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Light and lighting — Maintenance factor determination — Way of working

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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ISO collaborates closely with the International Commission on Illumination (CIE) on all matters of standardization for light and lighting.

This document was prepared by Technical Committee ISO/TC 274, *Light and lighting*. The document has been jointly prepared with CIE JTC 11, *Light and Lighting — Maintenance factor — Way of working*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Continuous maintenance of lighting installations is essential as it ensures that the performance of a system stays within the design limits and promotes safety and efficient use of energy. In the design phase this is taken into account through the use of the maintenance factor. The maintenance factor combines several different factors such as the assumed product/installation behaviour, the environmental parameters and maintenance and cleaning schedules.

The methodology of determining the maintenance factor has been extensively documented by CIE (see Clause 2 and bibliography). However, as the focus of these technical reports was predominantly on incandescent and gas discharge light sources, more clarity is needed to ensure the proper use/translation of the existing methodology towards technologies such as light emitting diodes (LED).

Technologies such as LED distinguish themselves from other technologies by their long lifetime, low failure rate and their integration of components which were previously seen as separate components. As such the previous methods used to determine the depreciation and survival of luminaires might seem unusable and cause uncertainty. However, based on work by IEC (see Clause 2) the luminous flux depreciation and light source failure parameters have now been (re)established for LED-based light sources and allow for translation into an updated way of working to determine the maintenance factor using the existing CIE methodology and data for luminaire and surface dirt depreciation.

This document combines insights from IEC standards with regard to product performance of luminaires and light sources currently in the market with the existing determination methodology from CIE Technical Reports. Furthermore, it references the data in the CIE Technical Reports with regard to the impact of the environment on luminaires (accumulation of dirt on surfaces and luminaires).

This document provides the following:

— background information with respect to the principles of the maintenance factor and the relevant parameters for indoor and outdoor applications;

— a detailed way of working on how to apply the maintenance factor determination method (as described in CIE 154:2003 and CIE 097:2005) for outdoor and indoor lighting designs using the technologies available in the market;

— explanation and examples on how to apply the maintenance factor and how to ensure proper operation over time corresponding to the determined values.

Light and lighting — Maintenance factor determination — Way of working

1 Scope

This document specifies a standardized way of working for determining the maintenance factor for both outdoor and indoor lighting installations using the methodology as described in CIE 154:2003 and CIE 097:2005.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

CIE 097:2005, *Maintenance of Indoor Electric Lighting Systems*

CIE 154:2003, *Maintenance of Outdoor Lighting Systems*

CIE S 017, *ILV International Lighting Vocabulary*

IEC 62722-2-1, *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 CIE S 017 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
abrupt failure value
AFV
percentage of LED based products failing to operate at median useful life (L_x)

[SOURCE: IEC 62717:2014+AMD1:2015, modified — generalized to products]

3.2
cleaning interval
planned time between cleaning of (parts of) the products and/or components

3.3
CLO lifetime
time over which the *CLO* (3.5) feature ensures a constant luminous flux

3.4
component replacement interval
planned time between replacement of one or more specified luminaire component(s)

3.5
CLO
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

3.6
failure probability
p_f
probability that the component (e.g. light source, luminaire) catastrophically fails

Note 1 to entry: Failure probability is expressed as a factor.

3.7
installation lifetime
time over which the installation is expected to function as designed

3.8
maintenance period
total time over which the maintenance is planned

Note 1 to entry: Within a single maintenance period different maintenance cycles can be planned for different activities (e.g. cleaning, light source replacement).

Note 2 to entry: The maintenance period is often expressed in years.

3.9
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

3.10
surface refurbishment interval
planned time between surface refurbishment instances where the reflecting properties of the room or area surfaces are restored to their original state, including cleaning or painting of interior surfaces such as walls and ceilings

Note 1 to entry: The concept ‘surface refurbishment interval’ does not refer to surfaces which are an integral part of the luminaire.

3.11
survival probability
p_s
probability that a component continues to operate at a certain point in time

Note 1 to entry: Survival probability is expressed as a factor.

Note 2 to entry: The component can be e.g. a light source, a luminaire.

Note 3 to entry: There is a distinct difference between the survival factor (see 6.3) and the survival probability. The survival probability describes the performance of an individual component whereas the survival factor describes the outcome of the determination process as described in 6.3.

3.12
useful life
$L_{x,\mathrm{B}y}$[1)]
<of LED luminaires> length of time until a percentage *y* of a population of operating LED luminaires reaches gradual light output degradation of a percentage *x*, expressed in general in the '$L_{x,\mathrm{B}y}$' format

Note 1 to entry: Useful life can be specified on different product levels such as on individual LED, LED module or LED luminaire level. As for example luminaire design impacts thermal design, the useful life of the LED module might be different from the useful life of the luminaire.

[SOURCE: IEC 62717:2014+AMD1:2015, modified — specifier <of LED luminaires> and quantity symbol added to the term]

4 Symbols and units

The symbols and units in Table 1 apply.

Table 1 — Symbols and units

Symbol	Term	Unit
E_A	measured illuminance	lx
$E_\mathrm{A,c}$	corrected measured illuminance	lx
E_m	maintained illuminance	lx
E_in	initial illuminance	lx
f_LF	luminous flux factor (see 6.2)	1
f_LLM	lamp luminous flux maintenance factor	1
f_LM	luminaire maintenance factor (see 6.4)	1
f_m	maintenance factor (see 6.1) NOTE In this document the term "maintenance factor" is used for luminaires either with integrated or separate light sources, in contrast to CIE 97 and CIE 154 where the light source is generally seen as separate from the luminaire.	1
f_S	survival factor (see 6.3)	1
f_SM	surface maintenance factor (see 6.5)	1
Φ_L	luminaire luminous flux	lm
Φ_CLO	CLO-corrected luminaire luminous flux	lm
Φ_S	standard luminaire luminous flux	lm
Φ_e	end-of-life luminaire luminous flux	lm
Φ_i	initial luminaire luminous flux	lm
L_x	median useful life (see 3.8) for *x* % remaining luminous flux	h
$L_{x,\mathrm{B}y}$	useful life	h
p_f	failure probability	1
p_s	survival probability	1

1) Note that in the source IEC 62717 the expression "L_xB_y" is incorrectly presented as a quantity symbol for the term "useful life". As such, this document introduces the symbol $L_{x,\mathrm{B}y}$ for the term "useful life" for use in this document and further usage.

5 Influencing factors

5.1 Luminaire and/or light source characteristics

Depreciation of the luminaire and/or light source due to regular ageing and/or product-related characteristics shall be taken into account. This includes the following components:

— luminous flux depreciation (either of the light source or the luminaire, depending on the luminaire design) (see 6.2);

— light source and/or luminaire catastrophic failure (depending on luminaire design) (see 6.3).

5.2 Recoverable external factors

Recoverable factors concern those external factors, causing depreciation of the lighting installation performance, of which the effects can be economically reversed or mitigated during service and/or routine maintenance. The following factors shall be taken into account:

— removable pollution in/on the luminaire (see 6.4);

— depreciation of room or area surface characteristics relevant to the lighting installation (i.e. reduction of reflectance due to degradation of walls or ceiling finishes) (see 6.5).

5.3 Non-recoverable external factors

Influencing external factors are classified as non-recoverable when they are caused by external (environmental) factors and cannot be reversed during normal maintenance or are uneconomical to restore. These factors include the ageing/fading of (non-replaceable) components due to the environmental conditions and/or the irreversible soiling of components in applications due to specific (aggressive) substances.

Although these factors should be taken into account during the design and maintenance planning phase, they are not included in the maintenance factor as described in this document.

5.4 Maintenance period, cleaning, replacement and surface refurbishment interval

The choice of maintenance period, cleaning and replacement interval has a large impact on the maintenance factor. Prior to determination of the maintenance factor, the following information shall be determined:

— maintenance period (often expressed in years);

— cleaning interval of luminaires (often expressed in years);

— component replacement interval (often expressed in burning hours) and

— surface refurbishment interval (often expressed in years).

6 Maintenance factor determination

6.1 Basic description of the method

The maintenance factor f_m is determined using the Formula (1).

$$f_m = f_{LF} \cdot f_S \cdot f_{LM} \cdot f_{SM} \tag{1}$$

where

f_{LF} is the luminous flux factor (see 6.2);

f_S is the survival factor (see 6.3);

f_{LM} is the luminaire maintenance factor (see 6.4);

f_{SM} is the surface maintenance factor (see 6.5).

Annex A provides examples demonstrating the determination of these factors.

NOTE The methodology described in this document is a replacement of the methodology as described in CIE 097:2005 and CIE 154:2003. Terminology has been changed to suit a more generalized approach for luminaires either with integrated or separate light sources. Terminology changes are further specified in the relevant paragraphs.

6.2 Luminous flux factor

6.2.1 Luminous flux factor determination — General

The luminous flux factor, f_{LF}, expresses the depreciation of the luminous flux over time due to ageing of the 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.

For luminaires with an integrated light source the luminous flux factor, f_{LF}, shall be determined for the (full) luminaire. For luminaires with a non-integrated light source the luminous flux factor, f_{LF}, shall be determined for the light source (i.e. lamp).

NOTE 1 In CIE 097:2005 and CIE 154:2003 the equivalent of the luminous flux factor, f_{LF}, is the lamp luminous flux maintenance factor (f_{LLM}, abbreviation: LLMF). See Note in 6.1 for further information.

NOTE 2 The luminous flux factor, f_{LF}, determined at luminaire level will better reflect reality as this includes all components and operating conditions. Therefore, this is the default method for all types of luminaires. However, for luminaires with non-integrated light sources it is often not possible to determine this for the full luminaire as data is only available for the light source and as such the luminous flux factor, f_{LF}, on light source level is accepted for luminaires with non-integrated light sources.

For LED-based luminaires the luminous flux factor, f_{LF}, shall be determined based upon the light source or luminaire replacement interval and shall be provided by the luminaire supplier according to the definitions in IEC 62722-2-1.

The replacement interval can correspond to the median useful life, L_x. In this case the luminous flux factor, f_{LF}, equals $x/100$.

EXAMPLE 1 L_{80} = 50 000 h translates to 80 % remaining luminous flux at 50 000 h. If the luminaire or light source is also planned to be replaced at 50 000 h this would result in a luminous flux factor f_{LF} = 0,80.

If the replacement interval is different from the published values, the correct luminous flux factor, f_{LF}, needs to be supplied by the manufacturer. Alternatively, the tables with example values provided in Annex B may be used as an approximation.

NOTE 3 In some cases the depreciation values are not individually stated, but can be obtained from the lifetime values which will be presented as the median useful life, L_x, or the useful life '$L_{x,By}$' value. In both cases, only the x value of the L_x value is relevant for the luminous flux factor determination, the B_y element of '$L_{x,By}$' is not taken into account in the f_{LF} and consequently the f_m determination (e.g. the luminous flux factor f_{LF} = 0,80 after 50 000 h for both $L_{80,B50}$ = 50 000 h and $L_{80,B10}$ = 50 000 h specifications).

NOTE 4 In some cases the depreciation values will be presented as 'L_xF_y' values. The 'L_xF_y' is a (no longer in use) indication of lifetime not just taking into account depreciation but takes into account multiple maintenance factor parameters (namely luminous flux depreciation and survival factor). As such, this value is not appropriate for the determination of the maintenance factor as it does not allow for separation of the luminous flux factor, f_{LF}, and the survival factor, f_S.

For light sources such as halogen lamps, high pressure sodium lamps, metal halide lamps or fluorescent lamps, the depreciation of the luminous flux is often provided as a separate characteristic for given lifetimes.

EXAMPLE 2 If the planned maintenance period is at 16 000 h and the rated lamp luminous flux maintenance factor f_{LLM} provided by the manufacturer at 16 000 h is 0,90, then the luminous flux factor f_{LF} is 0,90.

NOTE 5 Dimming and/or switching behaviour can have a positive or negative effect on the depreciation of the light source, but this depends upon the luminaire and/or light source design. Information on these effects can be requested from the manufacturer of the light source or luminaire.

6.2.2 Luminous flux factor determination — Special case: Constant light output (CLO)

Luminaires utilizing constant light output techniques constantly 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 functionality needs to be captured in the determination of the luminous flux factor, f_{LF}.

The CLO feature is realized by initially dimming the light source to the predicted end-of-life luminous flux and steadily 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 The increasing power consumption over time also has an effect on the electrical design and energy calculations for the installation but is also a factor when comparing different CLO and non-CLO luminaires.

NOTE 2 In the context of this TS, CLO refers to the stand-alone 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}. Other systems using external input to correct for depreciation exist but are not a part of this document.