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PUBLICLY AVAILABLE SPECIFICATION

PRE-STANDARD

colour inside

LED modules for general lighting – Performance requirements

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LED MODULES FOR GENERAL LIGHTING – PERFORMANCE REQUIREMENTS

FOREWORD

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The text of this PAS is based on the following document:	This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document
Draft PAS	Report on voting
34A/1444/PAS	34A/1462/RVD

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INTRODUCTION

This first edition of a performance PAS for LED modules for general lighting applications acknowledges the need for relevant tests for this new source of electrical light, sometimes called "solid state lighting". The publication is closely related to simultaneously developed and edited performance standards publications (or PAS) for luminaires in general and for LED-luminaires. Changes in the LED module PAS will have an impact on the luminaire standards and vice versa, due to the behaviour of LEDs. Therefore, in the development of the present PAS, a close collaboration of experts on both products has taken place.

The provisions in the PAS represent the technical knowledge of experts from the fields of the semiconductor (LED chip) industry and of those of the traditional electrical light sources.

Three types of LED-modules are covered: with integral controlgear, with means of control on board, but with separate controlgear ("semi-ballasted"), and with complete external controlgear.

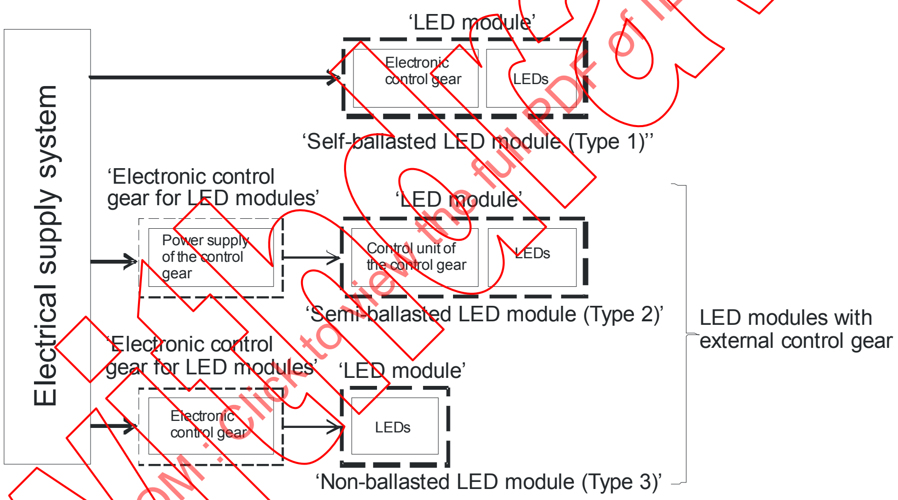
LED MODULES FOR GENERAL LIGHTING – PERFORMANCE REQUIREMENTS

1 Scope

This PAS specifies the performance requirements for LED modules, together with the test methods and conditions, required to show compliance with this PAS.

The following types of LED modules are distinguished (see Figure 1):

– Type 1: Self-ballasted LED modules for use on d.c. supplies up to 250 V or on a.c. supplies up to 1 000 V at 50 Hz or 60 Hz;
– Type 2: LED modules operating with external controlgear connected to the mains voltage, and having further control means inside ("semi-ballasted") for operation under constant voltage, constant, current or constant power;
– Type 3: LED modules where the complete controlgear is separate from the module for operation under constant voltage, constant current or constant power.



The power supply of the controlgear for semi-ballasted LED modules (Type 2) is an electronic device capable of controlling currents, voltage or power within design limits.

The control unit of the controlgear for semi-ballasted LED modules (Type 2) is an electronic device to control the electrical energy to the LED's.

A LED module with external controlgear can be either a non-ballasted LED module or a semi-ballasted LED module.

Figure 1 – Types of LED modules

The requirements of this PAS relate only to type testing.

Recommendations for whole product testing or batch testing are under consideration.

This PAS covers LED modules that intentionally produce white light, based on inorganic LEDs.

These performance requirements are additional to the requirements in IEC 62031 safety standard for LED modules.

Life time of LED modules is in most cases much longer than the practical test times. Consequently, verification of manufacturer's life time claims cannot be made in a sufficiently confident way, because projecting test data further in time is not standardised. For that reason, the acceptance or rejection of a manufacturers life time claim, past 25 % of rated life (with a maximum of 6 000 h), is out of the scope of this PAS.

Instead of life time validation, this PAS has opted for lumen maintenance codes at a defined finite test time. Therefore, the code number does not imply a prediction of achievable life time. The categories are lumen-depreciation character categories showing behaviour in agreement with manufacturer's information which are provided before the test is started.

In order to validate a life time claim, an extrapolation of test data is needed. A general method of projecting measurement data beyond limited test time is under consideration.

The pass/fail criterion of the life time test as defined in this PAS is different from the life time metrics claimed by manufacturers. For explanation of recommended life time metrics, see Annex C.

NOTE 1 When modules are operated in a luminaire, the claimed performance data can deviate from the values established via this PAS due to e.g. luminaire components that impact the performance of the module.

NOTE 2 The external electronic controlgears for LED modules as mentioned in Type 2 and Type 3 are not part of the testing against the requirements of this PAS.

NOTE 3 For protection for water and dust ingress, see Clause B.4.

It may be expected that self-ballasted LED modules which comply with this PAS will start and operate satisfactorily at voltages between 92 % and 106 % of rated supply voltage. LED modules with external controlgear are expected to start and operate satisfactorily in combination with the specified controlgear complying with IEC 61347-2-13 and IEC 62384. All LED modules are expected to start and operate satisfactorily when operated under the conditions specified by the module manufacturer and in a luminaire complying with IEC 60598-1.

For compliance with EMC requirements, reference is made to regional requirements. For relevant standards, see Bibliography.

NOTE It should be regarded that only those types of LED modules are subject to EMC requirements which

– in case of harmonic current are directly connected to the mains and have active elements on board;
– in case of radiated or conducted disturbances are directly connected to the mains (Type 1) or to a battery;
– in case of immunity are directly connected to the mains (Type 1) or to a battery.

2 Normative references

The following referenced documents are indispensable for the application 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.

IEC 60050-845, *International Electrotechnical Vocabulary – Part 845: Lighting*

IEC 60068-2-14, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60081:1997, *Double-capped fluorescent lamps – Performance specifications*

IEC 60598-1, *Luminaires – Part 1: General requirements and tests*

IEC/TR 61341, *Method of measurement of centre beam intensity and beam angle(s) of reflector lamps*

IEC 61347-2-13, *Lamp controlgear – Part 2-13: Particular requirements for d.c. or a.c. supplied electronic controlgear for LED modules*

IEC 62031:2008, *LED modules for general lighting – Safety specifications*

IEC 62384, *DC or AC supplied electronic control gear for LED modules – Performance requirements*

IEC/TS 62504, *General lighting – LED and LED modules – Terms and definitions*

CIE 13.3:1995 (CD008-1995 included), *Method of measuring and specifying colour rendering properties of light sources*

CIE 121:1996, *The photometry and goniophotometry of luminaires*

CIE 177:2007, *Colour rendering of white LED light sources*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-845 and IEC/TS 62504 apply, together with the following.

3.1
rated value
quantity value for a characteristic of a LED module for specific operating conditions

The value and the conditions are specified in this PAS, or assigned by the manufacturer or responsible vendor.

3.2
test voltage, current or power
input voltage, current or power at which tests are carried out

3.3
lumen maintenance
value of the luminous flux at a given time in the life of a LED module divided by the initial value of the luminous flux of the module and expressed as a percentage x of the initial luminous flux value

NOTE The lumen maintenance of a LED module is the effect of decrease of lumen output of the LED(s) or a combination of this with failure(s) of LED(s) if the module contains more than one LED.

3.4
initial values
photometric and electrical characteristics at the end of the ageing period and/or stabilisation time

3.5
maintained values
photometric and electrical characteristics at an operational time as stated in 6.1, including stabilisation time

3.6
rated life
length of time during which a population of LED modules provides more than claimed percentage x of the initial luminous flux, published in combination with the failure fraction, as declared by the manufacturer or responsible vendor

NOTE 1 For sample size, see Clause 6.

NOTE 2 Note 2 and Note 3 of 3.7 apply.

NOTE 3 For explanation of the figure L_xF_y, see Annex C.

3.7
life (of an individual LED module)
$\boldsymbol{L_x}$
length of time during which a LED module provides more than claimed percentage x of the initial luminous flux, under standard conditions

NOTE 1 A LED module has thus reached its end of life, when it no longer provides claimed percentage x of the initial luminous flux. Life is always published as combination of life (L_x) at lumen maintenance x and failure fraction F_y, see 3.8.

NOTE 2 Any built-in electronic controlgear, however, may show a sudden end of life failure. The definition under 3.7 implies that a LED module giving no light at all, due to an electronic failure, has actually reached end of life, since it no longer complies with the minimum luminous flux level as declared by the manufacturer or responsible vendor.

3.8
failure fraction
$\boldsymbol{F_y}$
percentage y of a number of LED modules of the same type that at their rated life designates the percentage (fraction) of failures

NOTE 1 This failure fraction expresses the combined effect of all components of a module including mechanical, as far as the light output is concerned. The effect of the LED could either be less light than claimed or no light at all.

NOTE 2 For LED modules, normally a failure fraction of 10 % or/and 50 % are being applied, indicated as F_{10} and/or F_{50}.

3.9
photometric code*
colour designation of a LED module giving white light is defined by the correlated colour temperature and the CIE 1974 general colour rendering index

* Under consideration

NOTE Definition of photometric code is given in IEC/TS 62504 as light colour designation.

3.10
stabilisation time
time which the LED module requires to obtain stable photometric conditions with constant electrical input

NOTE LED modules may be regarded stable at stable thermal conditions.

3.11
ageing
preconditioning period of the LED module

3.12
type
LED module, representative of the production

3.13
family
group of LED modules that have

- the same method of control and operation (self-ballasted, semi-ballasted, non-ballasted);
- the same classification according to the method of installation (reference is made to IEC 62031, Clause 6);
- the same class of protection against electrical shock;
- the same design characteristics, distinguished by common features of materials, components, and/or method of processing

3.14
type test
conformity test on one or more LED modules, representative of the production

3.15
type test sample
one or more LED modules submitted by the manufacturer or responsible vendor for the purpose of the type test

3.16
t_p-point
the designated location of the point where to measure the performance temperatures t_p and $t_{p\ max}$ at the surface of the LED module

3.17
t_p temperature
temperature at the t_p-point, related to the performance of the LED module

NOTE 1 $t_p \leq t_c$. This is only the case if the location of t_p and t_c is the same. For t_c, see 3.10 of IEC 62031.

NOTE 2 The location of t_p and t_c can be different, but the value of t_c is leading.

NOTE 3 For a given life time, the t_p temperature is a fixed value, not a variable.

NOTE 4 There can be more than one t_p, depending on the life time claim.

3.18
recommended maximum LED module operating temperature value
$t_{p\ max}$
maximum t_p temperature as declared by the manufacturer or responsible vendor

NOTE 1 $t_{p\ max} \leq t_c$. This is only the case if the location of $t_{p\ max}$ and t_c is the same. For t_c, see 3.10 of IEC 62031.

NOTE 2 The location of $t_{p\ max}$ and t_c can be different, but the value of t_c is leading.

3.19
semi-ballasted LED module
module which carries the control unit of the controlgear, and is operated by the separated power supply of the controlgear

NOTE In this standard, semi-ballasted LED modules are designated “Type 2”.

3.20
control unit of the controlgear
electronic device, being part of the controlgear, responsible for controlling the electrical energy to the LEDs as well as colour mixing, response to depreciating luminous flux and further performance features

NOTE In semi-ballasted LED modules, the control unit of the controlgear is on board the module and separate from the power supply of the controlgear.

3.21
power supply of the controlgear
electronic device, being part of the controlgear, capable of controlling current, voltage or power within design limits. This device contains no additional LED control capabilities.

NOTE 1 For semi-ballasted LED modules, the power supply of the controlgear is separate from the LED module on a distant location.

NOTE 2 The energy source of a power supply can be either a battery or the electrical supply system.

3.22
LED module efficacy
quotient of the luminous flux emitted by the power consumed by the LED module

NOTE The efficacy is expressed in lm/W.

3.23
LED die
block of semi-conducting material on which a given functional circuit is fabricated

NOTE For a schematic built-up of a LED die, see Figure F.1.

3.24
LED package
assembly of one or more LED-dies, possibly with optical element and thermal, mechanical, and electrical interfaces

The device does not include the control unit of the controlgear, does not include an IEC standardised lamp cap, and is not connected directly to the mains.

NOTE A LED package is a discrete component and part of the LED module. For a schematic built-up of a LED package, see Figure F.2.

4 Marking

4.1 Mandatory marking

Information on the parameters shown in Table 1 shall be provided by the manufacturer or responsible vendor and be located as described.

The information shall be related to the maximum performance operating temperature $t_{p\ max}$, except for the t_p-point (item j), the dimensions (item n) and the availability of a heat sink (item o).

NOTE This information is in addition to the mandatory marking required by IEC 62031.

For scaleable modules, refer to 6.1 and mark the reference dimensions in the leaflet.

Table 1 – Mandatory marking and location of marking [a]
(x = required, - = not required)

Parameters	Product	Packaging	Product datasheets, leaflets or website
Rated luminous flux (lm)	-	x	x
Photometric code (See Annex D)[d]	-	x	x
Rated life (h) and the associated rated lumen maintenance (x)	-	x	x
Failure fraction (F_y), corresponding to the rated life	-	x	x
Lumen maintenance code (see Table 6)	-	-	x
Rated chromaticity co-ordinate values both initial and maintained (see Table 5)	-	-	x
Correlated colour temperature (K)	-	-	x
Rated Colour Rendering Index	-	-	x
$t_{p\ max}$ [c] of LED module (°C)	x [b]	-	x
t_p-point	x [c]	-	x
Ageing time (h), if different to 0 h	-	-	x
Ambient temperature range	-	-	x
Efficacy (lm/W)	-	-	x
Dimensions, including dimensional tolerances	-	-	x
Availability of a heat sink	-	-	x

[a] Regional requirements may apply and overrule.

[b] If the space on the module is not large enough, marking on the packaging only is sufficient.

[c] In case t_p and t_c are at the same location, then $t_{p\ max}$ is not marked separately on the module, but given in the product datasheet.

[d] Under consideration.

4.2 Additional marking

If the module does not have an own heat sink, the module manufacturer shall provide this information.

For built-in and integral LED modules with or without heat management means, the relations between at least 3 temperatures at the t_p-point including recommended $t_{p\ max}$ according to Table 1 and each estimated life time may be provided by the manufacturer or responsible vendor. See Table 2 as an example.

For independent LED modules, the relations between at least 3 ambient temperatures including 25 °C and each estimated life time may be provided by the manufacturer or responsible vendor. See Table 2 as an example.

Table 2 – LED module life time information

t_p temperature (°C) measured at the t_p-point	XX *	XX *	XX *
Rated life time (h)	XX XXX*	XX XXX*	XX XXX*
* values to be declared by the LED module manufacturer.			

NOTE 1 Additional information from the LED module manufacturer to the tabled t_p temperatures and life time is allowed. For the chosen life time, t_p is a fixed value.

NOTE 2 Verification is currently not covered by this PAS.

In addition to 4.1, the marking as given in Table 3 may be used.

Table 3 – Optional marking and location of marking
(x = required, - = not required)

Parameters	Product	Packaging	Product datasheets, leaflets or website
Luminous intensity distribution	-	-	x
Beam angle	-	-	x
Peak intensity	-	-	x

5 Dimensions

All of the tested items in a sample shall be within the dimensional tolerances as declared by the manufacturer or responsible vendor.

Compliance is checked by inspection.

6 Test conditions

6.1 General test conditions

Testing duration is 25 % of rated life time up to a maximum of 6 000 h.

NOTE Additional LED modules within the same family (see 3.13) may be subjected to decreased testing duration. For identification of a family, see Table 4, for details on sample sizes for family testing, see Table 7.

Test conditions for testing electrical and photometric characteristics, lumen maintenance and life are given in Annex A.

All tests are conducted on “n” LED modules of the same type. The number “n” shall be a minimum of products as given in Table 7. LED modules used in the endurance tests shall not be used in other tests.

In case of Type 2 and Type 3 LED modules, testing requires operation with an external reference power supply and reference controlgear, respectively. Specification of the reference power supply and reference controlgear shall be made by the LED module manufacturer or responsible vendor.

LED modules with dimming control shall be adjusted to maximum output for all tests.

LED modules with adjustable colour point shall be adjusted / set to one fixed value as indicated by the manufacturer or responsible vendor.

LED modules which are scaleable, e.g. modules of linear geometry, but very long length, shall be tested at a length of 50 cm or, if not scaleable there, at the nearest value to 50 cm. The module manufacturer shall indicate which controlgear is suitable for this length.

6.2 Creation of module families to reduce test effort

6.2.1 General

The introduction of family aims to guide LED module manufacturers towards to platform designs thus to allow the possibility to use data of the existing baseline product that had already been tested at an operational time as stated in 6.1. The baseline product is considered to be the first LED module complying this PAS and designated to be part of the family.

6.2.2 Variations within family

Each family of LED modules requires a case-by-case consideration. The range of LED modules should be manufactured by the same manufacturer, under the same quality assurance system. The type variations of the range (e.g. CCT) should be essentially identical with respect to materials used, components and construction applied. Type test sample(s) should be selected with the cooperation of the manufacturer and the testing station.

Requirements for the identification of a family of LED modules for type testing are given in definition 3.13 and used in Table 4.

Testing time may be reduced within family for 1 000 h (see Note 3) in case variations within part characteristics are fulfilled with conditions given in Table 4.

Table 4 – Allowed variations within family

Part characteristics intended to be varied	Conditions for acceptance
Housing/chassis, heat sink/heat management	Temperature measurement point value of LED package (location and its value given by the LED module supplier) and other components remains the same value as indicated and specified by the manufacturer or responsible vendor (see also Note 1 of this subclause).
Optics (see NOTE 2)	The test results showing the effect of optical material change shall be documented in the manufacturer's technical file.
LED package	t_p remains at the same value as indicated and specified by the manufacturer or responsible vendor (see also Note 1 of this subclause).
Controlgear (Applicable for Type 1 or Type 2 LED modules)	t_p remains at the same value as indicated and specified by the manufacturer or responsible vendor. A statistical failure rate calculation based on a MTBF calculation by manufacturer must show equal or lower failure rate of the electronic controlgear.

NOTE 1 The value of t_p can be used as long as the correlation between the temperature measurement value of LED and t_p is defined (process under consideration).

NOTE 2 Optics includes for instance secondary optics (lenses), reflectors, trim and gasket and their interconnections. The results should relate to changes in luminous flux, luminous peak intensity, luminous intensity distribution, beam angle, shift in colour co-ordinates, shift in CCT and shift in CRI.

NOTE 3 Value under consideration.

NOTE 4 Any change on part tolerances is documented in the manufacturer's technical file.

6.2.3 Compliance testing of family members

The following performance characteristics of members within a family at initial and after reduced testing time shall be in line with the values provided by the responsible manufacturer or vendor of the module:

- chromaticity co-ordinates,
- colour rendering index,
- lumen maintenance code,
- results of acceleration operated life test.

Documentation of data shall be provided to the testing station in manufacturer's technical file.

Compliance is checked as follows:

For all of the tested items in a sample, the measured values of a LED module (the initial and maintained value) shall not move beyond the values as indicated by the manufacturer or responsible vendor. The measured values shall be of the same category or code as the provided values or better. All the LED modules in a sample shall pass the test.

7 Module power

Measurements are conducted under the most adverse condition. For conditions, see Annex A.

Compliance is checked as follows:

The initial power consumed by each individual LED module in the measured sample shall not exceed the rated power by more than 10 %.

The 97,5 % one-sided upper confidence limit for the sample mean of power shall not exceed 110 % of the rated power value.*

The 97,5 %* upper confidence limit for sample size n according Table 7 is calculated by the formula:

$$\overline{X} + (t_{n-1,0{,}975} \cdot \frac{S}{\sqrt{n}})$$

where $\overline{X}$, S and n are the sample average, standard deviation and number of LED modules respectively and $t_{n-1,\ 0{,}975}$ is the t-statistic for a 97,5 % confidence limit for n-1 degrees of freedom.

* Under consideration; in discussion: 95 % one-sided confidence interval.

NOTE 1 Note 2 of Clause 1 should be regarded.

NOTE 2 For sample sizes, see calculations in Annex E.

8 Light output

8.1 Luminous flux

Luminous flux is measured according to Annex A.

Compliance is checked as follows:

The initial luminous flux of each individual LED module in the measured sample shall not be less than 90 % of the rated lumen output.

The 97,5 % one-sided lower confidence limit for the sample mean of luminous flux shall exceed 90 % of the rated luminous flux value.*

The 97,5 %* lower confidence limit for sample size n according Table 7 is calculated by the formula:

$$\overline{X} - (t_{n-1;0,975} \cdot \frac{S}{\sqrt{n}})$$

where $\overline{X}$, S and n are the sample average, standard deviation and number of LED modules respectively and $t_{n-1;\ 0,975}$ is the t-statistic for a 97,5 % confidence limit for n-1 degrees of freedom.

* Under consideration; in discussion: 95 % one-sided confidence interval.

NOTE 1 For sample sizes, see calculations in Annex E.

8.2 Luminous intensity distribution, peak intensity and beam angle

8.2.1 General

The requirements of 8.2.4 and 8.2.5 are to be applied to LED modules having a directional (spot) distribution.

NOTE Luminous intensity distribution of a LED module may be specific for an application.

8.2.2 Measurement

The intensity of light emitted from the LED module in different directions is measured using a goniophotometer. All photometric data shall be declared for the LED module operating at its temperature t_p per Clause A.1.

NOTE The allowed photometric variations detailed are to take account of manufacturing tolerances.

8.2.3 Luminous intensity distribution

The distribution of luminous intensity shall be in accordance with that declared by the manufacturer.

Compliance is under consideration.

8.2.4 Peak intensity value*

Where a peak intensity value is provided by the manufacturer or responsible vendor, the initial peak intensity of each individual LED module in the measured sample shall not be less than 75 % of the rated intensity.

Compliance is checked according to Annex A.

* Average value and confidence level are under consideration.

8.2.5 Beam angle value*

Where a beam angle value is provided by the manufacturer or responsible vendor, the beam angle value of each individual LED module in the measured sample shall not deviate by more than 25 % of the rated value.

Compliance is checked according to Annex A.

* Average value and confidence level are under consideration.

8.3 Efficacy

LED module efficacy shall be calculated from the measured initial luminous flux of the individual LED module divided by the measured initial input power of the same individual LED module.

Compliance is checked as follows:

For all tested items in a sample, the LED module efficacy shall not be less than 90 % of the rated LED module efficacy as declared by the manufacturer of responsible vendor.

9 Chromaticity co-ordinates, correlated colour temperature (CCT) and colour rendering

9.1 Chromaticity co-ordinates

The initial chromaticity co-ordinates are measured. A second measurement of maintained chromaticity co-ordinates is made at an operational time as stated in 6.1. The measured actual chromaticity co-ordinate values (both initial and maintained) shall fit within one of 4 categories (see Table 5), which correspond to a particular MacAdams ellipse around the rated chromaticity co-ordinate value, whereby the size of the ellipse (expressed in n-steps) is a measure for the tolerance or deviation of an individual LED module.

Compliance is checked as follows:

For compliance of family members, refer to 6.2.3.

For all of the tested items in a sample, the measured chromaticity co-ordinate values of a LED module (the initial value and maintained value) shall not move beyond the chromaticity co-ordinate tolerance category as indicated by the manufacturer or responsible vendor (see Table 5). The measured values shall be of the same category as the rated values or better. The sample items for the chromaticity coordinate measurement shall be selected from four different batches.*

Table 5 – Tolerance (categories) on rated chromaticity co-ordinate values

Size of MacAdam ellipse, centred on the rated colour target	Colour variation category	
	initial	maintained
3-step	3	3
5-step	5	5
7-step	7	7
>7-step ellipse	7+	7+

The behaviour of the chromaticity co-ordinates of a LED module shall be expressed by stating the two measurement results of both initial chromaticity co-ordinates and maintained chromaticity co-ordinates. For an example, see Annex D.

NOTE 1 This PAS applies to LED modules for which it is in most cases possible to choose a CCT value that best fulfils the requirement of a particular application. Standardised colour points are under consideration.

NOTE 2 The tolerance areas are based on the ellipses defined by MacAdam, published in the Journal of the Optical Society of America, 1943, as normally applied for fluorescent lamps and other discharge lamps.

NOTE 3 See Annex A for measurement method of chromaticity co-ordinate values for LED modules.

*The colour variation between the items in a sample from different production runs resembles the variation within longer periods of production.

9.2 Correlated colour temperature (CCT)

Preferred values to ensure interchangeability are under consideration. The four-digit CCT value is divided by 100 and the resulting figure is rounded off to the next integer number, when using the photometric code in Annex D.

Compliance is checked as follows:

For compliance of family members, refer to 6.2.3.

For all of the tested items in a sample, the measured correlated colour temperature shall not move beyond the values as declared by the manufacturer or responsible vendor.

9.3 Colour rendering index (CRI)

The initial colour rendering index (CRI) of a LED module is measured. A second measurement is made at an operational time as stated in 6.1.

Compliance is checked as follows:

For all tested items in a sample, the measured CRI values shall not have decreased by more than

– *3 points from the rated CRI value (see Table 1) for initial CRI values, and*
– *5 points from the rated CRI value (see Table 1) for maintained CRI values.*

10 LED module life

10.1 General

Life of a LED module (as defined in 3.7) is the combined effect of gradual light output degradation, mostly caused by material degradation (see 10.2) and abrupt light output degradation, mostly caused by electrical component failure (see 10.3, endurance tests as an indication for reliability and life). Both elements are tested.

Reference is made to the definitions 3.3 and 3.8, the latter describing the indicated fraction of tested modules of a total sample (F_y) that may fail the requirements of the tests under 10.2 and 10.3.

NOTE On request, reduction of luminous flux due to zero lumen output and due to degradation of the LED material in the measured sample may be given separately.

10.2 Lumen maintenance

The lumen maintenance figure may vary depending on the application of the LED module. This PAS applies a minimum value of 70 %. Dedicated information on the chosen percentage should be provided by the manufacturer.

NOTE 1 As the typical life of a LED module is (very) long, it is within the scope of this PAS regarded impractical and time-consuming to measure the actual lumen reduction over life (e.g. L_{70}). For that reason, this PAS relies on test results to determine the expected lumen maintenance code of any LED module.

NOTE 2 The actual LED behaviour with regard to lumen-maintenance may differ considerably per type and per manufacturer. It is not possible to express the lumen-maintenance of all LED's in simple mathematical relations. A fast initial decrease in lumen output does not automatically imply that a particular LED will not make its rated life.

NOTE 3 Other methods providing more advanced insight in lumen depreciation over LED module life are under consideration.

This PAS has opted for "lumen maintenance categories" (see Figure 2) that cover the initial decrease in lumen output until an operational time as stated in 6.1. There are three categories of lumen maintenance compared to the initial lumen output (see Table 6).

Table 6 – Lumen maintenance code at an operational time as stated in 6.1

Lumen maintenance %	Code
≥90	9
≥80	8
≥70	7

The initial luminous flux shall be measured. The measurement is repeated at an operational time as stated in 6.1. The initial luminous flux value is normalized to 100 %; it is used as the first data point for determining module life. The measured luminous flux value at an operational time as stated in 6.1 shall be expressed as maintained value (= percentage of the initial value).

NOTE 4 It is recommended to measure the lumen output values at 1 000 h intervals (expressed as a percentage of the initial value) for a total equal to an operational time as stated in 6.1).

NOTE 5 This will give additional insight as to the reliability of the measured values, but assigning a code does not imply a prediction of achievable life time. Code "1" could be better or worse than Code "3".

For marking of the lumen maintenance (L_x) and the lumen maintenance categories, see Table 1.

Compliance at 25 % of rated life with a maximum of 6 000 h test duration:

For compliance of family members, refer to 6.2.3.

An individual LED module is considered having passed the test when the following criteria have been met:

a) The measured flux value at 25 % of rated life (with a maximum duration of 6 000 h) shall never be less than the maximum lumen maintenance value related to the rated life as defined and provided by the manufacturer or responsible vendor.

b) The measured lumen maintenance shall correspond with the "lumen maintenance code" as defined and provided by the manufacturer or responsible vendor.

Given a sample of n pieces (individuals) of LED modules according to Table 7 being subjected to the 6 000 h (or 25 % of rated life), it is deemed to having passed the test, if at the end of the test, the number of failed items is smaller or equal to the number claimed by the manufacturer. This PAS gives the following guide for calculation:

When F_{50} is specified, at least n-2 individual modules shall have passed;

when F_{10} is specified, at least n individual LED modules shall have passed.

NOTE 6 Calculation, based on 25 %* of claimed failure fraction F_y:
Claimed failure fraction F_{50} gives 25 % x F_{50} (= 50 %) x n (= 20) = 2,5, rounded off to next lower integer gives 2 LED modules allowed to fail.

Claimed failure fraction F_{10} gives 25 % x F_{10} (= 10 %) x n (= 20) = 0,5, rounded off to next lower integer gives 0 LED modules allowed to fail

*Assuming test time lower than the claimed life time, failure fraction at the end of the test is lower than the failure fraction at rated life. There is also no general relation between the failures at the end of the test in relation to the claimed failure fraction.

In order to set a practical pass/fail criteria of reasonable quality, this PAS has chosen for a linear relation of the claimed failure fraction with the specified test time, being 25 % of rated life (with a maximum of 6 000 h).

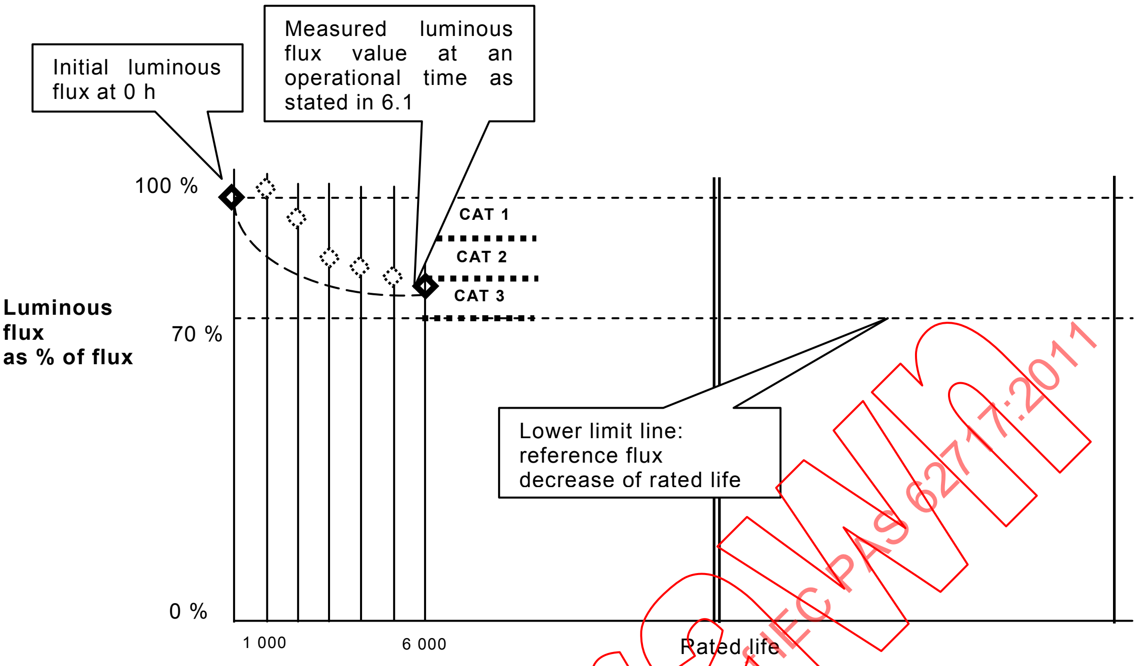


Figure 2 – Luminous flux depreciation over test time

10.3 Endurance tests

10.3.1 General

LED modules shall be subjected to the following tests specified in 10.3.2 to 10.3.4.

NOTE All tests can be carried out in parallel with different LED modules.

10.3.2 Temperature cycling test

Temperature cycling test according IEC 60068-2-14, Test Nb: Change of temperature with specified rate of change.

The LED module is placed in a test chamber in which the temperature is varied from – 10 °C to +50 °C* over a 4 h period and for a test duration of 250** periods (1 000 h). A 4 h period consists of 1 h holding on each extreme temperature and 1 h transfer time (1K/min) between the temperature extremes. The LED module is switched on and off for 17 min.

Compliance is checked as follows:

At the end of the test, all the LED modules shall operate and have a luminous flux which stays within the claimed lumen maintenance code for a period of at least 15 min and show no physical effects of temperature cycling such as cracks or delaminating of the label.

* under consideration. When the manufacturer declares in his literature a temperature range with minimum and maximum temperatures, these values should be used.

** under consideration.

NOTE 1 The switching period of 34 min is chosen to get a phase shift between temperature and switching period.

NOTE 2 The temperature requirements of Clause A.1 do not apply.

10.3.3 Supply switching test

At test voltage, current or power, the module shall be switched on and off for 30 s each. The cycling shall be repeated for a number equal to half the rated life in h (example: 10k cycles if rated life is 20k h.).

NOTE The temperature requirements of Clause A.1 do apply.

Compliance is checked as follows:

At the end of the test, all the LED modules shall operate and have a luminous flux which stays within the claimed lumen maintenance code for a period of at least 15 min.

10.3.4 Accelerated operation life test

The LED module shall be operated continuously without switching at test voltage and at a temperature corresponding to 10 K (see Note 2) above the maximum recommended operating temperature $t_{p\ max}$, over an operational time as stated in 6.1. Any thermal protecting devices that would switch off the LED module or reduces the light output at a threshold temperature > $t_{p\ max}$, shall be bypassed.

Compliance is checked as follows:

For compliance of family members, refer to 6.2.3.

At the end of this period, and after cooling down to room temperature, all the modules shall remain alight (see Note 3) for at least 15 min.

NOTE 1 An accelerated test should not evoke fault modes or failure mechanisms which are not related to normal life effects. For example, a too high temperature increase above $t_{p\ max}$ would lead to chemical or physical effects from which no conclusion on real life can be made.

NOTE 2 LED module manufacturer or responsible vendor may declare higher temperature above $t_{p\ max}$ as indicated, but Note 1 must be respected.

NOTE 3 "Alight" means the claimed lumen maintenance according to Table 6, with an acceptable decrease of x % ("x" is under consideration).

NOTE 4 The temperature requirements of Clause A.1 do not apply.

11 Verification

The minimum sampling size for type testing shall be as given in Table 7. The sample shall be representative of a manufacturer's production.

Table 7 – Sample sizes

1	2	3	4
Clause or sub-clause	**Test**	**Minimum number of items in a sample for an operational time as stated in 6.1**	**Minimum number of items in a sample for testing a family at reduced test duration after changing product feature according to 6.2**
4.1	$t_{p\ max}$	Same 5 items for all tests	Same 5 items for all tests
4.1	t_p-point		
5	Dimensions including dimensional tolerances		
8.2.3	Luminous intensity distribution		
8.2.4	Peak intensity value		
8.2.5	Beam angle value		
7	Power	Same 20 items for all tests	Same 5 items for all tests
8.1	Luminous flux		
8.3	Efficacy		
9.1	Chromaticity tolerance		
9.2	Correlated colour temperature		
9.3	Colour rendering index		
10.2	Lumen maintenance		
10.3.2	Temp. cycling, energised	20	5
10.3.3	Supply voltage switching	20	5
10.3.4	Accelerated operation life test	10	5

12 Information for luminaire design

For information for luminaire design, see Annex B.

Annex A
(normative)

Method of measuring LED module characteristics

A.1 General

Unless otherwise specified, all measurements shall be made in a draught-free room at a temperature of 25 °C with a tolerance of ± 1 °C, a relative humidity of 65 % maximum and steady state operation of the LED module.

NOTE For air movement requirements, see CIE 121, section 4.3.2.

Maintenance (see 10.2) and supply switching (see 10.3.3) operation shall be conducted in the temperature interval ($t_{p\ max}$-5, $t_{p\ max}$). For the supply switching test, the temperature requirement is applicable only to the ON time. The value of $t_{p\ max}$ shall not be exceeded. An appropriate heat sink or additional heating may need to be applied to obtain the correct $t_{p\ max}$ value. For testing purposes, the t_p-point shall be marked easily accessible.

Final test results are to be presented as if testing had been executed at the maximum recommended operating temperature ($t_{p\ max}$) of the LED module. Tests may be performed at different temperatures; for this, the relation between the two temperatures has to be established at beforehand in an unambiguous manner. In case of doubt, depending on the type of control circuit the module manufacturer is using, the t_p measurement shall be done at the most onerous condition of operation. The value of $t_{p\ max}$ shall be reported in the marking clause.

The manufacturer shall provide, on request, information on the method used to reproduce the reference characteristics declared at t_p-point.

The test voltage, current or power shall be stable within ± 0,5 %, during stabilisation periods, this tolerance being ± 0,2 % at the moment of measurements. For ageing and luminous flux maintenance testing, the tolerance is 2 %. The total harmonic content of the input shall not exceed 3 %. The harmonic content is defined as the r.m.s. summation of the individual harmonic components using the fundamental as 100 %.

Measurement of light output and module operating voltage, current or power within the 15 min stabilisation period shall be taken once per minute. During the final 5 min of stabilisation time, the difference of maximum and minimum readings of light output and module operating voltage, current or power shall be less than 1 % of the average of the final 5 readings. If this is not feasible, a subsequent 15 min stabilisation period shall be taken. A maximum of 3 stabilisation periods of 15 min is considered sufficient for all type of LED modules.

All tests shall be carried out at rated frequency. Unless otherwise specified for a specific purpose by the manufacturer or responsible vendor, modules shall be operated in free air for all tests including lumen maintenance tests.

Over life tests and at measurement, in order to avoid any measurement disturbance, the test sample shall be free from pollution (dust, etc.) that can occur during the testing period.

A.2 Electrical characteristics

A.2.1 Test voltage, current or power

The test voltage, current or power shall be the rated voltage, current or power (for tolerance, see Clause A.1). In the case of a range, measurements shall be carried out at the input value corresponding to the most adverse effect to the temperature of the module.

A.2.2 Ageing

LED modules do not require any ageing prior to testing.

A.3 Photometric characteristics

A.3.1 Test voltage, current or power

The test voltage, current or power shall be the rated voltage, current or power (for tolerance, see Clause A.1). In the case of a range, measurements shall be carried out at the input value corresponding to the most adverse effect to the temperature of the LED module.

A.3.2 Luminous flux

The initial and maintained luminous flux shall be measured after stabilisation of the LED module.

NOTE 1 Reference is made to document CIE 84. IES LM-79-08 as well as Annex B of JIS C 8155 contain valuable information on measuring luminous flux.

NOTE 2 Method of measuring the luminous flux of LED modules is under consideration.

NOTE 3 If the LED module requires additional heating or heat sinking, provisions in the measurement setup should be taken to maintain the requested temperature at t_p. The manufacturer should provide, on request, information on the method used to reproduce the reference characteristics declared at t_p.

A.3.3 Luminous intensity distribution

Luminous intensity distribution shall be measured in accordance with CIE 121 and IEC/TR 61341.

Luminous intensity distribution data shall be available for all variations of the LED module and any optical attachments or accessories that the LED module has been specified for use with. Luminous intensity distribution data shall be provided for the LED module in accordance with an established international or regional format*.

* Information regarding acceptable regional standards for photometric data formats is under consideration.

A.3.4 Peak intensity

The peak intensity shall be measured in accordance with IEC/TR 61341.

A.3.5 Beam angle

The beam angle shall be measured in accordance with IEC/TR 61341.

NOTE It should be taken care that the beam angle is not determined by the half peak, but by the half centre beam intensity.

A.3.6 Colour rendering

Measurement of colour rendering index shall be made in accordance to CIE 13.3 and CIE 177.

A.3.7 Chromaticity co-ordinate values

Reference is made to IEC 60081, Annex D: Chromaticity co-ordinates.

Chromaticity co-ordinate values of LED modules may depend on the radiation angle. The manufacturer shall provide information on the method used.

Annex B
(informative)

Information for luminaire design

B.1 Temperature stability

It should be safeguarded that the LED module performance temperature t_p is not exceeded.

B.2 Binning procedure of luminous flux of LEDs

Under consideration.

B.3 Binning procedure of white colour LEDs

Under consideration.

B.4 Ingress protection

In case a 'built-in' LED module makes part of the luminaire enclosure and applies in an application with a certain IP classification, the module specification must reflect this. Final assessment will be done on the luminaire.

NOTE The LED module design with regard to IP rating should specified between the LED module maker and the LED luminaire maker.

An "independent" classified LED module should be tested to the specified IP rating according to IEC 60598-1.

LED modules classified as "integral" should not be separately tested.

Annex C
(informative)

Explanation of recommended life time metrics

C.1 General

Life time of LED modules can be far more than what practically can be verified with testing. Furthermore, the decrease in light output differs per manufacturer making general prediction methods difficult. This PAS has opted for lumen maintenance categories that cover the initial decrease in luminous flux until an operational time as stated in 6.1. Due to this limited test time, the claimed life of a LED module cannot be confirmed nor rejected in most cases. The recommended metrics for specifying LED module life time is explained below and differs from the pass/fail criterion of the life time test as in 10.2.

C.2 Life time specification

It is recommended for LED modules to specify the lumen maintenance apart from the catastrophic failures in a standardised way giving more insight in light output behaviour (see marking).

C.3 Life time specification for gradual light output degradation

Example: $L_{70}B_{50}$ is understood as the life time where light output is ≥70 % for 50 % of the population.

The failure fraction for B_y expresses only the gradual light output degradation as a percentage y of a number of LED modules of the same type that at their rated life designates the percentage (fraction) of failures. Abrupt light output degradation is exempted. The light output threshold level for L and failure fraction for B_y is free to be chosen by the manufacturer. See Clause C.6 for recommended fraction values for B_y.

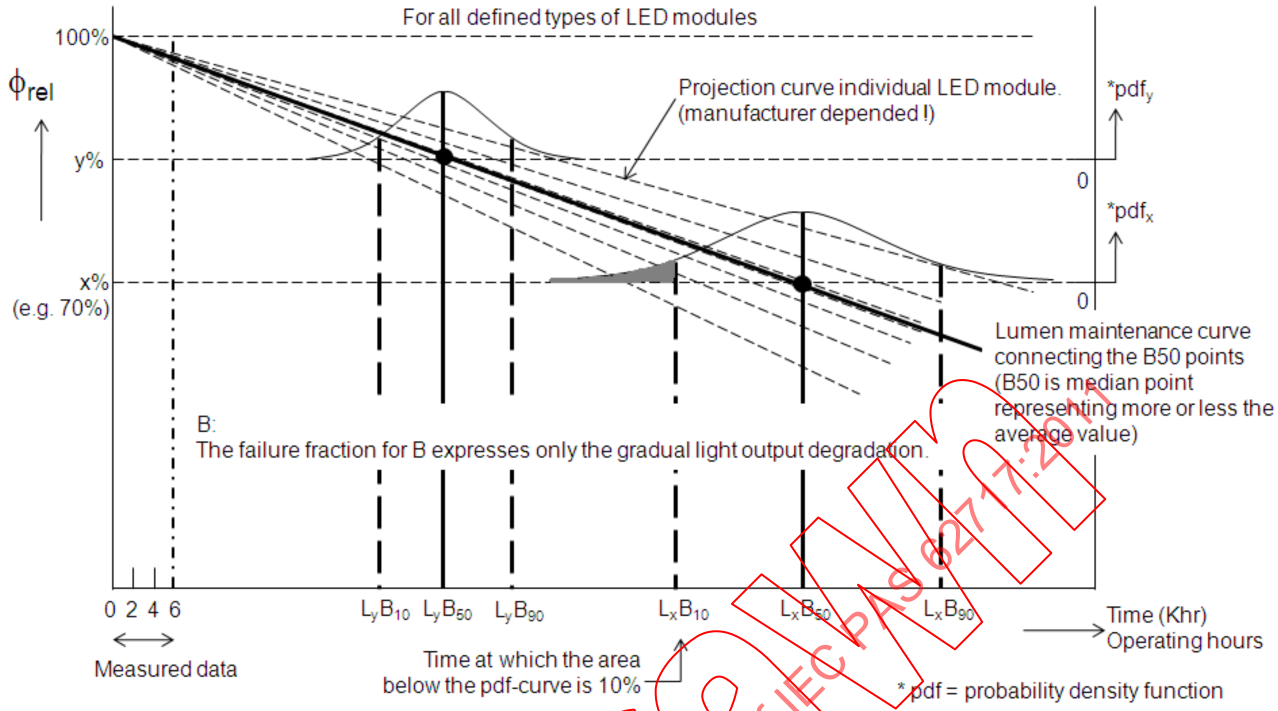


Figure C.1 – Life time specification for gradual light output degradation

The shape of the probability density function (pdf) and the shape of the projection curve in Figure C.1 is for illustration purpose only. Probability density function can be Weibull, Lognormal, Exponential or Normal depending on the measured data and used projection method.

The failure function F(t) or cumulative distribution function (CDF(t)) is the failure percentile as function of time. This is mathematically expressed as follows:

$$F(t) = CDF(t) = \int_0^t pdf(t)dt$$

By definition F(t=infinite) is 1 (100 %). In other words, the total area below the pdf curve from time is zero to time infinite is one, meaning the whole population failed.

Explanation of failure fraction for B:

Example: Considering a lumen maintenance threshold level of 70 %, 10 % of the population failed at time $L_{70}B_{10}$ indicated by the grey area in Figure C.1, mathematically expressed as follows:

$$F(L_{70}B_{10}) = CDF(L_{70}B_{10}) = \int_0^{L_{70}B_{10}} pdf_{70}(t)dt = 0.1 \rightarrow 10\%$$

The reliability function equals: $R(t) = 1 - F(t)$, expressing reliability.

C.4 Life time specification for abrupt light output degradation (see Figure C.2)

Example: L_0C_{10} is understood as the life time where light output is 0 % for 10 % of the population.

The failure fraction for C_y expresses only the abrupt light output degradation as a percentage y of a number of LED modules of the same type that at their rated life designates the percentage (fraction) of failures. The failure fraction for C_y is free to be chosen by the manufacturer. See Clause C.6 for recommended fraction values for C_y.

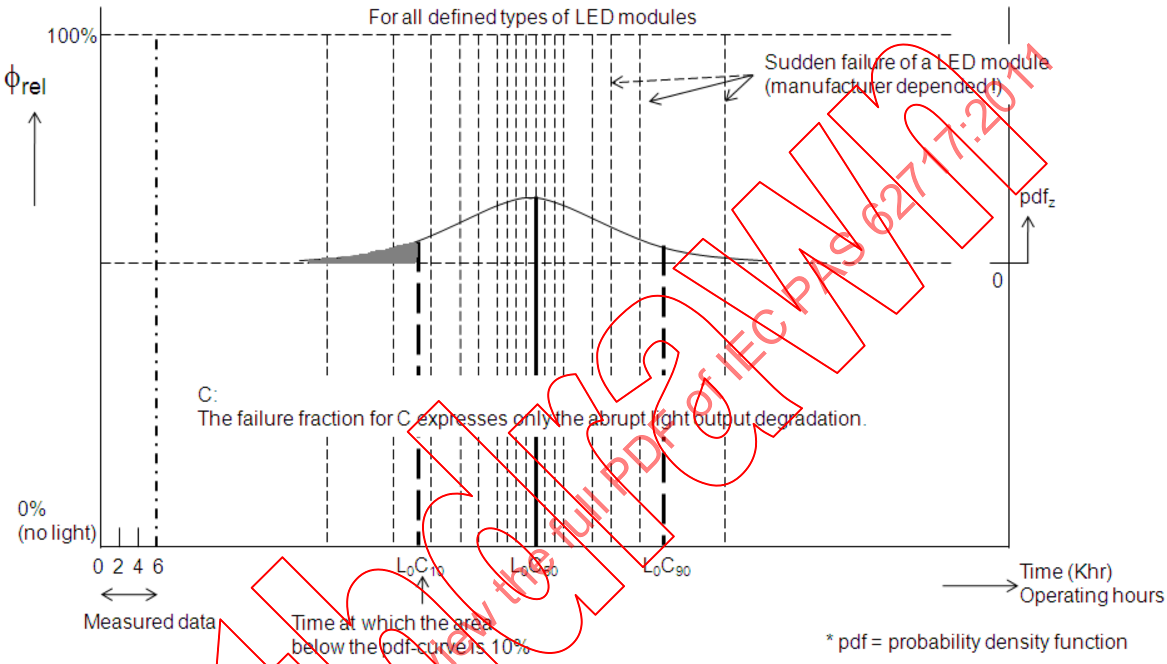


Figure C.2 – Life time specification for abrupt light output degradation

C.5 Combined gradual and abrupt light output degradation

Example: $L_{70}F_{50}$ is understood as the life time where light output is ≥70 % for 50 % of the population.

The failure fraction for *F* expresses the gradual light output degradation including abrupt light output degradation. The light output threshold level for *L* and failure fraction for *F* is free to be chosen by the manufacturer.

The combined gradual (*B*) and abrupt (*C*) light output degradation can be constructed from the above two specifications via reliability curves in three steps.

Step 1: Reliability curve for gradual light output degradation (see Figure C.3)

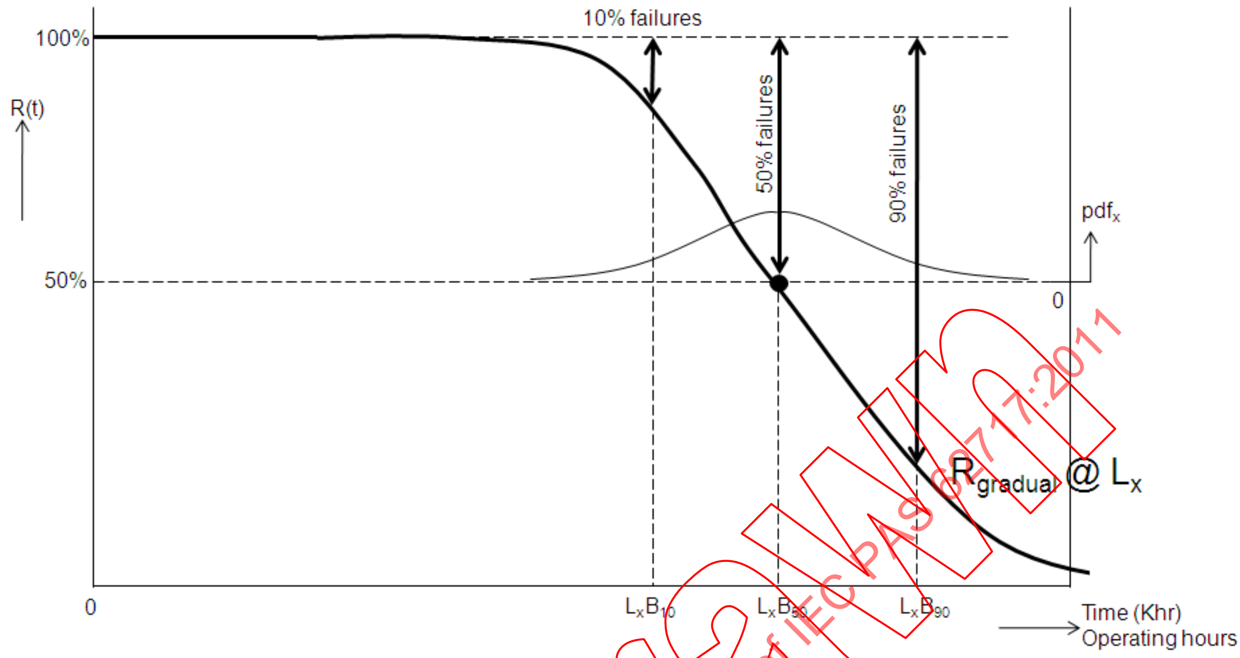


Figure C.3 – Reliability curve $R_{gradual}$ for gradual light output degradation

Step 2: Reliability curve for abrupt light output degradation (see Figure C.4)

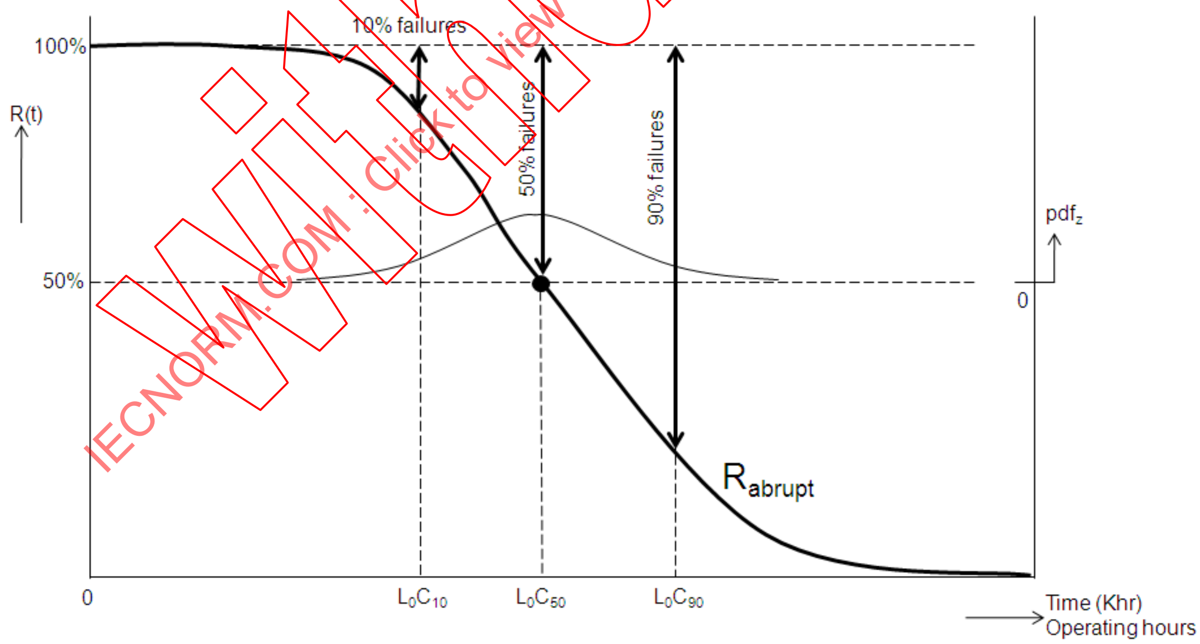


Figure C.4 – Reliability curve R_{abrupt} for abrupt light output degradation

Above reliability curve expresses also the survivals of the LED module.

Step 3: Reliability curve for combined degradation (see Figure C.5)

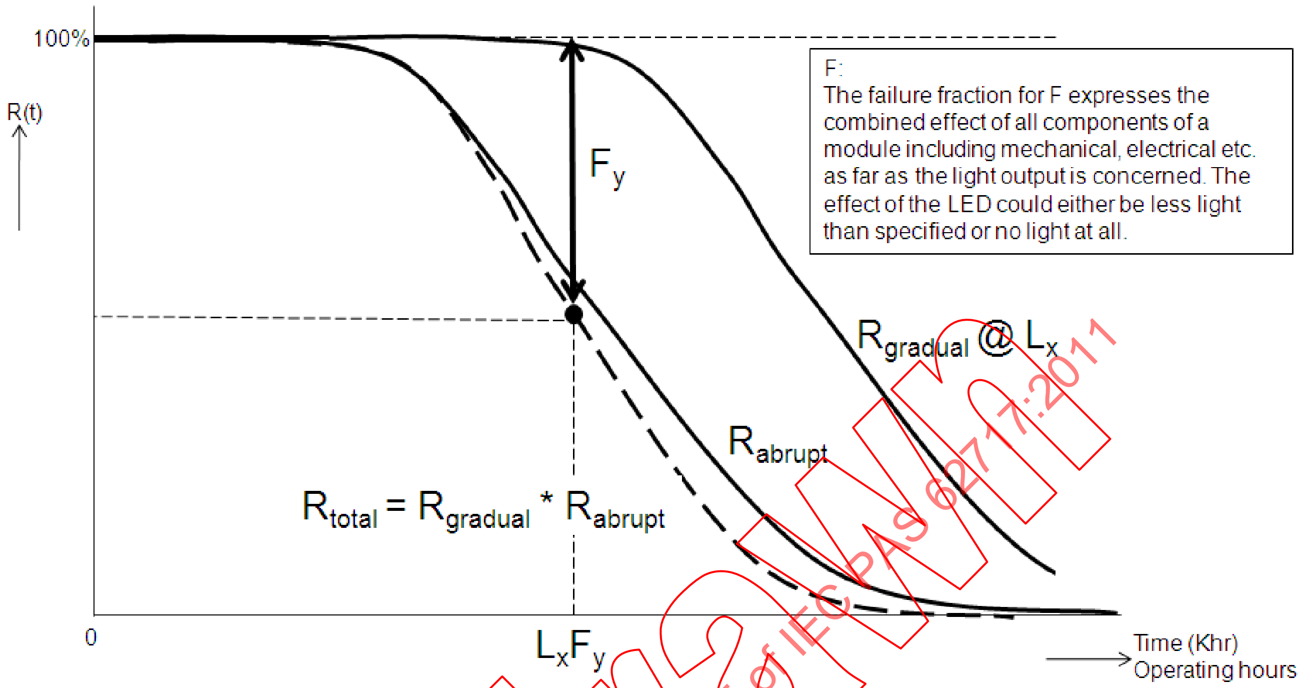


Figure C.5 – Combined $R_{gradual}$ and R_{abrupt} degradation

C.6 Recommended life time metrics

For purpose of distinctness and comparability, it is recommended to limit the use of possible values for x and y in L_xB_y, L_0C_y and L_xF_y.

See Table C.1 below for recommended values x and y.

Table C.1 – Recommended x and y values for life time metrics to be used in life time specification

	L_xB_y						L_xC_y		L_xF_y					
x	70		80		90		0		70		80		90	
y	10	50	10	50	10	50	10	50	10	50	10	50	10	50

NOTE LED modules with constant lumen output are under consideration.

Individual LED packages or LED dies within the LED module are not addressed.

Annex D
(normative)

Explanation of the photometric code

Example of photometric code like 830/359, meaning:

8	**3**	**0**	**/**	**3**	**5**	**9**

– initial CRI of e.g. 77

– initial CCT of 3 000K

– initial spread of chromaticity co-ordinates within a 3-step MacAdam ellipse

– maintained spread of chromaticity co-ordinates at 25 % of rated life (with a maximum duration of 6 000 h) within a 5-step MacAdam ellipse

– code of lumen maintenance at 25 % of rated life (with a maximum duration of 6 000 h), in this example: ≥90 % of the 0 h value.

The colour rendering value is expressed as one figure which is obtained by using the intervals:

CRI = 67 – 76 → code “7”

CRI = 77 – 86 → code “8”

CRI = 87 – ≥90 → code “9”

The highest value is 9.