FEDERATION INTERNATIONALE DE L'AUTOMOBILE

CIRCUIT FLOODLIGHTING GUIDELINES

INTERNAL GUIDELINES FOR CIRCUIT FLOODLIGHTING CONSTRUCTION & SAFETY

FIA PERFORMANCE SPECIFICATION

Motor racing circuit floodlighting for competition vehicles without headlights

A study by the Circuits Commission
EDITION 2 – March 2020

DISCLAIMER

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CONTENTS

1. SCOPE

This document considers the power supply and structural elements required to physically carry the lights, as well as lighting levels and verification procedures as part of the lighting system.

A glossary of terms as used in the various articles of these FIA Circuit Lighting Guidelines is to be found in *Appendix A: Definitions and Recommended Principles*.

2. OBJECTIVE

The primary aim of this document is to provide a guide for the design, approval, and verification of lighting systems that meet the performance criteria to deliver a quality of illumination of motor racing circuits necessary for drivers, officials and marshals to perform their tasks in a safe environment.

The secondary aim of this document is to provide a guide for the design, approval, and verification of lighting systems that meet the performance criteria to deliver the required level and quality of illumination on a motor racing circuit for high quality television broadcast.

3. RISKS

In general sport lighting practice, it is assumed that, once sufficient provision has been made for the visual needs of spectators and or broadcast television, the lighting will also meet the participant's requirements. However, the risks associated with lighting for participants and officials in motor sport are such as to claim priority over the spectator and or television lighting requirements.

The mitigation of the fundamental risks to the participants forms the core of this specification. However due to the high-performance targets set in this document, the resultant visual conditions for spectators and broadcast television cameras would be superior than those required in more typical sport lighting specifications.

The main concerns are:

- Dazzling of participants
- Insufficient and or poorly distributed light
- Poor TV image quality
- System & component failure
- Accidents
- Interference
- Logistics
- Weather

4. PRIORITIES

The performance targets in this document are set to produce a safety driven lighting system design outcome based on the following fundamental principles in order of priority:

- Minimize the risk of damage or injury to participants, officials and the public.
- Minimize the risk of dazzling or disorientation of a driver.
- Minimize the risk of causing effective darkness on all or part of the track during a race due to a failure of some part of the lighting system or by a reasonably foreseeable event on the circuit.
- Provide the quantity and quality of lighting required by drivers and officials to make consistently accurate visual judgments under the dynamic conditions of motor sport regarding the condition of the circuit and the position, speed and direction of the cars.

5. LIGHTING EQUIPMENT SPECIFICATION

In addition to the normal safety procedures associated with large lighting systems in public places, it is vital to ensure that the lighting system does not introduce new impact risks to competitors.

The design must minimize the possibility that competitors might come into contact with the mechanical and electrical equipment in the lighting system, its supporting structures or the power supply during an accident.

Standard electrical, structural and mechanical regulations and good practice are considered as the minimum required for any competently designed system. The installation must legally comply with such safety regulations as are in force at the location.

5.1. Electrical

- All electrical equipment, cables and controls should be physically located where they cannot come into direct contact with an out of control vehicle, or debris caused by an accident.
- Where it is impossible to locate the equipment as specified in the above, additional passive physical barrier safety measures must be provided to deliver the same protection.
- All electrical equipment must be designed and located so that it does not impede operational safety of the race officials, marshals, media and other support staff.
- All electrical equipment must be located out of reach of the public.
- Circuits and connectors must be designed so that exposure to live electrical equipment will not occur in case of the accidental detachment of exposed elements of the system.

5.2. Mechanical & Structural

- All equipment must be designed and located to operate safely in normal contact with the race officials, marshals, media and other support staff.
- The equipment must remain safe after damage by an accident to allow operational safety of the race officials, marshals, media and other support staff.
- Where it is foreseeable that a car or parts of it could contact the lighting equipment, it must be designed to minimize the possibility of elements falling on the track or any occupied areas.

5.3. Thermal

- The equipment must be designed to ensure that all elements exposed to normal contact with the race officials, marshals, media and other support staff remain sufficiently cool not to cause harm to exposed skin contact.
- Components that operate at elevated temperatures must be protected from contact by suitable enclosures, where forced ventilation is used the system must include at least one level of redundancy.
- Equipment outside normal contact must be clearly marked with warning labels.

5.4. Materials

- All lighting equipment, cables and controls should be produced from materials that will not introduce new fire or pollution risks in case of an accident.
- The materials must be able to withstand exposure to race fuel, fire suppression and cleaning chemicals with no reduction in the safety of the equipment.
- Insulation materials must not produce any toxic smoke and must be flame retardant.

5.5. Colour

- The CRI of the lighting system should be > 90 to allow accurate and consistent recognition of colour. This is not only important for the race control cameras but also for emergency medical staff and TV broadcasting (some broadcasters do accept CRI of 80, but it is generally deemed insufficient for High Definition broadcast requirements).
- The CCT of all the lamps in the lighting system should not vary by more than 200 K from the nominal value: this ensures consistent colours from all cameras.
- The nominal CCT for lighting system of venues that host a race that starts in late afternoon and continues into darkness is preferably 4000 K – 5000 K; where races are run only under artificial lighting 6000 K is preferred.

5.6. Location & Aiming

The lighting equipment should be designed to allow accurate and repeatable adjustment of orientation to occur, to ensure that the system meets the specification requirements in Section 7 (Lighting Specification), within a tolerance of ± 10 % at all times.

5.7. Operation, Control & Procedures

- Clear and comprehensive manuals should be established for the installation and operation of the structural, lighting, electrical, control and communication equipment under normal and emergency conditions.
- The necessary documentation must be made available and the systems tested and demonstrated to the satisfaction of the relevant approval authority before an event is held.
- The effects of dust, fog, rain, snow, pollution and any other atmospheric effects on light transmission can be significant but are dynamic by nature and it is thus hard to make specific allowances; race officials will apply existing practice relating to acceptable visibility.

5.8. Maintenance Requirements

- The equipment must be designed to allow immediate safe repair to ensure that an accident in one race does not affect the lighting to following events on the same day.
- If a lighting installation is installed for a significant period or permanently it is important to make design allowances for the effect of dirt, lamp degradation and other factors that will diminish the light output over time. The performance of the lighting system after allowance for these factors is the "maintained illuminance".

6. ELECTRICAL POWER SUPPLY

Specific measures are required to ensure that the system will remain safe and continue to operate normally under most reasonably foreseeable race conditions, and some level of lighting will be delivered under abnormal conditions.

6.1. Damage and insulation

The design must demonstrate proof against current leakage and lighting interruption from foreseeable damage, or measures to prevent damage under at least the following conditions:

- Support vehicles crossing cable ways
- Damage to lighting equipment by an on-track accident
- Water exposure from heavy rains or fire-fighting equipment
- Minor impacts with generating equipment and lighting support structures caused by service vehicles for example

6.2. Redundancy

- At least two power sources each with capacity to carry the full load connected to each circuit must be available.
- Change-over of supplies under full load without interruption of the lighting during the loss of one supply must be demonstrated.
- The cabling system to the lights must be redundant and allow the removal and replacement of one supply cable in a circuit without interruption of the lighting in that circuit to be demonstrated.
- The lighting system must be designed so that the loss of any one light source (lamp/globe) will not cause the illumination on the section of track serviced by it to be affected by more than 15% *(E ave)*.
- The lighting system must be designed so that the loss of any section of dual supply cable or power supply point will not cause the illumination on the section of track serviced by it to be affected by more than 50% *(E ave).*
- The system must include fail-safe back up lighting capable of immediately delivering not less than 15% of the normal *Eh ave* on the track for 30 minutes if the main system fails catastrophically.

6.3. Voltage regulation

The power supply voltages must be regulated to ensure the lighting system meets the local governing specifications.

7. LIGHTING SPECIFICATION

7.1. Illumination levels (*E ave*) – Recommended [Lux]

Average illumination level (maintained)	Track	Pit lane	Garages (if TV)	Track including 2 m shoulder each side	Run-off area	Official area behind safety fence
Horizontal *Eh ave* (ground level)	1250	1250	800	800	500	250
Vertical *Ev ave* (0.7 m above ground level)	750	750	-	-	-	-
For High Definition TV						
Horizontal *Eh ave* (ground level)	1500	1500	1250	1250	1000	500
Vertical *Ev ave* (0.7 m above ground level)	1000	1000	-	1000	750	-
Vertical *Ev ave* (1.5 m above ground level)	750	-	750	-	-	-

Note 1: *Lighting in run-off areas and escape roads should be lower, such as to show that they are not part of the track.*
Note 2: *Particular attention should be paid to the illumination of high-speed braking areas.*
Note 3: *As a reference, these values are in line with a UEFA Level A Lighting standard.*

7.2. Lighting Distribution

The distribution and variance of light in the defined illuminated area is an important factor, contributing substantially to the ability to make accurate judgments of speed, and minimizing the need for adaptation changes.
Considering the speed at which participants must view and judge their environment uniformity of illumination may be considered more important than absolute illumination levels.
In general terms our eyes will adapt to the highest luminance in view – poor uniformity will then render some areas in practical darkness, regardless of actual light level.

- **Uniformity (U1)**

E min / E ave	• Track • Pit lane • Garages (if TV)	• Track including 2 m shoulder • Run-off area • Officials' area behind safety barrier
Horizontal (ground level)	0.5	0.4
Vertical (0.7 m above ground level)	0.5	0.3

- **Diversity (U2)**

E min / E max	• Track • Pit lane • Garages (if TV)	• Track including 2 m shoulder • Run-off area • Officials' area behind safety barrier
Horizontal (ground level)	0.5	0.3
Vertical (0.7 m above ground level)	0.3	0.3

7.3. Glare

Two categories of glare are defined in lighting engineering terms: discomfort glare and disability glare.

- **Discomfort glare**

Does not affect the observer's ability to see and it is not a safety risk – hence it is not considered further in this context.

- **Disability glare**

Is a significant safety risk due to its involuntary physiological nature: the loss of retinal image contrast as a result of intraocular light scatter from a source outside the current adaptation level. The impact of disability glare is prolonged because the eye takes a considerable time to re-adapt to the ambient light after the excessive light has passed.

Based on the key risks stated in Section 3, minimizing, and wherever possible elimination of disability glare is a design priority. Applying typical sports lighting glare criteria is not sufficient in this context. Glare rating can be assessed using the standard CIE 112-1994, obtaining a scale from 10 to 90. The lower the glare rating, the better the situation. A value below 50 is strongly advised.

To overcome the limitations of other specifications and standards this document limits the luminance of all objects in the drivers' field of view – managing the risk at origin. This approach also enables the regulators and operators to manage the impact of lights in locations outside the racing zone but visible to the participants.

Recommended maximum average luminance of any 1° cone field of view facing observer in the defined field of view:

Driver view	Position	Field of view	Max average luminance
In direction of racing	0.7 m above track on race line including pit lane.	± 30° horizontal and ± 30°vertical (Fig 1)	200 kcd/m^2
All other directions	0.7 m above track on race line including pit lane	± 150° horizontal and ± 30°vertical (Fig 1)	500 kcd/m^2

Note: *The luminance limitations should not only be applied for all track illuminating equipment, but also to secondary lighting in public areas since the disability glare impact on participants is the same regardless of origin.*

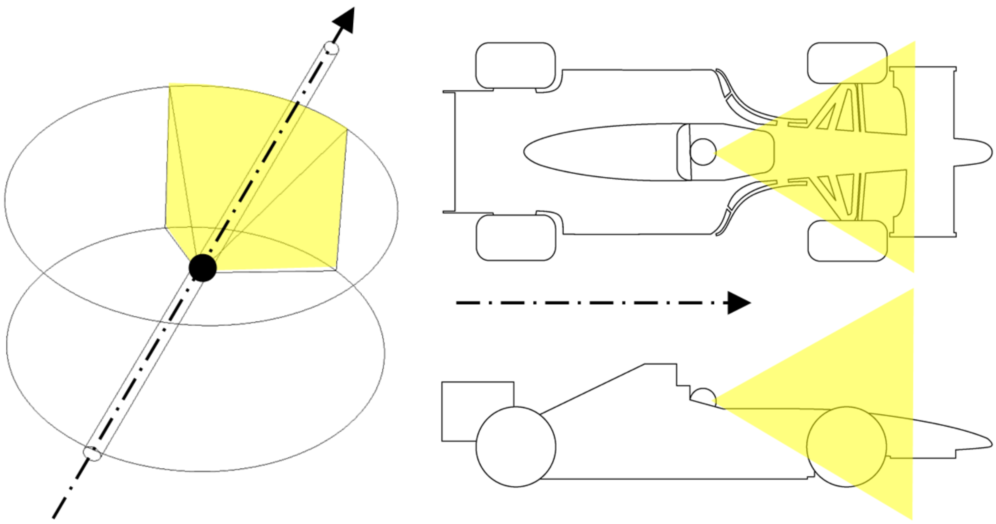

Figure 1 Driver Field of View (Arrow denotes Race Direction)

7.4. Stroboscopic effects

For TV filming purposes electrical power supply should ensure that adjacent lights illuminating the track are operated from different supply phases if the lighting system uses conventional control gear operating at supply frequency.

If high frequency "Flicker Free" electronic control gear is used this requirement is superfluous from a stroboscopic effect but remains good electrical engineering practice.

7.5. Flicker

Flicker is the effect of individual lights on the peripheral vision of drivers as they circulate around the circuit.

Flicker in the 5 Hz to 10 Hz range is disturbing and should be avoided, the effect is physiological and while it is possible to cope with flicker it will diminish visual acuity of the drivers. Lighting equipment should be spaced so that drivers will not experience flicker in the disturbing range over the full range of race speeds. This may require different light spacing around the track.

Example for light spaced 15 m apart

- Race speed 90 km/h → 25 m/s Flicker frequency = 1.7 Hz (<5 Hz)
  Spacing is OK

- Race speed 350 km/h → 97 m/s Flicker frequency = 6.5 Hz (5 Hz< & <10 Hz)
  Spacing is too close

In order to measure the flicker factor, the following formula is used:

$$FF(\%) = \frac{E_{max} - E_{min}}{E_{ave}} \cdot 100$$

A value below 10 % is strongly advised.

7.6. Shadows

- The lighting system should not cast solid shadows onto the track of either the track infrastructure or the participants on the track [Figure 2].
- The lighting system should ensure that the track and run-off area is not covered by a solid shadow if a competitor stops on the track [Figure 3].
- The lighting system should not cast long shadows across the track [Figure 4].
- To minimize the disturbing negative effects of shadows on competitors it is preferable to ensure that shadows falling across the track are short with the longer shadows along the racetrack [Figure 5].

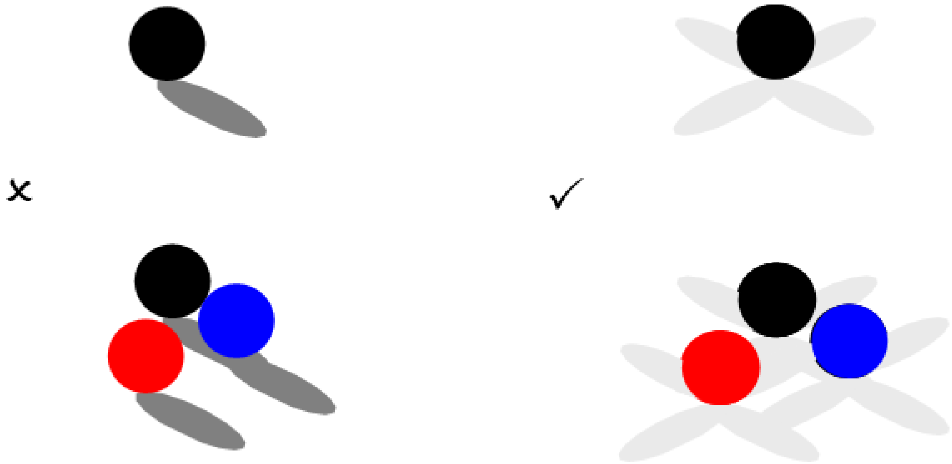

Figure 2

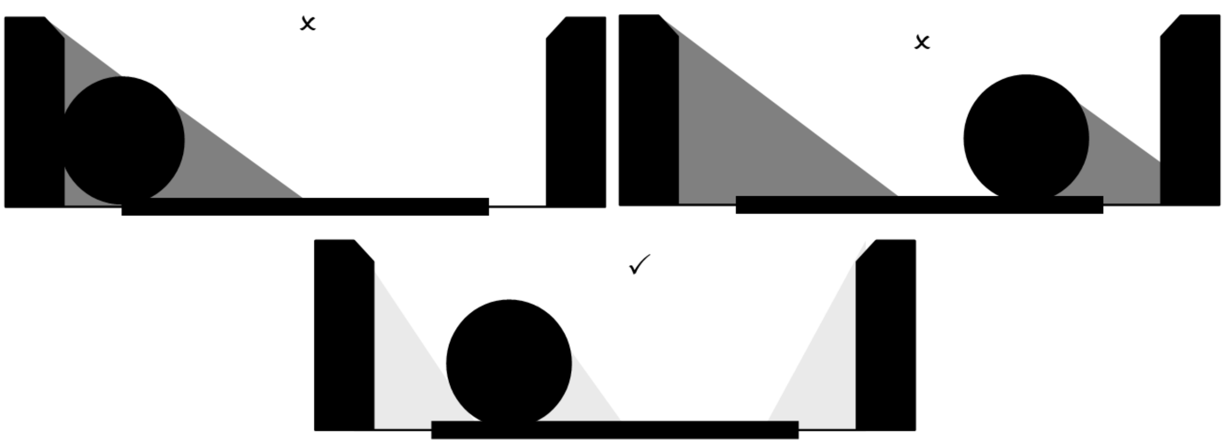

Figure 3

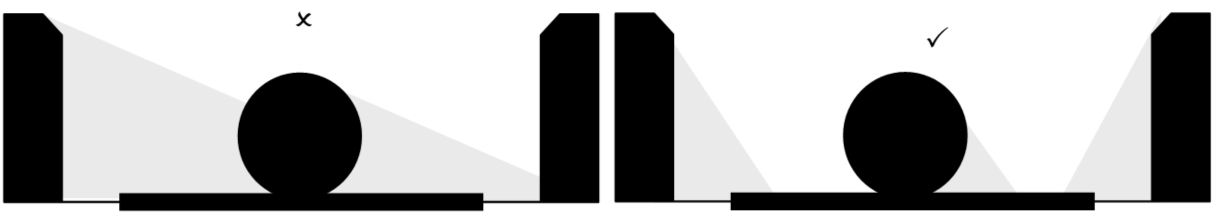

Figure 4

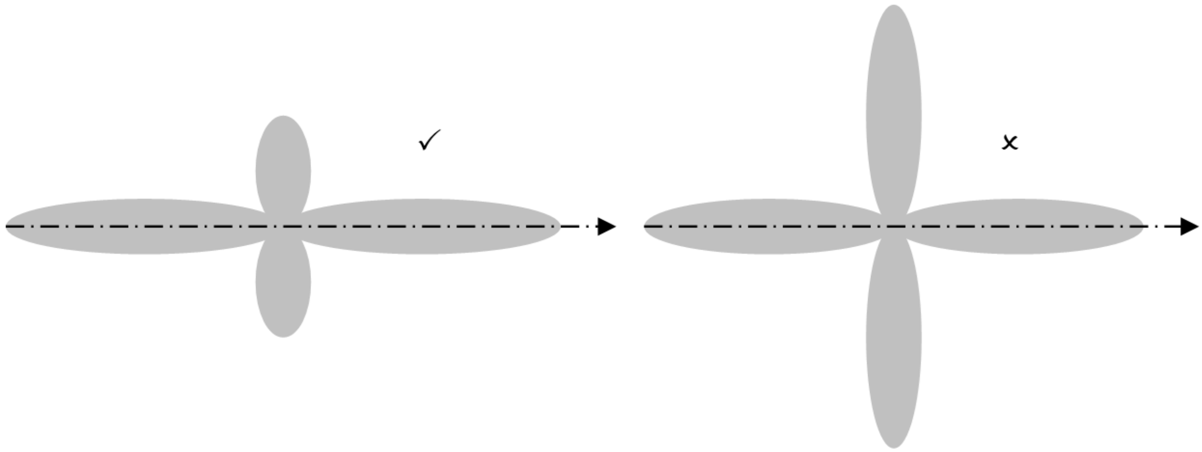

Figure 5

7.7. Spill light control

The illumination levels specified in section 7.1 apply to the track Area **A** and Area **B** where race officials and support staff operate [Figure 6].

The public area outside the safety fence Area **C** [Figure 6] is not covered by the section 7.1. Due to the high illumination levels specified in Areas **A** & **B** some light will spill into Area **C**.

The illumination in the 10 m closest to the safety fence Area **C** need not exceed 20% of the requirements for Area **B** (*Eh ave* of 100 lux).

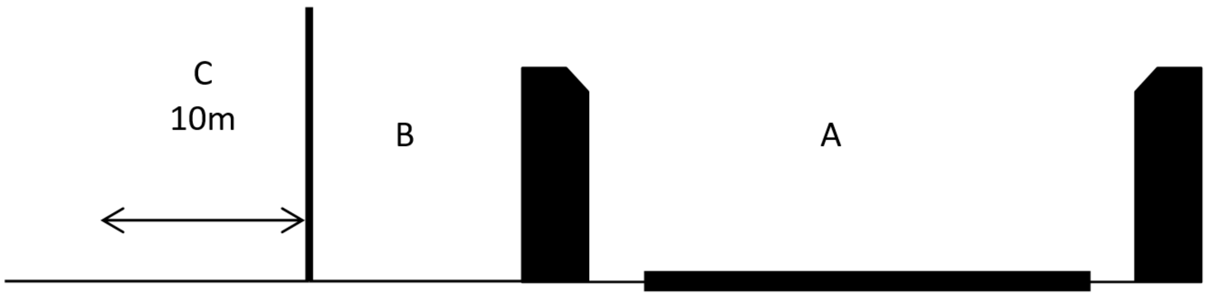

Figure 6

8. SYSTEM PERFORMANCE VERIFICATION

Due to the risks of injury in motor sport and the complex high-value contracts associated with broadcast rights, racetrack operators should be able to demonstrate compliance of the lighting system after the fact and under conditions of legal discovery.

Permanent and temporary installations should be capable of demonstrating and documenting the following:

- The supplied equipment conforms to the equipment specified in the design approved by the client.
- The equipment is installed as per the design approved by the client.
- The system met all the performance specifications approved by the client.
- Permanent installations should have the additional requirement to document repairs and maintenance carried out after commissioning to the same level.

Recommendations concerning contractual requirements and tools for verifying that systems perform in conformity with their specification are available from the FIA. Article 7.2.6 of EN 13201-3:2014 “Road Lighting- Part 3: Calculation of Performance” can be taken as a good practice for the measurement of lighting levels.

9. APPENDIX A: Definitions and Recommended Principles

- **Luminous Intensity [candela, cd]**

A finite amount of (light) radiation emitted in a finite cone surrounding the direction – for many practical applications the source is considered a point and the cone infinitely small, i.e. a simple direction.

- **Luminous Flux [lumen]**

The radiation of light into a 4π solid angle / sphere. Typically used to define the output of a light source or a luminaire.

- **Illuminance [lux = lumen/m²]**

The luminous flux per unit area falling on a surface is called the *illumination* or *illuminance* of the surface.

- **Horizontal illuminance (Eh)**

Illumination of an actual or imaginary plane/s parallel to the ground (this can become more complex in real life when the ground surface is rarely perfectly flat).

- **Vertical illuminance (Ev)**

Illumination on an actual or imaginary plane/s perpendicular to the ground. The plane may be orthogonal or facing a specific point like a camera or observer.

- **Luminance [cd/m²]**

Illuminated surfaces differ greatly in their response to incident light. A specular reflecting surface, such as that of a metal, reflects the light according to the laws of reflection and forming a distinct image while a diffuse surface scatters light into all directions. Most surfaces behave somewhere in between – and the relative specular behaviour changes with viewing angle. The combined effect of reflective type with surface colour determines on the incident light determines the actual luminance to the observer.

- **Modeling**

To make adequate depth and shape judgment of objects requires suitably supportive lighting that highlights the surface shape and texture, this largely subjective aspect is termed modeling.

- **Calculation grid**

Illuminance is normally calculated and measured for a grid of points of sufficient density to provide a suitably accurate representation for the task. It is possible to calculate *Eh* as well as *Ev* values (often multiple *Ev* values) for each grid point. Practical limitations generally impose more limits on the measurement grid density, and it is thus common practice to measure to lower grid densities than the design density.

- **Uniformity (U1)**

Uniformity is generally defined as *Emin / Eave* and a limit is specified, example: $U_1 \geq 0.7$; it is important to note that it must be used in context to a defined area and measurement grid to have any value. Changes in the grid density, origin, and area will make most likely comparisons meaningless.

- **Diversity (U2)**

Diversity is closely related to Uniformity is generally defined as *Emin / Emax* and a limit is specified, example: $U_2 \geq 0.5$; it is important to note that it must be used in context to a defined area and measurement grid to have any value. Changes in the grid density, origin, and area will make most likely comparisons meaningless.

- **Horizontal Illuminance uniformity in a defined grid**

Horizontal illuminance uniformity is important to avoid adjustment problems for both humans and cameras. It is important also that there is not too great a change in horizontal illuminance over a given distance.

- **Vertical illuminance uniformity in a defined grid facing a point**

Different vertical illuminance values across the circuit can be disturbing when tracking an object or panning a camera from a specific point, especially when covering rapid action sports.

- **Vertical illuminance at a grid point facing different points**

The uniformity of vertical illuminance at a single grid point over the four orthogonal planes facing the sides of the track should not exhibit large differences. Fulfilment of this requirement will ensure that the vertical planes facing an actual observer or camera position somewhere in that area or areas will have sufficiently high illuminance. It also enables multiple cameras to make shots of the same object / area that appear equally bright. Finally, the fulfilment of this requirement guarantees adequate modelling of the objects.

- **Relation between Horizontal and Vertical Illuminance**

As the illuminated area forms a major part of the field of view of the observer and camera alike, an adequate horizontal illuminance is important. A sufficiently good balance between the horizontal and vertical lighting levels is required for ensure good modeling and to ensure that the large top surface of cars appear to be of similar brightness as the vertical sides.

- **Colour temperature (CCT)**

In the case of outdoor installations with a significant daylight contribution, the colour temperature of the artificial lighting must minimise apparent colour changes in the scene when daylight is replaced progressively by artificial where floodlighting is used during the day and into dusk.
Colour temperature and colour rendering are connected in incandescent lamps, but these aspects are not related in discharge lamps. Colour temperature is normally quoted in degrees Kelvin (K) and stated as Correlated Colour Temperature (CCT) for discharge lamps.

- **Colour rendering (CRI)**

The colour-rendering index (CRI) of the lighting is the ability of the lamp to produce light of which its colour content allows accurate and consistent rendition of colour. In the present context it is important that the lighting system should ensure that the colour balance system of the camera minimises visual differences between direct viewing, day-light events and night-time viewing on television.
High quality colour rendering of artificial lighting has also been shown to reduce fatigue and improve response times in drivers and is thus a secondary contributor to safety.

- **Stroboscopic effects**

Discharge lamps switch on and off with each cycle of the electrical supply (50 Hz / 60 Hz) normally our visual system integrates the discrete light pulses into a continuous scene, but film and television cameras do not.

- **Flicker factor**

Refers to the amount of modulation of luminance during a complete cycle. It denotes the relationship between the maximum luminance value and the minimum luminance value over a full cycle and is expressed as a percentage.

10.APPENDIX B: Recommended Contractual Requirements & Performance Verification for Circuit Floodlighting Systems

10.1. Introduction

Due to the risk of injury in motor sport and the complex high value contracts associated with broadcast rights racetrack operators should be able to demonstrate compliance of the lighting system after the fact and under conditions of legal discovery.

10.2. Documentation

Operators of lighting installations should be capable of demonstrating and documenting the following:

- The supplied equipment conforms to the equipment specified in the design approved by the client.
- The equipment is installed as per the design approved by the client.
- The system meets all the performance specifications approved by the client (calculation and design grid: ≤ 1 m x 1 m).
- Permanent installations should document repairs and maintenance carried out after commissioning to the same level.

10.3. Tools

10.3.1. Lighting Measurement

- Lighting measurement tools must have current valid and traceable calibrations to ISO 23539:2005 at the time of measurement.
- Illuminance measurement at ground level must be carried out across the whole area of the track and run-off area
- Illuminance measurement & verification grid: 2 m x 2 m
- Luminance measurement to find the highest luminance source, every 5m on the racing line, with the source and location documented.
- Luminance measurements from all camera positions to find the highest luminance source in the specified camera coverage area, with the source and location documented.
- It is suggested that the measurement equipment is of the type that can record data electronically to eliminate manual transfer errors and reduce the workload.
- Key illumination level reference points should be established at several points on the circuit and monitored continuously. The data should be recorded and displayed in real time in the Operating Centre Room.

10.3.2. Electrical measurement

- Electrical measurement tools must have current valid traceable calibrations to IEC 17025:2005 at the time of measurement.
- Supply voltage and currents should be monitored continuously at each supply point, as well as key control points in the system. The data should be recorded and displayed in real time in the Operating Centre Room.

10.3.3. Geo spatial measurement

- The track and site must be measured to confirm it conforms to the design, and the location of the lighting equipment on the track must be verified to conform to the approved design.
- The location of lighting equipment on the track must be referenced to known points on the track and recorded.

10.3.4. Software requirements

Software tools used in the design and verification must be secure and approved to ensure data integrity is maintained.

10.3.5. Data management and security

The performance verification data must be downloaded into an agreed format for storage, and if required the associated software to access the same complete with operating manuals. The supplier as well as the circuit operator should make provision to archive the data in a secure environment for 5 years from last date of use.

10.4. Process

10.4.1. Tolerance & uncertainty agreements

All measurements and goods are subject to tolerances. Unless otherwise agreed the basic allowed tolerances are:

- All approved construction drawings must include tolerances.
- Deviation from approved design illuminance ± 10 %
- Deviation from approved design luminance ± 20 %
- Track & associated infrastructure location variation from design must be approved by the client.
- Lighting equipment location variation from design must be approved by the client.

10.4.2. Design verification against performance specification

- The circuit operator and supplier must submit supporting documents for approval, demonstrating compliance of the lighting system design to the performance specification.
- Computer calculations of the lighting system performance using CIE 171:2006 approved software would be considered an absolute minimum.
- Additional physical data and or demonstrations may be required to demonstrate compliance.

10.4.3. Installation verification against design specification

- This verification should be made prior to a race or at the request of the client.
- The circuit operator must submit supporting documents for approval demonstrating compliance of the system as installed to the approved design.
- Physical measurements as per section 3 are a mandatory component of the submission.

10.4.4. Installed performance verification against design specification

In general, the process described in section 4.2 and 4.3 ensures that the installed system meets the performance specification.

NB: Additional requirements specific to each circuit may be required.