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RECENT DEVELOPMENTS IN LUMINAIRE SAFETY

Historical perspective

It is an instructive observation that the time span of the use of electricity for public illumination has only just overtaken that of gas. A historical analysis may help put the modern requirements in a proper perspective.

Coal gas was described as a means of illumination when burnt as long ago as 1684, but it was only the work of a Mr. Murdoch during 1792 - 1798 and the entrepreneurial activities of Frederick Windsor in 1803 - 1807 which developed the public use of gas as a means of illumination. This culminated in the first granting of a Charter for a Gas Light and Coke Company in 1812.

The resultant development of the use of gas as a means of illumination was rapid, but could hardly be said to have contributed to any increase in public safety. The use of a fuel which was toxic, flammable and, in appropriate concentrations, explosive, was quite bad enough; but when frequently connected by friable, flexible (rubber or leather) connections and burnt as open flames to give the required light the recipe was set for considerable destruction and carnage. Some idea of the risks run and seemingly tolerated can be gauged by the problems that faced the various places of entertainment such as Theatres.[1]

Fire was the great hazard with open flame gas lighting used in abundance amongst inflammable scenery cloths. Many theatres were burnt down - some more than once! In 1865 at the Theatre Royal, Edinburgh, the "gas man" accidentally fired the theatre by careless use of his spirit torch gaslighter on the end of its long pole. The theatre was rebuilt, only to be burned again following an explosion in a limelight during the pantomime of 1874- 75. Nor was property the only victim; as can be imagined much human suffering occurred. The use of flowing stage costumes in conjunction with low sited, side stage burners and footlights ensured many tragedies. Typical was that of the unfortunate Ballerina, Clara Webster, who sustained fatal burns in full view of the audience at Covent Garden in 1844[2] Whilst such accidents attracted particular publicity, many more were hurt in the panic during fires with over 122 of the audience dying in the crush caused by a fire at the Exeter Theatre in 1887.

There was some attempt at regulating the safe use of gas light at such premises. However, it came rather late in the day and was initially framed as rather ineffectual regulations by the Lord Chamberlain in 1864. These merely required the fitting of guards (if possible!) on the gas burners and the keeping to hand of wet blankets and water buckets. It was left to the London Fire Brigade, enabled by an 1878 Act, to issue stricter regulations in 1879[3] accompanied by the need for inspection and approval. These directions taken by London, which were frequently the prototypes of other municipalities, were vigorously developed and pursued by their head, Captain Shaw, who ultimately achieved immortality as the "Captain Shaw" serenaded by the Fairy Queen and Chorus in Iolanthe.[4] Though valuable, the Captain's strictures were to be rapidly overtaken by far more radical developments. Almost simultaneously in 1879, both Joseph Wilson Swan in the UK and Thomas Alva Edison in the USA succeeded in devising a simple and effective means of converting electricity to light: the carbon filament electric lamp.

Development of electric light

It could be fairly said that this development has been the greatest ever single improvement in luminaire safety, and by 1881 was being brought into public use. There had been some earlier attempts since 1876 at public lighting using "Jablochkoff Candles" a variety of carbon-arc, but the constant need for maintenance and the open noisy flame caused them to be soon replaced by the incandescent lamps. That the latter represented such a dramatic safety improvement is evidenced by a typical public demonstration. This involved wrapping a flammable gauze round a lighted lamp and smashing it with a hammer, whereupon the incredulous audience witnessed that the "flame" (filament) extinguished immediately without even singeing the fabric. Whilst

perhaps we know better now, when Captain Shaw inspected the first UK Theatre to use electric light - the Savoy in 1881 - his inspection report on the electric lighting in 1882 observed that: "the lighting is principally by electricity, which does not perceptibly raise the temperature and with good arrangements, as in this house, appears to be absolutely safe."

Naturally the transition from gas to universal electric lighting was gradual since it depended on the development of an infrastructure to generate and supply electricity, with the first public street lighting being installed in Godalming, also in 1881. During this period the hazards present with electricity became better appreciated and recognised, and as early as 1902 the first electrical Inspector of Factories was appointed. His concern was clearly the responsible generation and use of electrical power, with electric light having hazards such as the risk of electric shock, fire from the self-heating of the lamp or poor contacts and impact from the risk of mechanical failure. The development of the mercury discharge lamp and subsequent other discharge lamps, brought the real hazard of UV radiation and in 1956 the tungsten halogen lamp's debut brought with it the danger of explosion from the high internal operating pressures.

Whilst the prototypical "Electricity Regulations, 1908" recognised the need to regulate the safety of electricity supply, on the whole, the attitude of public administration through most of the 20th Century seems to have had some similarity to the 19th Century's use of gas; prepared to regulate the safe use of electricity only in areas of particular public danger. There was, however, a steady development of voluntary standards and practices, with the IEE's Wiring Regulations providing evidence of a generally successful self-regulation of electrical installations. Regarding luminaire safety, standards were drawn up for the safety of lamps and lamp holders (e.g. BS5971 and BS5042) and through 1969 - 1971 BS4533 was introduced (replacing the earlier BS3820, 1964) covering the safety in construction and use of luminaires. It is interesting to note that this standard provided the model for IEC in the development of IEC598, now an accepted worldwide safety standard for luminaires. However, apart from regulations on a few particular items, UK electrical apparatus in general and luminaires in particular, had no legal need to comply with any particular safety standards.

The low voltage directive

However, the situation began to change as a result of joining the EEC in 1972. In 1973 the EEC issued the "Low Voltage Directive, 7 3/23/EEC"[5] requiring all low voltage (under 1000V) electrical equipment sold in the EEC to be safe as measured by common safety standards. This had as its prime purpose the elimination of barriers to trade, by ensuring all states recognised common standards of safety and accepted products for free sale if certified to these standards by a third party or the manufacturer. It also had an intention to ensure that all electrical equipment sold was safe, and it was this, in fact, which required the UK Government to enact general legislation for the first time to require all electrical equipment sold to be safe. This was achieved by the issuing of the Electrical Equipment (Safety) Regulations 1975 and Electrical Equipment (Safety) (Amendment) Regulations 1976 under the Consumer Protection Act 1961. It was followed in 1977 by a DTI publication, "Administrative guidance" on the above regulations and in this was contained an explicit reference to BS4533 as being considered a sufficient safety standard for luminaires. Thus, 94 years after the first public use of electric lighting, there was a legal duty to provide luminaires to a particular safety standard.

This, though, was only the harbinger of changes to come, since there was no common agreed EC safety standard for luminaires and the UK's interpretation of the LV. Directive was imperfect. Developments in both these areas were to run parallel for some years, then merge again with particular effect! The early European Standards making body, CEE, had already metamorphosed into two: CEN concerned with mechanical and other engineering standards, and CENELEC concerned with electrical standards. Their task is to put into place accepted European standards, preferably by a process of adaptation and modification where necessary, of existing IEC or Member state standards. These are then issued as complete Euro-Norms (ENs) or Harmonisation Documents (HDs) where other standards are referred to. Thus, when CENELEC came to consider luminaire safety, IEC568 was a readily available standard for initial reference. However, being first issued in 1979, this standard was not felt to fully meet the Community needs. Thus, considerable review of the standard was undertaken until IEC598 Second Edition was adopted with an agreed set of Common Modifications as EN60598 in 1989.

The UK Government had been quite prompt in implementing the LV. Directive, compared to other Member states, but the interpretation into legislation was inexact. It failed to acknowledge the primacy of harmonised European Standards and contained too many exceptions to suit particular UK practise, allowing UK standards still to be used as a barrier to trade. Consequently, after representations by the European Commission, acceptable replacement regulations - "The Low Voltage Electrical Equipment (Safety) Regulations 1989" - were issued under the new Consumer Protection Act 1987, and came into force on 1st June 1989.

This completed the confluence mentioned earlier, since these regulations require compliance

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with harmonised European Standards as the overriding means of achieving safety. Thus when in October 1989 the new European Standard on luminaires was published it became effective and legally required immediately!

Euro-norm EN60598

Since EN60598 is now the required standard, it may be of some interest to look at its general structure and content. The following is not intended to replace the need for direct study and is certainly not proposed as any form of design guide. As is required by E C regulations, EN60598 has been published as a new BS4533, 1990 by BSI where reference may be made. The structure of the standard is a set of general requirements and tests contained in Part 1, followed by a schedule of particular requirements for individual classes of luminaires in each sub-section of Part 2.

Examination of Part 1 shows that safety has to be maintained by attention to mechanical, electrical and thermal properties and use, which in turn depends on the particular electrical classification of the luminaire, whether Class 1 (earthed) or Class II (double insulated). These may be summarised as below:

Electrical (if above Safety Extra Low Voltage = 50Vac)

- Adequate insulation of live parts by double insulation, reinforced insulation and proper earthing of exposed metalwork.
- Adequate insulation resistance, creepage and clearances taking account of any HV ignitors.
- Adequate fastening of wires and contact systems etc.
- Adequate provision for and protection of external wiring.
- Protection against electric shock during use (inc. re-lamping).

Thermal

- Adequate endurance with the intended lamp in operation.
- No risk of fire of objects near to the luminaire or on which the luminaire is mounted.
- Safe operating temperatures of parts intended to be manually operated.
- Safe operation during reasonable abnormal conditions.
- Insulating parts to be resistant to heat and ignition.

Mechanical

- Adequate protection against dust and water as required for declared use.
- Adequate retention of electrical components.
- Construction and mechanical components designed to maintain safety in the structure and assembly.
- Suspension system to have an adequate factor of safety.
- Limitation on weight suspended on electrical cables.
- Suspension or adjusting devices to not damage connecting cords.
- Safety shields to protect against tungsten halogen lamp explosion and broken glass risk.

Use

- Marking on luminaire to show ratings and any information vital for safe use.
- Instructions to enable and maintain safe use to accompany luminaire.

Part 2 gives particular requirements for various styles of luminaire and already contains a comprehensive list of sections covering all common and many uncommon luminaires. These are:

1 Fixed general purpose luminaires
2 Recessed luminaires
3 Luminaires for road and street lighting
4 Portable general purpose luminaires
5 Floodlights
6 Luminaires with built-in transformers for tungsten filament lamps
7 Portable luminaires for use in gardens and the like
8 Hand lamps
9 Photo and film luminaires (non-professional).
10 Portable, child appealing luminaires
17 Luminaires for stage lighting, television and film studios (outdoor and indoor)
18 Luminaires for swimming pools and the like
19 Air-handling luminaires (safety requirements)
20 Lighting chains
22 Luminaires for emergency lighting

In addition there is the recently released EN60570, 1989, published as BS4533: Section 102.57:1990 titled "Electrical supply track systems for luminaires".

Whilst a complete review of all the requirements of the above list is beyond this paper, study of a few key sections is of some interest.

"Section One - Fixed General Purpose Luminaires" requires no extra standards to be met over Part 1. This is not the case for several others, and Section Five - "Floodlights" has extra requirements on marking and construction to ensure safe installation and use, such as requiring two independent fastenings for floodlights intended for mounting over 3m high.

Section Seventeen - "Luminaires for stage lighting, television and film studios (outdoor and

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indoor)" has many particular extra requirements. The general use of high power lamps leads to a particular need to protect against broken lamp fragments escaping, lamp burn, lamp explosion even after turning off, UV hazards and particular thermal hazards. The generally temporary use and high weight of these luminaires requires higher safety factors in the suspension and a proven secondary suspension with no risk of accessories falling. Electrical isolation before relamping is required except for luminaires intended for professional use.

Compliance example

An illustration of how a luminaire's requirements can be met is given by a study of a small commercial display luminaire. This contains a 150W discharge lamp and is intended to highlight areas in large architectural schemes. The mains inlet is via an approved CEE22 re-wireable plug, thus ensuring easy re-wiring to approved terminals and reducing the maximum cable temperature. The plug allows easy disconnection for relamping, and only after the plug is removed can the top cover be removed with the use of a tool (screwdriver). Internal wiring is restrained and has basic insulation, the external metalwork being earthed as per Class I, by either direct connection to earth or via thread forming screws and paint cutting lockwashers. The high voltage leads from the ignitor are appropriately insulated and the UV hazard from the lamp negated by elimination of direct light paths and the use of a glass lens which attenuates UV adequately and guards against lamp explosion. The suspension system exceeds the four times safety factor and there is provision for an independent secondary suspension if mounted above 3m.

Further legislation and duties

If the earlier part of the century could be accused of regulatory laxity, that charge can certainly not be levelled now, as three further pieces of legislation increase the onus on the manufacturer and supplier to provide safe products. In 1985, the EEC issued an other Directive 85/374/EEC[6] generally known as the Product Liability Directive, which was intended to make the EC laws in this area uniform. This was implemented in the UK by the Consumer Protection Act 1987, Chapter 43, in two parts. In Part I a statutory duty with strict liability is imposed on all manufacturers, importers, or own branding factors, to provide safe product. Thus, a plaintiff suffering loss or damage only has to demonstrate a defect existed and caused damage, not negligence. It is up to the producer to establish a defence and the range available is limited. Whilst Part I is only for civil actions, Part II establishes that new products "ordinarily intended for private use and consumption" shall be safe, with contravention a criminal offence, though again some defences are allowed.

By the same Act, the Health and Safety at Work Act 1974, Section 6, was amended in 1987, becoming effective in 1988, and placed a new responsibility on all those who manufacture and supply articles for use at work. They have to ensure the articles are safe as far as is reasonably practicable, through design, construction and instruction for use, and take into account any reasonably foreseeable use. This is quite important since, whilst reckless misuse is clearly not intended to be covered, reasonable operator mistakes or genuine likely errors need to be considered. Luminaires are inevitably included and for those intended for use (i.e. handled or operated in some way) at a place of work, the responsibility for safety has thus been extended to include reasonable and foreseeable "misuse".

Yet another responsibility for the safe use of electricity was occasioned by The Electricity at Work Regulations 1989 made under the Health and Safety at Work Act 1974 and which came into force on 1st April 1990. These replaced the original 1908 Regulations and a plethora of subsequent special orders, with a new set of clear and deceptively simple duties requiring the safe installation and use of electrical equipment. Thus, by merely requiring that "systems (including all electrical equipment from the point of supply to the equipment of use) shall be both constructed and maintained to prevent, so far as is reasonably practicable, danger", a further duty is automatically generated for employers to maintain electrical appliances, such as luminaires, safely.

This obligation is better explained in the Memorandum of Guidance on the Electricity at Work Regulations 1989 published by the Health and Safety Executive. Here is described the obligation to perform inspection and maintenance "of such quantity and frequency that should be sufficient to prevent danger as far as is reasonably practicable". Clearly it is rarely going to be practicable to repeat the full gamut of tests described in EN60598, however, it is possible and reasonable to test and inspect against the prime cause of danger, electrocution, and inspect for any other practical incipient problem. This engendered the recent surge of interest in portable appliance testers which enable a test of insulation resistance (2M ohm at 500Vdc), insulation strength (1,500Vac) and earth resistance to exposed metalwork (0.1 ohm at 25A). These form the essence of the EN60598 tests, and in conjunction with inspection against other dangers such as damaged wires, inadequate or damaged shields, guards, or suspensions, may form the basis of an adequate programme to fulfil the new duty. Such a programme of course needs to be reviewed by a competent person to ensure its adequacy.

Older luminaires in use made (possibly) to earlier safety standards could now need to be modified to sufficiently protect against danger.

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Certainly all exposed metalwork that may become live in case of an electrical failure must be reliably bonded to earth. All wiring should be inspected and if sufficiently deteriorated replaced with new of appropriate rating (including temperature). Mechanical alterations may be required to ensure assemblies, accessories and suspensions are adequately secured and shields added to protect against the hazard of tungsten halogen lamp explosion if this could constitute a danger in actual use.

Thus a complete framework now appears in place. Explicit European-wide safety standards for luminaires are established, recognised and compliance with them required for legal trading. Clear duties to supply safe luminaires are established for general commerce and especially for the consumer and place of work, and at the latter, the employer has a duty to maintain that equipment's safety.

The EMC directive

Whilst perhaps it might be thought enough legislation is already being brought to bear on luminaire products more is on the way, though not directly regarding safety. The EEC's recent Directive 89/336/EEC, the "EMC Directive"[7] requires member states to enact legislation requiring all electrical and electronic equipment to meet particular electromagnetic compatibility standards. Equipment must not exceed certain levels of emissions, and be immune to certain levels of disturbance. A full review is outside the scope of this paper, and the detail standards and legislation have yet to be settled, but are intended to apply during 1992 to 1993. The humble GLS lamp is certain to be deemed to comply, but the increasing use of discharge and low voltage lamps with magnetic and electronic ballast gear is clearly within the scope of these regulations. The likely emission standard for all luminaires is EN55015, the current standard for fluorescent luminaires. However, this contains no immunity criteria and thus the draft generic immunity standard prEN50082-1 may well apply. This is particularly onerous and it is hoped some more modest requirement may be implemented before compliance is enforced.

Conclusions

The HSE reports[8] that every year around 50 people are killed at work by electricity. It is hoped that very few, if any, of these are killed by failure of electrical luminaires. Certainly, the great safety improvement of electricity over gas lighting has in no small part ensured that the scale of tragedy in the Exeter Theatre reported earlier has never been surpassed. However, modern electrical safety standards have frequently been the result of hard lessons. Who now would wish to emulate the early experiments of natural philosophers, striving to understand and make the connection between lightning and static electricity, such as Benjamin Franklin's Philadelphia Kite Experiment of 1751[9] here repeated.

Philadelphia, October 1

As frequent mention is made in the News Papers from Europe, of the success of the Philadelphia Experiment for drawing the Electric Fire from clouds by means of pointed Rods of Iron erected on high Buildings, etc., it may be agreeable to thee same Experiment has succeeded in Philadelphia, tho' made in a different and more easy Manner, which any may try, as follows Make a small Cross of two light Strips of Cedar the Arms so long as to reach to the four Corners of a large thin Silk Handkerchief when extended; tie the Corners of the Handkerchief to the Extremities of the Cross so you have the Body of a Kite; which, being properly accommodated with a Tail, Loop and String, will rise in the Air like those made of Paper, but this being of Silk is fitter to bear the Wet and Wind of a Thunder Gust without tearing. To the Top of the upright Stick of the Cross is to be fixed a very sharp pointed Wire, rising a Foot or more above the Wood. To the End of the Twine, next the Hand, is to be tied a silk Ribbon, and where the Twine and the silk join a Key may be fastened. This Kite is to be raised when a Thunder Gust appears to be coming on, and the Person who holds the String must stand within a Door, or Window, or under some Cover, so that the Silk Ribbon may not be wet; and Care must be taken that the Twine does not touch the Frame of the Door or Window. As soon as any of the Thunder Clouds come over the Kite, the pointed Wire will draw the Electric Fire from them, and the Kite, with all the Twine, will be electrified, and the loose Filaments of the Twine will stand out every Way, and be attracted by an approaching Finger. And when the Rain has wet the Kite and Twine, so that it can conduct the Electric Fire freely, you will find it stream out plentifully from the Key on the Approach of your Knuckle. At this Key the Phial may be charged; and from Electric Fire thus obtained, Spirits may be kindled, and all the other Electric Experiments be performed, which are usually done by the Help of a rubbed Glass Globe or Tube; and thereby the sameness of the Electric Matter with that of Lightning completely demonstrated.

Standards of electrical safety have certainly improved much over the years. This is necessarily so to maintain the present perceived standards of safety in the face of the relentless expansion of the use of electricity and electrical lighting. Many beneficial changes have recently taken place in the applicable standards and duty of care and, married to a responsible implementation of these, the industry now stands in good stead for the 21st Century.

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