TECHNICAL SPECIFICATION

NMF01:2018 LED luminaires – requirements

Edition 1.0 1.6.2018

NMF – Nordic co-operation group in the field of road equipment

NMF – Nordiskt Möte för Förbättrad vägutrustning

Contents

Foreword

This Technical Specification presents the requirements for outdoor LED luminaires. This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

In this Technical Specification, the following print types are used:

- requirements: Arial type.
- references: *italic type*.
- notes: smaller Arial type.

This publication was prepared by a working group:

Petter Hafdell	Swedish Transport Administration
Joakim Frank	Swedish Transport Administration
Arne Jørgensen	Norwegian Public Roads Administration
Pål Larsen	Norconsult AS
Thomas Hansen	Danish Road Directorate
Aleksanteri Ekrias	LiCon-AT Oy (representing the Finnish Transport Agency)

NMF
May 2018

Introduction

This Technical Specification has been prepared to achieve consistency, clarity and increased quality in all types of procurements for lighting on roads and in railway areas. The Specification has four main aims:

- to create a basis for improvement of national guidelines by harmonizing requirements for LED luminaires in the Nordic countries,
- to have a greater effect on the market as harmonised requirements for LED luminaires,
- to ease and increase the interaction with the manufacturers and
- to enforce a level of quality consistency of products available on the market in Nordic countries.

This Technical Specification is based on the current national guidelines of four road authorities: the Swedish Transport Administration, the Norwegian Public Roads Administration, the Danish Road Directorate and the Finnish Transport Agency. Furthermore, the publication is based on ongoing CIE technical committee work, current ISO, IEC, CEN standards and standard drafts, Zhaga publications as well as experiences from different outdoor lighting procurements. The purchasers, tenderers, lighting designers, manufacturers and contractors have been heard during the preparation stage of this document.

1 Scope

This Technical Specification covers technical requirements for LED luminaires used on roads and in railway areas. This includes road lighting, tunnel lighting, lighting under bridges, decorative lighting, railway lighting and railway tunnel lighting.

The requirements for LED luminaires presented in this publication shall be followed in all forms of contracts in lighting design, new construction, rehabilitation and maintenance on roads and in railway areas.

Target groups for this document are purchasers, tenderers, lighting designers, manufacturers and contractors.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

CIE 017:2016 ILV International Lighting Vocabulary

IEC 62717:2015 LED modules for general lighting - Performance requirements

IEC 62722-1:2014 Luminaire performance - Part 1: General requirements

IEC 62722-2-1:2014 Luminaire performance - Part 2-1: Particular requirements for LED luminaires

3 Terms and definitions

For the purposes of this document, the terms and definitions given in the documents *CIE 017:2016*, *IEC 62717:2015*, *IEC 62722-1:2014* and *IEC 62722-2-1:2014* as well as the following apply.

NOTE 1: the terms and definitions given in the *CIE 017:2016* are published on http://eilv.cie.co.at/.

3.1
decorative lighting
lighting that is purely ornamental and installed for aesthetic effect. Decorative lighting shall not include general lighting.

Note to entry: usually means lighting fixtures provided primarily to enhance areas with a public use or pedestrian orientation, or to highlight key architectural elements, landscaping and similar design elements

3.2
ingress protection IP class
used to define levels of sealing effectiveness of enclosures against intrusion from foreign matter (tools, dirt etc.) and moisture. Ratings are defined in the standard *EN 60529:1992*.

3.3
rated maximum ambient temperature (t_a)
temperature assigned to a luminaire by the manufacturer to indicate the highest sustained temperature in which the luminaire may be operated under normal conditions

3.4
external wiring
wiring generally outside a luminaire

Note 1 to entry: in outdoor lighting, usually a cable between the luminaire's and the column's wiring blocks

Note 2 to entry: external wiring is not necessarily outside a luminaire for its full length

3.5
rated useful lifetime
time over which the luminaire is expected to function as designed

Note to entry: generally defined by a client

3.6
median useful life
L_x
length of time until 50 % of a population of operating LED products reaches gradual light output degradation of a percentage *x*

3.7
time to abrupt failure
length of time during which *y* % of a population of initially operating LED products of the same type fail to produce any luminous flux

3.8
group replacement
replacement of many components at one chosen time in an installation

3.9
spot replacement
replacement of a single component at one chosen time in an installation

3.10
luminaire group replacement interval
planned time between group replacement of luminaires

3.11
constant light output
functionality to constantly adjust the luminous flux of the light source based on the known or predicted depreciation behaviour of the light source to enable a constant luminous flux over time

Note to entry: generally abbreviated to CLO

3.12
CLO lifetime
time over which the CLO control ensures a constant luminous flux

3.13
luminaire cleaning interval
planned time between cleaning of (parts of) luminaires

Note to entry: in outdoor lighting cleaning usually indicates cleaning of the luminaire's optics e.g. luminaire's flat glass

3.14
protection against external mechanical impacts IK class
classification of the degrees of protection provided by enclosures against external mechanical impacts when the rated voltage of the protected equipment is not greater than 72,5 kV. Ratings are defined in the standard *EN 62262:2002.*

3.15
outdoor luminaire controller
device, that provides an interface between the control gear of a luminaire and the lighting control system or other controllers

Note to entry: can be installed to a socketed receptacle

3.16
luminaire receptacle
socketed device that enables an installation or replacement of the outdoor luminaire controller without tools, and enables communication between the luminaire controller and the luminaire control gear

3.17 Annual Average Daily Traffic AADT
term used to provide the projected future average traffic volume in both directions on a section of road

3.18
DALI (Digital addressable lighting interface)
DALI is an industry-standardised protocol defined by the standard *IEC 62386*

Note 1 to entry: the standard *IEC 62386* is published in multiple parts, with several new parts in development

Note 2 to entry: DALI-2 is based on the second edition of the standard *IEC 62386*, which also includes control devices

3.19
stand-alone dimming
lighting control that is integrated into the control gear of a luminaire and does not require any external command

Note 1 to entry: is usually preprogrammed

4 Symbols, units and abbreviations

The symbols, units and abbreviations in Table 1 apply.

Table 1. Symbols, units and abbreviations.

Symbol/ abbreviation	Description	Unit
CLO	constant light output (see 3.11 and 7.6)	-
t_a	rated maximum ambient temperature (see 3.3)	°C
t_q	rated ambient performance temperature (see *IEC 62722-2-1:2014*, 3.3)	°C
R_a	general colour rendering index (see *CIE 017:2016*, 17-22-112)	-
T_{cp}	rated correlated colour temperature (see *CIE 017:2016*, 17-23-068)	K
L_x	median useful life (see 3.6) for *x* % remaining luminous flux	h
C_y	time to abrupt failure (see 3.7)	h
η_l	luminaire luminous efficacy (see *IEC 62722-2-1:2014*, 3.5)	lm/W
f_M	maintenance factor (see 7.4)	-
f_{LF}	luminous flux factor (see 7.5 and 7.6)	-
f_{LM}	luminaire maintenance factor (see 7.7)	-
Φ_L	luminaire luminous flux	lm
Φ_{CLO}	CLO-corrected luminaire luminous flux (see 7.6)	lm
Φ_e	luminaire luminous flux at the end of rated useful lifetime (see 7.6)	lm
Φ_i	initial luminaire luminous flux (see 7.6)	lm
H_M	luminaire mounting height (*CIE 017:2016*, 17-29-187)	m
DALI	Digital Addressable Lighting Interface (see 3.18)	-
λ	circuit power factor (see *IEC 62384:2006* 3.2)	-
AADT	Annual Average Daily Traffic (see 3.17)	-

5 Light sources in lighting installations

In this publication, light sources used in luminaires are considered to contribute to the performance of the luminaire as a system. No individual requirements for the light sources as such are stated.

When constructing new lighting and in the rehabilitation of current lighting installations only the LED luminaires shall be used.

For functional road, tunnel and railway lighting, only phosphor-converted inorganic LEDs producing white light shall be used.

6 Safety requirements

6.1 Low Voltage Directive

A luminaire shall comply with the *Low Voltage Directive 2014/35/EU*, and it shall fulfil the luminaire safety requirements specified in the Directive in accordance with the standards mentioned in Table 2. Standards other than those mentioned in Table 2 can also be used to demonstrate compliance with the Directive. In that case, sufficient background for demonstrating compliance with the Directive shall be presented.

Fulfilment of the luminaire safety requirements shall be evidenced with a manufacturer's declaration of conformity related to the CE marking and its technical documents, or with test results by a conformity assessment body. The conformity assessment body shall comply with the *Regulation (EC) No 765/2008*.

Table 2. Safety standards specified in the Low Voltage Directive 2014/35/EU.

Standard Number	Description	Road and tunnel lighting *	Flood-lighting **	Evacuation lighting ***
EN 60598-1:2015	Luminaires - Part 1: General requirements and tests	X	X	X
EN 60598-2-3:2003	Luminaires - Part 2-3: Particular requirements - Luminaires for road and street lighting	X		
EN 60598-2-5:2015	Luminaires - Part 2-5: Particular requirements - Floodlights		X	
EN 60598-2-22:2014	Luminaires - Part 2-22: Particular requirements - Luminaires for emergency lighting			X
EN 62493:2015	Assessment of lighting equipment related to human exposure to electromagnetic fields	X	X	X

* *NOTE 1: also includes street lighting, lighting for pedestrian and cycle areas, etc.*

** *NOTE 2: includes areas and objects illuminated by floodlights, for example interchange area lighting, parking area lighting, railway lighting, decorative lighting, etc.*

*** *NOTE 3: includes tunnel evacuation lighting, railway tunnel evacuation lighting, etc.*

A luminaire shall be equipped with marking in accordance with the standard *EN 60598-1:2015*. The durability of the marking shall fulfil the test requirements defined in the standard *EN 60598-1:2015*.

NOTE 1: markings to be observed during maintenance should be visible on the outside of a luminaire or behind a cover that is removed during control gear or other component replacement.

A luminaire shall be assessed for blue light hazard according to the technical report *IEC/TR 62778:2014*. The requirement is included in the standard *EN 60598-1:2015*.

The luminaire control gear voltage is 230 V. The luminaire control gear circuit power factor shall be $\lambda \geq 0.90$ for luminaires with a rated input power of ≤ 50 W and $\lambda \geq 0.95$ for luminaires with a rated input power of > 50 W (100 % power, initial luminaire luminous flux Φ_i). The control gear circuit power factor of a dimmed luminaire (dimmed to 20 % of the initial luminous flux Φ_i) shall be $\lambda \geq 0.60$. A luminaire shall be built in a way that prevents unreasonable impairment in the electrical network service when the luminaire has been connected to the network and the network is used in normal operating conditions.

A luminaire including all electronics shall operate without malfunctioning at an ambient temperature of $-35 \leq t_a \leq +25$ °C.

NOTE 1: in Danish Road Directorate projects, a luminaire including all electronics should operate without malfunctioning at an ambient temperature of $-20 \leq t_a \leq +25$ °C.

Road and railway luminaires shall have protection class II.

NOTE 1: in Finnish Transport Agency and the Norwegian Public Roads Administration projects, road luminaires with protection class I can be used.

For the external wiring of all outdoor lighting installations, the nominal cross-sectional areas of the cable's wires shall be ≥ 1.5 mm^2.

NOTE 1: in Danish Road Directorate projects, wires with a nominal cross-sectional area of 1.0 mm^2 can also be used.

NOTE 2: longer external cables may require a higher nominal cross-sectional area due to mechanical strength or electrotechnical requirements, for example 2.5 mm^2. This is also dependent on the cable type used.

The external cable type shall be such that it remains undamaged when pulled through a normal column and bracket or when it is bent permanently with a bending radius of at least three times the cable diameter. For the requirements above, the lowest permitted handling ambient temperature is t_a = -15 °C.

External cables exposed to ultraviolet radiation or temperatures above 70 °C shall be fitted with protection for their unsheathed sections.

NOTE 1: in installations with overhead wiring, the cable sheath can be made of lead-free weatherproof PVC, for example.

In metal column installations, in which a fuse protecting a luminaire has been placed inside the column and there is a multicore external cable between the luminaire's and the column's wiring blocks, the cable end on the fuse side shall be equipped with cable end sleeve for crimping.

The surge immunity of a luminaire shall be at least 6 kV in differential mode and 8 kV in common mode. The test shall be performed according to the standard *EN 61000-4-5:2014* using a 1.2/50 µs – 8/20 µs combination wave with a 2 Ω source impedance in differential mode and a 12 Ω source impedance in common mode.

NOTE 1: for installations with overhead cabling or masts, the surge immunity of a luminaire should be at least 10 kV in differential mode and 10 kV in common mode. If a separate surge protective device is applied, the test should be performed according to the standard EN 61643-11:2012, test class III, using a 1.2/50 µs – 8/20 µs combination wave with a 2 Ω generator impedance. In that case the surge immunity requirement corresponds to the open source voltage.

NOTE 2: for luminaires with external control gear, the overvoltage protection should be located before the external control gear.

NOTE 3: the overvoltage protection in road and railway tunnels can be in a technical room or operation room and should protect the lighting system in general.

NOTE 4: In 230 V IT system maximum continuous operating voltage Uc of a surge protection device should be:

- type 2: ≥ 350 V and
- type 3: ≥ 440 V between L – PE and ≥ 275 V between L – L (phase to phase).

6.2 Electromagnetic Compatibility Directive

A luminaire shall comply with the *Electromagnetic Compatibility (EMC) Directive 2014/30/EU*, and it shall fulfil the EMC requirements specified in the Directive in accordance with the standards mentioned in Table 3. Standards other than those mentioned in Table 3 can also be used to demonstrate compliance with the Directive. In that case, sufficient background for demonstrating compliance with the Directive shall be presented.

Fulfilment of the EMC requirements shall be evidenced with a manufacturer's declaration of conformity related to the CE marking and its technical documents, or with test results by a conformity assessment body. The conformity assessment body shall comply with the *Regulation (EC) No 765/2008*.

Table 3. EMC standards specified in the Electromagnetic Compatibility (EMC) Directive 2014/30/EU.

Standard Number	Description	Road and tunnel lighting *	Flood-lighting **	Evacuation lighting ***
EN 55015:2013	Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment	X	X	X
EN 61000-3-2:2014	Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤16 A per phase)	X	X	X
EN 61000-3-3:2013	Electromagnetic compatibility (EMC) - Part 3-3: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16 A per phase and not subject to conditional connection	X	X	X
EN 61547:2009	Equipment for general lighting purposes. EMC immunity requirements.	X	X	X

* *NOTE 1: also includes street lighting, lighting for pedestrian and cycle areas, etc.*

** *NOTE 2: includes areas and objects illuminated by floodlights, for example interchange area lighting, parking area lighting, railway lighting, decorative lighting, etc.*

*** *NOTE 3: includes tunnel evacuation lighting, railway tunnel evacuation lighting, etc.*

Tunnel luminaires shall not cause radiated disturbance in the Tetra frequency band (380 – 400 MHz). Conformity related to the standard *EN 55015:2013* does not guarantee that luminaire is not able to cause radiated disturbance in the Tetra frequency band, and thereby violate the requirements stated in *Electromagnetic Compatibility (EMC) Directive 2014/30/EU Annex I*. To ensure that the luminaire is not causing radiated disturbance in the Tetra frequency band, a following test shall be conducted; after measuring the equipment according to the standard *EN 55015:2013*, and using the same measurement setup, change the frequency of the measurement instrument to the Tetra band (380 – 400 MHz) and use a low-resolution bandwidth (RBW, 10 kHz). If the test shows specific noise components in the Tetra frequency band, even if the radiated levels are well below the accepted levels stated in the standard *EN 55015:2013*, there will be imminent danger of degrading the efficiency of critical emergency communications. This is not allowed in installations where Tetra emergency communications are used, see also Annex 3 of the publication *Guide for the EMCD:2018*.

NOTE 1: this is especially valid in, but not limited to, road tunnels with Tetra coverage.

NOTE 2: it should be noted that Tetra emergency communications are not a specific Nordic phenomenon, as Tetra emergency communication in the same frequency band is used in almost all countries in Europe.

6.3 RoHS 2 Directive

A luminaire shall comply with the *Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS 2)* and it shall fulfil the requirements specified in the Directive in accordance with the standard *EN 50581:2012*. Standards other than *EN 50581:2012* can also be used to demonstrate compliance with the Directive. In that case, sufficient background for demonstrating compliance with the Directive shall be presented.

Fulfilment of the RoHS 2 requirements shall be evidenced with a manufacturer's declaration of conformity related to the CE marking and its technical documents, or with test results by a conformity assessment body. The conformity assessment body shall comply with the *Regulation (EC) No 765/2008*.

7 Performance requirements

7.1 Photometric data

A luminaire shall have the light distribution characteristics in the C - γ - system measured in accordance with the standards *EN 13201-3:2015*, *EN 13032-1:2004* and *EN 13032-4:2015.*

The light distribution files shall be delivered in EULUMDAT file format.

7.2 Performance requirements for luminaires

The technical specifications and the performance of a luminaire shall be presented in accordance with the standards *IEC 62722-1:2014*, *IEC 62722-2-1:2014* and *IEC 62717:2015*, taking the specifications of this document into account. A recommendation for the format used in presenting the technical specifications and the performance of a luminaire can be found in Annex A.

7.3 Rated useful lifetime of a luminaire

The rated useful lifetime of a luminaire is defined by the client. If no value is given by the client, the rated useful lifetime of the luminaire is the value presented in Table 4.

NOTE 1: the luminaire group replacement interval of an installation should follow the rated useful lifetime of the luminaire.

The *h* values of the median useful life L_x and the time to abrupt failure C_y shall follow the given rated useful lifetime of the luminaire. The manufacturer shall provide the values L_x and C_y (values *x* and *y*) at the rated ambient temperature t_q = 25 °C for the given rated useful lifetime of the luminaire according to the standards *IEC 62722-2-1:2014* and *IEC 62717:2015*. *x* and *y* values shall fulfil the minimum requirements presented in Table 4.

Table 4. Minimum requirements for a luminaire's rated useful lifetime, gradual light output degradation and abrupt light output degradation.

Luminaire type	Rated useful lifetime	Gradual light output degradation	Abrupt light output degradation
Road luminaire, interior zone luminaire (road tunnel), luminaire under bridge	100 000 h	L_{90}	C_{10}
Floodlight, decorative lighting luminaire	50 000 h	L_{80}	C_{10}
Threshold and transition zone luminaires (road tunnel)	50 000 h	L_{90}	C_{10}
Evacuation lighting luminaire	25 000 h	L_{90}	C_{10}

7.4 Maintenance factor

The maintenance factor f_M shall be employed in lighting designs to ensure that the target requirements are met throughout the rated useful lifetime of a luminaire when the luminaire is maintained according to the defined maintenance schedule.

The maintenance factor f_M is determined using the following formula:

$$f_M = f_{LF} \cdot f_{LM} \qquad (1)$$

where

f_M is the maintenance factor,
f_{LF} is the luminous flux factor (see 7.5 and 7.6), and
f_{LM} is the luminaire maintenance factor (see 7.7).

EXAMPLE 1: Road lighting. The given rated useful lifetime of a luminaire = 100 000 h, the received gradual light output degradation value = L_{90}, no CLO, and the luminaire cleaning interval every 6 years.

$f_M = 0.90 \cdot 0.90 = 0.81$

In outdoor lighting, the survival factor and the surface maintenance factor are not considered in the determination of the overall maintenance factor.

NOTE 1: in outdoor lighting, it is usually not possible to compensate for the failed luminaire by increasing the initial luminous flux of other luminaires due to the survival factor. For that reason, the survival factor is not considered in the determination of the maintenance factor f_M (or set to 1.0). For failed luminaires, a spot replacement regime is applied with agreed response times.

NOTE 2: in outdoor lighting the surface maintenance factor is not considered (or set to 1.0) because depreciations of surface reflections of the area of interest are usually not known (for example, road surface and surroundings of a carriageway). In tunnels and underpasses, the effects of the surface maintenance factor are compensated for by the use of a lower luminaire maintenance factor; see Table 5.

7.5 Luminous flux factor

The luminous flux factor f_{LF} describes the depreciation of the luminous flux over time due to the ageing of a light source or luminaire during regular operation (this excludes external factors). This is defined as the ratio of depreciated luminous flux to the initial luminous flux Φ_i.

For outdoor lighting the luminous flux factor f_{LF} shall be determined at luminaire level.

The f_{LF} shall be determined based on the rated useful lifetime of a luminaire (see 7.3) and shall be provided by the manufacturer according to the standard *IEC 62722-2-1:2014* and section 7.3 of this document. In this case *x* of the the median useful life L_x equals f_{LF}.

EXAMPLE 1: the median useful life L_{90} = 100 000 h translates to 90 % remaining luminous flux at 100 000 h, which results in f_{LF} = 0.90.

NOTE 1: if constant light output control is used, the luminous flux factor f_{LF} should be determined based on section 7.6.

7.6 Constant light output

A constant light output (CLO) control of a luminaire shall always be used, if available, for the selected luminaire type.

The CLO lifetime shall be the same as the rated useful lifetime of a luminaire, see 7.3.

NOTE 1: In CLO installations, light source behaviour and control gear behaviour are interlinked. In the case of premature control gear failure, the replaced components should match the performance and behaviour of the original part prior to failure.

Luminaires utilising a constant light output control adjust the luminous flux based on the known or predicted depreciation behaviour of the light source to enable a constant luminous flux over time. This is realised by initially dimming the light source to the predicted end-of-life flux and increasing the current (and as such the power consumption) over time to compensate for the depreciation in luminous flux due to ageing of the light source.

NOTE 1: if CLO control is used, the manufacturer should provide the average rated input power of the luminaire (W) for the rated useful lifetime of the luminaire and the rated input power of the luminaire (W) at the end of rated useful lifetime.

NOTE 2: the increasing power consumption over time should be considered in the electrical design and energy calculations for the installation, but also when comparing different luminaires with and without CLO.

NOTE 3: CLO refers to the standalone feature based on known or predicted depreciation and does not include external input such as sensors. As such, it only applies to the luminous flux factor f_{LF}.

Figure 1 shows a simplified representation of a luminaire not using CLO, based on L_{90} = 100 000 h (i.e. 10 % depreciation after 100 000 hours). Both power and luminous flux are set to their maximum value (point A). Over time, power remains the same (line between point A and B) whereas the luminous flux depreciates to the luminaire luminous flux at the end of the rated useful lifetime Φ_e (line between point A and C, 90 % of initial luminaire luminous flux Φ_i).

Figure 2 shows a simplified representation of the same luminaire, but with CLO control. Both power and luminous flux start at 10 % below their maximum value at 0 h (point D – as in the operation of the luminaire without CLO the total flux depreciation is 10 % at the end of the rated useful lifetime). Over time, luminous flux is kept constant (line between point D and F) by increasing the power (line between point D and E). Note that at the end of rated useful lifetime, both luminaires have the same power consumption (B versus E) and the same luminous flux (C versus F).

In practice, there are two ways CLO luminaire specifications are provided by manufacturers. Depending on which of the two options is used, the luminous flux factor f_{LF} shall be determined differently. The current known options are:

1. the initial (without CLO control) specifications are specified, Figure 1 – point A (in which case the CLO correction needs to be done by using the luminous flux factor f_{LF}, as there was no CLO control)
2. the corrected luminous flux is given, Figure 2 – point D (in which case no correction is needed as this is already represented in the corrected luminous flux, f_{LF} = 1.00).

For CLO luminaires, the luminous flux factor f_{LF} shall be determined as follows:

If $\Phi_L = \Phi_{CLO}$, then f_{LF} = 1.00 (2)

If $\Phi_L = \Phi_i$, then $f_{LF} = \Phi_e / \Phi_i$

where

Φ_L is the specified luminaire luminous flux,
Φ_{CLO} is the CLO-corrected luminaire luminous flux (i.e. Figure 2 – point D),
Φ_e is the luminaire luminous flux at the end of the rated useful lifetime without CLO control (i.e. Figure 1 – point C),
Φ_i is the initial luminaire luminous flux without CLO control (i.e. Figure 1 – point A).

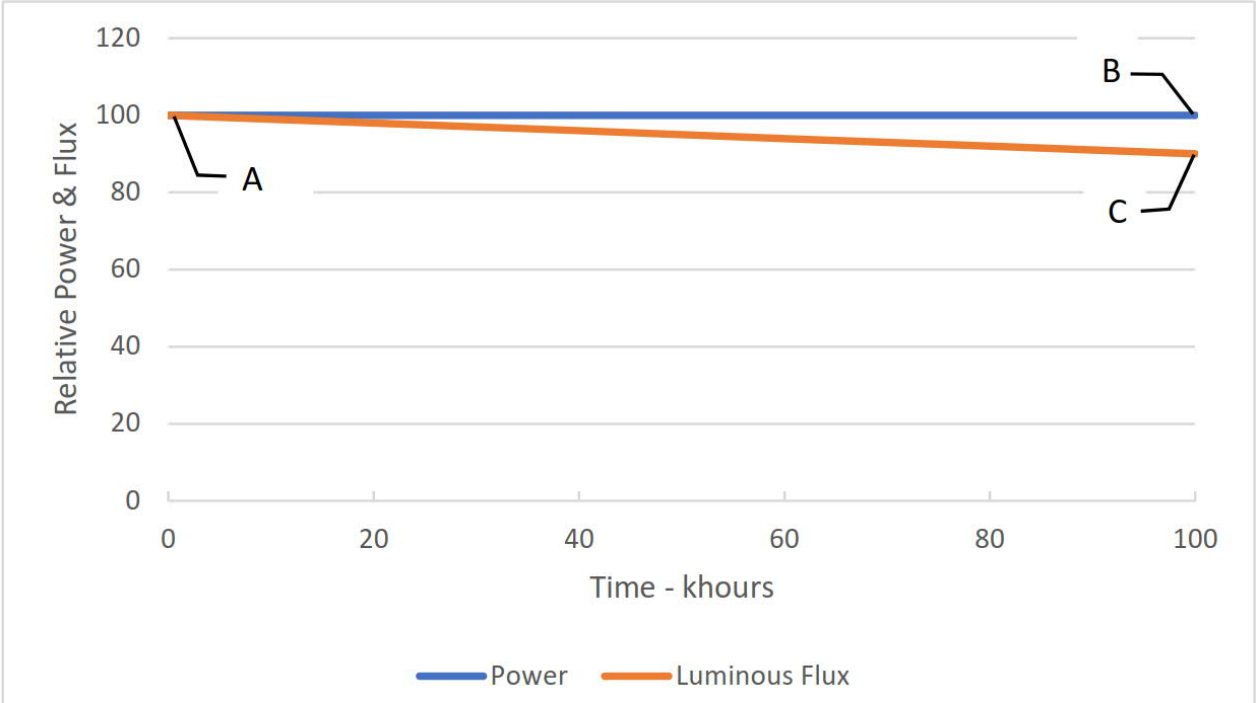

Figure 1. Illustration of CLO principle using simplified graph representation. A luminaire without CLO control.

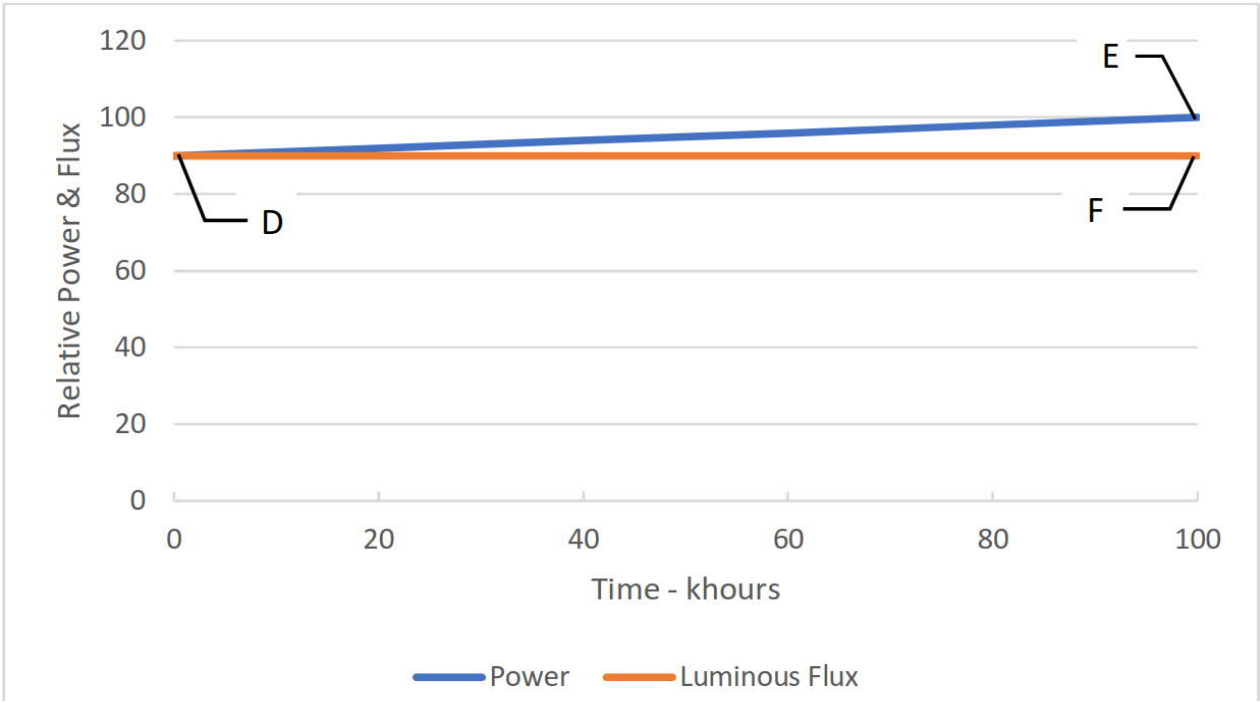

Figure 2. Illustration of CLO principle using simplified graph representation. A luminaire with CLO control.

7.7 Luminaire maintenance factor

The luminaire maintenance factor f_{LM} describes the relative output of a luminaire due to dirt deposited on light sources, optical components or other external factors influencing the luminaire output. The luminaire maintenance factor f_{LM} shall be based upon a luminaire's characteristics and environmental conditions.

The luminaire maintenance factor f_{LM} for outdoor luminaires shall be based upon the combination of luminaire design (rated according to IP class), the environmental pollution category and the

luminaire cleaning interval.

The luminaire cleaning interval has a significant impact on the maintenance factor. The minimum requirements for luminaire cleaning intervals for various locations are shown in Table 5. Based on these minimum requirements, the f_{LM} values for different applications are defined in Table 5.

The luminaire cleaning interval is defined by the client. If no value is given by the client, the cleaning interval is the value presented in Table 5. The luminaire cleaning interval of the road tunnel is dependent on the annual average daily traffic volume (AADT), tunnel type and tunnel location.

Table 5. The minimum requirements for luminaire cleaning intervals for various locations and corresponding f_{LM} values.

Location	Luminaire cleaning interval	Luminaire maintenance factor f_{LM}
Roads, railway areas, decorative lighting, luminaire mounting height $H_A \geq 4.0$ m	every 6 years	0.90
Roads, railway areas, decorative lighting, luminaire mounting height $H_A < 4.0$ m	every 6 years	0.85
Road tunnels	dependent on the AADT, tunnel type and tunnel location	0.85
Railway tunnels with a brake curve	every 3 years	0.50
Railway tunnels without a brake curve	every 3 years	0.70

7.8 Colour rendering index and colour temperature

The nominal values of the luminaire's general colour rendering index R_a and the rated correlated colour temperature T_{cp} shall be set according to Table 6.

NOTE 1: luminaire luminous efficacy increases with increasing colour temperature. Therefore, it is recommended to use 4 000 K correlated colour temperature where no other specific requirements are set.

NOTE 2: in urban and public areas 3 000 K can be used for instance to create atmosphere and with certain products to achieve a higher general colour rendering index.

Table 6. The general colour rendering index R_a and the rated correlated colour temperature T_{cp} requirements in various locations.

Location	Correlated colour temperature T_{cp}	Colour rendering index R_a
Roads in rural areas, road and railway tunnels, railway yards	4 000 K	$R_a \geq 70$
Roads in urban areas, public areas and railway stations	3 000 K 4 000 K *	$R_a \geq 80$ $R_a \geq 70$ *

* *Values 3000 K and $R_a \geq 80$ or 4000 K and $R_a \geq 70$ shall be used based on the national guidelines.*

The performance requirements specified in Table 6 do not apply to safety lighting and decorative lighting.

7.9 Chromaticity coordinate values

For luminaires of the same type within a lighting installation, rated chromaticity coordinate values, both initial and maintained, shall fulfil the tolerance requirements presented in Table 7.

Table 7. Tolerance (category) requirements on rated chromaticity coordinate values.

Distance between luminaires within a lighting installation	Colour variation tolerance, size of MacAdam ellipse, centred on the rated colour target	
	Initial	Maintained
< 5 m	5	5
≥ 5 m	7	7

7.10 Luminaire luminous efficacy

The luminaire luminous efficacy of road and tunnel luminaires shall be $\eta_l \geq 110$ lm/W (100 % power, initial luminaire luminous flux Φ_i).

The luminaire luminous efficacy requirements do not apply to safety lighting and decorative lighting.

7.11 Road tunnel evacuation lighting requirements

The performance requirements for evacuation lighting luminaires in tunnels shall be in accordance with the standard *EN 16276:2013.*

If an LED strip is used for an evacuation route lighting, it shall fulfil the following performance requirements:

- the minimum opening of 120 degrees,
- the average luminous efficacy of $200 \leq \eta_l \leq 250$ lm/m,
- the minimum luminous efficacy of $\eta_l \leq 100$ lm/m for the entire length and
- the rated correlated colour temperature of $3\,000 \leq T_{cp} \leq 5\,000$ K.

If an LED strip is used for emergency exit lighting, it shall fulfil the following performance requirements:

- the average luminous efficacy of $200 \leq \eta_l \leq 300$ lm/m and
- the minimum luminous efficacy of $\eta_l \leq 200$ lm/m for the entire length.

8 Structural requirements

8.1 General structural requirements

All electronics of a luminaire shall be protected against moisture, condensation and corrosion.

NOTE 1: protection against moisture and condensation can usually be achieved by an adequate IP class of enclosures, good luminaire design, and the adequate pressure equalisation of a luminaire housing.

NOTE 2: adequate pressure equalisation can be achieved by using vents, for example.

The ingress protection class of a luminaire shall be IP66 in accordance with the standards *EN 60598-1:2015* and *EN 60529:1992*.

NOTE 1: in Danish Road Directorate projects, the ingress protection class of a luminaire can be IP65.

NOTE 2: in decorative lighting, luminaires with the ingress protection class of IP65 can also be used.

The ingress protection class for spaces in a luminaire not containing electronics or optics shall be at least IP4X.

The ingress protection class of a luminaire shall remain the same for the whole rated useful lifetime of the luminaire, including appropriate maintenance.

NOTE 1: this can be achieved by using an elastic material that maintains its characteristics throughout the rated useful lifetime of the luminaire as the luminaire's seal, for example.

NOTE 2: if glue is required to attach the seal, the glue should not become brittle and cause the luminaire's IP class to deteriorate during use.

Cable entries shall provide the degree of protection against dust or moisture in accordance with the ingress protection class of the luminaire, when an appropriate external cable is installed.

NOTE 1: for cable entries the degree of protection against dust and moisture can be ensured by using cable glands with adequate IP class or weather and temperature resistant cable TET grommets, for example.

Cable entries shall have rounded edges with a minimum radius of 0.5 mm.

If the luminaire mounting height is H_M < 4.0 m, the protection class of the luminaire against external mechanical impacts shall be at least IK10 in accordance with the standard *EN 62262:2002*.

If the mounting height of a road or tunnel luminaire is H_M ≥ 4,0 m, the protection class of the luminaire against external mechanical impacts shall be at least IK08 in accordance with the standard *EN 62262:2002*.

NOTE 1: IK class requirements do not include external components, such as outdoor controllers.

A luminaire housing (not including flat glass, seals, vents, nuts, screws, latches and so on) shall be made from die cast aluminium, extruded aluminium or stainless steel. The service life of the luminaire housing shall be at least the same as the rated useful lifetime of the luminaire.

NOTE 1: Luminaire housing parts, that are not exposed to direct sunlight can also be made from materials other than die cast aluminium, extruded aluminium or stainless steel.

NOTE 2: in Danish Road Directorate projects, a luminaire housing can also be made from other materials. In this case, sufficient background for choosing that material instead of die cast aluminium, extruded aluminium or stainless steel should be provided.

The hot dip galvanised coating of a luminaire housing and exterior luminaire components shall be performed in accordance with the standard *EN ISO 1461:*2009.

The corrosion resistance of a luminaire and exterior luminaire components shall fulfil the requirements of the standard *EN 60598-1:2015* and the requirements of the corrosivity categories of Table 8.

Metal parts of a luminaire shall be galvanically separated when different metals are in interaction.

The exterior nuts, screws, latches and other fasteners of a luminaire shall be made from stainless steel A4-80 according to the standard *EN ISO 3506:2009*.

The cord anchorage of a luminaire shall fulfil the requirements of the standard *EN 60598-1:2015* so that the external cable and wires are relieved from strain, including twisting, when they are connected to the wiring block of the luminaire.

A luminaire with an installation height H_A < 4.0 m shall not be openable without tools except for in tunnels and areas closed to the public.

NOTE 1: the usage of anti-vandal fasteners is recommended.

A luminaire shall not be disposable, in other words it shall be possible to replace the control gear, LED modules and optics of the luminaire on-site or indoors. All components mentioned above shall be available as spare parts.

Table 8. Corrosivity category requirements for corrosion resistance in different environments.

Corrosivity category *	Material	Environment
C5 (I-M)	Aluminium and steel	Tunnels. Coastal areas with high salt content. **
C4	Aluminium and steel	Industrial areas and coastal areas with moderate salt content.
C3	Aluminium and steel	Other environments.

* *The corrosivity categories are in accordance with the standard EN ISO 9223:2012*.

** *Distances to the sea are defined at the national level.*

Road and tunnel luminaires shall be equipped with flat, protective glass. Flat glass refers to an even, two-dimensional surface. The service life of the flat glass shall be at least the same as the rated useful lifetime of the luminaire. Curved glass luminaires and luminaires with flat glass lens modules are not permitted. Curved glass refers to a gently curving surface, usually created by bending. Lens module refers to a module put in the place of flat protective glass, with several lenses on the module surface.

NOTE 1: flat glass is required to ensure a high luminaire maintenance factor f_{LM} value, to ease and to enhance the cleaning of the luminaire, and to reduce glare and obtrusive light produced by the luminaire.

NOTE 2: the flat glass protects lenses from ultraviolet radiation, to some extent.

A luminaire shall have no electromechanical parts.

8.2 Additional road luminaire requirements

The luminaire post top or side entry fixing equipment shall be compatible with the standard *EN 40-2:2004*

8.3 Additional road tunnel luminaire requirements

A tunnel luminaire shall be equipped with tempered flat glass.

8.4 Additional road tunnel evacuation lighting requirements

Evacuation lighting luminaires shall be equipped with a transparent protective cover that, fulfils the class V-0 requirements according to the standard *UL94:2013*.

8.5 Additional railway tunnel luminaire requirements

Luminaires in railway tunnels shall withstand 5 kPa in pressure and 5 kPa in suction.

9 Lighting control requirements for road luminaires

9.1 General requirements

A road luminaire shall enable the luminaire luminous flux to be controlled using one or several of the following lighting control methods:

1. preprogrammed stand-alone dimming,
2. outdoor luminaire controller and external control,
3. mains voltage amplitude modulation (additional requirement).

NOTE 1: the methods 1 and 2 are used in Norwegian Public Roads Administration, Danish Road Directorate and Finnish Transport Agency projects. The methods 1, 2 and 3 are used in Swedish Transport Administration projects.

9.2 Preprogrammed stand-alone dimming

In preprogrammed stand-alone dimming, the luminaire control gear shall enable a preprogrammed dimming schedule with four lighting levels and five time intervals to be used throughout the day. An example of a dimming schedule for the preprogrammed stand-alone luminaire control used on roads is shown in Figure 3.

Preprogrammed stand-alone dimming shall operate together with the constant light output control.

NOTE 1: CLO control can be considered as a “dimming” factor following line D – E in Figure 2 of this document.

		Time, the starting hour																		
		15	16	17	18	19	20	21	22	23	00	01	02	03	04	05	06	07	08	09
Lighting class	**Lighting classes for adaptive lighting**	**Residual average luminance percentage**																		
M1, C0 and C1	M1 – M2 – M3 – M2 – M1	100	100	100	100	100	75	75	50	50	50	50	50	50	50	75	100	100	100	100
M2, C2	M2 – M3 – M4 – M3 – M2	100	100	100	100	100	75	75	50	50	50	50	50	50	50	75	100	100	100	100
M3, C3	M3 – M4 – M5 – M4 – M3	100	100	100	100	100	75	75	50	50	50	50	50	50	50	75	100	100	100	100
M4, C4	M4 – M5 – M6 – M5 – M4	100	100	100	100	100	60	60	40	40	40	40	40	40	40	60	100	100	100	100
M5, C5	M5 – M6 – P5 – M6 – M5	100	100	100	100	100	60	60	40	40	40	40	40	40	40	60	100	100	100	100
Residual average illuminance percentage																				
P1	P1 – P2 – P3 – P2 – P1	100	100	100	100	100	75	75	50	50	50	50	50	50	50	75	100	100	100	100
P2	P2 – P3 – P4 – P3 – P2	100	100	100	100	100	75	75	50	50	50	50	50	50	50	75	100	100	100	100
P3	P3 – P4 – P5 – P4 – P3	100	100	100	100	100	60	60	40	40	40	40	40	40	40	60	100	100	100	100
P4	P4 – P5 – P6 – P5 – P4	100	100	100	100	100	60	60	40	40	40	40	40	40	40	60	100	100	100	100
P5	P5 – P6 – P5	100	100	100	100	100	60	60	60	60	60	60	60	60	60	60	100	100	100	100

Figure 3. Example of a dimming schedule for a preprogrammed stand-alone luminaire control. The dimming is implemented using a maximum of three lighting levels and five time intervals depending on the normal (design) lighting class and the time of year (period of darkness). The times in the schedule are indicative. In preprogrammed stand-alone dimming the times are usually determined by the median point of the period of darkness, which varies by location. In the C classes a luminance and illuminance class correspondence table is used. The dimming is implemented in accordance with the M classes.

9.3 Outdoor luminaire controller

If the outdoor luminaire controller is required, a road luminaire shall be equipped with at least one luminaire receptacle. The mechanical and electrical interface of the receptacle and the outdoor luminaire controller shall be set according to the *Zhaga Book 18:2017*. Placing the outdoor luminaire controller inside the luminaire is not permitted.

NOTE 1: the receptacle intended for an installation of the outdoor luminaire controller should be placed on top of the luminaire. The receptacle (second one) intended for other purposes should be placed on the glass-side of the luminaire.

NOTE 2: in Danish Road Directorate projects, the receptacle can also be placed inside the luminaire.

The socketed receptacle shall be built into a luminaire. The placing of the socketed receptacle shall

be performed by the luminaire manufacturer at the luminaire assembly stage. The luminaire with the receptacle shall always be equipped with a sealing cap. The receptacle, together with the sealing cap, shall provide a degree of protection against dust or moisture (IP class) in accordance with the classification of the luminaire.

The communication between the outdoor luminaire controller and the luminaire control gear shall be based on DALI 2.0 according to *IEC 62386-101:2014* and *EN 62386-102:2014*.

If a road luminaire is equipped with the receptacle, it shall enable the selection of the control method between the preprogrammed stand-alone dimming and the external control by using the outdoor luminaire controller without opening the luminaire on-site.

9.4 Additional requirements on mains voltage amplitude modulation

When mains voltage amplitude modulation is in use, a road luminaire shall enable the luminous flux to be controlled using amplitude of the mains voltage. The luminaire control gear shall enable a preprogrammed dimming using at least four different lighting levels. The lighting levels of the luminaire shall be reprogrammable using amplitude of the mains voltage.

To avoid an unintended change in lighting levels due to small fluctuations in the main voltage amplitude, a minimum difference of 5 V shall be used to trigger the change of the preprogrammed lighting level.

The luminaire control gear shall enable the selection of the control method between the preprogrammed stand-alone dimming and mains voltage amplitude modulation using Near-field communication (NFC).

10 Other requirements

Luminaire technical specifications described in Annex A, except the declaration of conformity, shall be published and made publicly available.

NOTE 1: available and downloadable without registration.

The declaration of conformity of a luminaire shall be provided on request.

Installation instructions for a luminaire shall be delivered together with the luminaire. The instructions shall correspond to the product delivered. The instructions shall not contradict with the requirements of this document.

Annex A (informative) Technical specifications of an LED luminaire

Red fields should be filled by the client, if necessary
Green fields should be filled by the manufacturer

Luminaire manufacturer	
Luminaire type and product code	

Parameters	**Requirement**	**Value**
Rated input power of the luminaire (W)		
Average rated input power of the luminaire (W) for the rated useful lifetime of the luminaire, if CLO control is used		
Rated input power of the luminaire (W) at the end of the rated useful lifetime, if CLO control is used		
Luminaire control gear circuit power factor λ		
Initial luminaire luminous flux Φ_i (lm) (see 7.6)		
CLO-corrected luminaire luminous flux Φ_{CLO} (see 7.6), if CLO control is used		
Rated luminaire luminous efficacy (lm/W)		
Rated correlated colour temperature T_{cp} (K)		
General colour rendering index R_a		
Rated chromaticity co-ordinate values, initial and maintained, size of the MacAdam ellipse		
Rated useful lifetime of a luminaire (h)		
Gradual light output degradation at the ambient temperature of t_q = 25 °C for the rated useful lifetime of a luminaire, L_x, x value		
Abrupt light output degradation at the ambient temperature of t_q = 25 °C for the rated useful lifetime of a luminaire, C_y, y value		
Ingress protection class of a luminaire, IP class		
Protection against mechanical impacts, IK class		
Protection class (I or II)		
Overvoltage protection (kV)		
Luminaire weight (kg)		
Luminaire's effective projected wind surface area		
Luminaire colour (default RAL colour)		
Luminaire's guarantee period (years)		
Other information, documents and files to be delivered		
Description of the luminaire's materials (housing, reflectors, optical cover, lenses, heat sinks etc.)		
Description of the luminaire's control options		
Luminaire's dimensions		
Installation instructions for a luminaire		
Luminaire's photometric files in EULUMDAT file format, or information on where they can be acquired (on request)		
Declaration of conformity (on request)		

Bibliography

CIE 017:2016 ILV International Lighting Vocabulary, 2nd Edition

Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment

Electromagnetic Compatibility (EMC) Directive 2014/30/EU on the harmonisation of the laws of the Member States relating to electromagnetic compatibility

Guide for the EMCD:2018 (Directive 2014/30/EU) ANNEX 3 - EMC assessment where harmonised standards do not exist or are not fully (applied).

EN 13032-1:2004 Light and lighting - Measurement and presentation of photometric data of lamps and luminaires - Part 1: Measurement and file format and

EN 13032-4:2015 Light and lighting - Measurement and presentation of photometric data of lamps and luminaires - Part 4: LED lamps, modules and luminaires

EN 13201-3:2015 Road lighting - Part 3: Calculation of performance

EN 16276:2013 Evacuation Lighting in Road Tunnels

EN 40-2:2004 Lighting columns. General requirements and dimensions.

EN 50581:2012 Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances

EN 55015:2013 Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment

EN 60529:1992 Degrees of protection provided by enclosures

EN 60598-1:2015 Luminaires - Part 1: General requirements and tests

EN 60598-2-3:2003 Luminaires - Part 2-3: Particular requirements - Luminaires for road and street lighting

EN 60598-2-5:2015 Luminaires - Part 2-5: Particular requirements – Floodlights

EN 60598-2-22:2014 Luminaires - Part 2-22: Particular requirements - Luminaires for emergency lighting

EN 61000-3-2:2014 Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤16 A per phase)

EN 61000-3-3:2013 Electromagnetic compatibility (EMC) - Part 3-3: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16 A per phase and not subject to conditional connection

EN 61000-4-5:2014 Electromagnetic compatibility (EMC). Testing and measurement techniques. Surge immunity test

EN 61547:2009 Equipment for general lighting purposes. EMC immunity requirements

EN 61643-11:2012 Low-voltage surge protective devices – Part 11: Surge protective devices connected to low-voltage power systems – Requirements and test methods

EN 62262:2002 Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts

EN 62493:2015 Assessment of lighting equipment related to human exposure to electromagnetic fields

EN ISO 1461:2009 Hot dip galvanized coatings on fabricated iron and steel articles. Specifications and test methods.

EN ISO 3506:2009 Mechanical properties of corrosion-resistant stainless steel fasteners. Bolts, screws and studs.

EN ISO 9223:2012 Corrosion of metals and alloys. Corrosivity of atmospheres. Classification, determination and estimation.

EN 62386-101:2014 Digital addressable lighting interface – Part 101: General requirements – System components

EN 62386-102:2014 Digital addressable lighting interface – Part 102: General requirements – Control gear

IEC 62384:2006 DC or AC supplied electronic control gear for LED modules – Performance requirements

IEC 62717:2015 LED modules for general lighting - Performance requirements

IEC 62722-1:2014 Luminaire performance - Part 1: General requirements

IEC 62722-2-1:2014 Luminaire performance - Part 2-1: Particular requirements for LED luminaires

IEC/TR 62778:2014 Application of IEC 62471 for the assessment of blue light hazard to light sources and luminaires

ISO/CIE TS WD 22012:2017, Light and Lighting – Maintenance Factor Determination – Way of Working, draft 15.12.2017

Low Voltage Directive 2014/35/EU on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits

Regulation (EC) No 765/2008 setting out the requirements for accreditation and market surveillance relating to the marketing of products and repealing Regulation (EEC) No 339/93

UL94:2013 Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

Zhaga Book 18:2017, Edition 1.0, Luminaire extension module & receptacle