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COMMISSION INTERNATIONALE DE L'ECLAIRAGE
INTERNATIONAL COMMISSION ON ILLUMINATION
INTERNATIONALE BELEUCHTUNGSKOMMISSION

TECHNICAL REPORT

PRACTICAL DESIGN GUIDELINES FOR THE LIGHTING OF SPORT EVENTS FOR COLOUR TELEVISION AND FILMING

CIE 169:2005

UDC: 621.397.132
628.971.7

Descriptor: Colour television
Lighting of sports grounds

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2. To develop basic standards and procedures of metrology in the fields of light and lighting.
3. To provide guidance in the application of principles and procedures in the development of international and national standards in the fields of light and lighting.
4. To prepare and publish standards, reports and other publications concerned with all matters relating to the science, technology and art in the fields of light and lighting.
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1. De constituer un centre d'étude international pour toute matière relevant de la science, de la technologie et de l'art de la lumière et de l'éclairage et pour l'échange entre pays d'informations dans ces domaines.
2. D'élaborer des normes et des méthodes de base pour la métrologie dans les domaines de la lumière et de l'éclairage.
3. De donner des directives pour l'application des principes et des méthodes d'élaboration de normes internationales et nationales dans les domaines de la lumière et de l'éclairage.
4. De préparer et publier des normes, rapports et autres textes, concernant toutes matières relatives à la science, la technologie et l'art dans les domaines de la lumière et de l'éclairage.
5. De maintenir une liaison et une collaboration technique avec les autres organisations internationales concernées par des sujets relatifs à la science, la technologie, la normalisation et l'art dans les domaines de la lumière et de l'éclairage.

Les travaux de la CIE sont effectués par 7 Divisions, ayant chacune environ 20 Comités Techniques. Les sujets d'études s'étendent des questions fondamentales, à tous les types d'applications de l'éclairage. Les normes et les rapports techniques élaborés par ces Divisions Internationales de la CIE sont reconnus dans le monde entier.

Tous les quatre ans, une Session plénière passe en revue le travail des Divisions et des Comités Techniques, en fait rapport et établit les projets de travaux pour l'avenir. La CIE est reconnue comme la plus haute autorité en ce qui concerne tous les aspects de la lumière et de l'éclairage. Elle occupe comme telle une position importante parmi les organisations internationales.

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8. Richtlinien für die Anwendung von Prinzipien und Vorgängen in der Entwicklung internationaler und nationaler Normen auf dem Gebiet der Lichttechnik zu erstellen.
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10. Liaison und technische Zusammenarbeit mit anderen internationalen Organisationen zu unterhalten, die mit Fragen der Wissenschaft, Technik, Normung und Kunst auf dem Gebiet der Lichttechnik zu tun haben.

Die Arbeit der CIE wird in 7 Divisionen, jede mit etwa 20 Technischen Komitees, geleistet. Diese Arbeit betrifft Gebiete mit grundlegendem Inhalt bis zu allen Arten der Lichtenwendung. Die Normen und Technischen Berichte, die von diesen international zusammengesetzten Divisionen ausgearbeitet werden, sind von der ganzen Welt anerkannt.

Tagungen werden alle vier Jahre abgehalten, in der die Arbeiten der Divisionen überprüft und berichtet und neue Pläne für die Zukunft ausgearbeitet werden. Die CIE wird als höchste Autorität für alle Aspekte des Lichtes und der Beleuchtung angesehen. Auf diese Weise unterhält sie eine bedeutende Stellung unter den internationalen Organisationen.

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This Technical Report has been prepared by CIE Technical Committee 5-11 of Division 5 "Exterior and other lighting applications" and has been approved by the Board of Administration of the Commission Internationale de l'Eclairage for study and application. The document reports on current knowledge and experience within the specific field of light and lighting described, and is intended to be used by the CIE membership and other interested parties. It should be noted, however, that the status of this document is advisory and not mandatory. The latest CIE proceedings or CIE NEWS should be consulted regarding possible subsequent amendments.

Ce rapport technique a été élaboré par le Comité Technique CIE 5-11 de la Division 5 "Eclairage extérieur et autres applications" et a été approuvé par le Bureau de la Commission Internationale de l'Eclairage, pour étude et emploi. Le document expose les connaissances et l'expérience actuelles dans le domaine particulier de la lumière et de l'éclairage décrit ici. Il est destiné à être utilisé par les membres de la CIE et par tous les intéressés. Il faut cependant noter que ce document est indicatif et non obligatoire. Il faut consulter les plus récents comptes rendus de la CIE, ou le CIE NEWS, en ce qui concerne des amendements nouveaux éventuels.

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PRACTICAL DESIGN GUIDELINES FOR THE LIGHTING OF SPORTS EVENTS FOR COLOUR TELEVISION AND FILMING

SUMMARY

This technical report gives practical guidance to those concerned with the designing and planning of sports facilities where lighting is required to meet the needs of colour television and filming.

The report should be read in conjunction with CIE 83-1989, which defines the quantitative lighting requirements. This report is arranged in three main sections:

Firstly, there is general guidance on sports lighting design including luminaires and lamp types, calculation methods, and electrical installation.

The second section lists 51 sports with specific advice on the lighting of each.

The third section gives references to relevant standards and in particular publications in which new sports lighting installations may be described.

RECOMMANDATIONS PRATIQUES POUR LES PROJETS D'ECLAIRAGE DES MANIFESTATIONS SPORTIVES POUR LA TELEVISION COULEUR ET LES FILMS

RESUME

Ce rapport technique donne des conseils pratiques aux acteurs concernés par les projets et la mise en oeuvre des installations sportives où l'éclairage est censé respecter les besoins de la télévision couleur et des prises de vue pour les films.

Ce rapport doit être consulté en parallèle avec la publication CIE 83-1989 qui définit quantitativement les exigences d'éclairage. Ce rapport est composé de trois parties principales:

Premièrement, il s'agit d'un guide général sur les projets d'éclairage des installations sportives traitant des types de luminaires et de lampes, des méthodes de calcul et de l'installation électrique.

La deuxième partie comporte une liste de 51 sports avec les conseils d'éclairage spécifiques pour chacun d'eux.

La troisième partie donne les références des normes appropriées et en particulier des publications dans lesquelles de nouvelles installations d'éclairage sportif peuvent être décrites.

RICHTLINIEN ZUR ENTWURFSPRAXIS VON FARBFERNSEH- UND FILMGERECHTER BELEUCHTUNG VON SPORTVERANSTALTUNGEN

ZUSAMMENFASSUNG

Dieser Technische Bericht bietet praktische Hinweise für den Entwurf und die Ausführung von Sportanlagen, deren Beleuchtung den Anforderungen für Farbfernseh- und Filmaufnahmen gerecht werden soll.

Der Bericht ist zusammen mit der Publikation CIE 83-1989 zu lesen, in der die lichttechnischen Anforderungen quantitativ beschrieben sind. Der Bericht ist in drei Hauptabschnitte gegliedert:

Im ersten finden sich generelle Hinweise zur Planung von Sportstättenbeleuchtungen, zur Auswahl von Lampen und Leuchten, sowie zu Berechnungsmethoden und zur elektrischen Installation.

Im zweiten Abschnitt sind 51 Sportarten mit jeweils spezifischen Empfehlungen zur Beleuchtung aufgelistet.

Im dritten Abschnitt werden Verweise auf einschlägige Normen gegeben und im besonderen wird auf Veröffentlichungen hingewiesen, in denen Beschreibungen neuer Sportstätten-Beleuchtungsanlagen gefunden werden können.

PART A: INTRODUCTION AND GENERAL ASPECTS

1. INTRODUCTION

This guide gives practical advice to architects, consultants, and lighting designers on the realisation of good quality installations for sports lighting for colour television and filming. The basic recommendations are laid down in CIE 83-1989. However, broadcasting unions have often extended the standards and, moreover, the television directors have developed over time specific methods of covering games in relation to the particular type of sport. The ongoing development in camera quality has exploited both with respect to use and portability of (auxiliary) cameras.

The practical guidance in this report reflects the state of the art of modern sports lighting design world-wide. The report is divided into a general section with guidelines on design, maintenance and hardware (lamps, luminaires, and systems) valid for many different types of sport and a section that specifically covers all individual sports listed in CIE 83-1989. For each of the sports, a separate paragraph is devoted to giving the typical lay-out of the playing area, the preferred location of the lighting, the most important camera locations, and the points for special attention to avoid pitfalls in the lighting design for that particular sport.

It should be noted that many suppliers of lamps and luminaires regularly publish details of new installations and various sports federations, both national and international, published guidelines, including lighting for their specific field of interest. It is recommended that advice should be sought of specialists in designing sports lighting installations suitable for CTV (colour television) coverage, especially for large international tournaments and games. Also, under each sport, the address of the particular International Sports Federation is given. Many of these federations have extensive information available on details of their specific requirements, many of which are relevant to the lighting design.

2. GENERAL DESIGN CONSIDERATIONS

In CIE 83-1989, the various lighting parameters and, as far as possible, the quantitative values for each of the parameters are given. Sports are divided into three categories, determined mainly on the basis of the speed of action occurring during camera shots and maximum shooting distance. The illuminance values are service values, in that report. Since they were published, the concept of maintained illuminance has been introduced, whereby the quoted values should be the lowest that will occur during the life of the installation. So the minimum requirement is the maintained illuminance averaged over the calculated grid points. Consequently, to adjust the illuminance values in CIE 83-1989 to those for maintained illuminance, the CIE 83-1989 values should be multiplied by 0,8. This is in line with what has been done in the CEN (European) draft standard. The modified table for vertical illuminance in CIE 83-1989 is shown in Section 9, Table 1 of this report. The graph in Fig. 1 illustrates the expected reduction of the initial performance related to lamp lumen depreciation and luminaire cleaning as detailed in CIE 154:2003 "The maintenance of outdoor lighting systems".

Typical maintenance factors are (for the same lamp/luminaire combination):

$$E_{\text{service}} = 0,8 \cdot E_{\text{initial}},$$

$$E_{\text{maintained}} = 0,8 \cdot E_{\text{service}} = 0,64 \cdot E_{\text{initial}}$$

Maintenance is required at the time the illuminance value falls below the specified maintained illuminance as given in Section 9 of Part A, Table 1.

The value of such maintenance programme is indicated as an example in Fig. 1. Clearly the depreciation in the un-maintained scheme will fall by around 65% of the initial value within 3 years, and it will continue to decline. By comprehensive cleaning, the decline is checked at under 40% depreciation.

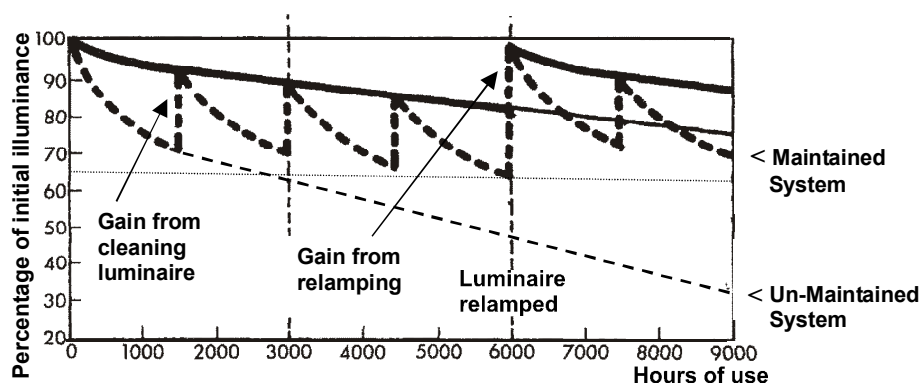


Fig. 1. The effect of maintenance program.

It is evident that the concept of minimum requirement for the maintained illuminance offers options for lower initial illuminance values for high quality lamp/luminaire combinations (see Section 4 of Part A).

A maintenance factor should be included to compensate for ageing and soiling of the lamps, reflectors, and front glasses. This factor is dependent on the type of lamp (see manufacturers' data), the local conditions (to be specified on the basis of local experience) and the luminaire type (e.g. IP classification). In the absence of relevant information, CIE 83-1989 recommends a maintenance factor of 0.8. In designing a CTV lighting installation, the lighting criteria for other users (i.e. players and spectators) besides the CTV viewers should be given full consideration. The players and referee(s) must be able to see clearly all that is going on in the playing area, so that they can achieve their best possible performance. Spectators have to be able to follow the players and developments of the game in an agreeable environment, and in a comfortable way. This means that they must be able to see their surroundings and immediate neighbours as well. The lighting should also support safe entry to and departure from the sports venue. Especially with large crowds, the security aspect is of utmost importance. With respect to comfort and performance for both players and spectators, glare should be kept to a minimum.

The lighting criteria for players and spectators might conflict with the CTV requirements and could limit the number of camera locations or the area covered for a particular camera, for example. This is especially so in those cases where luminaires and floodlights cannot be installed in the preferred positions due to physical limitations of the sports facility. In this respect, it is of primary importance that architects and lighting specialists work closely together straight from the conceptual design phase until final completion of the new sports venue. In many cases, the ultimate lighting quality can benefit greatly from an integrated approach. Such co-operation is even more important in the case of integration of the lighting installation in the building construction, whether it be indoor (e.g. ceiling system) or outdoor (e.g. in the roof of a stadium). Unacceptable glare, direct or indirect (e.g. in swimming pools), can largely be avoided if in the conceptual architectural design phase the lighting requirements are taken into account.

Daylight effects can have a negative influence on the overall lighting quality, both in indoor and outdoor venues.

Indoors, the penetration of daylight, both sunlight and sky brightness, should be avoided as they will give unacceptably high brightness and shadows. This is especially true in the case of glossy floors, and water surfaces in sports halls, and swimming complexes. Properly designed sun blinds, preferably only partly translucent, can avoid these effects.

In outdoor venues, direct sunlight can cause harsh shadows resulting in unacceptable contrasts for the television cameras when shifting from the bright illuminated area to the shadowed area of a playing field. Where certain parts of a grass playing field area are always in shadow, uniformity problems under artificial lighting might occur because of the darker colour of the grass in the shadowed part.

These effects can be avoided in the design phase, or at least be reduced by choosing the best possible orientation with respect to the movement of the sun and by using translucent roof materials to reduce the contrast in the playing area. Moreover, a proper choice of the time of day that the games take place can improve this situation. It should be noted that artificial lighting generally can't nullify or compensate for the high contrasts due to shadowing. For the electric lighting installation, care should be taken, that as far as possible, the artificial lighting matches the daylight colour temperature for games taking place over the transition period from light to dark.

In designing sports lighting installations, notice should be taken that broadcasting directors, in televising an event, strive to make it as spectacular as possible. Multi-camera coverage with portable or moveable cameras is developing rapidly as a result of ongoing improvements in camera equipment and its usage. Numerous examples can be noted if one carefully follows games on TV, e.g. replays of important moments from various angles, cameras above the centre of the pitch, moving cameras in track events such as speed skating, under water cameras, close-ups with a portable camera, etc.

The consequence of this development will lead to a requirement that the playing field and its surroundings should be illuminated in such a way that camera coverage will be possible from any direction, minimally from both cross-wise and length-wise directions. This is further complicated due to the fact that sports venues for economic reasons are used not only for a variety of sports (e.g. in multipurpose sports halls) but also for non-sports activities. Concerts and other cultural events take place in the same facility, both in multipurpose sports halls and in outdoor stadiums. It can be expected that almost any activity is going to take place in these venues with large crowds, especially with the large outdoor venues having moveable roof structures which can be closed under adverse weather conditions. Large sports facilities provide, in many cases, congress and conference services, restaurants, and shopping facilities next to the sports training facilities to make them economically exploitable. In this respect, and also in the interests of sponsors and advertisers, these issues should be borne in mind in designing sports lighting installations. Advertising signs along the perimeter of the playing area should be carefully illuminated to provide clear picture quality when appearing in the background of a televised scene. This can be rather conflicting with the glare criteria of the spectators, especially when the stands are close to the playing area.

Because of the multiple use, it is recommended to provide partial switching of the light installation, firstly to meet the specific requirements for the sports activity taking place (e.g. switching for handball, volleyball, table tennis, etc.) but also for recreational, training or competition level, and maintenance/cleaning. In this way, running costs are reduced, but more important, the lighting quality is better guaranteed for each type of sport taking place in a particular sports' facility.

For economic reasons, so called asymmetrical lighting systems are used (e.g. in stadiums). At the main camera side, the lighting installation provides the specified CTV illuminance values, while at the opposite side the vertical illuminance is for example 60% of that value. It is evident that this results in reduced investment cost for the total lighting installation compared to a full symmetrical system. The disadvantage of such systems is that it might conflict with the broadcasting requirements to have maximum flexibility in camera location, for example during an athletic event.

3. CTV CAMERA SYSTEMS

A pickup device of a television camera captures images in a manner similar to a photographic camera, in that an image of the scene is formed by a lens. The quantity of light required depends upon sensitivity of the pick-up device, which are nowadays electronic devices instead of the vacuum "tube". Camera sensitivity has increased dramatically over the years with the development of new generation CCD cameras. The CCD, Charged Coupled Device, also overcomes the problem of image lag associated with tube cameras. Moreover, CCD cameras are smaller, making the distinction between studio and portable cameras less obvious. Picture quality is expressed as a signal to noise ratio (S/N), measured in dB. Today, a S/N ratio greater than 45 dB is required for broadcast purposes and modern CCD cameras can have a specific S/N ratio as high as 60 dB. However, cameras should not be compared

solely on the basis of S/N ratio, but also take into account image device size, nominal aperture, and scene illumination, all of which can be found in the camera documentation.

Pictures are captured at a nominal rate of 60 or 50 frames per second, so within 16 ms - 20 ms. A S/N ratio of 45 dB should be achieved. For slow motion exposure, times of 5 ms - 2 ms are used (frame ratio of 200 - 500/s). The use of high shutter speeds requires more light or an increased lens aperture to allow more light into the camera. Aperture sizes commonly used are $f/5,6$ and $f/8$ with 25 mm image devices. For 18 mm and 12,5 mm image devices, to achieve the same depth of field will require 1 and 2 extra stops in lens aperture, respectively. These "f stops" give a good depth of field and are suitable to focus on e.g. group of players in a team game. Reducing exposure time and increasing depth of field requires more light to achieve the same picture quality.

Television cameras record scene brightness (luminance), which is related to the light reflected from the scene. Average reflectance will lie between 30% and 40%, but it can be substantially lower (e.g. the green surface of a tennis court will have a 15% - 20% reflection). Camera manufacturers commonly specify illuminances for scenes with reflectances of 90%, or 60%. On this basis, cameras of different types can be compared; however, it does not give an indication of the illuminance required for CTV coverage of a sports event. To achieve the same picture quality from a scene with a reflectance of 30%, 3 and 2 times more light, respectively, is required compared with the given value for the particular camera (at 90% or 60%, respectively).

Modern cameras have the option to amplify the picture signal (e.g. if low or failing conditions are encountered). This results in increased picture brightness, but it also increases picture "noise". This so-called gain control, is specified by the camera manufacturers and expressed also in dB. A difference of one aperture stop is equal to the difference of 6 dB gain. Gain control can be used to limit deviations in picture brightness (e.g. in cases where a number of cameras are used to cover a large playing area). Gain can also be used to extend aperture range or to enable higher shutter speeds. Modern cameras are making use of chips with reduced noise, increasing the dynamic range of the image device and allowing a broader range of contrast to be accommodated. In addition, video circuit improvements enable a film like appearance and a greater range of scene contrast.

These latest developments have resulted in almost equal sensitivity for both Standard and High definition TV (HDTV) cameras. HDTV is based on 1250/1025 lines for Europe and the USA, respectively, compared to 625/525 for Standard definition TV (SDTV). Consequently modern cameras both SDTV and HDTV can operate in the same lighting conditions, though the S/N ratio for HDTV is about 10 dB lower (due to incised band width). Ongoing developments will make HDTV cameras more sensitive than present SDTV systems. As a consequence, the lighting levels as indicated in CIE 83-1989 can also be adopted for the modern CCD - HDTV camera systems. Special attention is required in case of differences in camera operating frequency and local supply frequency (or in cases of the external power source for broadcasting system not being synchronised with the power supply system of the sports' venue). In case of a S/N ratio of 45 dB for a synchronised system (both 50 c/s or 60 c/s), a non synchronised system requires more light to achieve the same S/N ratio e.g. camera frequency/local supply frequency of 50/60 or 60/50 c/s needs respectively 1,9 and 1,6 times more light (or an increase of lens aperture of +0,9 and 0,7, respectively).

Colour film cameras, unlike CTV cameras, do not have the ability to "white balance" to any colour temperature environment nor the facility to add in extra gain at the time of shooting. Consequently, it is very important that the exposure is correctly calculated taking into account the loss of any colour correction filter used on the camera.

Assuming that the exposure time is 1/50 s, the necessary film ISO rating can be calculated from:

$$\text{ISO Rating} = \frac{13450 \cdot f_{no}^2}{E}$$

E is in lux. The tendency in the film industry is to use the old "imperial" measurement for incident light – the foot-candle. To convert this to lux, multiply it by 10,76, (e.g., for an illuminance of 35 foot-candles (376,6 lx) and $f/2,0$ aperture, the required ISO rating would be:

$$\frac{13450 \cdot 2 \cdot 2}{376,6} = 143)$$

This figure would then need to be modified according to the loss of any filter used on the camera (refer to manufacturers' data).

When the film speed is doubled, the ISO rating is also doubled.

4. DETAILED DESIGN CONSIDERATIONS

4.1 Drawing up a lighting specification

Drawing up a complete lighting installation specification is the first guarantee for a good quality sports lighting installation. It should minimally contain the performance specification in terms of lighting level, uniformities, gradients, illuminance ratios (modelling), glare rating, obtrusive light, colour temperature and colour rendering. The quantitative data should be provided in a prescribed calculation grid over the specified area for each of the sports taking place in a particular sports facility. In addition, calculations for different switching steps for each sport can be required (e.g. CTV level, competition level, training, etc.). The calculation grids should include the total area, the principal area, stands, and any other specific grid related to the specific requirements for a particular sport as indicated in the dedicated chapter for each sport. The location of the lighting units should be in line with the recommendations per type of sport.

Maintenance factors should be included in the calculations, based upon an agreed maintenance schedule, the lamp depreciation data and a given dirt deterioration factor prevailing in the area where the sports facility is situated. In addition to the performance specification, a specification for hardware (lamps, ballasts, luminaires) can be added. With respect to lamps, this should include lamp types, lamp wattage, luminous flux, life and light depreciation curves, and eventually hot-restrike option, ballast type, ballast losses, power correction capacitors suitable for the prescribed supply voltage and frequency. For the luminaire, it should include light distribution data, materials used, heat resistance, operating temperature, sturdiness, weight, size, shape, ease of lamps replacement and maintenance, corrosion-, dirt- and moisture resistance, IP classification, IEC or any other electrical specification, installation details, etc. (see for detailed information also Sections 5 - 8 of Part A).

To illustrate the effect of depreciation/mortality of the lamp/ballast combination, consider the following simplified comparison of three different lighting solutions for maintenance free operation for 4000 hours.

Lamp/ballast characteristics:

- a) constant light output, mortality 10%, dirt deterioration 10% (at 4000 h);
- b) lamp depreciation 20%, mortality 10%, dirt deterioration 10% (at 4000 h);
- c) lamp depreciation 40%, mortality 20%, dirt depreciation 10% (at 4000 h).

In these cases, the maintenance factors to be applied are:

- a) $1 \cdot 0,9 \cdot 0,9 = 0,8$;
- b) $0,8 \cdot 0,9 \cdot 0,9 = 0,65$;
- c) $0,6 \cdot 0,8 \cdot 0,9 = 0,45$.

For a maintained illuminance of 800 lx, the initial illuminance to be installed is respectively 1000 lx, 1250 lx, and 1800 lx. This example shows that for each sports facility the maintenance factor should be well established and related to the quality of the lighting equipment (lamp, ballast, luminaire), the environmental influence on light deterioration, and the applied maintenance schedule.

The specification with respect to the electrical installation should be in line with Section 8. Commissioning and evaluation methods should follow the guidelines as given in one of the following parts of this section. All issues mentioned above should be included in the specification either as a requirement specification or as information to be supplied by the

tender. As such, the specification can be based upon a concept lighting design or request for a lighting design (in concept or detail). Mounting structure (e.g. catwalks or masts) should be included but are beyond the scope of this publication.

It should be noted that the lighting specification is in most cases part of the M&E (Mechanical & Electrical) contract specification, containing next to lighting a variety of other services (sound systems, air conditioning, general lighting, parking facilities, etc.).

4.2 Calculation grids and methods

In CIE 67-1986, guidance is given on the number of calculation grid points to be considered, depending on the size of the playing area. The objective of CIE 67-1986 is to provide a standard procedure for calculation, measurement, and reporting and make it possible to compare alternative lighting systems on a common basis at the design stage.

Also, the calculated values can be directly related to measured values on site when the lighting installation is complete. In CIE 67-1986, an approximate indication of the practical number of grid points is given.

By applying these figures, the work involved in calculation and measurement does not become excessive, especially where larger outdoor sports areas such as athletic stadium, soccer stadium, ball parks, etc. are concerned. For areas smaller than about 500 m², the number of grid points has to be determined from the specific requirements for a particular sport. The grid has to be agreed upon between user, specifier, and lighting designer (CIE 67-1986, Section 3.5).

With the rapid development of computer software, the time and effort needed to carry out a large number of calculations has been greatly reduced. As a result, current specifications for CTV lighting design especially cover a large variety of grid layouts with respect to number of grid points and grids located in horizontal, vertical, and sloped planes, etc. Therefore, definitive guidance on the grid, which is directly related to a specific sport, is included in this report. Note that the calculation grid and measuring grid should be considered separately to avoid an excessive number of measurements being demanded. The calculation grid should contain the measurement grid. For example, for a football ground the number of grid points according to CIE 67-1986 could be 7 x 11. However, for greater design precision, the calculation grid could also be 15 x 23 and contain a measurement grid of 8 x 12. For measurement comparison, the lighting designer can provide a separate print-out of the 8 x 12 grid additionally.

In the specific sections on individual sports both grids are included. The measurement grid has to be considered as the "minimum" grid which has to be provided in the design phase of a lighting project. The ultimate choice for the calculation grid and measuring grid has to be agreed upon between user, specifier and lighting designer. Further guidance is given in National Standards and Recommendations. For example: EN 12193 Sports Lighting.

The overall dimensions of the calculation grid are based on the *reference area*. This is the area over which the lighting requirements for colour TV and filming apply.

The Principal Area (PA) is the actual playing area required for the particular sport. This is generally the marked out "field" or "court".

The Total Area (TA) is the Principal Area (PA) with an additional surrounding safety areas or zones, which may be used in play.

The reference area used in these recommendations refers to that area covered by the calculation grid, and it is the area over which the lighting requirements apply. It is a rounded approximation of the Total Area, depending on the number and spacing of the grid points. The reference area is covered by rectangles and lighting values are calculated in the centres of these rectangles. The size of the rectangles should be rounded off to integers to prevent complicated measuring grids, except for very small and/or narrow reference areas, as for example, in boxing, billiards, and fencing.

The calculations should be carried out for the actual reference area as given (or determined) for the venue for which the lighting has to be designed. In Fig. 2, the general

approach of determining the grid points is shown for a rectangular court. Starting point for the calculation grid is the centre of the court C. Consequently, the number of grid points is odd in both longitudinal and transversal direction.

Where the measurement grid is double in spacing, the starting point is one of the corner points (e.g. A). Grid spacing for calculations should be 1 m, 2,5 m or 5 m depending upon the size of the reference area. For some sports it is recommended that deviating grids are used; these are shown in the particular sections.

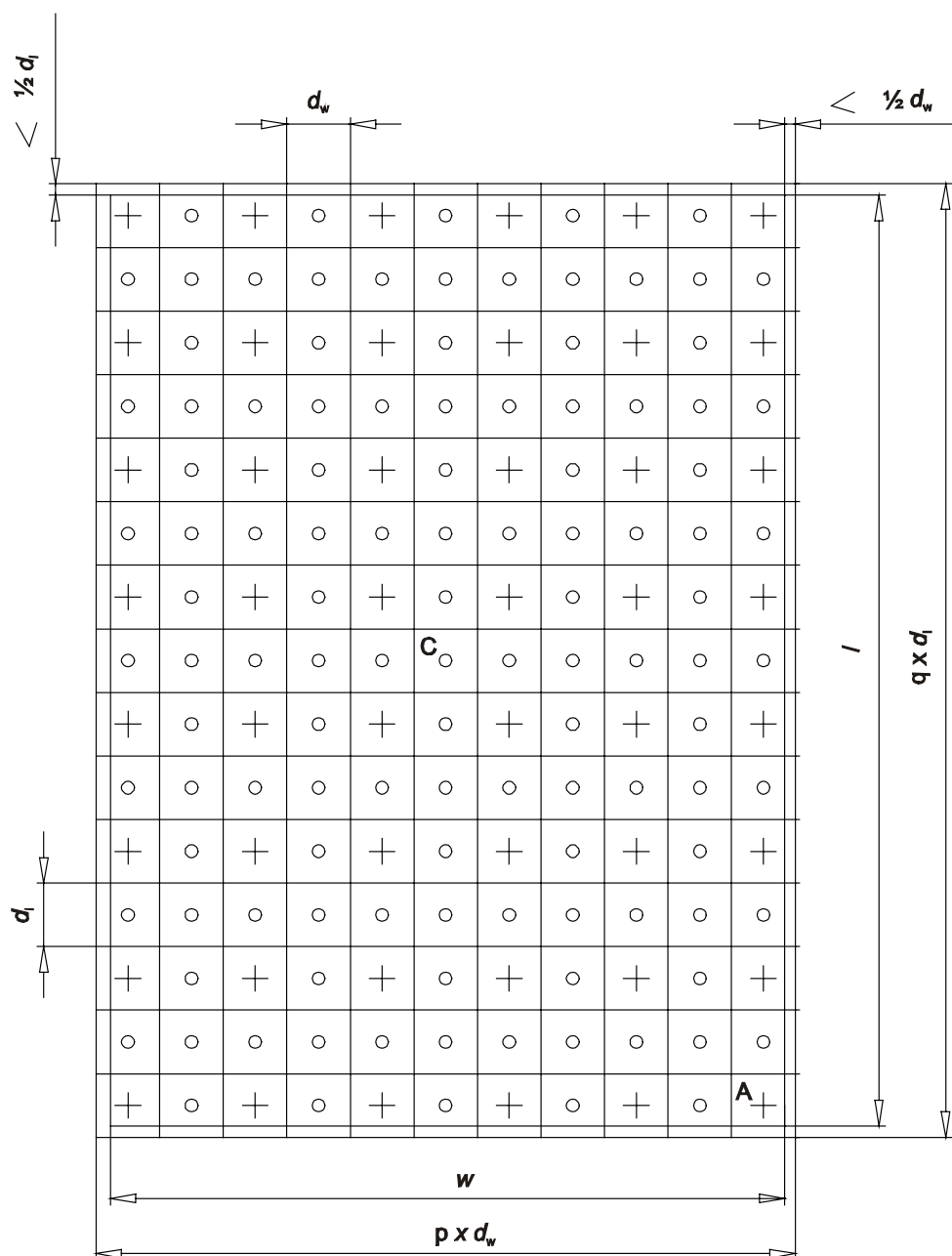


Fig. 2. Calculation and measurement grid for a typical rectangular sports area.

l = length of total area (TA), d_l grid spacing length-wise,

w = width of total area (TA), d_w grid spacing cross-wise,

p, q (number of grid points) - odd integers with

$$(q-1) \cdot d_l < l \leq q \cdot d_l \quad (p-1) \cdot d_w < w \leq p \cdot d_w$$

Then: $q \cdot d_l$ = length of reference (calculation) area,

$p \cdot d_w$ = width of reference (calculation) area,

$d_l, d_w \leq 5$ m with standard range: 1 m for $l, w \leq 10$ m,

2,5 m for $10 \text{ m} < l, w < 50$ m, and

5 m for $l, w > 50$ m.

○, + calculation grid points (determined by starting from centre point C)

+ measurement grid points (determined by starting from corner point e.g. A)

4.2.1 Calculation methods

CIE 83-1989 gives guidance on the recommended values for illuminances and uniformities. The average values for illuminance are determined by:

$$E_{ave} = \frac{1}{n} \sum_{i=1}^n E_i$$

(n = total number of grid points)

Horizontal illuminance is normally calculated at ground level, while the vertical illuminances are calculated at 1 m above field level and normally towards the four sides of the playing area in case of rectangular reference areas. Main directions are indicated per sport. Occasionally, for fixed cameras, the illuminance in the direction of the cameras is calculated (as well).

Uniformities are calculated on the basis of

$E_{min} : E_{max}$ with: E_{min} , minimum illuminance value of all grid points

E_{max} , maximum illuminance value of all grid points

for each of the illuminance calculations. In addition, uniformity on vertical planes at a grid point should be calculated with $E_{v,min}$ and $E_{v,max}$, respectively, minimum and maximum value of vertical illuminances at a particular grid point.

The ratio between the average horizontal and average vertical illuminance should be calculated for each main camera direction.

Glare calculations should be carried out, as far as applicable, to be conform to the guidelines given in CIE 112-1994.

4.3 Design criteria

In addition to the quantitative design parameters, like illuminance levels, uniformities and gradients, and glare rating for outdoor sports, a number of qualitative parameters should be considered in the design.

The quantitative parameters are laid down in the sections on grid format and calculation methods and are specified in, for instance, CIE 83-1989. However, in the design, a number of important qualitative criteria should be considered. Most important are modelling, glare (direct and indirect), and obtrusive light (light pollution).

The ability of lighting to reveal form and texture, in short, its "modelling" ability, is particularly important if it is to give a pleasant overall impression for the spectator both "live" and on the TV screen. It should be noted that the eye can cope with a much wider brightness range than a television camera. Consequently, uniformity requirements are more stringent for CTV installations, which is the reason why a gradient is often specified. In this respect, it is evident that harsh shadows should be avoided, especially from sunlight. Glare, both direct and indirect, should be avoided. For outdoor sport, the glare rating method as laid down in CIE 112-1994 can be applied. In the sections on each type of sport, specific pitfalls have been indicated where applicable. Obtrusive light - spill-light emitted by a lighting installation

which gives rise to annoyance, discomfort, distraction, or reduction of the ability to observe - should be minimised.

This is, of course, of primary importance for outdoor sports lighting installations; here spill-light can affect occupants in the neighbourhood, users of adjacent roads and other transport means (air, marine, rail) as well as astronomers. It should be noted that objects used in playing sports, for example, a tennis ball, must still be seen in the space above the playing area to an appropriate height. Consequently, depending on the structure of the sports venue and the type of lighting installation, obtrusive light cannot always be avoided.

In CIE 150:2003, the design aspects with respect to obtrusive light are given and should preferably be implemented in the design specification. The amount of obtrusive light can be reduced by good lighting design based upon optimal location and choice of lighting units, which should be properly aimed and maintained. As the majority of outdoor lighting CTV installations are in stadium, special care is needed for lighting solutions realised by mast lighting systems. Luminaires integrated, for example, in roof structures, minimise, to a large extent, obtrusive light in the environment, although well controlled beams are still necessary to reduce spill-light emitted to the sky.

4.4 Installation and commissioning

In the lighting design phase, some aspects of carrying out the installation need attention to achieve optimal quality. In Section 8, a number of aspects of the electrical installation are included.

In addition, care should be taken that switching of the various partial luminaire arrangements is in logical groups to avoid the impression that some lighting units are failing. As such, the lighting layout of the lighting units over a line or the head frame of the mast should be included. Moreover, the layout (and spacing of the luminaires) should be such that all lighting units can be aimed properly without screening of light by adjacent luminaires or structural elements. Aiming should be carried out accurately according to the recommendation of the luminaire supplier, supported by special tools available from the supplier (e.g. aiming telescopes or angular aiming devices). When commissioning the installation, the following points should be considered:

- a) *Check on luminaire position*
Both the distance and the height of the luminaires should be checked for compliance with the specifications. It should be noted that mast height is not usually equal to the light point height above the playing area level and the mast can be slightly shifted for good reasons, in the installation phase, without affecting the lighting designer's work.
- b) *Check on aiming*
A number of luminaires should be checked for compliance with the lighting design. Possible screening of the emitted light should be checked (by individual luminaires, roof edges, structural elements, etc.). It should be noted that in the installation phase changes might be implemented which have not been communicated to the lighting designers.
- c) *Judgement of visual impression*
To properly judge the overall impression under artificial lighting conditions, it is also necessary to visit the sports facility under daylight conditions to evaluate brightness and colour contrasts of the playing surface (e.g. in an outdoor stadium a shaded grass area might have a darker green colour).
- d) *Lighting measurements*
Measurements should be made after a known number of hours of running the lamps. The initial photometric measurements should be made at approximately 100 hours of lamp operation. The period between installation and measurement should preferably be as short as possible. Measurements should be taken with a light meter within its calibration period and with sufficiently accurate colour response and cosine correction. Ballast input voltage measurements should also be made in a regular sequence during the lighting measurements to avoid difficulties in comparing

measured and calculated data. Lamp voltages can be measured to check the voltage drops between ballast and lamp if applicable. The measuring grid is usually based on half the number of calculated grid points (see specific sports).

As many CTV installations have one or more axes of symmetry, measurements can be carried out on half (or quarter) of the field. However, the remaining positions should be checked by measuring a few critical points. If significant differences occur, the total playing area must be measured after adjusting the installation. A tolerance in each measured value of $\pm 10\%$ about the calculated value is acceptable. This tolerance will include luminaire constructional tolerances, electrical ballast tolerances, etc.

Measurements of partial switching steps, not used for CTV, can be measured on a larger grid, as these are not so critical: a walk over the playing area is usually sufficient. All measured data should be properly recorded, including data on voltages, instrument used, weather conditions, and any other local aspect valid in evaluating the measured data. Measurements include horizontal and vertical illuminances, and finally luminances to check the glare rating *GR*. Other non-measurable aspects, (e.g. indirect glare,) should be noted, especially if they deviate from the expected overall impression.

5. MAINTENANCE

The recommended lighting levels given in Section 9 are maintained values and derived from Publication CIE 83-1989. Consequently, an appropriate maintenance factor should be included in the design calculations. The most significant factors contributing to light depreciation are the gradual decrease in luminous flux emitted by the lamp and soiling of the optics and luminaire light emitting surface.

The lamp depreciation largely depends on the type of light source used and should be taken from the data issued by the lamp manufacturer, preferably in combination with their indication for the (group) replacement cycle in burning hours of the installation. The severity of luminaire depreciation depends upon IP classification of a luminaire, quality of reflectors, the amount of pollution locally present, and the time interval between cleaning operations (which is usually equal to group lamps replacement for indoor and, preferably annually for outdoor venues).

In clean environments and lamps with low lumen depreciation, the total annual loss can easily be 10%, while for polluted environments this could increase to 20%. In case of high lamp lumen depreciation, these values might rise to 20% and 40%, respectively, depending upon the number of burning hours per year. A careful estimation of the value of the maintenance factor on the basis of lamp type, cleaning/replacing cycles, and actual conditions prevailing will ensure that lighting levels occurring during operation are neither too low nor needlessly high, with corresponding high energy costs.

Cleaning of luminaires in outdoor installations is, apart from light loss, strongly recommended to minimise obtrusive light. If for specific installations care has been taken that well controlled luminaires are required to minimise obtrusive light, this will be offset by dirt accumulation on reflectors and front glass.

Lamp life and a limited number of early failures are especially important to minimise maintenance in CTV installations. Long life of the lamp is extremely important for (indoor) venues that normally are in daily use (thus having a high number of burning hours). Early failures need to be replaced, especially where very high wattage lamps are used in narrow beam floodlights. In principle, the lamps should be checked before each CTV broadcast, especially in those venues where only occasional CTV broadcasts take place.

Cleaning or even re-lamping also might be necessary to upgrade the resultant illuminance to the required level. In very specific cases, even re-aiming might be required to achieve the required vertical illuminances. This might be necessary in cases where originally the lighting was not designed for CTV broadcasting or when a game is broadcast for which

the lighting was not designed or when the main playing direction is changed (e.g. with table tennis in a changed table setting).

General information on maintenance can also be found in CIE 97:1992 and CIE 154:2003. Maintenance can be facilitated when the structural elements carrying the lighting system provide easy access to the luminaires or when special servicing equipment is taken into account in the constructional design.

Well designed catwalks and platforms in masts, accessible via safety ladders or "raising" platforms, can improve ease of maintenance. In general, for major venues these aspects are taken into account by the architectural/structural design, because servicing of all electrical systems (sound, score boards, etc.) is carried out from similar structural elements. Although these provisions increase the investment costs, it is evident that where special equipment has to be brought to the venue for maintenance those costs will be high, apart from the complexity and possible damage to floors and other equipment.

6. LAMPS

In CTV installations, the most important light sources are metal halide lamps, tubular fluorescent lamps, and (halogen) incandescent lamps. Occasionally, a mix of light sources is used (e.g. metal halide with fluorescent or with high pressure sodium).

Metal halide lamps are the most important light sources for colour TV sports lighting installations, both outdoor and indoor. Fluorescent lamps and halogen lamps are used only for a limited number of specific sports (e.g. sports which require a relatively small playing area such as squash and billiards). In the section on a specific sport, the recommended light source is indicated.

Metal halide lamps of various types and wattages are applied, having luminous efficacy from 60 lm/W to 100 lm/W and colour rendering index from 65 to more than 90. Lamps can be single or double ended with linear or compact discharge tube and with or without outer bulb. The lamp depreciation characteristics differ substantially for the different types and wattages. Consequently, in case of the lighting design, the relevant data from the suppliers of the lamp under consideration should be implemented in the design.

The life time characteristics can also differ largely. For large outdoor lighting installations this is not very critical, because, in those cases, the number of burning hours is relatively low (e.g. a stadium with one night match per week results in 200 hours/year only). It should be noted, however, that the number of early failures (lamp burning out in the first few hundred hours) is generally much higher for lamps with a relative short life, resulting in additional maintenance (and possibly dark spots). For indoor installations, long life lamps should be applied because of the generally large number of burning hours/year.

Colour temperature of metal halide lamps vary depending upon the types and doses of metal halides used from 3000 K to 6500 K. For outdoor installations, generally, 4000 K and higher are applied to match better with the daylight, especially in the twilight period. For indoor, usually 4500 K and lower are applied, which normally provide a warmer colour impression (also dependent upon the spectral distribution).

The choice of the wattage(s) (or better lumen package) depends upon the uniformity requirements for the lowest switching step (e.g. professional training does not require the whole installation being switched on). For this part (if required), a lower wattage (e.g. 400 W) can be used in combination with high wattages, to achieve CTV level (e.g. 2 kW). With respect to the highest wattages care should be taken that individual lamp failure does not result in a dark spot (also true if very narrow beam types are used).

Stray light reduction is, generally, better with single envelope, double ended lamps, which can be precisely positioned in the optical (reflector) system.

Metal halide lamps can be of the standard type or hot-restrike type. The hot-restrike type is applied to overcome supply interruption problems (for further reading, see Section 8 of Part A, Electrical systems).

Tubular fluorescent lamps have luminous efficacies of the order of 100 lm/W. Their colour characteristics and colour rendering property depend on the coating. Ranges vary from 2700 K to 6000 K and CRI from 50 to 90.

These lamps are only used in sports venues with a relatively low ceiling height to achieve glare free installations.

Halogen incandescent lamps have the advantage of low initial costs and excellent colour properties. The efficacy, however, is low compared to the majority of metal halide lamps and the lifetime is relatively short. These lamps are applied for some specific small area sports and, occasionally, for temporary installations. Major application in sports is for emergency lighting, because of the instant light property of these lamps.

Sometimes, a mix of metal halide lamps and high pressure sodium (HPS) lamps is used because of a better overall efficacy (HPS lamps have lm/W values up to 130). However, the colour rendering of HPS lamps is low, resulting, depending upon the mix, in a CRI in the order of 40 - 50. In case of such combinations care should be taken that the contributions from both lamp types are identical on all locations in the arena. Consequently, the only good solution is the application in twin lamp floodlights/luminaires with optical systems providing such a mix. Occasionally, such a mix is used in indirect lighting systems in indoor halls, creating a warmer atmosphere. It should be noted that in such cases the gain in efficacy is offset by the lower efficiency of such indirect systems.

A mixture of metal halide lamps and tubular fluorescent lamps is sometimes used in indoor halls. The tubular fluorescent lamps contribute to the total colour TV lighting installation and can be used alone as a lower switching step for general non-CTV-lighting (e.g. for training and club matches, and also for emergency lighting).

7. LUMINAIRES

7.1 Photometric characteristics

Two photometric characteristics are of major importance to achieve an economic lighting solution: The light distribution, suitable for the specific sports lighting installation, and a high light output ratio. A design combining these two in an optimal way results in a good quality lighting at minimum operating cost. The majority of the CTV sports lighting installations are based upon floodlights equipped with metal halide lamps. The tubular fluorescent tube is the only lamp type not used in floodlights.

a) *Fluorescent luminaires*

The light distribution applied for a particular sport, usually indoor, depends upon the arrangement of the luminaires and can vary from rather diffuse to directional. Asymmetric distribution can be applied if certain areas in a ceiling should be avoided (e.g. to minimise glare).

A batwing shape of light distribution can be used where the transverse spacing is large (e.g. because of constructional limitations). The lengthwise spacing is normally small because of the diffuse light distribution in that direction, so continuous lines are often used to achieve good uniformity. Depending upon the type of sports and the arrangement, louvers or screens are required to avoid glare due to the brightness of the lamp.

b) *Floodlights*

The required light distribution of a floodlight is determined by its location (height above and distance to the field) and projected intensity. Generally, the longer the throw, the narrower the beam (and the higher the intensity) is needed. Due to the high (il)luminance values required for CTV, wide beam types and relatively small lumen packages are uneconomic. This holds for the majority of the sports, even for smaller distances and/or smaller fields.

Medium and narrow beam types are therefore recommended. Floodlights can, generally, be divided into circular and rectangular types. Circular floodlights, generally

with a parabolic reflector, have a rotationally symmetrical light distribution. These floodlights are normally of a narrow/medium beam type and used in long throw applications to achieve a more efficient installation (e.g. 4 mast, corner arrangement in a soccer pitch). Rectangular floodlights usually provide light distribution which is symmetrical in the horizontal plane and symmetrical or asymmetrical in the vertical plane. These types normally have a wide distribution horizontally and narrow to medium vertically. Asymmetric types are preferable to limit the amount of glare, especially if screens are provided to mechanically cut-off the light above certain angles (in the vertical light distribution). Such screens can also be provided in circular floodlights. For efficacy reasons, the screen can act as a reflector for the lower part of the beam in the vertical plane.

Rectangular floodlights are normally used for line and side mast arrangements, as their light distributions normally provide a trapezoidal light pattern on the field resulting in a high utilisation factor. With respect to glare limitation, CIE gives practical rules, for example, soccer lighting: $0,1 I_{\max}$ at 12° above the optical axis containing $I_{\max}$. This requirement might, however, not meet the requirements to limit the stray light outside of the sports venue sufficiently, especially in stadiums with high mast arrangements.

7.2 Other requirements

a) *Heat resistance/Operating temperature*

Materials used within the floodlight and its body should be capable of withstanding the heat produced by the lamp at the ambient temperatures prevailing. At the same time, the temperature should not rise above the maximum operating temperature of the lamp and gear (if integrated on the luminaire).

b) *Construction*

The luminaire should be of a sturdy construction to ensure a proper functioning in prevailing weather conditions, steady in positioning, no damage to reflectors in case of hail storms, etc. Material for the body should be corrosion proof and resistant to any other prevailing outdoor condition (e.g. close to seaside, pollution in air, etc.). In case of open luminaires for fluorescent lamps, special grids should be provided (in case of ball games) to prevent accidents as well as damage to the lamps/reflectors.

c) *Electrical characteristics*

The floodlight should be such that it is safe to all those involved in its handling (installation, maintenance, aiming, etc.) and should meet the relevant national and/or international standards (e.g. IEC).

d) *Ergonomic design*

Mounting, aiming, re-lamping, and cleaning is, in case of floodlights, usually carried out high above ground level. The design should be such to make these operations as easy as possible. Covers, front glass units, etc., if applicable, should be hinged and no special tools should be required to open floodlights. In this way, people have both their hands free to carry out maintenance and cleaning.

e) *Dirt and moisture resistance*

Open-air floodlights especially should be protected against dirt accumulation and meet the relevant national or international classification (IP). In this respect, it should be noted that in case of dirt the photometric light distribution is changing towards a wider distribution, especially in case of narrow beam type floodlights. As a consequence, the amount of stray light in the surrounding will increase.

8. ELECTRICAL SYSTEMS

To minimise stroboscopic effects, the lighting at each point of the playing area should be provided by contributions from lighting units connected to each of the three phases of the electrical supply systems. Three phase supply systems are commonly used for lighting systems; therefore, stroboscopic effects can be avoided by proper design of the aiming pattern and the electrical division over the three phases. Electrotechnically, the total electrical load should in addition be symmetrically loaded on to the three phases to prevent unbalanced transformer loads. It is appropriate to use more than one, at least two, transformers, each carrying an equal share of the total load.

In the case of partial switching options (e.g. steps for CTV, competition, training, etc.), care should also be taken to ensure symmetrical loading. The lights themselves should be turned on in groups to avoid unacceptably high starting currents.

Throughout the world supply voltage varies from about 100 V to 480 V. The highest possible voltage is preferred because of the lower currents in the supply cables; these lower currents mean reduced cross-sections of the cables and, consequently, lower cabling costs. Moreover, the voltage drop in the cables can be reduced and, consequently, also the reduction of light output of the lamps. Cable cross-section needs to be selected carefully on the basis of the acceptable voltage drop, the current, and the distance from supply to the ballast/lamp circuits. In addition, the cable between ballast and lamp should be specified to minimise losses and prevent too high a cable capacitance, which might negatively influence the ignition behaviour of, for example, metal halide lamps.

The electrical system should be operated with a power factor conforming to the regulations of the power supplier (often the Public Works Department) in the country involved. Power factors required are often at least 0,9, requiring in many cases power correction capacitors (e.g. in the case of inductive ballast often having power factors of only 0,5).

CTV broadcasting companies often require, for important sports events, a guarantee of maintaining broadcasting in the event of power failure. This can be realised by connecting the system to at least two independent power supplies (e.g. to the mains supply and to mobile generator sets). Each of the two systems carries a load that, for example, allows the minimum lighting requirement for the main camera to be realised in the case of break-down of one of the two systems. Care should be taken in the lighting and electrical design that this can be achieved when required.

Although expensive, a UPS (uninterruptible power system) can also be used for part of the installation.

In this respect, it should be noted that metal halide lamps can only be re-ignited after a 10 - 15 minutes cooling period, even if the black-out is as short as half a cycle of the supply system. This problem might be avoided by using hot-restrike (metal halide) lamps. However, this remedy is offset by the step by step re-ignition to avoid high currents. Secondly, if the supply system is restored after, say, two minutes, no light will be available during this time which is, in many cases, unacceptable.

Hot-restrike lamps and ignitors, which are very expensive, are therefore only applicable where there is a very reliable power supply system, having only very short black-outs of the order of a couple of cycles of the supply frequency.

For safety reasons, guaranteed emergency lighting should be provided, conforming to the regulations in the country concerned. Emergency generators should provide current for maintaining the required lighting levels on stands and exit areas to prevent accidents and allow people to leave the sports venue safely. Often tungsten halogen or fluorescent lamps are used, sometimes with battery back-up. Metal halide lamps can also be used, but they should be of the hot-restrike type, or a UPS (uninterruptible power system) should be adopted with standard metal halide lamps. Finally, in the case of high mast lighting, the required obstruction lighting (for aircraft) must be provided that conforms to the specification of the Aviation authorities (or ICAO).

9. SUMMARY AND USE OF RECOMMENDATIONS

In Part B of this guide, each sport is considered separately. Features of the area, camera locations and lighting recommendations are given for each sport televised or filmed under artificial lighting.

The features of the area include the typical dimensions and the specific visual needs. The typical dimensions are divided into the Principal Area (PA), and additional safety areas around the PA, which are combined to give the Total Area (TA). It should be noted that in the lighting design the real dimensions of the PA and TA should be used, because deviations from the preferred values are allowed for a number of sports by the international and/or national sports federations. As a consequence, the reference area can also deviate from the values given in section B of this report. The reference (calculation) area is a close approximation of the total area and is the area over which lighting calculations have to be carried out. The height of the grid above ground or floor level is also stated.

A diagram of the lay-out is included for sports that make use of non-rectangular playing areas (e.g. track events).

If applicable, the minimum free height above the playing area (either PA or TA) is also indicated for indoor sports. Under specific visual needs, a short description of the sports is included in case this results in special lighting design requirements.

Camera locations include both main cameras (usually covering the total area) and auxiliary cameras, which can be in fixed position, portable or running.

In the section lighting recommendations, the lighting class is stated as given in CIE 83-1989. A summary of the recommendations is given here, modified to maintained values as explained in Section 2.

Table 1. Vertical illuminance for various sports classes (maintained values)

shooting distance	25 m	75 m	150 m
Class A	400 lx	560 lx	800 lx
Class B	560 lx	800 lx	1120 lx
Class C	800 lx	1120 lx	

Illuminance ratios/uniformities

$E_{h \text{ average}} : E_{v \text{ ave}} = 0,5 - 2$ (for the reference area)
$E_{v \text{ min}} : E_{v \text{ max}} \geq 0,4$ (for the reference area)
$E_{h \text{ min}} : E_{h \text{ max}} \geq 0,5$ (for the reference area)
$E_{v \text{ min}} : E_{v \text{ max}} \geq 0,3$ (at each grid point, for 4 directions)

Glare rating $GR < 50$, for outdoor sports only, in relevant directions
(see CIE 112-1994)

The recommended lighting systems include a short description of how the lighting needs can be met, as well as lamp and luminaire types and their preferred locations (or locations which should be avoided). The recommendations are given for a single court only. In the case of multiple courts (for the same sport or different sports), some guidance is given under multipurpose sports venues.

The paragraph on calculations gives the reference area and the number of grid points that should be used at the particular spacing. Any specific guidance on measurements is included here.

Finally, the address of the relevant international sports federation - where known - is included in each section.

PART B: SPECIFIC SPORTS

1. AMERICAN FOOTBALL

1.1 Features of the area

1.1.1 Typical dimensions

Principal area (PA): 109,75 m (360 ft) x 48,8 m (160 ft).

Additional safety zone: 1,8 m (6 ft) at all sides.

Total area (TA): 113,4 m x 52,5 m.

1.1.2 Specific visual needs

The height of the goal can be up to 9 m (depending upon the rules applied by the competent governing body). Consequently, it should be insured that the flight of the ball can be easily followed at these heights, especially in the goal areas.

1.2 Camera positions

Main camera: located on extended centreline (50 yard line) of the field.

Auxiliary cameras: at side line and behind goals.

1.3 Lighting recommendations

1.3.1 Lighting class

American football is classified as class B.

1.3.2 Lighting system

A similar lighting system as for soccer is applied (see Section 21 of Part B).

1.3.3 Calculations

Grid spacing 5 m x 5 m. Grid height: 1 m above ground level.

Reference (calculation) area	Typical No. of points	Remarks
115 m x 55 m	23 x 11	

1.4 Address of the international federation:

National Football League
410 Park Avenue
New York, NY 10022; USA
Fax number: +1 212 758 1742

2. ARCHERY

2.1 Features of the area

Archery can take place indoors as well as outdoors. Strict safety regulations conform national/international requirements, those have to be followed.

2.1.1 Typical dimensions

Shooting distances vary from 18 m to 90 m. A 90 m track is common for important matches (e.g. Olympics). Centre of the target is 1,3 m above ground level. Normally, a number of tracks (e.g. 8 or 13) are located in parallel. Lines indicated are:

Spectator line, waiting line, shooting line, and target line for:

spectators	officials and participants	participants waiting for their run	shooters → targets
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2.1.2 Specific visual needs

The flight of the arrows as well as the targets should be clearly visible to allow for compensation of deviations for wind conditions and, of course, for safety reasons. Glare towards shooters should be strictly avoided.

2.2 Camera positions

Cameras can be located at various positions along the shooting line and in the area between waiting and shooting line.

2.3 Lighting recommendations

2.3.1 Lighting class

Archery is classified as class A.

2.3.2 Lighting system

Outdoor

Floodlighting systems with medium to high wattage metal halide lamps. Beam type depending upon size of the area. The floodlights should be mounted behind the waiting position of the archers.

Indoor

Line lighting system based upon fluorescent luminaires (protected for impact of arrows) mounted on the ceiling.

2.3.3 Calculations

Grid spacing: Indoor 2,5 m x 2,5 m, Outdoor 5 m x 5 m.

Vertical illuminance calculations should be made at 1 m and 2 m height both across and along the track.

2.4 Address of the international federation FITA:

Fédération Internationale de Tir à l'Arc
Bureau Administratif: Via Bartolini 39
IT - 20155 Milan, Italy
Fax number: +39 2 392 156 37

3. ATHLETICS

3.1 Features of the area

3.1.1 Typical dimensions (see Fig. 3)

Area inside track: length 157,4 m, width 73 m, (total infield circumference 388,12 m, the 400 m track is measured 0,30 m from inner circumference).

Track: lane width: 1,22 m (outer lane 1,5 m).
total width 6 lanes: ~ 7,6 m 8 lanes: ~ 10 m 10 lanes: ~ 12,5 m;
length of 100 m track: ~ 140 m.

(Note: long jump, triple jump, pole vault can also be located outside the track for example where there is a soccer field inside the track.)