonyak on www.bbc.co.uk/news/technology-19886534. The next half-century could well belong to the AC-LED and particularly the ACRE-LED.

**Ben Papé is a former chairman of the IET Built Environment Technology and Professional Network. Between 1997-2006 he was the China Business Adviser to UK Trade & Investment, where he focused on the introduction of energy-conserving and low-carbon development concepts. He subsequently helped form the UK-China Eco-Cities Group, working in partnership with China to develop 250 Eco-Cities in China. He was a co-author of the research paper 'Progressing Eco-City Policies into Mainstream Practice in China'.**

**One of the objectives of the Eco-Cites Group was to identify technologies for transfer that would bring low-carbon benefits to both China and the UK. The ACRE LED lamp was one of such potentially beneficial technologies identified by the group.**

**The ACRE LED has been developed by Sichuan Sunfor Light Ltd – finalists in the Built Environment and Power/Energy categories of the IET 2012 Innovation Awards.**

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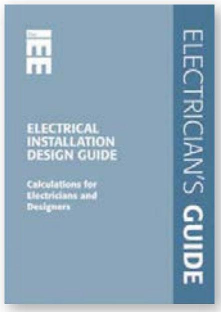


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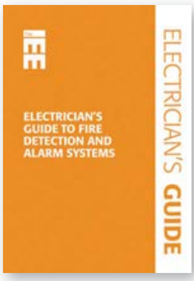


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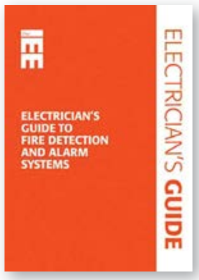


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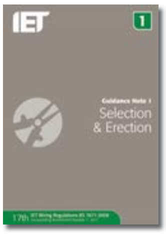


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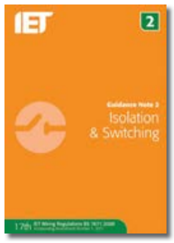


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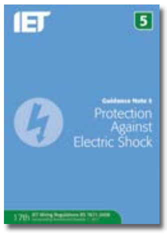


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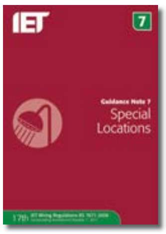


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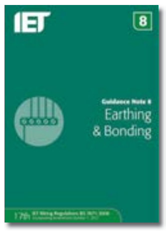


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# MARINAS AND JETTIES

## We review the requirements for electrical installations in marinas, examining the risks associated and future European-level developments for inland navigation vessels

By Geoff Cronshaw


CORBIS

SECTION 709 of BS 7671 contains requirements for marinas and similar locations. This is based on European CENELEC Harmonisation Document HD 60364-7-709.

Most, if not all, of the measures used to reduce the risks in marinas may equally apply to electrical shore connections for inland navigation vessels using the network of navigable rivers and canals throughout Europe, for which CEN is developing a standard.

One of the major differences between supplies to small craft in a typical marina and those required for electrical shore connections for European inland navigation vessels is the size of the supply which may be required. For example, seagoing vessels accessing river navigations can be up to 10,000 gross tonnes and motor barges and tugs used on inland waterways in Europe are considerably larger than the average size of vessel berthed in marinas; these are generally recreational craft (up to 24m length) or work boats and small commercial vessels and fishing boats.

Generally socket outlets with a rating of 16A will be provided for each craft in a marina. The risks associated with electrical installations in marinas, such as the presence of water, movement of structures and harsh environmental conditions, are the same as for electrical shore connections for larger inland navigation vessels.

In this article we summarise some of the existing key requirements for electrical installations in marinas and similar locations. The CEN requirements for electrical shore connections for larger inland navigation vessels are expected to be very similar to those in CENELEC HD 60364-7-709 and there is a joint working group set up to address convergence of the requirements.

### Protection against electric shock

The protective measures of obstacles, placing out of reach, non-conducting location and protection by earth-free local equipotential bonding, are not permitted in section 709 (of BS 7671) for marinas. These measures are contained in Sections 417 and 418 of BS 7671:2008, and are not for general application. The protective measures of section 417 provide basic protection only, and are for application in installations controlled or supervised by skilled or instructed persons. The fault protective provisions of Section 418 are special and, again, subject to control and effective supervision by skilled or instructed persons.

### Supplies

Regulation 709.313.1.2 states that the nominal supply voltage of the installation for the supply to small vessels, recreational crafts or houseboats shall be 230V a.c. single-phase, or 400V a.c. three-phase. It is important to note that where the supply system is protective multiple-earthed (PME), Regulation 9(4) of the Electricity Safety, Quality and Continuity Regulations 2002 prohibits the connection of a combined neutral and protective conductor to any metalwork of a caravan or boat.

### Operational conditions and environmental factors

Electrical equipment to be installed on or above jetties, wharves, piers or pontoons must be selected according to the external influences that may be >

**Socket outlet details**

| | |
|---|---|
| Up to 63 A | Should comply with BS EN 60309-2 |
| Above 63 A<br>IP rating | Should comply with BS EN 60309-1<br>At least IP44. Alternatively this IP rating can be provided by an enclosure.<br>(Note that if AD5 (water jets) or AD6 (waves) is applicable, the IP rating should be at least IPX5 or IPX6 respectively) |
| Located as close as practicable to the berth to be supplied | |
| Installed in a distribution board or in a separate enclosure | |
| A maximum of four socket-outlets should be installed in any one enclosure | |
| One socket- outlet should supply one leisure craft or houseboat | |
| Placed at a height of not less than 1 m above the highest water level except for floating pontoons or walkways where this height may be reduced to 300 mm providing appropriate additional measures are taken to protect against the effects of splashing | |

present. In the marina environment consideration must also be given to the possible presence of corrosive or polluting substances. Equipment should be located to avoid any foreseeable impact, be provided with local or general mechanical protection and have a degree of protection for external mechanical impact – IK08.

Any wiring system or equipment selected and installed must be suitable for its location and able to operate satisfactorily without deterioration during its working life. Suitable protection must be provided, both during construction and for the completed installation. Regarding presence of solid foreign bodies, a minimum degree of protection of IP3X is required. For presence of water the following applies:

- Presence of water splashes – IPX4
- Presence of water jets – IPX5
- Presence of waves of water – IPX6

## Devices for fault protection by automatic disconnection of supply RCDs

Regulation 709.531.2 requires that socket-outlets shall be protected individually by an RCD having the characteristics specified in Regulation 415.1.1. Devices selected shall disconnect all poles, including the neutral. Final circuits intended for fixed connection for the supply to houseboats shall be protected individually by an RCD having the characteristics specified in Regulation 415.1.1. The device selected shall disconnect all poles, including the neutral.

## Isolation

Regulation 709.537.2.1.1 requires that at least one means of isolation shall be installed in each distribution cabinet. This switching device shall disconnect all live conductors including the neutral conductor. One isolating switching device for a maximum of four socket outlets shall be installed.

## Types of wiring system

The following systems should not be used above a jetty, wharf, pier or pontoon:

- cables suspended from or incorporating a support wire;
- non-sheathed cables in cable-management systems;
- cables with aluminium conductors;
- mineral insulated cables.

Conduit and ducting installations should have apertures or holes and be fixed at an angle sloping away from the horizontal, to allow for moisture drainage.

Cables should be selected and installed so that mechanical damage due to tidal and other movement of craft and other floating structures is prevented. To clarify this requirement, cables should be installed so that they are protected from damage due to:

- displacement by movement of craft or other structures;
- friction, tension or crushing;
- exposure to adverse temperatures.

At locations where cables are subject to flexing, flexible cables should be used, such as:

- cross-linked insulated flexible cables harmonized type H07RN-F, H07BN4-F or H07RN8-F (insulated and sheathed), e.g. cables to Tables 14, 15, 16, 17 and 20 of BS 7919:2001;
- thermosetting insulated flexible cables harmonized type H07Z-K, e.g. cables to BS 7211 Table 3b within flexible wiring systems.

**Note 1** Many cable types including PVC insulated and sheathed cables are not suitable for continuous immersion in water. Suitability should be checked with the cable manufacturers. Floating pontoons are usually manufactured with a service void in them, enclosed and accessible from above, to accommodate cables and water piping.

**Note 2** Take care when installing cables to prevent damage from abrasion due to movement between pontoon sections, etc. Cables must be adequately fixed, protected and supported, and, if necessary, cable types suitable for flexing must be used.

## Distribution boards, feeder pillars and socket outlets

Socket outlets when mounted on floating installations or jetties should be fixed above the walkway and preferably not less than 1m above the highest water level. This may be reduced to 300mm if appropriate additional measures are taken to protect against the effects of splashing (IPX4), but care should be taken to avoid creating a low-level obstacle which may cause risk of tripping on the walkway. When mounted on fixed jetties they should be mounted not less than 1m above the highest water level.

## Galvanic corrosion

The immersion of metal components of a craft in water, particularly in salt water, provides the natural mechanism of galvanic corrosion. Where there are dissimilar metals on the electro-chemical series in proximity, the detrimental effect of galvanic couples can be exacerbated. As a counter measure, small vessels, recreational craft, houseboats, ships and many immersed metal structures are provided with sacrificial anodes (zinc for salt water) to which the more valuable/essential immersed metal parts, such as propellers, shafts, hull fittings and fixings are electrically bonded. The sacrificial anode(s) is preferentially depleted as a consequence of providing galvanic corrosion protection to the valuable/essential immersed parts.

Section 709 of BS 7671:2008 is based on European CENELEC Harmonisation Document HD 60364-7-709. Annex A of the document contains examples of methods of obtaining a supply in a marina. HD 60364-7-709 recognises that there is an additional risk of electrolytic corrosion resulting from circulating galvanic currents in the protective conductor from the shore supply to a vessel when connected to a shore supply.

There have also been reports of increased rate of depletion of the sacrificial anodes of recreational craft which are connected on a longer-term basis to shore supplies. Some observers believe this is associated with the connection of the recreational craft's protective earth terminal (to which immersed components and sacrificial anodes are bonded) to the shore supply earth in a marina or similar location.

HD 60364-7-709 recognises the use of an isolating transformer to prevent galvanic currents circulating between the hull of the vessel and the metallic parts on the shore side. The current standard for isolating transformers is BS EN 61558.

## Conclusion

This article only gives an overview of electrical installations in marinas and similar locations. For more information refer to section 709 of BS 7671:2008 incorporating Amendment 1. Be aware that requirements for electrical shore connections for inland navigation vessels are still at a very early stage of discussion and may or may not become a European standard.

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# PME SUPPLIES

## Looking at the principles of protective multiple earthing (PME) and the issues to be considered when PME electrical supplies are used outdoors or to supply external buildings.

By Mark Coles

THIS ARTICLE looks at the widely used Protective Multiple Earthing (PME) system and Protective Earth-Neutral (PEN) conductors. PME provides a robust and reliable means of distributing electricity but, under certain fault-conditions, a potential can develop between the conductive parts connected to the PME earthing terminal and the general mass of Earth.

First, let's look at the definitions of the terms:

- **CNE** – Combined neutral and earth;
- **DNO** – Distribution network operator;
- **Earth** – Capital 'E' to imply the general mass of Earth, i.e. true Earth, e.g. the ground that you walk on;
- **earth** – Lower-case 'e' to imply the earth of the electrical installation;
- **PEN conductor** – A conductor combining the functions of both protective conductor and neutral conductor;
- **PME (Protective multiple earthing)** – An earthing arrangement, found in TN-C-S systems, in which the supply neutral conductor is used to connect the earthing conductor of an installation with Earth, in accordance with the Electricity Safety, Quality and Continuity Regulations 2002 (as amended)
- **TN system** – A system having one or more points of the source of energy directly earthed, the exposed-conductive parts of the installation being connected to that point by protective conductors
- **TN-C-S** – A system in which neutral and protective functions are combined in a single conductor in part of the system
- **TN-C** – A system in which neutral and protective functions are combined in a single conductor throughout the system. Where: T – Terre (from the French, meaning 'Earth'), N – Neutral, C – Combined and S – Separate.

### How do the terms fit together?

On the low-voltage distribution network, the earthing and neutral functions are combined in the same conductor of the supply cable; this is known as a PEN conductor and the distribution arrangement is TN-C; note that DNOs can refer to the PEN conductor as CNE. Along the length of the low-voltage distribution cable the PEN conductor is earthed, using earth electrodes at regular intervals. To supply the electrical installation, the neutral and earthing functions of the PEN conductor are separated out to create neutral and earth provisions (see fig 1, p34).

Combining the neutral and earth functions in one conductor means that the cable costs are reduced and any fault between conductors will be line-to-line or line-neutral so that, owing to the low value of earth fault loop impedance, the protective device will operate very quickly to remove the fault. Compare this to a TN-S distribution arrangement where a neutral-to-earth fault could exist for a long period.

### History

PME has almost universally been adopted by distributors in the UK as an effective and reliable method of providing customers with an earth connection. According to National Grid, PME has become increasingly common on 400V distribution circuits in the UK since it was first introduced with pilot schemes in the 1930s and is now applied to about 85 per cent of overhead circuits, 65 per cent of underground circuits and 30 per cent of supplies to individual consumers in England and Wales (www.emfs.info/Sources+of+EMFs/distribution/UK/).

In cases where homes do not officially have a PME earthing arrangement, up to 20 per cent, probably more, may have accidental neutral-to-earth connections.

### Legal requirements

The Electricity Safety, Quality and Continuity Regulations 2002 (as amended) (ESQCR) permits the distributor to combine neutral and protective functions in a single conductor provided that, in addition to the neutral to Earth connection at the supply transformer, there are one or more other connections with Earth. The notes of guidance to the Electricity Safety, Quality and Continuity Regulations refer to Electricity Association (now Energy Networks Association Limited) publication G12/3 1995 for details of suitable earthing arrangements.

Note that suppliers are not obliged to provide an earth terminal to a consumer; 24(4) of the ESQCR states:

"Unless he can reasonably conclude that it is inappropriate for reasons of safety, a distributor shall, when providing a new connection at low voltage, make available his supply neutral conductor or, if appropriate, the protective conductor of his network for connection to the protective conductor of the consumer's installation."

### Low-voltage distribution network

The term 'protective multiple earthing' describes the method of earthing as used on the low-voltage distribution network. On the underground/buried network, electrodes are used to earth the neutral conductor at regular intervals, usually 25-40m apart, hence the term 'multiple earthing'. Where the low-voltage distribution network is overhead, earth electrodes are installed at transformers and at regular intervals at distribution poles.

It is important to note that in a TN-C-S (PME) system the neutral and protective earth conductor functions are combined in the supply and then are separated in the installation (see fig 1). The exposed-conductive-parts of the installation are connected by this separate protective conductor in the installation to the combined neutral and protective conductor of the supply back to the source. This installation protective conductor provides a return path for earth fault current to flow for the duration of a line-to-earth fault occurring in the installation. The combined neutral and >

protective conductor of the supply provides a return path both for neutral conductor current to flow under normal conditions and for earth fault current to flow for the duration of a line-to-earth fault occurring in the installation.

### Issues to consider with PME supplies

A PME earthing terminal provides an effective and reliable earthing facility for the majority of electrical installations. However, under certain supply system fault conditions, i.e. PEN conductor of the supply becoming open circuit external to the installation, a potential can develop between the conductive-parts connected to the main earthing terminal and the general mass of Earth. As there are multiple earthing points on the supply network, and provided that bonding within the building complies with BS 7671, it is unlikely that such a potential would in itself constitute a hazard. The situation is different outdoors.

Consider the situation where an electrical supply is being used at the end of a long garden (see fig 2). The supply to the property is PME and the last earth electrode on the low-voltage distribution network is 40m prior to the service cable entering the property. With such a long distance between the position of use and the last point of earthing on the distribution cable, a potential difference is possible between the earth of the electrical system and true Earth in normal operating conditions, i.e. no faults on the electrical installation of the property. Such a potential difference is common but a problem occurs when body contact resistance is low (little clothing, damp/wet conditions) and/or there is relatively good contact with true Earth; in such cases the potential difference may be perceptible.

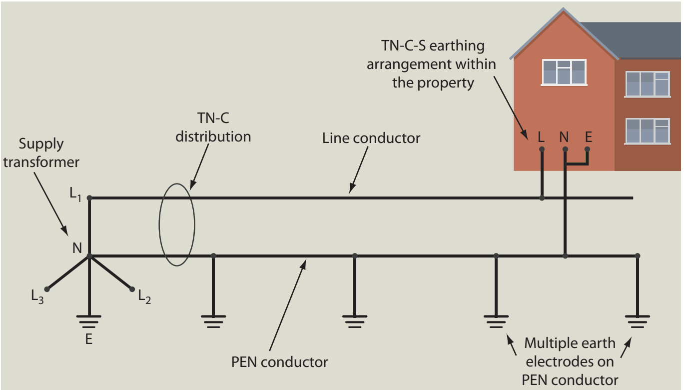



**Fig 1: TN-C low-voltage distribution network**

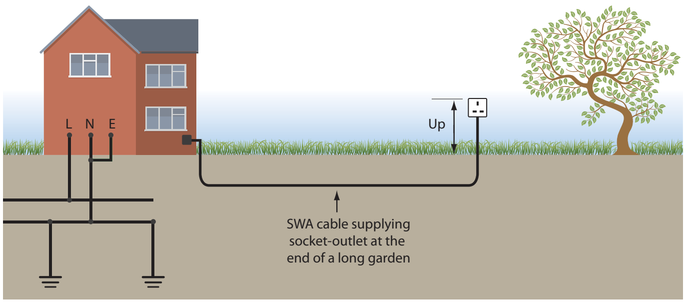
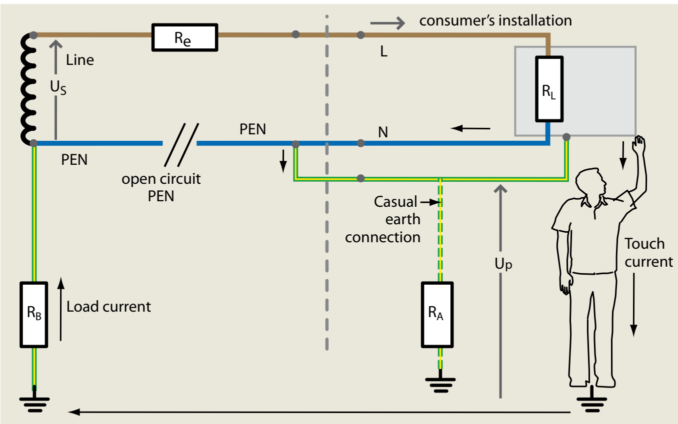



**Fig 2: Example of a PME supply with a socket-outlet in use at the end of a long garden**




$U_s$ is the nominal supply (source) voltage
$U_p$ is the touch voltage
$R_e$ is the external line supply resistance
$R_L$ is the load resistance ($V^2$/wattage)
$R_A$ is the resistance of the additional earth electrode including any parallel earths (e.g. water and gas pipes
$R_B$ is the resistance to Earth of the neutral point of the power supply

**Fig 3: Open circuit PEN conductor**

The main issue with PME supplies is the potential risk of loss of the neutral conductor. This is relatively uncommon, but could arise when, for example, groundwork has damaged a low-voltage distribution cable or when a vehicle has come into contact with an overhead cable and, in each case, the neutral conductor has been severed.

Fig 3 shows how the current path would look should the neutral conductor be severed (open circuit) and a person was to make contact with an exposed conductive part and true Earth; the route back to the transformer being by means of the person and the general conductive mass of the earth.

In a building, the risks are mitigated by protective equipotential bonding of extraneous-conductive-parts and the fact that persons are unlikely to be in contact with true Earth. Outside though, contact with true Earth is always possible and, if exposed-conductive-parts and/or extraneous-conductive-parts connected to the PME earthing terminal are accessible, people may be subjected to a voltage difference appearing between these parts and true Earth.

Where PME electrical supplies are used outdoors or to supply external buildings, it may be pertinent for the electrical installations of these areas to form part of a TT system. This is recognised in BS 7671:2008(2011) as requirements of Regulation 708.411.4, for example, prohibits the use of a PME earthing facility for caravans; the Regulation does, however, permit the use of a PME earthing facility for use within permanent buildings. The IET publication 'Code of Practice for Electric Vehicle Charging Equipment Installation' guides installers on the risk assessment process, primarily for electrical vehicle charging, but may be used for all electrical supplies used outdoors. It is important to note that no tragedies have occurred in the UK due to loss of the PEN conductor.

**Further reading:**
**IET Guidance Note 5** – Protection against electric shock
**IET Guidance Note 8** – Earthing and Bonding
**IET** - Code of Practice for Electric Vehicle Charging Equipment Installation
**Electricity Safety, Quality and Continuity Regulations 2002**
**ENA Engineering Recommendation G12/3** Requirements for the application of protective multiple earthing to low voltage networks