Temporary Power Systems
A guide to the application of BS 7671 and BS 7909 for temporary events

James Eade

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Contents

Foreword **xi**
Acknowledgments **xiii**
Glossary **xv**

1 Introduction **1**
1.1 The industry behind entertainment 1
1.2 The industry today 3
1.3 About this book 6
1.4 Conventions 6
1.5 Temporary versus permanent 7

2 Standards and legislation **9**
2.1 Hierarchy 9
2.2 The Health and Safety at Work etc. Act 1974 (HASWA) 10
2.2.1 Management of Health and Safety at Work Regulations 1999 11
2.2.2 Provision and Use of Work Equipment Regulations 1998 (PUWER) 11
2.2.3 Workplace (Health, Safety and Welfare) Regulations 1992 11
2.2.4 Electricity at Work Regulations 1989 12
2.2.5 Electrical Equipment (Safety) Regulations 1994 12
2.2.6 Construction (Design and Management) Regulations 2007 12
2.2.7 Supply of Machinery (Safety) Regulations 2008 12
2.2.8 Electromagnetic Compatibility Regulations 2006 13
2.2.9 Lifting Operations and Lifting Equipment Regulations 1998 (LOLER) 14
2.2.10 Electricity Safety, Quality and Continuity Regulations 2002 (ESQCR) 14
2.3 Standards 14
2.3.1 Harmonized Standards 15
2.3.2 International standards 15
2.3.3 BS 7671 Requirements for Electrical Installations 16
2.3.4 BS 7909 Code of Practice for temporary electrical systems for entertainment and related purposes 17
2.3.5 BS 7430 Code of Practice for earthing 19

2.4 Industry guidance 19
2.4.1 The event safety guide – A guide to health, safety and welfare at music and similar events 1999 20
2.4.2 Technical Standards for places of Entertainment 2009 20
2.4.3 Temporary demountable structures; Guidance on procurement design and use 2007 20
2.4.4 eGuide. Common regulative policy for major UK exhibition venues 2011 21
2.5 Summary 21

3 Management of events 23
3.1 Responsibilities 23
3.1.1 Senior Person Responsible 24
3.1.2 Persons Responsible 25
3.2 Small and simple events 25
3.2.1 Responsibilities for small events 26
3.2.2 Equipment supply and operation 27
3.2.3 Management of the small system 27
3.3 Large events 27
3.3.1 Management of large systems 28
3.3.2 Assessment and design 28
3.4 Equipment selection 29

4 Earthing and methods of protection 31
4.1 Supply arrangements 31
4.2 Protective earthing 32
4.2.1 Equipotential bonding 33
4.2.2 Protective conductor (PE) 34
4.2.3 Earthing conductor 35
4.2.4 Circuit Protective Conductor (CPC) 35
4.2.5 Exposed-conductive-part 35
4.2.6 Extraneous-conductive-part 35
4.2.7 Supplementary equipotential bonding 39
4.3 Methods of protection 40
4.4 Physiological effects of current 43
4.5 Equipotential zones 43
4.5.1 Touch voltages 45
4.6 Electrical environments 49
4.7 Lightning protection 51
4.8 Deriving earths from street furniture 51

5 Design principles and requirements 53
5.1 Assessment 54
5.1.1 Supply arrangements 54
5.1.2 Emergency and operational supplies 55

5.1.3 Maximum demand and nature of loads 56
5.1.4 Division of the TED 56
5.1.5 External influences 57
5.1.6 Structural requirements 58
5.2 Protection against thermal effects 58
5.3 Protection against overcurrent 58
5.3.1 Overload 58
5.3.2 Short-circuit and fault current 59
5.4 Protective devices 60
5.4.1 Circuit-breaker characteristics 60
5.4.2 Fuse characteristics 63
5.4.3 Residual Current Devices 63
5.4.4 Assessment of fault currents 69
5.4.5 Protective-device discrimination 71
5.5 Protection against electric shock 74
5.5.1 Automatic disconnection of supply 74
5.5.2 Extra low voltage (ELV) and reduced low voltage (RLV) 76
5.5.3 Electrical separation and transformers 80
5.6 Protection against voltage disturbances and measures against electromagnetic disturbances 83
5.7 Three-phase systems 84
5.7.1 Three-phase generation 84
5.7.2 Phase or neutral loss 89
5.7.3 Power factor 89
5.8 Harmonics 91
5.8.1 Cable ratings 92
5.8.2 Unbalanced loads 94
5.8.3 Overcurrent protection 95
5.9 Voltage drop 95
5.9.1 Voltage drop and power factor 96
5.9.2 Voltage drop caused by harmonics 97
5.10 Cable sizing 98
5.10.1 Current-carrying capacity and voltage drop tables 98
5.10.2 Overcurrent requirements 100
5.10.3 Correction factors 102
5.10.4 Cable size determination 107
5.11 High protective conductor currents 113
5.11.1 Protective conductor current not exceeding 10 mA 114
5.11.2 Protective conductor currents above 10 mA 114
5.12 Renewable energy sources 114
5.13 Uninterruptible power supplies (UPS) 115
5.13.1 UPS topologies 115
5.13.2 UPS circuit protection 117
5.13.3 Disconnection times 117

5.14 Parallel conductors 118
5.14.1 Protection of parallel conductors 118
5.14.2 Parallel conductor arrangements 118
5.15 Emergency lighting 119
5.15.1 Emergency lighting requirements 120

6 Equipment supply and testing 121
6.1 Selection of equipment for use in a TED 121
6.2 Connectors 122
6.2.1 Preferred connector types 123
6.2.2 Connectors used for isolation and switching 125
6.2.3 Conductor identification 125
6.3 High-current connectors 125
6.4 BS EN 60309 ('Ceeform') connectors 129
6.5 Multipole lighting distribution connectors 132
6.5.1 Round 19-pin connectors 133
6.5.2 Rectangular 16-pin connectors 134
6.6 Cable 134
6.6.1 Cable construction 136
6.6.2 Cable selection 136
6.6.3 Cable/connector combinations 140
6.7 Power distribution equipment 142
6.7.1 Construction {Appendix A} 143
6.7.2 Functionality 144
6.7.3 Surge protection devices 144
6.7.4 Indicators and controls 146
6.8 Inspection and testing of equipment prior to delivery to site 146
6.8.1 Frequency of testing 149
6.8.2 The verification process 150
6.8.3 User checks of equipment 150
6.8.4 Formal visual inspection 151
6.8.5 Combined inspection and test 152
6.8.6 Testing after repair 154
6.8.7 Labelling 154
6.8.8 RCD testing 155
6.9 Mobile and transportable units 155

7 Inspection and testing of temporary electrical distributions 159
7.1 Competencies and requirements 160
7.2 Inspections 162
7.2.1 User checks 162
7.2.2 Visual inspection 162
7.3 Electrical tests 165
7.3.1 Tests prior to energising the supply 167
7.3.2 Tests prior to putting a system into service 174
7.3.3 Earth fault loop impedance 175

7.4 Small system tests 176
7.5 Documentation 177
7.5.1 Completion Certificate 177
7.5.2 Schedule of Test Results 178
7.5.3 Confirmation of Electrical Completion 178
7.6 Testing RCDs 179
7.6.1 Testing procedure 179
7.7 Tests involving dimmers 180
7.8 Tests involving UPS 181
7.9 Periodic testing 182
7.10 Tests following changes or relocation 183
7.11 Special locations 183
7.11.1 Baths, basins, fountains and marinas 184
7.11.2 Exhibitions, shows and stands 185
7.11.3 Agricultural and horticultural premises 186
7.11.4 Mobile and transportable units 186

8 Generators and other sources of supply 187
8.1 Small generating sets 187
8.2 Earth electrodes 188
8.2.1 Earth plates 190
8.2.2 Earth spikes 190
8.2.3 Other electrodes 191
8.2.4 Testing earth electrodes 192
8.3 Connection of multiple generators or other sources 192
8.3.1 Main source with switched standby generator 193
8.3.2 Synchronised generators for large capacity using load-sharing 194
8.3.3 Synchronised generators for redundancy 194
8.3.4 Earthing of multiple generators or sources 195
8.4 Generator housekeeping 197
8.5 Street furniture supplies 198

9 Operational considerations 199
9.1 Disabling (bypassing) RCDs 199
9.2 Protection against damage and interference 201
9.2.1 Cables 201
9.3 Safe working practices 202
9.3.1 Live working 202
9.3.2 Identification and isolation of circuits 203
9.3.3 Emergency procedures 203
9.3.4 Unattended systems 204
9.4 Communications 204
9.5 Weather conditions 204

10 Venue information **205**
10.1 Provision of supplies 205
10.1.1 Diversity 206
10.1.2 Power quality and conductors 206
10.1.3 Connections for TED supply 207
10.1.4 Circuit protection 208
10.1.5 Labelling and marking 208
10.2 Earthing arrangements and external connections 209
10.2.1 Technical earths 210
10.3 Technical Standards for places of entertainment 211
10.3.1 General requirements 211
10.3.2 Switchgear 211
10.3.3 Wiring 211
10.3.4 Shock protection 212
10.3.5 Socket-outlets 212
10.3.6 Earthing 213

11 Electrical systems for temporary structures **215**
11.1 Exhibitions, shows and stands [711] 215
11.1.1 Protection against electric shock 215
11.1.2 Protective measures 215
11.1.3 Selection and erection 216
11.1.4 Lighting 217
11.1.5 Inspection and testing 217
11.1.6 AEV/ESSA guidance 217
11.2 Stage and studio sets 218

12 Mobile and transportable units **221**
12.1 Supplies 221
12.2 Protection for safety 222

Appendix A Bibliography **223**
Appendix B Useful electrical calculations **225**
Appendix C Rating factors for cables having more than four loaded cores **231**
Appendix D Reproduced tables from BS 7671 Appendix 4 for cables commonly used at events **233**
Appendix E Reproduced tables from BS 7671 Appendix 3 for MCBs **247**
Appendix F ABTT theatre electrical sheet **251**
Appendix G BS 7909 certification documentation **257**
Index **261**

Foreword

The provision of temporary electrical systems has come of age here in the UK and abroad. The size and complexity of these often multiple generator-fed systems has matured into a big business. The need for them is forecast to increase as the world's population continues to grow. There is a great need for a 'how-to' publication such as this book by James.

In the United Kingdom and in a number of other countries around the world, *BS 7671 Requirements for Electrical Installations* describes a set of parameters and principles that have to be met in order to provide a safe, secure and reliable electrical distribution system. Known colloquially as 'the 17th Edition' (or whichever the current version is), or sometimes misnamed as 'Electrical Regs', the basic principles on which these Requirements are built are often poorly understood and regrettably often unread by those who create temporary electrical systems. The Requirements describe various electrical conditions that have to be met but on the whole, do not inform the reader how to go about achieving them. Practical guidance is left to the ever expanding range of Guidance Notes and On-Site Guides published mostly by the Institute of Engineering and Technology (IET).

The necessity of providing a set of rules for temporary electrical supplies for short-term events such as music concerts and festivals became apparent in the UK when the electrical distribution systems at such events did not meet the electrical safety requirements of BS 7671. If it is not safe for a permanent installation then it is not safe for a temporary installation. In a 'here today but gone tomorrow' event world, there is simply not enough time to complete the required Electrical Installation Certificate for permanent installations. With this in mind, a pragmatic decision was taken to require a lot of the electrical testing of the temporary equipment to be completed in a timely and careful manner before the equipment arrived on site ready to plug together. Hence, the birth of BS 7909, which combines the essential safety requirements of permanent electrical installations with limited but essential 'live' testing of temporary installations once they are connected together and ready to be put to work.

As a preparation for writing this foreword, I carefully read the book page by page. I then re-read it and realised that in your hands is a rather succinct guide to BS 7671:2011. It takes you through the relevant requirements without having to search chapter to chapter. It also is a book that not only explains the first principles of electrical supplies, but also shows with simple line diagrams how they are designed and assembled. There are a number of key messages in this publication: the first is that it is essential that temporary electrical systems are carefully planned

and designed before arriving on site. The second is that earthing is king and supplementary protection afforded by devices such as RCDs is exactly that, supplementary. The third is that there should be no need to disable fundamental safety of life components such as RCDs in a properly designed temporary electrical distribution.

If you are reading this book as an experienced but perhaps untrained practitioner, it will go a long way towards explaining those mysterious and unwanted 'nuisance' trips (interruptions) we all have experienced when supplying electrical power to a temporary event.

James's book is an education for those who do not know and an aide-memoir for those that do.

Nestled within these pages are small explosions of myths often firmly held to be true but without foundation. These include the 'keeping sockets on different phases of supply at least two metres apart', which was abandoned as being unnecessary 30 years before this book was first published in 2013. Another follows on from the apparent fear that many production electricians seem to have regarding three-phase power, in that somehow this is more dangerous than single-phase power. If faced with, 'Ooh no, 'elf and safety won't allow three phases down that multi-core/on that socket outlet box', ask to see the risk assessment and the Electrical Requirement that prohibits the practice. Another fondly held belief explored in this book is that RCDs are a panacea (that is to say, a remedy that will cure all diseases), whereas they actually only guard against one of the many faults that can occur in a temporary electrical system.

After perusing this book, the reader will also discover why it is that modern electrical loads can present severe problems for generators and why it is that the predicted load in kilowatts presents an often much higher load than the apparently matching kVA (kiloVoltAmp) rating of the generator. If you need an answer as to why a 100kVA generator will not reliably power a 100kW lighting rig, then read this book.

Mark White
Chairman, Association of British Theatre Technicians
Chairman, The Theatre Safety Committee
November 2012

Acknowledgments

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Several other prominent members of the electrical industry also reviewed the content, as follows: Messrs Morton (HSE), Bradley (Electrical Safety Council), Kenyon (Ultra Electronics Airport Systems) and Coates (ERA Technology). I'm grateful to them all for taking the time and trouble, as well as to their employers for letting them do so.

My dearest wife, Joanna, and our boys, Rory and Rafe, are singled out for the most praise for putting up with me and my peripatetic lifestyle – as is required of someone working in the events industry. Their support and patience continues to be immeasurable. And finally, to my father, Bob; a truly inspirational engineer from whom I've learnt much.

Glossary

BOH	Back-of-House – area of an event to which the public do not have access, such as the back stage areas
c.s.a	Cross-sectional area
CDU	Central Distribution Unit
Class I	Equipment in which protection against electric shock does not rely on basic insulation only, but which includes means for the connection of exposed-conductive-parts to a protective conductor in the wiring of the electrical distribution. Refer to BS 2754.
Class II	Equipment in which protection against electric shock does not rely on basic insulation only, but in which additional safety precautions such as supplementary insulation are provided, there being no provision for the connection of exposed metalwork of the equipment to a protective conductor and no reliance upon precautions to be taken in the wiring of an electrical system. Refer to BS 2754.
Class III	Equipment in which protection against electric shock relies on a supply at SELV and in which voltages higher than SELV are not generated. Refer to BS 2754.
CNE	Combined Neutral and Earth (see also PEN)
CSU	Cable Splitter Unit
DNO	Distribution Network Operator
EFLI	Earth Fault Loop Impedance
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
FDU	Final Distribution Unit
FOH	Front-of-House – area of an event where the public have access, such as an auditorium
Gel	Colour filter used to colour the beam of a luminaire. Now normally made from plastic, original variants were made from a gelatine compound, thereby giving them the name
Gobo	Disc (usually metal or glass) with an etched pattern that is inserted into the optical path of a luminaire to project an image
Informative reference	A reference within a standard to another standard or publication that is provided to assist the reader, but of which the requirements of the referenced document do not apply
In-the-round	A format of show (usually theatrical) where the audience surround the stage or acting space. More commonly, theatres have a proscenium stage with the acting area behind a proscenium arch, and the audience positioned on the other side
Isochronous	Equal in duration or interval
ISU	Intake Switch Unit
MET	Main Earthing Terminal

Normative reference	A reference within a standard to another standard or document for which compliance is required in order to comply with the standard in question
Practical	The name given to an item of equipment used as part of a staged performance. Examples may include desk lights, telephones, hand-held candle lamps or similar props that actually have to work, rather than being made to look as if they are working
PEN	Protective Earth and Neutral (see also CNE)
PSCC	Prospective Short-Circuit Current
TED	Temporary Electrical Distribution
TES	Temporary Electrical System

Section 1

Introduction

Temporary power systems are perhaps more ubiquitous than might normally be imagined. For example, exhibition halls, theatres, hotels and conferencing venues all try to ensure that they keep themselves busy with back-to-back events ranging from parties to large corporate conferences. In the UK alone there are well over a hundred outside television broadcasts per week of news and sporting events, not including the recording on location of all the dramas, documentaries, films and similar material. Then in the summer months we also see plenty of festivals and concerts. But temporary electrical systems are not limited in scope to entertainment use: back-up supplies are often deployed where installed systems fail or need extra capacity, the defence and emergency services use them wherever they are deployed, Christmas lighting displays appear each winter, summer sees agricultural shows and sporting events and so on. Although the examples given in this book illustrate a focus on the entertainment sector, including staged shows, live spectacles or broadcasting, the content is equally applicable to other temporary events such as those outlined above.

1.1 The industry behind entertainment

In order to understand the rationale behind some of the guidance in this book and within British Standard BS 7909 (Code of practice for temporary electrical systems for entertainment and related purposes), it is necessary to understand a little about the nature of the entertainment industry. Historically, this has its roots in the advent of TV and film in the 1950s and, latterly, rock-and-roll in the 1960s and 1970s; developments in lighting, sound, staging and related infrastructure grew rapidly in this period and even today there is still a progressive philosophy of introducing new equipment, effects or techniques. It is a rare industry in which innovation is often engineering-led with engineers typically providing the creative vision as opposed to one where engineers are used to develop solutions to problems.

One of the first hurdles in staging live shows in the early days was the need to build sound systems large enough for the audience, and it was a common sight to see bands on stage with the backdrop being formed by stacks of guitar amplifiers. The emphasis on music alone gave way to an emphasis on providing a show and so lighting then played a bigger part. Early developments included the ubiquitous ‘parcan’, a spun-aluminium enclosure (although the very early versions were steel)

holding a par64 bulb and colour frame. These often formed the backbone of huge lighting rigs with some stadium-sized tours having up to 3,000 separate lights all cabled back to individual channels of dimming: a 3 MW load when, inevitably, they were all turned on for the finale.

Automation soon followed in the 1980s, where luminaires were fitted with moving mirrors on the front to provide remote control of the beam direction. Added to this were rotating colour wheels with different coloured 'gels' (colour filters originally made from gelatine, which gave them the name) followed by effects wheels and gobos – small metal discs with a pattern etched in them – used to project images in certain types of luminaire. The result was a light show with movement, beam effects and colour change all individually controlled using the standard 0–10 V analogue protocol. A big breakthrough came in the 1980s when the band Genesis invested in an American company who had demonstrated to them the first luminaire that actually moved itself (rather than using a moving mirror) called the Vari*Lite. It had built-in dichroic colour and effect wheels and was programmed using a computerised control console that enabled pan, tilt, colour and effects for individual (or groups of) luminaires to be recalled at the touch of a button; it debuted on the band's Abacab tour in 1981. This set the scene for today's lighting systems, which typically consist of highly refined variations of this original luminaire concept, each having multiple attributes such as colour mixing, multiple beam effects, remote shutters and more, all controlled from digital consoles using serial or Ethernet-based data.

Audio systems were not immune to change either. The early 'walls of sound' that could be seen behind a band gave way to separate stacks of speakers either side of the stage. Considerable research and development time was – and still is – spent on speaker technology as well as amplifiers and signal processing. The progress made with high power semiconductors was embraced by both lighting and audio companies, the former for dimming technology and the latter for audio amplifiers. Valves gave way to more robust solid-state amplifiers and early semiconductor-based design topologies are still refined today in a continual quest to achieve that warm valve amplifier sound without using the fragile valves themselves. High-power switching techniques have also been embraced with the latest 'digital' amplifiers using switch-mode supplies and pulse-width modulation techniques to actually drive the loudspeakers, giving the advantage of much smaller sizes and lower weight. Advances in materials science have allowed the development of small high-powered speaker drivers, which led to the old concept of the line-array speaker system being given a new lease of life with the net benefit of higher powered systems capable of high levels of controlled dispersion. This general progression towards digital and switched-mode signal processing results in less overall weight and trucking space required, potentially saving a typical tour tens of thousands of pounds compared to early analogue systems.

When the visual elements of lasers and lighting reached a technical plateau and attention turned towards animated graphics, U2 pioneered probably the first and largest (approximately 830 m^2) light emitting diode (LED) video screen of its time on its Popmart tour in 1997, when the blue LED was first becoming commercially

viable. The concept of a large animated backdrop behind a band that has video and live images streamed to it is today commonplace.

Such exponential development brings its own challenges for the power infrastructure and today's modern shows include a plethora of electronic and electrical processing equipment from motor drives for stage machinery to banks of video displays as well as lighting, sound and all the control and backstage infrastructure to accompany it. In the early 1980s most temporary power systems typically only had to cope with high levels of largely resistive lighting loads plus equipment with linear power supplies, although the film and TV industry had been dealing with discharge lighting and electronic ballasts for some time but generally on a smaller scale. Today, the hardware inventory has grown considerably and a significant quantity use switch-mode power supplies and other power processing devices leading to more of a focus on power-quality issues.

1.2 The industry today

In the industry's early years, there was a prevalent attitude that nothing but the show mattered and all the stops were pulled out to ensure that a show went ahead, with scant regard to working conditions or safety. Indeed such dedication to the job is still paramount and it is exceptionally rare to hear of an event cancelled because of a technical issue; typically where it has happened the issue has been severe, such as the collapse of a stage or other major infrastructure. Indeed, it is so rare that the phrase 'show-stopper' has entered the English vocabulary.

During these early years there was little industry-specific guidance on safe working and so it adopted its own methods along with an underlying misapprehension that it was somewhat of a 'special case'. These days, however, the industry is much more professional in its attitude as would befit one worth almost £15 billion per annum[1] to the UK economy (of which £1 billion is from live music events alone[2]), and it has worked hard in more recent years to ensure that it does comply with appropriate legislation and standards. It is true though that the industry is in some respects special, particularly when compared to its construction industry counterparts. It is not just differences in working hours, contractual arrangements, pay scales and conditions; it is a completely different culture with the entire crew of an event working hard towards one goal as a team. To quote Mark Fisher, Architect for the U2 tour, described below:

> For me, the thing that the rock-'n'-roll world delivers that the conventional construction world couldn't is the ability to deliver [the show] time after time, on time, in cities 400, 500 and even 1 000 miles apart. That's what

[1] *Digital Dividend Review*, 2007, Programme Making and Special Events (PMSE) Pro User Group Consultation Submission Friday 16 March; Ranelagh International Ltd.
[2] http://www.bbc.co.uk/news/business-13405724 [accessed 1 June 2013].

Figure 1.1 U2 360° tour [picture courtesy of Steve Moles]

the rock-'n'-roll world should really be proud of because it's developed a culture and skill base that allows that to happen.[3]

Although legislation dictates that the industry cannot be absolved of its 'special' status, when one considers the size and timescales of typical events, the differences become apparent. Not only can it be forgiven for thinking as such, but also some might agree – even the insurer Lloyds notes that 'rock-'n'-roll is not what it used to be'.[4]

By way of an example, the U2 360° tour was a stadium size show in-the-round, with a central stage 50 m tall and seating all around (see Figure 1.1). Although it set new boundaries for scale and complexity within the industry, such challenges are not unusual and the next supergroup tour will no doubt attempt to match or better the technical achievements. The show toured the world with three sets of structural steelwork transported in 114 trucks (one stage being dismantled, one in use and one being built) and around 50 articulated trucks carried all the main lighting, sound, video, generators, the rest of the staging and other infrastructure from venue to venue. The lighting alone used four 400 A three-phase supplies for the roof with another four similar supplies to service lighting at stage level. Add to that the audio comprising 300 speakers and over 150 10–14 kW amplifiers, a 50-tonne expanding

[3] *Mobile Production Monthly*, 2009, volume 2, issue 12.
[4] Lloyds press release, 14 April 2009.

video screen and other services, and the net generator requirement was in the region of 2 MW not including the standby plants.

It's certainly a large system and when complete the stage weighs over 400 tonnes. The construction time would be expected to be long, but no; excepting the main steel structure (which takes just over four days) everything including the temporary power distribution system is offloaded from the trucks, unpacked, rigged, checked and ready for the start of the show in under 40 hours. After the show, the process is reversed and the trucks are all gone in an even shorter timescale heading for the next venue. It is also worth noting that these events are not years in the making; it is not unusual for the concept to be developed over the course of a year or less with the suppliers and contractors being given orders to design and build everything around four to six months from the scheduled rehearsal dates.

Not all events are so streamlined and build times of several weeks are common for large one-off spectaculars. The XIX Commonwealth Games in India was a substantial temporary event with just under 1 000 automated lights on top of the 800 permanently installed LED units using up to 31 744 individually programmable channels of control, 32 high-power video projectors, over 230 amplifiers, 1,000 radio systems, 26 digitally networked audio mixing consoles for the broadcasting and 200 temporary structures including a rugby stadium.[5] The list could go on but suffice to say that the base temporary power load considerably exceeded 2.5 MW not including that required for the outside broadcasting, and given that it was erected in the monsoon season it didn't go without hitch either – some 300 automated lights gave up their power supplies to the cause. The more recent Olympics surpassed this load considerably as one might expect; Aggreko, the main generator supplier, provided just under 600 generating sets to the Olympic venues and distribution for over 220 MW of power, equivalent to about half the oil-fired power station capacity in the UK.

Closer to home many will be familiar with the long-running reality-TV competition *The X Factor*. Although in terms of scale this is much smaller (only a couple of hundred light fixtures, for example) the demands are no less real. Each contestant performs a new song with a new production each Saturday and the design may not be fully ratified until the day, requiring additional equipment or design changes during the afternoon before live broadcasting in the evening. Sunday sees the group performance and a guest band, which requires the show to be again reconfigured for the evening's television.

These examples aim to paint a broad picture of a part of what is involved in staging an event. In respect of the temporary electrical system, it will probably come as no surprise to realise that a blanket application of the requirements of BS 7671 (particularly inspection and testing) to such events is impractical given the size and timescales. For this reason the code of practice BS 7909 was developed to contextualise the requirements of the Wiring Regulations and to help enable the industry to ensure that the systems it deploys are safe and provide adequate safety for the users. Although it has been shown that the event industry has unusual demands of its equipment and crews, like any other it is bound to ensure that it

[5] *TPI* magazine, December 2010, issue 136.

operates in safe manner and both BS 7671 and BS 7909 are fundamental tools that can be used to achieve that from an electrical perspective.

Although challenges will always exist in making the next shows bigger, better and more technically advanced, the largest challenge facing the industry is sustainability. As has already been illustrated it is not one shy of consuming vast amounts of power and reducing this dependency will involve new greener technologies that, like the electrical industry in general, mean new skills and standards for the safe deployment of such technologies. In the meantime it is the aim of this book to help those in – or new to – the industry to gain a greater understanding and to ensure that temporary electrical systems get deployed in a safe manner.

Many allied industries use techniques and equipment developed by the entertainment industry. The requirement to erect and dismantle systems quickly and the need for portability limit the size and weight of distribution equipment and time and other constraints prevent the use of conventional fixing methods. Coupled with this are the routine problems of tight schedules, adverse weather and late changes of plan and as a result the equipment designed and used for temporary systems has to be suitably robust and flexible enough to be used in different configurations.

Generally, the equipment that has been designed and developed over the years for such use is very good and incredibly flexible; the very 'plug and play' nature of modern distribution equipment is key to the fast turnarounds that events typically require. Such technology, however, can engender a degree of complacency when it comes to designing systems; a connector and cable assembly is often regarded as being able to deliver its maximum rated current safely without regard to the length of the cable or the source to which it is connected, for example.

1.3 About this book

This book aims to be a guide only, and not a replacement for the standards it discusses. It covers a broad range of areas related to the provision, design and use of temporary power systems and some topics may or may not apply to individual circumstances. However, it illustrates what should be considered when a planning temporary power system and how to deal with issues arising from those considerations. It goes beyond the scope of both BS 7671 and BS 7909 on important topics such as stage sets and portable appliance testing, for example. There is also a section that covers design considerations for the electrical installations in venues that host temporary events.

1.4 Conventions

Throughout this book, references are made to both BS 7671:2011 incorporating Amendment 1 *Requirements for electrical installations; The IET Wiring Regulations 17th Edition* as well as BS 7909:2011 incorporating Amendment 1 *Code of practice for temporary electrical systems for entertainment and related purposes.*

It would make for uncomfortable reading to include the title of each Standard whenever a particular clause or cross reference is made, and so the following bracket convention is used:

- [433.3.1] – square brackets refer to a regulation in BS 7671;
- {6.3.2} – brace brackets refer to a recommendation in BS 7909.

Other references are given directly; for example, HSE Memorandum of Guidance on the Electricity at Work Regulations 1989. A full bibliography is given in Appendix A.

Confusion can often manifest itself when discussing 'installations' with respect to the nature of permanent or temporary installations. For this reason the word 'installation' is generally avoided when referring to temporary systems and, as in BS 7909, this book considers an installation to be permanently fixed electrical infrastructure, such as that which is integral to a building or other structure.

An electrical system erected solely for the purposes of an event and which will be entirely removed after it has finished is referred to as a Temporary Electrical Distribution (TED for brevity). Similarly, a distinction needs to be made for a complete system that includes electrical equipment connected to a TED, such as luminaires, but which themselves are not part of the distribution. This is referred to as a Temporary Electrical System (or TES for short).

BS 7671 makes no such distinction and where it makes references to an 'installation', it refers to an 'electrical Installation', which it defines as 'An assembly of associated electrical equipment having coordinated characteristics to fulfil specific purposes'. It also defines a Temporary Electrical Installation as being an 'Electrical installation erected for a particular purpose and dismantled when no longer required for that purpose'. So, in general, references in BS 7671 to an 'installation' are considered to apply to both a fixed electrical installation and a temporary electrical system.

1.5 Temporary versus permanent

One critical distinction between a temporary system that is suited for the application of BS 7909 compared to one for which BS 7671 is more appropriate, is the nature of the equipment and its supply. BS 7909 requires that all equipment is supplied in a 'kit' fashion comprising cables with connectors fitted and purpose-built distribution equipment, all of which has been proved to be safe and serviceable prior to delivery to site. This allows for a reduced verification routine designed to ensure that the requirements of the design are met.

If a temporary system is erected using cables 'off-the-drum' that need terminating, distribution equipment that needs mounting and cables terminated inside, or luminaires and other wiring accessories need installing and connections made, such a system is outside the scope of BS 7909 and should be designed, installed and verified in accordance with BS 7671, regardless of its intended duration. Similarly pre-assembled equipment that is dismantled to allow installation in a temporary

system should also be re-tested in accordance with BS 7671, because BS 7909 makes no provision for this. An example might be connectors removed from cables to allow the cables to be routed through small holes or ducts.

For the most part, typical events last for days or a few weeks and the TED would be erected specifically to service the requirements of that event. Some events such as a West End theatre show or television programme may have a defined period of existence at the outset that gets progressively extended owing to its success. Others may have a planned duration such as an outdoor ice-rink, a Christmas-lighting display or a temporary building. Technically, there is no limit on how long a temporary system may stay in existence, but the design must take into account the environmental and other factors to which it is likely to be subjected for the planned design period.

The designer must also take into account the possibility of the system remaining in use for longer than expected and where foreseeable design a system accordingly; more particularly the designer should ensure that a time limit is given before which the TES must be re-inspected and re-tested to ensure its safe continued use. Guidance on time periods for the inspection and testing are detailed in Section 7.

Index

A

ABTT theatre electrical sheet 251–5
AEV/ESSA Guidance 217–18
agricultural and horticultural premises 186
assessment 28–9, 54–8
  and design 28–9
  of fault currents 69–71
automatic disconnection of supply 74–6

B

baths, basins, fountains and marinas 184–5
bibliography 223–4
bonding structures 38–9
BS 7430 Code of Practice for earthing 19
BS 7671 Requirements for Electrical Installations 16–17
BS 7909 Certification documentation 257–60
BS 7909 Code of Practice for temporary electrical systems for entertainment and related purposes 17–19
BS EN 60309 ('Ceeform') connectors 129–32

C

cable/connector combinations 140–2
cables 134–42, 201–2
  construction 136
  on or in ground 201–2
  ratings 92–4
  selection 136, 139–40, 141
  selection and standards 98
  size determination 107–13
certificates, BS 7909 257–60
circuit breaker characteristics 60–3
circuit protection 208
Circuit Protective Conductor (CPC) 35
  Testing 174
CNE: *see* Combined Neutral and Earth
combined inspection and test 152–4
Combined Neutral and Earth, xv 32

communications 204
competencies and requirements 160–1
completion certificate 177–8
conductor identification 125
Confirmation of Electrical Completion 178–9
connection of multiple generators or other sources 192–7
connections for TED supply 207–8
connectors 122–5
  used for isolation and switching 125
construction 143–4
Construction (Design and Management) Regulations 2007 12
correction factors 102–5
correction of earth loop impedances for other temperatures 76
CPC: *see* Circuit Protective Conductor
current-carrying capacity and voltage drop tables 98–100, 233–45

D

design principles and requirements 53
determination of extraneous-conductive-parts 37–8
disabling (bypassing) RCDs 199–201
disconnection times 64, 74–5, 112–13
discrimination between circuit breakers 71–3
discrimination between circuit breakers and fuses 73
discrimination between RCDs 73
diversity 206
division of the TED 56–7
documentation 177–9
duration: *see* temporary system duration

E

earth continuity test 152–3
earth electrodes 168–70, 188–92
earth fault loop impedance 75–6, 175–6
earth loop 28
earth plates 190
earth spikes 190–1
earthing 213
earthing arrangements and external connections 209–11
earthing conductor 35
earthing of multiple generators or sources 195–7
earthing principles 31
eGuide. Common regulative policy for major UK exhibition venues. 2011 21

electric shock 203
electrical calculations, summary 225–30
electrical distribution equipment 199
electrical environments 49–51
Electrical Equipment (Safety) Regulations 1994 12
electrical separation
  protective measure 81
electrical systems for temporary structures 215
electrical tests 165–76
  see also testing; tests
Electricity at Work Regulations 1989 12
Electricity Safety, Quality and Continuity Regulations 2002 (ESQCR) 14
electromagnetic compatibility, xv 13, 53
Electromagnetic Compatibility Regulations 2006 13
electromagnetic interference, xv,13, 28, 50, 210
EMC: *see* electromagnetic compatibility
emergency and operational supplies 55
emergency lighting 119–20
  requirements 120
emergency procedures 203
EMI: *see* electromagnetic interference
equipment
  inspection 150–1
  not exceeding 10mA leakage 114
  selection 29–30, 121–2
  supply and operation 27
  supply and testing 121
  testing 121
equipotential
  bonding conductor 33
  bonding, design of 27
  conductor testing 168
  supplementary 39–40
  zone 43–9
equipotential zones 43–9
Event Manager 23, 24, 26, 28
The event safety guide – A guide to health, safety and welfare at music and similar events 1999 20
exhibitions, shows and stands 215–18
  testing 185
exposed-conductive-part 35
external influences 57
external supplies 217–18
extra low voltage (ELV) 76
extraneous-conductive-part 35–9
  examples 35–6

F

FELV: *see* functional extra low voltage
formal visual inspection 151–2
frequency of testing 149–50
functional extra low voltage (FELV) 79
functional testing 154
functionality 144
fuse characteristics 63

G

Gaffer 24
general requirements 211
generator housekeeping 197–8
generators and other sources of supply 187
grouping for multicore cables 107, 231
harmonics 91–5

H

Health and Safety at Work etc. Act 1974 (HASWA) 10–14
high protective conductor currents 113–14
high-current connectors 125–9

I

identification and isolation of circuits 203
indicators and controls 146
industry guidance 19–21
inspection and testing
  of equipment prior to use 146–55
  exhibitions shows and stands 217
  of temporary electrical distributions 159
inspections, visual 162–5
insulation resistance test 153–4

J, K

No entries

L

labelling 154–5
  and marking 208–9
large events 27–9
lifting Operations and Lifting Equipment Regulations 1998 (LOLER) 14
lighting 217
  protection 51
live working 202–3

M

main equipotential bonding and Earth conductors 168
management of events 23–30
Management of Health and Safety at Work Regulations 1999 11
management of large systems 28
management of the small system 27
maximum demand and nature of loads 56
methods of protection 40–3
mobile and transportable units
  main 221
  supplies to 82
  supply of 155–7
  testing 186
multicore cable, overload calculation example 111–12
multi-pole lighting distribution connectors 132–4

N

neutral
  earth faults 69
  generator connection 196–7
  harmonics 95
  loss of 89
neutral conductor overcurrent protection 95
neutral to earth faults 69

O

operational considerations 199
overcurrent protection 95
  requirements 100–2
overhead or flown cables 201
overload 58–9
  multicore example 111–12

P

parallel conductors 118–19
  arrangements 118–19
PELV: *see* protective extra low voltage
PEN: *see* Protective Earth and Neutral
periodic testing 182
Person Responsible 25
phase or neutral loss 89
physiological effects of current 43
power and lighting circuits, exhibitions, shows and stands 218
power distribution equipment 142–6
power factor 89–91
power quality, exhibitions, shows and stands 218
power quality and conductors, venues 206–7

PR: *see* Person Responsible
preferred connector types 123–5
protection against damage and interference 201–2
protection against electric shock 74–83, 212
  exhibitions, shows and stands 215
protection against overcurrent 58–60
protection against thermal effects 58
protection against voltage disturbances and measures against electromagnetic disturbances 83–4
protection for safety 222
protection of parallel conductors 118
protective conductor (PE) 34–5
protective conductor currents above 10 mA 114
protective device discrimination 71
protective devices 60–73
Protective Earth and Neutral, xvi 46, 47, 50, 53, 196, 209, 210
protective earthing 32–40
protective extra low voltage (PELV) 77–8
protective measures, exhibitions, shows and stands 215–16
Provision and Use of Work Equipment Regulations 1998 (PUWER) 11
provision of supplies, venues 205–9

Q

No entries

R

rating factors for cables having more than four loaded cores 231
RCD: *see* residual current devices
rectangular 16 pin connectors 134
reduced ambient temperatures 105–7
reduced current operation 105
reduced low voltage (RLV) 79–80
renewable energy sources 114–15
residual current devices 63–9
  disabling 199–201
  discrimination 68–9
  testing 155
  use 63, 65
responsibilities 23–5
  for small events 26–7
round 19 pin connectors 133–4

S

safe working practices 202–4
Schedule of Test Results 178
selection and erection, exhibitions, shows and stands 216
selection of equipment for use in a TED 121–2
SELV: *see* separated extra low voltage
Senior Person Responsible 24
separated extra low voltage (SELV) 76–7
shock protection: *see* protection against electric shock
short circuit and fault current 59–60
small and simple events 25–7
small generating sets 187–8
small system tests 176–7
small systems, description 26, 27
socket-outlets 212
special locations 183–6
SPR: *see* Senior Person Responsible
stage and studio sets 218–19
standards 14–19
  harmonized 15
  international 15–16
street furniture supplies 198
  deriving earths from 197–8
structural requirements 58
summary of relationship between BS 7671 and BS 7909 21
summary of useful electrical calculations 225–30
supplementary equipotential bonding 39–40
  conductors 170–3
  principle 40
  testing 170–3
supplies, in venues 221
supply arrangements 31–2, 54–5
supply cable example 109–10
supply configurations 33
Supply of Machinery (Safety) Regulations 2008 12–13
surge protection devices 144–5
switchgear 211
synchronised generators for large capacity using load-sharing 194
synchronised generators with redundancy 194–5

T

technical earths 210–11
Technical Standards for Places of Entertainment 2009 20, 211–13
Temporary demountable structures; Guidance on procurement design and use. 2007 20–1
Temporary Electrical Distribution, definition 7
Temporary Electrical System, definition 7
temporary system duration 8
testing
  earth electrodes 192
  equipment after repair 154
  procedures 179–80
  RCDs 179–80
tests
  following changes or relocation 183
  involving dimmers 180–1
  involving UPS 181–182
  prior to energising supply 167–74
  prior to putting system in service 174–5
three-phase systems 84–91
  generation 84–9
touch voltages 45–9
transformer secondary impedances 80

U

unattended systems 204
unbalanced loads 94–5
uninterruptible power supplies (UPS) 115–18
UPS circuit protection 117
UPS topologies 115–16
user checks
  equipment 150–1
  system 162

V

venue information 205
verification process 150
visual inspection 162–5
voltage drop 95–8
voltage drop caused by harmonics 97–8

W

weather conditions 204
wiring 211–12
Workplace (health, safety and welfare) Regulations 11

X, Y, Z

No entries

Temporary Power Systems
A guide to the application of BS 7671 and BS 7909 for temporary events

This book is a complete guide to designing, erecting and using temporary power systems for events and similar purposes. It details the requirements and application of both the relevant parts of *BS 7671:2008(2011) IET Wiring Regulations 17th Edition Incorporating Amendment No 1 and BS 7909:2011 Code of practice for temporary electrical systems for entertainment and related purposes*. Thorough guidance is given on the planning, design, verification and management of such systems including references to legislation as appropriate. The book also considers the duties of those supplying equipment and those at venues making power supplies available for temporary use. Whilst the focus and examples in the book are geared towards the entertainment and event industries, it will be invaluable to any who design, deploy or manage temporary electrical systems.

James Eade BEng(Hons) CEng MIET AMIMechE is a Chartered Engineer who has worked in the entertainment industry for over 20 years, covering most genres including touring, theatre, corporate events and permanent installations. As well as providing engineering consultancy services, he was until recently Technical Editor of *Lighting & Sound International* where he introduced and developed the technical content of the publication and was also Chair of the annual Industry Innovation Awards. He is involved with various trade associations and represents the industry on many national and international standards panels, particularly BS 7671 and BS 7909. In addition to writing and lecturing, he is still active in designing and commissioning electrical systems and acting in a consultancy role for several rental companies and broadcasters.

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