Outdoor Workplace Lighting according to CIE S 015:2005 / prEN 12464-2

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Standardisation Bodies and Lighting Societies
The current seven CIE Divisions (2006)

- Div. I Vision & Colour
- Div. II Physical Measurement of Light and Radiation
- Div. III Interior Environment and Lighting Design
- Div. IV Lighting and Signalling for Transport
- Div. V Exterior and other Lighting Applications
- Div. VI Photo-biology and Photo-chemistry
- Div. VIII Image Technology

CEN TC 169 Light and Lighting (2006)

- WG1 Basic Terms and Criteria (EN 12665)
- **WG2 Lighting of Work Places (EN 12464)**
- WG3 Emergency Lighting (EN 1838)
- WG4 Sports Lighting (EN 12193)
- WG5 Road Lighting (EN 13201)
- WG6 Tunnel Lighting (CR 14380)
- WG7 Photometry (EN 13032)
- WG8 Photobiology (EN 14255)
- WG9 Energy Performance of Buildings - Energy Requirements for Lighting (EN 14193)
Relevant CIE Publications for CIE S 015:2005

- CIE 112-1994 Glare Evaluation System for Use within Outdoor Sports and Area Lighting
- CIE 115-1995 Recommendations for the Lighting of Roads for Motor and Pedestrian Traffic
- CIE 140-2000 Road Lighting Calculations
- CIE 150-2003 Guide on the Limitations of the Effects of Obtrusive Light from Outdoor Lighting Installations
- CIE 154-2003 Maintenance of Outdoor Lighting Systems


- A.F.E. „Recommandations relatives à l´éclairage des voies publiques“
- CIBSE LG6 „The Outdoor Environment“
- DIN 5035 „Beleuchtung mit künstlichem Licht“
- ICAO „International Standards and Recommended Practices Aerodromes“
- DB 954.9103 „Beleuchtungsanlagen im gleisnahen und/oder sicherheitsrelevanten Bereich“

etc.
**Lighting Design Criteria (CIE S 015:2005)**

- Luminance distribution (description only)
- Illuminance levels (maintained values), uniformities, and diversities (for task areas and surroundings)
- Limitation of glare (for train drivers and passengers)
- Directionality of light (description only)
- Colour appearance and colour rendering
- Avoidance of flicker and stroboscopic effects (description only)
- Limitation of obtrusive light

**Illuminances, CIE S 015:2005 (I)**

- All values of illuminances in this standard are **maintained illuminances** over the task area on the reference surface which may be horizontal, vertical or inclined.
- The **task area** is defined as the partial area in the work place in which the visual task is carried out.
- For places where size and/or location of the task area are **unknown**, the area where the task **may occur** is the task area.
Illuminances, CIE S 015:2005 (II)

- The maintained illuminance of the **surrounding area** shall be related to the maintained illuminance of the task area and should provide a well-balanced luminance distribution in the field of view.

- The surrounding area is regarded as a **strip surrounding the task area in the field of view**; the width of this strip should be at least **2 m**.

<table>
<thead>
<tr>
<th>Task illuminance</th>
<th>Illuminance of surrounding areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 500 lx</td>
<td>100 lx</td>
</tr>
<tr>
<td>300 lx</td>
<td>75 lx</td>
</tr>
<tr>
<td>200 lx</td>
<td>50 lx</td>
</tr>
<tr>
<td>150 lx</td>
<td>30 lx</td>
</tr>
<tr>
<td>50 lx ≤ E_m ≤ 100 lx</td>
<td>20 lx</td>
</tr>
<tr>
<td>&lt; 50 lx</td>
<td>no specification</td>
</tr>
</tbody>
</table>

Surrounding area is a strip surrounding the task area **within the field of view**; this strip should have a width of at least **2 m**.
Uniformity and Diversity (CIE S 015:2005)

- Illuminance uniformity $U_o$ is defined as the ratio of minimum to average illuminance on a surface.
- The uniformity of the task area shall not be less than the values given in table 5 of CIE S 015:2005, the uniformity of the surroundings shall not be less than 0.10.
- Illuminance diversity $U_d$ is defined as the ratio of minimum to maximum illuminance on a surface.
- The diversity is an important quality criterion for railway lighting, and shall not be less than the values specified in table 5 of CIE S 015:2005.

Illuminance Grid Size (CIE S 015:2005)

Maximum grid size (A. Stockmar):

$$p = 0.2 \cdot 5 \log d$$

$p$ ... grid cell size (m), $p_{\text{max}} = 10$ m
$d$ ... longer dimension of area (m) if the ratio of the longer to the shorter side is less than 2, otherwise
$d$ ... shorter dimension of area (m)
Illuminance Grid Size (CIE S 015:2005)

Illuminance grid size as function of area dimension,
example: $d = 48 \text{ m}$, $p = 3 \text{ m}$, $n = 16$

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Maintained Illuminance - Maintenance Factor,
CIE S 015:2005 (I)

- The maintained illuminance is defined as the value below which the illuminance on a specified surface is not allowed to fall.

- The lighting scheme should be designed with a maintenance factor calculated for the selected lighting equipment, space environment and specified maintenance schedule.

- The maintenance factor depends on the maintenance characteristics of the lamp and control gear, the luminaire, the environment and the maintenance programme.
Maintained Illuminance - Maintenance Factor, CIE S 015:2005 (II)

According to CIE Publication 154-2003 „The Maintenance of Outdoor Lighting Systems“

The **maintenance factor** is defined as the ratio of the luminance / illuminance produced by the lighting system after a certain period to the luminance / illuminance produced by the same system when new.

Determination of Maintenance Factor (I)

\[ MF = LLMF \cdot LSF \cdot LMF (\cdot SMF) \]

**MF** .......... **Maintenance Factor**

**LLMF** ..... **Lamp Lumen Maintenance Factor**

**LSF** ....... **Lamp Survival Factor**

**LMF** ........ **Luminaire Maintenance Factor**

**SMF** ........ **Surface Maintenance Factor**
Determination of Maintenance Factor (II)

Influencing factors (positive)

- Application of lamps with modest luminous flux depreciation (dependent on hours of operation)
- Application of luminaires with modest tendency to accumulate dirt
- (Application of electronic control gear)
- (Few annual lamp operating hours)
- Few switching cycles
- Short cleaning and/or maintenance periods, spot and group replacement of lamps
- Clean environment (airborne dirt)
- Modest tendency to accumulate dirt and/or modest degradation of reflecting surfaces

Determination of Maintenance Factor (III)

Influencing factors (negative)

- Application of lamps with high luminous flux depreciation (dependent on hours of operation)
- Application of luminaires with strong tendency to accumulate dirt
- Application of poor quality control gear
- Many annual lamp operating hours
- (Numerous switching cycles)
- Long cleaning and/or maintenance periods, group replacement of lamps only
- Polluted environment (airborne dirt)
- Strong tendency to accumulate dirt and/or high degradation of reflecting surfaces
**Colour Appearance and Colour Rendering, CIE S 015:2005 (I)**

<table>
<thead>
<tr>
<th>Colour appearance</th>
<th>Correlated colour temperature $T_{cp}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm</td>
<td>below 3300 K</td>
</tr>
<tr>
<td>Intermediate</td>
<td>3300 K to 5300 K</td>
</tr>
<tr>
<td>Cool</td>
<td>above 5300 K</td>
</tr>
</tbody>
</table>

Minimum values of the **general colour rendering index** for distinct areas, tasks or activities are given in the schedule of lighting requirements (e.g. $R_a \geq 20$, also $\geq 40$ or $\geq 60$)

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**Colour Appearance and Colour Rendering, CIE S 015:2005 (II)**

CIE test colours for the evaluation of the general colour rendering index $R_a$ (1-8) and the special colour rendering indices (8-14)
CIE Glare Rating Method (I)

Calculation formula according to CIE 112-1994 „Glare Evaluation System for Use within Outdoor Sports and Area Lighting“:

\[ GR = 27 + 24 \cdot \log \left( \frac{L_{vl}}{L_{ve}^{0.9}} \right) \]

- \( L_{vl} \) ... Veiling luminance caused by the lighting installation
- \( L_{ve} \) ... Equivalent veiling luminance of the environment

CIE Glare Rating Method (II)

Observers at grid positions at 45° intervals radially about the grid points (CIE S015:2005)
CIE Glare Rating Method (III)

Application dependent observer positions and viewing directions every 15° from -30° to +30°:
1) roof of covered platform, 2) open platform

Limitation of Obtrusive Light, Definitions as given in CIE 150:2003

- **Obtrusive Light**: Light, outside the area to be lit, which, because of quantitative, directional or spectral attributes in a given context, gives rise to annoyance, discomfort, distraction or a reduction in the ability to see essential information.

- **Curfew**: The time after which stricter requirements (for the control of obtrusive light) will apply; often a condition of use of lighting applied by a government controlling authority, e.g. the local government.
Limitation of Obtrusive Light, Environmental Lighting Zones

<table>
<thead>
<tr>
<th>Zone</th>
<th>Surrounding</th>
<th>Lighting Environment</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>Natural</td>
<td>Intrinsically dark</td>
<td>National parks, protected sides</td>
</tr>
<tr>
<td>E2</td>
<td>Rural</td>
<td>Low district brightness</td>
<td>Industrial or residential rural areas</td>
</tr>
<tr>
<td>E3</td>
<td>Suburban</td>
<td>Medium district brightness</td>
<td>Industrial or residential suburbs</td>
</tr>
<tr>
<td>E4</td>
<td>Urban</td>
<td>High district brightness</td>
<td>Town centres, commercial areas</td>
</tr>
</tbody>
</table>

Problem: Which zone is to be applied if location of interest for the assessment differs from zone where the lighting is installed?

Limits of Obtrusive Light for Outdoor Lighting, CIE S 015:2005

- Maximum vertical illuminance ($E_v$) on properties (for pre- and post-curfew hours)
- Maximum luminous intensities of individual light sources into potentially obtrusive directions (for pre- and post-curfew hours)
- Maximum upward light ratios (ULR)
- Maximum average luminances of building facades ($L_b$) and signs ($L_s$)
- Maximum threshold increments (TI) for users of nearby roads
## CIE 150:2003 Methodology (I), Maximum Obtrusive Light permitted

<table>
<thead>
<tr>
<th>Zone</th>
<th>Illuminance on Properties $E_v$ in lx</th>
<th>Luminaire Intensity $I$ in cd</th>
<th>Upward Light Ratio ULR in %</th>
<th>Luminance $L_b$ in cd/m²</th>
<th>$L_s$ in cd/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-curfew</td>
<td>Post-curfew</td>
<td>Pre-curfew</td>
<td>Post-curfew</td>
<td>Building facade</td>
</tr>
<tr>
<td>E1</td>
<td>2</td>
<td>0</td>
<td>2500</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>E2</td>
<td>5</td>
<td>1</td>
<td>7500</td>
<td>500</td>
<td>5</td>
</tr>
<tr>
<td>E3</td>
<td>10</td>
<td>2</td>
<td>10000</td>
<td>1000</td>
<td>15</td>
</tr>
<tr>
<td>E4</td>
<td>25</td>
<td>5</td>
<td>25000</td>
<td>2500</td>
<td>25</td>
</tr>
</tbody>
</table>

Problem: Values are given for the *summation* of all contributing lighting installations. How to apply these values if lighting systems are installed *one after each other*?

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## CIE 150:2003 Methodology (II), Maximum Values of Threshold Increments

<table>
<thead>
<tr>
<th>Road classification</th>
<th>No road lighting</th>
<th>M5</th>
<th>M4/M3</th>
<th>M2/M1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Threshold increment (TI)</strong></td>
<td>15% based on adaptation luminance of 0.1 cd/m²</td>
<td>15% based on adaptation luminance of 1.0 cd/m²</td>
<td>15% based on adaptation luminance of 2.0 cd/m²</td>
<td>15% based on adaptation luminance of 5.0 cd/m²</td>
</tr>
</tbody>
</table>

Problems: Road classification is not in line with EN 13201-2. Lighting installations could increase veiling luminance at the observer's eye without necessarily increasing the average luminance in the field of view.
- General circulation areas at outdoor workplaces
- Airports
- Building sites
- Canals, locks and harbours
- Farms
- Fuel filling stations
- Industrial sites and storage areas
- Off-shore gas and oil structures
- Parking areas
- Petrochemical and other hazardous industries
- Power, electricity, gas and heat plants
- Railways and tramways (5.12)
- Saw mills
- Shipyards and docks
- Water and sewage plants

Avoid glare for vehicle driver, special attention is to be paid to the edge of the platform.
### Lighting Requirements for Areas, Tasks and Activities II (table 5.12 of CIE S 015:2005)

<table>
<thead>
<tr>
<th>No.</th>
<th>Type of area, task or activity</th>
<th>( E_{m} )</th>
<th>( U_{o} )</th>
<th>( U_{d} )</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.12.11</td>
<td>Railways, lines, terraces</td>
<td>70 0.45 40</td>
<td>50 0.45 40</td>
<td>Avoid glare for vehicle drivers</td>
<td></td>
</tr>
<tr>
<td>5.12.12</td>
<td>Railways, handling areas</td>
<td>10 0.45 40</td>
<td>50 0.45 40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.12.13</td>
<td>Coupling area</td>
<td>10 0.45 40</td>
<td>50 0.45 40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.12.14</td>
<td>Sheds, small and medium-sized stations</td>
<td>10 0.45 40</td>
<td>50 0.45 40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.12.15</td>
<td>Open platforms, inter-city services</td>
<td>10 0.45 40</td>
<td>50 0.45 40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.12.16</td>
<td>Covered platforms, suburban or regional trains or inter-city services with small number of passengers</td>
<td>10 0.45 40</td>
<td>50 0.45 40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.12.17</td>
<td>Covered platforms, short distance operations</td>
<td>10 0.45 40</td>
<td>50 0.45 40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.12.18</td>
<td>Covered platforms, inter-city services</td>
<td>100 0.50 40</td>
<td>100 0.50 40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.12.19</td>
<td>Stairs, lobbies</td>
<td>100 0.50 40</td>
<td>100 0.50 40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.12.20</td>
<td>Covered platforms, long distance operations</td>
<td>100 0.50 40</td>
<td>100 0.50 40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.12.21</td>
<td>Inter-roto brake</td>
<td>100 0.50 40</td>
<td>100 0.50 40</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Passenger Volume Dependent Lighting Requirements for Platforms (CIE S 015:2005)

<table>
<thead>
<tr>
<th>Type of Platform</th>
<th>( E_{m} )</th>
<th>( U_{o} )</th>
<th>( U_{d} )</th>
<th>( G_{R_{L}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open platforms, rural and local trains, small number of passengers</td>
<td>15 lx</td>
<td>0.25</td>
<td>0.125</td>
<td>50</td>
</tr>
<tr>
<td>Open platforms, suburban and regional trains with large number of passengers or inter-city services with small number of passengers</td>
<td>20 lx</td>
<td>0.40</td>
<td>0.20</td>
<td>45</td>
</tr>
<tr>
<td>Open platforms, inter-city services</td>
<td>50 lx</td>
<td>0.40</td>
<td>0.20</td>
<td>45</td>
</tr>
<tr>
<td>Covered platforms, suburban or regional trains or inter-city services with small number of passengers</td>
<td>50 lx</td>
<td>0.40</td>
<td>0.20</td>
<td>45</td>
</tr>
<tr>
<td>Covered platforms, inter-city services</td>
<td>100 lx</td>
<td>0.50</td>
<td>0.33</td>
<td>45</td>
</tr>
</tbody>
</table>

*Illuminance level as function of passenger volume*
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End