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Commission Internationale de l'Eclairage
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TECHNICAL REPORT

Guide for the Lighting of Sports Events for Colour Television and Film Systems, 3rd Edition

CIE 083:2019

UDC: 28.971.7

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Descriptor: Lighting of public squares. Lighting of sports
grounds, stadiums etc.
Lighting of stadiums

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COMMISSION INTERNATIONALE DE L'ECLAIRAGE
CIE Central Bureau
Babenbergerstrasse 9, A-1010 Vienna, AUSTRIA
Tel: +43(1)714 31 87
e-mail: ciecb@cie.co.at
www.cie.co.at

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This Technical Report has been prepared by Technical Committee (TC) 4-55 of CIE Division 4 "Transportation and Exterior Applications" (formerly TC 5-26 of Division 5 "Exterior Lighting and Other Applications") and has been approved by the Board of Administration and by Division 4 of the Commission Internationale de l'Eclairage. The document reports on current knowledge and experience within the specific field of light and lighting described, and is intended to be used by all with an interest in excellence in light and lighting. The information provided here is advisory, and not mandatory.

Ce rapport technique a été élaboré par le Comité Technique (TC) 4-55 de la CIE Division 4 "Transport et autres applications" (autrefois TC 5-26 de la Division 5 "Eclairage extérieur et autres applications") et a été approuvé par le Bureau et Division 4 de la Commission Internationale de l'Eclairage. 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 tous ceux qui s'intéressent à l'excellence de la lumière et de l'éclairage. Les informations fournies ici sont données à titre indicatif et non obligatoire.

Dieser Technische Bericht ist vom Technischen Komitee (TC) 4-55 der CIE Division 4 "Transport- und Außenanwendungen" (ehemals TC 5-26 der Division 5 "Außenbeleuchtung und andere Lichtanwendungen") ausgearbeitet und vom Vorstand sowie Division 4 der Commission Internationale de l'Eclairage gebilligt worden. Das Dokument berichtet über den derzeitigen Stand des Wissens und Erfahrung in dem behandelten Gebiet von Licht und Beleuchtung. Es ist zur Verwendung durch alle an Licht- und Beleuchtungsqualität Interessierte bestimmt. Die in diesem Dokument gegebenen Informationen sind eine Empfehlung und keine Vorschrift.

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The following members of TC 4-55 (formerly TC 5-26) "Guide for the Lighting of Sport Events for Colour Television and Film Systems" took part in the preparation of this Technical Report. The committee comes under Division 4 "Transportation and Exterior Applications" (formerly Division 5 "Exterior Lighting and Other Applications").

Authors:**Smith, N.A. (Chair)**

Austin, K.J.

Lecocq, J.

Lewis, D.

Major, G.

Nielsen, T.K.

Page, G.

Schwarcz, P.

United Kingdom

United Kingdom

France

Australia

Hungary

Norway

France

Hungary

Advisors:

Jones, P.

Lemons, T.M.

Australia

USA

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GUIDE FOR THE LIGHTING OF SPORTS EVENTS FOR COLOUR TELEVISION AND FILM SYSTEMS, 3RD EDITION

Summary

This document is an extended and revised edition of Publication CIE 83-1989 *Guide for the lighting of sport events for colour television and film systems, 2nd edition*. It replaces CIE 83-1989.

The document summarizes television and film techniques with regard to their influencing and determining the lighting needs.

Detailed quantitative guidance is provided on the quality aspects to be fulfilled for colour television and colour film including vertical illuminance, uniformity of horizontal illuminance, flicker, colour temperature and colour rendering of the lighting together with lighting requirements on the surrounding spectator areas. Reference is made to HDTV broadcasting techniques.

GUIDE POUR L'ECLAIRAGE DES MANIFESTATIONS SPORTIVES POUR LES PRISES DE VUE EN COULEURS POUR LA TELEVISION ET LE CINEMA, 3^{EME} EDITION

Résumé

Ce document est une édition étendue et révisée de la publication CIE 83-1989 *Guide pour l'éclairage des manifestations sportives pour les prises de vue en couleurs pour la télévision et le cinéma, 2^{ème} édition*, qu'il remplace.

Le document fait le bilan des techniques télévisuelles et cinématographiques dans la mesure ou elles exercent une influence déterminante sur les besoins en éclairage.

Des recommandations quantitatives détaillées sont données sur les critères de qualité à remplir pour la télévision et les films couleur, notamment l'éclairage vertical, l'uniformité de l'éclairage horizontal, le flicker, la température de couleur et le rendu des couleurs de l'éclairage, ainsi que les exigences d'éclairage dans les tribunes entourant le terrain. Il est fait référence aux techniques de diffusion HDTV.

LEITFADEN FÜR DIE BELEUCHTUNG VON SPORTEREIGNISSEN FÜR FARBFERNSEHEN- UND FARBFILMSYSTEME, 3. AUSGABE

Zusammenfassung

Dieses Dokument ist eine erweiterte und überarbeitete Ausgabe der Publikation CIE 83-1989 *Leitfaden für die Beleuchtung von Sportereignissen für Farbfernsehen- und Farbfilmsysteme, 2. Ausgabe*. Er ersetzt CIE 83-1989.

Das Dokument fasst Fernseh- und Filmtechniken hinsichtlich ihrer Beeinflussung und Festlegung des Beleuchtungsbedarfs zusammen.

Eine detaillierte zahlenmäßige Orientierung zu den bei Farbfernsehen und Farbfilm zu erfüllenden Qualitätsaspekten, inklusive vertikale Beleuchtungsstärke, Gleichmäßigkeit der horizontalen Beleuchtungsstärke, Flimmern, Farbtemperatur und Farbwiedergabe der Beleuchtung, im Zusammenhang mit Beleuchtungsanforderungen an die umgebenden Zuschauerbereiche. Auf HDTV-Übertragungstechniken wird Bezug genommen.

1 Overview

1.1 Introduction

The electronic television camera and associated video recording is now the principal medium of the cameraman. The use of film is confined mainly to specialized recording, perhaps of specific events, for editing into feature films and using high-speed film cameras to study various activities. This report therefore concentrates on the lighting requirements for television, but indicates where these requirements will differ for film recordings.

When considering the televising of sports events the visual task pathway is fundamentally the sequence of stages through which the sporting scene is transmitted to, and perceived by, the television viewer, shown in Figure 1.

The scene to be transmitted is focused by lenses on the image sensors located within the television camera. This produces the picture signal; synchronization and blanking pulses are then added so as to develop the complete composite video wave form. This composite video signal together with the audio signal are then imposed onto a carrier wave and transmitted through the atmosphere or via a cable network. After detection by a receiving antenna (or cable input) at the viewer's television receiver, the signals are demodulated back to their original frequencies and fed to the receiver's display monitor and speaker(s). The eye views and interprets the image produced on the television receiver.

The eye captures light continuously on the retina whereas a standard camera must capture at the rate of typically 25 images per second in order to create the appearance of continuous motion within a scene. This illusion begins to take effect at about 16 frames per second. Television cameras are less sensitive to light than the eye and as a consequence sports lighting systems with broadcast provision are designed primarily to meet the needs of video cameras.

High definition television (HDTV) is a form of digital television that uses an aspect ratio of 16:9 compared with the original 4:3 aspect ratio that had previously prevailed. As a consequence of 'stretching' the screen a wider field of view becomes available to the eye. This is particularly advantageous when viewing sports events and movies. In addition, the greatly increased screen resolution is an added advantage. The resolution is influenced by the number of pixels – the greater the number of pixels the higher the screen resolution. Earlier televisions had approximately 300 000 pixels, whereas HD televisions offer typically more than one million pixels. HDTV also enables far greater depth of contrast and colour vibrancy than standard definition television (SDTV), producing a significantly improved viewing experience. 4K has become the common name for ultra-high-definition television (UHDTV). It has a horizontal resolution of approximately 4 000 pixels (hence 4K).

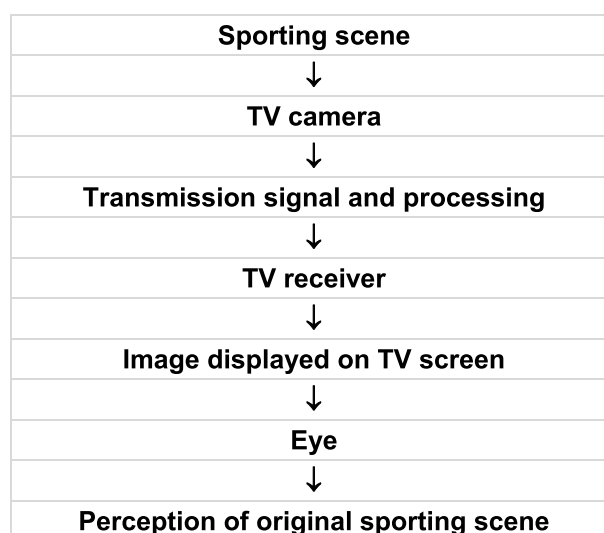


Figure 1 – The visual task pathway

1.2 The sporting scene

Sporting activities can be subdivided into outdoor and indoor sports. In both cases it is essential that the pictures captured by the array of cameras located around the playing area will detect, with suitable resolution, details of the participants in the sport together with any associated playing equipment – ball, javelin for example, which may vary in size. The speed of action is also an important factor when considering the television requirements for broadcasting. A faster moving projectile, examples of which include footballs, golf balls, etc., will require more light to be able to see both the object and its trajectory compared with slower moving items. Similarly, the size of the projectile will be an important factor when deciding on lighting requirements since a smaller object is clearly more difficult to see under the same lighting conditions. Contrast of the projectile against the background is also important.

Additional information that needs to be factored into calculations at the planning stage of outdoor events is the likelihood of the action taking place:

- during the hours of darkness;
- starting in daylight and then including the transition between daylight and darkness.

When the sporting action moves quickly along the direction of view, the camera lens system must have a sufficiently large depth of field – the term used to indicate the range of distance over which objects stay in focus. This subsequently places a requirement for a small lens aperture and proportionately higher light levels in order to provide suitable balance.

The apparent size of an object is influenced by the distance between the object and the camera – referred to as the ‘pick-up distance’. When a telephoto – or zoom lens – is used to increase the apparent size of an object or participant, there is a corresponding requirement for greater lighting levels since the greater the focal length of the zoom lens the smaller the available aperture.

The speed of a sporting scene being televised is dependent upon the movement of projectiles and participants within the scene, and also by the relative movements of the camera(s), e.g. panning (side-to-side), tilt (up and/or down), zooming in and out, or rotating. Television producers and directors strive to enhance their coverage of sporting scenes with new and novel viewing angles with the ultimate aim of bringing television viewers the illusion of actually being present at the event in person. The television production style significantly dictates the lighting requirements. To capture the image as intended by the producer, there is an increasing emphasis on the incorporation of imaginative and conceptually creative lighting techniques.

1.3 The television camera

The characteristics of cameras are essential when considering the broadcasting of sports events. State-of-the-art camera technology allows viewers to experience a multitude of different aspects of sports events. Viewers of sports broadcasts have the opportunity to see the game from many angles around the stadium, arena or playing area and, in addition, from the player's point-of-view. Historically dedicated types of cameras have been developed with the intention of providing the best possible coverage of particular sports events. For example, robotic cameras, typically automatic or remotely controlled, are used to be able to broadcast many live sports events seen from many different angles.

Cameras incorporating solid state CCD (charge-coupled device) imagers were introduced in the mid-1980s. They became an almost instant success primarily because when compared with cameras that relied on cathode ray tubes:

- they had greater stability;
- they were less likely to drift;
- they didn't require a warm-up or calibration time prior to use;
- they were not prone to image burn-in or lag caused by very bright light sources in the frame.

Professional video cameras typically incorporate an optical prism block directly behind the lens. This prism block, is a trichroic assembly, typically consisting of two dichroic prisms – that separates the image captured into the three RGB (red, green, and blue) primary colours. The trichroic assembly directs each colour into a separate charge-coupled device (CCD) or active pixel sensor (complementary metal oxide semiconductor or CMOS image sensor) which is mounted to the face of each prism. An active-pixel sensor (APS) is an image sensor that consists of an integrated circuit that includes an array of pixel sensors. Each pixel typically contains a photo detector and an active amplifier.

The comparatively weak signal created by the sensors is subsequently amplified before being encoded into analogue signals for use by the viewfinder and monitor outputs. It is also encoded into digital signals for onward transmission.

Electronic Field Production (EFP) cameras are versatile and can be shoulder-mounted which makes them ideal for use by the 'mobile' cameraman positioned on the side of the playing area. They typically have long focal length zoom lenses, but do not have an intrinsic recording facility usually transmitting their signals back to the broadcast truck. Remote cameras are typically very small camera heads designed to be operated by remote control and are finding increasing uses in the televising of sport.

Super-slow-motion (Super-Slo-Mo; SSM) cameras operate at a frame rate of 75 frames per second compared with 25 frames per second for standard Phase Alternating Line (PAL) cameras. As a result, the sensitivity of the SSM camera is lower by 2 f-stops compared to standard cameras, the f-number being the ratio of focal length to aperture opening. A minimum vertical illuminance of typically 1 400 lx towards SSM camera positions is critical for acceptable performance. Flicker can be a problem with light sources (including light emitting diodes (LEDs)). This is discussed in detail in 2.4.

The development of specialized television cameras including the robot cameras and point-of-view (POV) cameras has led to additional facilities for television production teams to enhance the quality of their programmes. Aerial shots often employ helicopters with gyrostabilized cameras, 2D and 3D cablecam systems and (increasingly) drones.

NOTE 'fps' is an abbreviation for 'frames per second' but can be confused with 'fields per second'. This document uses the former when referring to camera speed.

1.4 Signal transmission

Communications satellites located in geostationary orbit about the Earth are used to transmit television signals directly to the homes of viewers using a form of signal transmission referred to as direct broadcast satellite (DBS) television. The end user receives data from a high-frequency satellite in geosynchronous orbit (GEO).

The term 'geosynchronous' refers to the satellite's orbital period being exactly one sidereal day, i.e. it has an orbital period equal to the Earth's rotation. For a satellite to also be 'geostationary' it must be placed in an orbit that puts it in the vicinity over the equator. These two in combination make the satellite appear in a constant area of visibility when viewed from the surface of the Earth thereby enabling continuous operation from one point on the ground. The special case of a geostationary orbit is the most common type of orbit for communications satellites.

A geostationary orbit is a circular orbit approaching 36 000 km above the Earth's equator. Communications satellites use geostationary orbits, so that the satellite antennae that receive the television signals do not have to constantly move to track the satellites, but can be pointed permanently at the position in the sky where they appear to be stationary.

Transmission occurs in the *Ku band* which is a portion of the electromagnetic spectrum in the microwave range of frequencies. *Ku band* is primarily used for satellite communications at

frequencies of approximately 12 GHz. At these frequencies the receiving antenna is a small dish-shaped assembly, typically 46 cm in diameter.

Digital television has expanded the scope of broadcasting that, when considering the televising of sports events, allows viewers to experience greater in-depth game effects together with improved screen and sound quality. Most cable television programmes are distributed over communication satellites.

The basic recommendations for sports lighting are given in this document whereas CIE 169:2005 (CIE, 2005a) gives practical advice to architects, consultants and lighting designers on the realization of good quality installations for sports lighting for colour television and filming.

2 Camera technology

2.1 Introduction

This clause is intended to provide the lighting designer with a general overview of camera technology. Modern television cameras utilize electronic light sensors which produce an output directly proportional to the light they receive.

2.2 CCDs and CMOS active pixel image sensor technology

CCDs (Charged Coupled Devices) were used extensively in earlier broadcast cameras. However, there are many advantages of CMOS (Complementary Metal Oxide Semiconductor) imagers compared with CCD, including higher resolution, higher frame rates and no 'smear' under extreme lighting conditions. The CCD can show unwanted smear as a vertical stripe above and below the highlight. CMOS imagers do not show any highlight smear.

Rolling shutters used in TV cameras allow image sensors to continue to gather photons during the acquisition process. This effectively increases sensitivity and is found on many digital still and video cameras using CMOS sensors. The effect is most noticeable when imaging extreme conditions of motion, e.g. sporting action. While some CMOS sensors use a global shutter, the majority found in the consumer market utilize a rolling shutter.

2.3 Slow-motion, super-slow-motion and ultra-slow-motion cameras

Originally slow-motion replay clips were accomplished with a normal speed camera recording which was then slowed down during the replay. The resultant image was often blurred and jerky.

The first generation slow-motion camera was a standard (live) broadcast camera that captured the motion three times faster than the standard 25 fps or 30 fps in National System Television Committee (NTSC) countries. NTSC is the video system or standard used in North America and most of South America.

The action is therefore captured on separate images at three times the normal speed. When played back at normal speed, the effect is to create smooth slow motion without blur or jerkiness. The pictures have the same quality as a standard speed camera. However, as super-slow-motion footage is based on an increased number of frames per second, this inevitably means that the lighting levels need to be increased for the same quality image.

This type of broadcast SSM type camera is able to equally operate at (1×), (2×), (3×) and (6×) speeds. Advances in television technology has seen the development of cameras, derived from the military environment, where the action is recorded at very high speeds (up to 100 000 fps but practical HD broadcast limits of 1 000 fps) and then played back when required. This ultra-slow-motion (USM) camera is not a 'live' camera and is only used for replays. There is also a broadcast camera that can be used as a live camera as well as a slow motion-replay camera with speeds of up to 1 000 fps.

2.4 Effects of replaying super-slow-motion footage showing cyclic variation in electrical supply – flicker

One of the biggest challenges of using SSM cameras is the so-called mains flicker. Historically, almost every major or large sports venue uses or has used high intensity gas discharge (HID) lamps operated on AC mains frequency (50 Hz/60 Hz). The double speed camera does not have a problem because the frame rate is an exact multiple of the mains power frequency. The triple speed camera and faster cameras do however have a problem with mains flicker.

A well balanced single-phase lamp/luminaire/ballast lighting system on a three-phase power system can alleviate the problem for the (3×) SSM camera but not entirely eliminate it. Three single-phase luminaires with the same beam distribution each on a different phase aimed at the same point is, theoretically, the best that could be achieved – although in reality a significant pragmatic challenge.

Cross aiming and balancing the aiming across the three phases can produce reasonable results for the 3× cameras, but the issue becomes increasingly a problem for the ultra-slow-motion cameras – irrespective of the increased need for additional illuminance as the pictures become unstable.

The flicker issue is more noticeable in relatively smaller fields of play – e.g. basketball, tennis, etc., compared with the larger stadiums, e.g. athletics, football. The larger arenas benefit from the inherently larger number of luminaires involved – usually mounted at varying distances and heights from the field of play (FOP) – and the increased effect from inter-reflections and the greater number of luminaires aimed within the same vicinity (on different phases) due to the increased distances involved.

2.5 Apparent luminance of sporting scene on television compared with actual scene

The human eye can distinguish a vast range of luminance levels. In comparison, the television camera and the TV receiver covers a very much smaller range.

The term used to describe this phenomenon is called "dynamic range". In older TV systems, this problem was exemplified with the classic shot of a football being kicked from bright daylight into the stadium shadow. The current dynamic range of television images is vastly improved, though still lower than that experienced by the human eye in the real world. New technology is continuously improving and addressing those limitations, expanding the ratio between the lightest and darkest parts of the video image.

Standard definition digital equipment had a slight improvement over analogue, but the HD cameras and HDTV screens are integrating technology known as high dynamic range (HDR) – almost doubling the luminance steps range.

Particularly suitable to sports broadcasts, HDR is significantly different because it alters the picture. Blacks appear deeper, whites whiter and in general colours more vibrant and objects more defined. Hues are more pronounced between warm and cool tones in the same picture image. HDR allows for a more vivid and natural looking image bringing pictures closer to what the human eye sees.

The need for HDR is vital to ultra-high-definition (UHD) 4K television systems. Higher resolution is not enough, nor is increased frame rates – the desire for more natural looking images is equally important.