Zhaga

Zhaga Interface Specification

Book 1
Edition 1.7
May 2015

OVERVIEW AND COMMON INFORMATION

Zhaga Interface Specification Book 1

Summary (informative)

Background
The Zhaga Consortium is a global lighting-industry organization that aims to standardize LED light engines and associated components such as LED modules, holders and electronic control gear (LED drivers).

Zhaga has created a set of interface specifications, known as Books. Each Book defines an LED light engine and/or associated components by means of the mechanical, photometric, electrical, thermal, and control interfaces of the product to its environment. This makes such products interchangeable in the sense that is easy to replace one product with another, even if they have been made by different manufacturers.

Contents
This book 1 is a special book, because it does not define a LED light engine or associated components. Instead, this book gives an overview of the Zhaga terminology as well as common information that aims to explain the general aspects of the interfaces defined by Zhaga.

This book also defines a set of generic compliance tests, which are used to verify if a Zhaga product meets the requirements defined in the relevant Zhaga interface specification.

Intended Use
This book should be read to become familiar with the basic principles of the Zhaga interface specifications. In particular, the other Zhaga interface specifications rely on the information provided in this book. This information is not duplicated in those other books.

Zhaga Interface Specification

Book 1: Overview and Common Information

Edition 1.7

May 2015

CLASSIFICATION

The information contained in this document is for public use.

NOTICE

For any further explanation of the contents of this document, or in case of any perceived inconsistency or ambiguity of interpretation, visit www.zhagastandard.org or contact info@zhagastandard.org.

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1 General

1.1 Introduction

The Zhaga Consortium is a global organization that aims to standardize LED Light Engines and associated components. A LED Light Engine is a light source for general lighting that is based on solid state technology, and typically consists of one or more LEDs combined with an Electronic Control Gear. Examples of associated components are LED Modules, Electronic Control Gears, and Holders. Zhaga has created a set of interface specifications, known as Books defining interfaces between LED Light Engines, associated components and Luminaires.

Book 1 is a special Book in the sense that it provides common information, which is relevant to all other Books in the series. In addition, Book 1 defines requirements and compliance tests, which are applicable across multiple Zhaga books. Such Books refer to those requirements and compliance tests as applicable.

1.2 Scope

This Book 1 defines the common concepts that underlie the Zhaga interface specifications. In addition, this Book 1 specifies general requirements for Zhaga compliant LED Light Engines, associated components and Luminaires.

Each of the other Zhaga interface specifications details the requirements and the tests for particular types of Zhaga products. These Books are published separately for ease of revision and additional Books will be added as and when a need for them is recognized.

The objective of this Book 1 is to provide a set of requirements and compliance tests which are applicable to most Zhaga products and which can be called up as required by the other Books. Accordingly, the provisions of this Book 1 apply only in the specific contexts defined in the other Books. The other Books, in making reference to any of the sections in this Book 1, specify the extent to which that section is applicable. The other Books may also include additional requirements as necessary.

All Zhaga Books are self-contained and therefore do not contain references to other Zhaga Books apart from this Book 1.

1.3 Conformance and references

1.3.1 Conformance

All provisions in the Zhaga interface specifications are mandatory, unless specifically indicated as recommended, optional or informative. Verbal expressions of provisions in the Zhaga interface specifications follow the rules provided in Annex H of ISO/IEC Directives, Part 2. For all clarity, the word “shall” indicates a requirement that is to be followed strictly in order to conform to the Zhaga interface specifications, and from which no deviation is permitted. The word “should” indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required, or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited. The word “may” indicates a course of action permissible within the limits of the Zhaga interface specifications. The word “can” indicates a possibility or capability, whether material, physical or causal.

1.3.2 Normative references

[ANSI C78.377]	American National Standard for electric lamps—Specifications for the Chromaticity of Solid State Lighting Products, ANSI NEMA ANSLG C78.377
[CIE 13.3]	Method of measuring and specifying colour rendering properties of light sources, CIE 13.3
[IEC61341:2010]	IEC technical report 61341:2010 Method of measurement of centre beam intensity and beam angle(s) of reflector lamps

[IEC 62732]	IEC technical report 62732: Three-digit code for designation of colour rendering and correlated colour temperature.
[IES LM-79-08]	IES Approved Method for the Electrical and Photometric Measurements of Solid-State Lighting Products, IES LM-79-08
[NIST TN 1297]	NIST Technical Note 1297; 1994 Edition—Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results
[Zhaga-ECG]	Zhaga Interface Specification, Book 13 Separate Electronic Control Gear.

1.3.3 Informative references

[Zhaga LTLA]	Zhaga Logo Trademark License Agreement

1.4 Common definitions[1]

Ambient Temperature — Average temperature of the air in the environment where the Luminaire (or Test Fixture) is applied. A few typical examples are:

- In case of an outdoor Luminaire or a suspended indoor Luminaire, the Ambient Temperature is the temperature of the air in the vicinity of the Luminaire.
- In case of a recessed Luminaire, the Ambient Temperature is the temperature of the air in the room, below the ceiling and in the vicinity of the Luminaire.

Authorized Testing Center	Organization that is authorized by the Zhaga consortium to perform certification tests for a specific Book.
Book	A Zhaga interface specification.
Built-in ECG	An ECG generally designed to be built into a luminaire, a box, an enclosure or the like and not intended to be mounted outside a luminaire, etcetera without special precautions.
Compatible	Two or more Zhaga products are Compatible if the combination can function as intended. Designation A code which identifies a Zhaga compliant product.
Electronic Control Gear	A unit that is located between the external power and one or more LED Modules to provide the LED Module(s) with an appropriate voltage or current. It may consist of one or more separate components, and may include additional functionality, such as means for dimming, power factor correction, and radio interference suppression.
External Power	The electrical power that is supplied to the LED Light Engine. Typically this is the mains power, but it can also be from another source like a battery or an application specific power grid.
Holder	A component that maintains the LED Light Engine or the LED Module in a functional position, and establishes electrical contact with the LED Light Engine or the LED Module.
Independent ECG	An ECG consisting of one or more separate elements so designed that it can be mounted separately outside the luminaire, with protection according to the marking of the ECG and without any additional enclosure. This may consist of a Built-in ECG housed in a suitable enclosure which provides all the necessary protections according to its marking.

[1] The definitions are possibly further restricted in the other Zhaga Books.

Integrated ECG	An ECG of a LLE that is accommodated in the same housing as the LED module(s) of the LLE. This combination is an Integrated LED Light Engine.
Integrated LED Light Engine	A LED Light Engine that consists of a single housing. This is the same as a "LED Light Engine with Integrated ECG". Note that a module, complying with a specific Book that describes a LLE with Separate ECG but that is directly connected to external power would be an Integrated LLE and thus would be out of scope of that Book.
Interchangeable	Two Zhaga products are Interchangeable if replacement of the first product with the second product in a system results in comparable photometric and dimming properties of that system.
LED Light Engine	A combination of one Electronic Control Gear and one or more LED Modules and means for interconnecting these components. A LED Light Engine may consist of multiple housings.
LED Module	A light source that is supplied as a single unit. In addition to one or more LEDs, their mechanical support and their electrical connection, it may contain components to improve its photometric, thermal, mechanical and electrical properties, but it does not include the Electronic Control Gear.
Light Emitting Surface	A surface of a LED Light Engine or LED Module with specific dimensions, position and orientation through which the light is emitted.
Luminaire	A lighting fixture which provides an appropriate environment for one or more LED Light Engines.
Luminaire Optics	Set of one or more optical elements, which shape the light output of the LLE, not being part of the LLE itself.
Measurement Uncertainty	Measurement Uncertainty is the same as "expanded uncertainty" as defined in [NIST TN 1297].
Optics Contact Area	Physical surface in the LLE or LED Module with a defined shape and position which allows for a stable and functional positioning of the Luminaire Optics on the LLE or LED Module.
Product Data Set	The combined data in the product data sheet, product label and product Designation. Rated <parameter> The value of the <parameter> as listed in the Product Data Set. Examples: the Rated voltage, the Rated frequency, etcetera.
Rated Operating Temperature	Value of the Reference Temperature (t_r) at which the Rated LLE or LED Module values are specified.
Reference Temperature	The temperature at a specified position on the Thermal Interface Surface under steady state operating conditions. The exact coordinates of this position are defined for each type of LLE or LED Module in the respective Book.
Relative Partial Luminous Flux	Percentage of the luminous flux that is emitted by a light source into the rotationally symmetric solid angle bounded by two polar angles (see also section 4.4).
Separate ECG	An ECG of an LLE that is accommodated in a housing that is separate from the LED module(s) of the LLE.
Test Engine	A device that is used to define and measure properties of a Luminaire.
Test Fixture	A device that is used to define and measure properties of a LED Light Engine or a LED Module.

Thermal Interface Material	Material at the Thermal Interface Surface which has the purpose to improve the heat transfer from the LLE or LED Module to the heat sink of the Luminaire.
Thermal Interface Surface	The surface of the LLE, LED Module or Thermal Test Engine that makes physical contact with the surface of the heat sink of the Luminaire.
Zhaga Consumer Product.	A Zhaga Consumer Product is intended to be applied and replaced by consumers.
Zhaga Professional Product	A Zhaga Professional Product is intended to be applied by a Luminaire maker.

1.5 Common acronyms

ATC	Authorized Testing Center
CCT	correlated color temperature
CRI	color rendering index
DUT	device-under-test
ECG	Electronic Control Gear
LED	light emitting diode
LES	Light Emitting Surface
LLE	LED Light Engine
NA	not applicable
OCA	Optics Contact Area
PETF	Photometric & electrical Test Fixture
PCB	printed circuit board
RMS	root mean square
TIM	Thermal Interface Material
TIS	Thermal Interface Surface
TPTF	thermal power Test Fixture
TTE	thermal Test Engine
TUTF	thermal uniformity Test Fixture

1.6 Common symbols

P_{el}	Electrical power consumed by the LLE (unit: W).
$P_{\mathrm{el,mod}}$	Electrical power consumed by the LED Module (unit: W).
P_{vis}	Radiant flux of the LLE or LED module in the wavelength range from 380nm up to 780nm (unit: W).
P_{th}	Thermal power generated in the LLE or LED Module (unit: W).
$P_{\mathrm{th,rear}}$	Thermal power that is drained from the LLE or LED Module through the Thermal Interface Surface (unit: W)
$P_{\mathrm{th,front}}$	Thermal power that is drained from the LLE or LED Module by convection and IR radiation (unit: W)
R_{th}	Thermal resistance from the Thermal Interface Surface to the environment (unit: K/W).
$R_{\mathrm{th,max}}$	Value of the thermal resistance from the Thermal Interface Surface to the environment for which holds: $t_{\mathrm{r}} = t_{\mathrm{r,max}}$ (unit: K/W).

$R_{\mathrm{sp}}(i,j)$	Thermal spreading resistance between measurement points i and j (unit: K/W).
$R_{\mathrm{sp}}^{\mathrm{max}}$	Maximum thermal spreading resistance (unit: K/W).
$SPD(\lambda)$	Spectral Power Distribution (unit: W/nm). $SPD(\lambda)$ corresponds to what is expressed as "total spectral radiant flux" in [IES LM-79-08].
t_{a}	Ambient Temperature (unit: °C).
t_{r}	Reference Temperature (unit: °C).
$t_{\mathrm{r,max}}$	Rated Operating Temperature (unit: °C).

1.7 Common conventions

1.7.1 Cross references

Unless indicated otherwise, cross references to sections in either this document or documents listed in section 1.3, refer to the referenced section as well as the sub sections contained therein.

1.7.2 Informative text

With the exception of sections that are marked as informative, informative text is set in italics.

1.7.3 Terms in capitals

All terms starting with a capital are defined in section 1.4.

1.7.4 Units of physical quantities

Physical quantities are expressed in units of the International System of Units.

1.7.5 Decimal separator

The decimal separator is a comma (",").

2 Overview of Zhaga (informative)

2.1 About Zhaga

Zhaga has created a set of interface specifications, known as Books defining the interfaces between Zhaga products. A Zhaga product can be a LED Light Engine, an associated component or a Luminaire. Examples of associated components are LED Modules, Electronic Control Gears, and Holders. The Zhaga Consortium aims to facilitate easy exchange of LED Light Engines and associated components in a Luminaire. Replacement may be attractive because of superior characteristics of the new LLE or component featuring new technology or for second source choices for optimizing the logistic process or simply to be open for more cost effective alternatives. Another important use case is the replacement of a LLE or component by another one with (photometric) properties that better fit a new application. The replacement of LED Light Engines or associated components is facilitated by defining the following interfaces between LLEs, components and Luminaires:

- mechanical interface
- photometric interface
- electrical interface
- thermal interface
- control interface

The minimum requirements for the information in the Product Data Set are also defined in each Book.

A Zhaga interface specification defines either a Zhaga Professional Product or Zhaga Consumer Product. A Zhaga Professional Product is intended to be applied by a Luminaire maker while a Zhaga Consumer Product is intended to be applied and replaced by consumers.

The Zhaga interface specifications do not define safety requirements (electrical, thermal etcetera) of Zhaga products. There is only a recommendation to specify in the Product Data Set of the LLE or LED Module the implemented electrical insulation.

Note that a type of LED Light Engine or LED Module which is defined in a Book may be further categorized in that Book, for example in categories having different dimensions, different external powers or different Optics Contact Areas.

2.2 Zhaga building blocks and interfaces

In this section, the definitions of Zhaga building blocks are elaborated in their context. Each Book defines interfaces between Zhaga products being LED Light Engines, associated components and Luminaires (see section 2.1).

In the context of the Zhaga interface specifications, a Luminaire is a lighting fixture which provides an appropriate environment for one or more LED Light Engines and associated components (see Figure 2-1 and Figure 2-1Figure 2-2). A Luminaire typically (but not necessarily) is comprised of a heat sink to carry away the heat generated in the LLEs, optical devices to reshape the light beam of the LLEs, means to supply electrical power to the LLEs, and means to attach the Luminaire to a wall, ceiling, stand, etcetera.

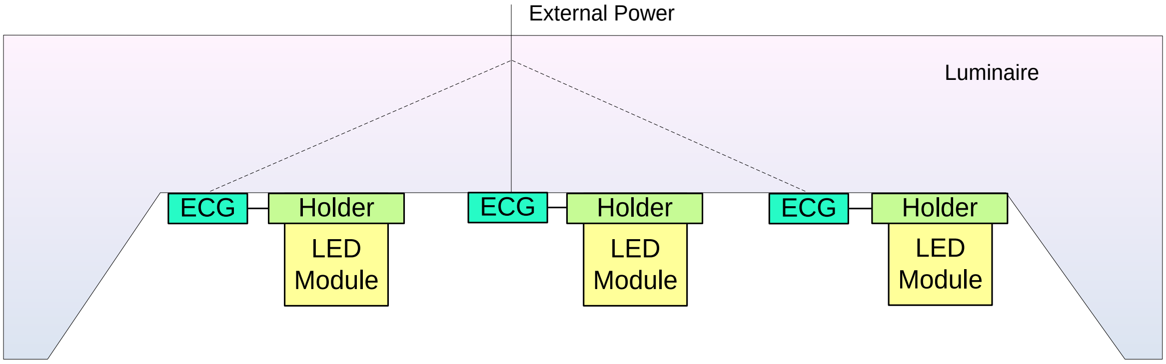


Figure 2-1: Schematic overview of a Luminaire and one or more non-integrated LED Light Engines

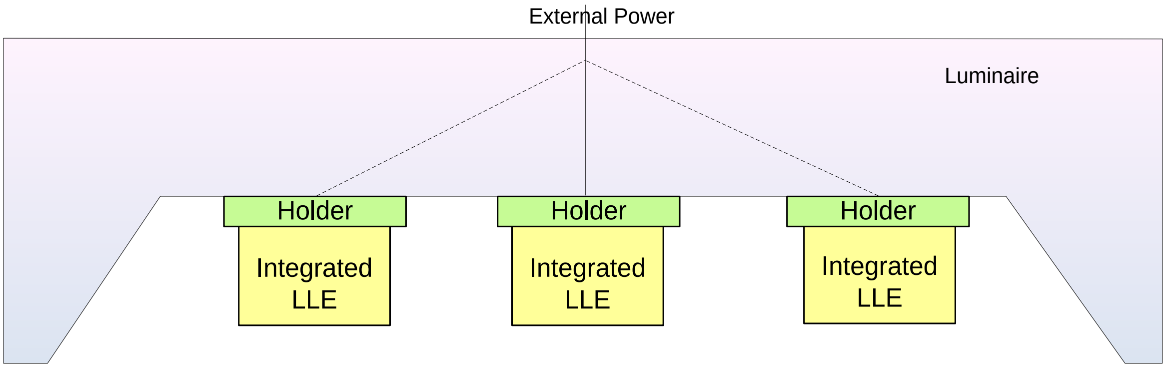


Figure 2-2: Schematic overview of a Luminaire and one or more integrated LED Light Engines

A LED Light Engine is defined as a combination of one Electronic Control Gear and one or more LED Modules (see Figure 2-3 and Figure 2-4).

A LED Module is defined as a light source that is supplied as a single unit. In addition to one or more LEDs, their mechanical support and their electrical connection, it may contain components to improve its optical, thermal, mechanical and electrical properties, but it does not include the Electronic Control Gear.

The Electronic Control Gear is defined as a unit that is located between the External Power and one or more LED Modules to provide the LED Module(s) with an appropriate voltage or current. It may consist of one or more separate components, and may include additional functionality, such as means for dimming, power factor correction, and radio interference suppression.

The LED Module(s) and the Electronic Control Gear can be in one housing as depicted in Figure 2-3. Such a system is denoted as a LED Light Engine with Integrated ECG, or alternatively as an Integrated LED Light Engine.

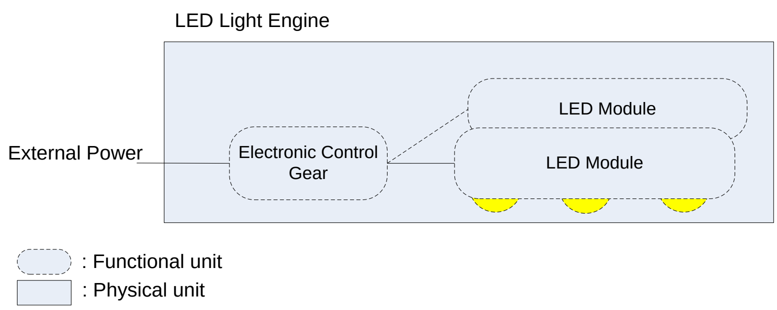


Figure 2-3: Schematic overview of a LED Light Engine with Integrated ECG

Alternatively, the LED Light Engine consists of an Electronic Control Gear and one or more LED Modules in separate housings as depicted in Figure 2-4. Such a system is denoted as a LED Light Engine with Separate ECG.

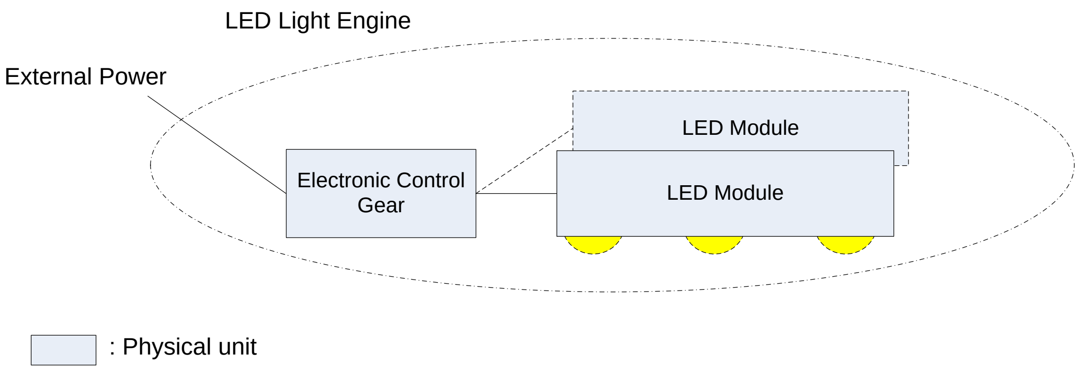


Figure 2-4: Schematic overview of a LED Light Engine with Separate ECG

2.3 Compatibility and Interchangeability

The Zhaga Consortium aims to define LED Light Engines and associated components which are Interchangeable in the sense that LED Light Engines or associated components, possibly designed by different manufacturers, can be interchanged without complications. Practically speaking this means that a professional lighting expert can replace one LLE or associated component by another one while maintaining essentially the same functionality. The Zhaga defines two concepts: Compatibility and Interchangeability that are relevant in this context.

Two Zhaga products are Compatible if the combination can function as intended. Two or more Zhaga products are Interchangeable if replacement of the first product with the second product in a system results in comparable photometric and dimming properties of that system.

Note that to ensure Interchangeability, the Luminaire also should be designed for Interchangeability. As an example, the Luminaire Optics should incorporate diffusing elements to account for different granularity of light emission by different LLEs or LED Modules.

2.4 Product Data Set

The Product Data Set is defined as the combined data in the product data sheet, product label and product Designation. The requirements with respect to the Product Data Set of a Zhaga product are defined in the applicable Book. These requirements guarantee that the Product Data Sets of Zhaga products contain the information which

- enables a check on Compatibility and
- enables a prediction of the (photometric) properties of a combination of Zhaga products.

2.5 Compliance testing

The basic principle of Zhaga is that, for example one manufacturer brings to the market a Zhaga certified product A while another manufacturer brings to the market a Zhaga certified product B. At a later point in time, a professional lighting expert may combine product A and product B in a Luminaire (product C) for a specific application.

One of the challenging issues is that the characteristics of the product A-B-C combination in terms of performance and lifetime depend on the characteristics of all three products and on how these three sets of characteristics match. In order to effectively cope with this situation, the Zhaga has defined procedures with tests to be conducted by manufacturers and Authorized Testing Centers and checks to be conducted by the one who intends to use these products. The checks are described in section 2.6 while the procedures with tests are described in sections 2.5.1 and 2.5.2.

2.5.1 Certification

Before market introduction of a Zhaga product, the following procedure with test is conducted. See also Figure 2-5. Next to measurements and tests that may be required for internal purposes and regulations, the manufacturer of a Zhaga product performs all measurements that are needed to generate the Product Data Set that is required by the Zhaga interface specification. The measurements are performed as defined in the Zhaga interface specification. The outcome of these tests is laid out in the Product Data Set that is provided with the product.

- The manufacturer sends the product (or product family) with associated Product Data Set to an Authorized Testing Center. The ATC performs all tests that are listed in the corresponding Zhaga Book and returns a test report and a test report summary to the manufacturer.
- The manufacturer sends the test report summary to the Zhaga Logo License Administrator. If the test report summary indicates that the product has passed all tests, the Zhaga Logo License Administrator certifies the product.

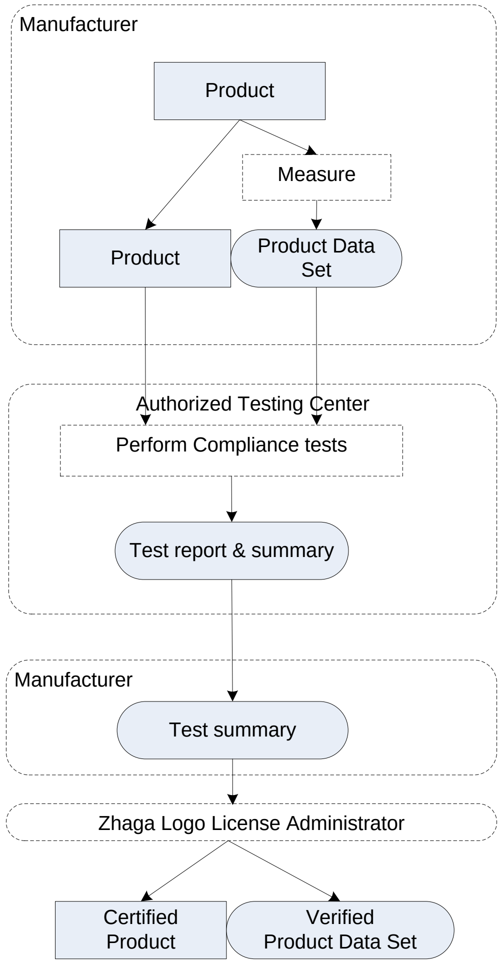


Figure 2-5: Overview of test and certification of Zhaga products

2.5.2 Market surveillance

After market introduction of a Zhaga product, a market surveillance procedure may be initiated to check for the compliance of the product. For details on the market surveillance procedure and consequences of non-compliance see [Zhaga LTLA].

2.6 Compatibility check

Using the Product Data Set of the Zhaga certified products, the Luminaire maker or, for some LLEs the end-user, can check whether two or more Zhaga products are Compatible.

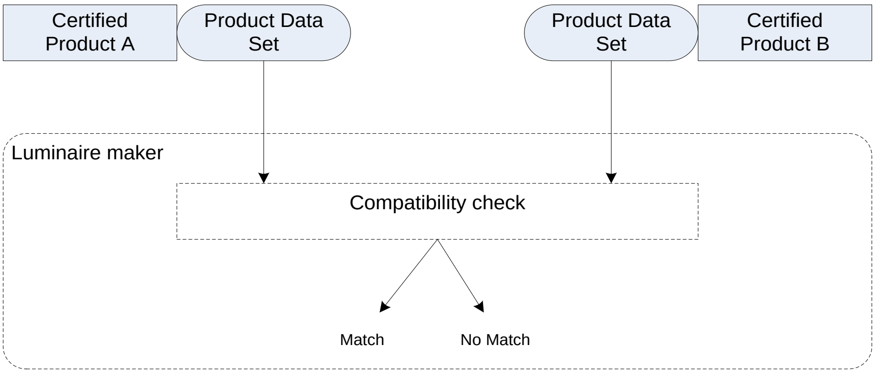


Figure 2-6: Compatibility check

2.7 Zhaga product certification

The Zhaga Consortium prohibits use of its trademark on products and on product documentation without a trademark license. Members can obtain a conditional trademark license by signing the so-called Zhaga Logo Trademark License Agreement [LTLA]. This agreement licenses the Zhaga Logo for use on products that have been tested and certified to be compliant with the Zhaga interface specification.

3 Mechanical interface

3.1 Drawing principles

Unless indicated otherwise, the characteristics of the mechanical interface are specified according to the following principles:

- The dimensions are in millimeters.
- The minimum and maximum values provided in tables that accompany the drawings represent absolute limits, without any implied tolerance (neither positive, nor negative).
- Typical values as well as values between parentheses are informative.

3.2 Mechanical interface between Separate ECG and Luminaire.

The mechanical interface between the Separate ECG and the Luminaire is defined in [Zhaga-ECG].

3.3 Thermal expansion

The mechanical dimensions are verified at a temperature in the range 25 $\pm$ 5 °C. This is the temperature at which an LLE or LED Module is typically mounted in a Luminaire. Manufacturers should take all necessary measures to ensure that thermal expansion or contraction is accommodated for the complete operating temperature range.

4 Photometric interface

4.1 Light Emitting Surface

A Light Emitting Surface (LES) is a surface associated to a LED Light Engine or a LED Module with specific dimensions, position and orientation through which the light is emitted and that has the following characteristics:

- All substantial light generated by the LED Light Engine or the LED Module is emitted through this surface.
- The center of the Light Emitting Surface coincides with the reference point of the luminous intensity distribution (See Figure 4-1).
- The LES is generally described by simple a geometrical shape, e.g. a circle or a rectangle. It has a physical boundary or is a virtual surface in the surrounding area of the LLE or the LED Module.

(Informative)

For each type of LLE or LED Module the definition of the LES may be further restricted in the respective Book according to the following principles:

- *When seen along the reference Z-axis, all parts of the light emitting area (LEDs, diffuse cover and/or mixing chamber) are covered by the LES.*
- *The position of the LES is chosen in a way, that all light emitting parts are behind the LES, when seen along the reference Z-axis.*
- *Inside a circular shaped LES, the LEDs may be placed in any arrangement, for example in a rectangular arrangement.*
- *A clear dome or cover above one or more LEDs is allowed to exceed the LES height.*

Examples LES definitions:

- *The LES is the domed cover of a multichip, phosphor covered LLE or LED Module.*
- *The LES is a circle or a rectangle which is large enough to encompass all silicone domes of packaged LEDs in the LLE or LED Module completely.*
- *In case the LEDs are encircled by the nearly vertical walls of a light guiding, mixing or diffusing element, the LES is described by the opening of this element.*
- *In the case of a diffuse cover covering the LEDs, the LES is described by the light emitting area of the diffuse cover.*

For each type of LLE or LED Module the requirements for the LES are defined in the respective Book.

4.1.1 LES categories

The Zhaga interface specifications define circular LES categories as listed in Table 4-1.

LES category designation	Minimum LES diameter[2]	Maximum LES diameter
LES6.3	4,5	6,3
LES9	6,3	9,0
LES13.5	9,0	13,5
LES19	13,5	19,0
LES23	19,0	23,0
LES30	23,0	30,0
LES40	30,0	40,0

Table 4-1: Definition of circular LES categories

4.2 Operating conditions for measuring photometric parameters

In general, the characteristics of the light generated by a LED Light Engine or a LED Module depend on the operating conditions. This section defines the operating conditions that shall be applied when measuring the photometric parameters defined in this chapter.

In case the device-under-test is a LED Module the operating conditions for photometric tests shall be as follows:

- The LED Module shall be mounted in Test Fixture PETF according to the LED Module manufacturer's mounting instructions.
- The LED Module shall be connected to a power source according to the manufacturer's instructions. The input current and voltage shall be within 0,2% of the Rated values.
- The ambient temperature shall be stable within the range 25 ± 1 °C.
- The heat sink of the test fixture shall maintain the Reference Temperature (t_r) within the range $t_{r,max} \pm 1$ °C
- The photometric output of the LED Module shall not be affected in any way by objects (reflectors, glass or plastic windows, heat sink features, etcetera) that are exterior to the LED Module and the Test Fixture.

In case the device-under-test is a LED Light Engine the operating conditions for photometric tests shall be as follows:

- The LLE or LED Module(s) in case of an LLE with Separate ECG shall be mounted in Test Fixture(s) according to the LLE manufacturer's mounting instructions.
- The voltage and frequency of the External Power of the LLE shall be within 0,2% of the Rated values.
- The ambient temperature shall be stable within the range 25 ± 1 °C.
- The heat sink(s) of the test fixture(s) shall maintain the Reference Temperature (t_r) within the range $t_{r,max} \pm 1$ °C
- The photometric output of the LLE shall not be affected in any way by objects (reflectors, glass or plastic windows, heat sink features, etcetera) that are exterior to the LLE and the Test Fixture(s).
- In case of an LLE with Separate ECG, the ECG should be mounted at a distance from the LED Module such that the ECG does not influence the results of the measurement.
- In case of an LLE with Separate ECG, the LED Module(s) shall be electrically connected to the ECG according to the LLE manufacturer's instructions.

[2] The range of LES diameter values for a specific LES category is excluding the lower bound and including the upper bound. For example, A LES with a diameter of 9,0 mm shall have a designation LES-9.

- In case the LLE features adjustable settings (for example output current of the ECG or de-rating settings), these settings shall be according to the manufacturer's instructions.
- In case of an LLE with Separate ECG and more than one LED Module, photometric properties shall be measured on one LED Module, while the other LED Modules are also operated according to the manufacturer's instructions to enable equal photometric output. If no instructions are provided, the other LED Modules shall be operated in environmental conditions equal to the conditions of the LED-Module-under-test. The measurement setup should be such that the light output of the other LED Modules has no effect on the measurement result.

4.3 Luminous flux

The Zhaga interface specifications define luminous flux categories as listed in Table 4-2. In case of an LLE with multiple LED Modules, luminous flux is defined per LED Module.

luminous flux category	Minimum luminous flux [lm]	Typical luminous flux [lm]	Maximum luminous flux [lm]
100	90	100	150
150	135	150	250
250	225	250	350
350	315	350	500
500	450	500	800
800	720	800	1000
1000	900	1000	1500
1500	1350	1500	2000
2000	1800	2000	3000
3000	2700	3000	4000
4000	3600	4000	5000
5000	4500	5000	6000
6000	5400	6000	8000
8000	7200	8000	10000
10000	9000	10000	15000
15000	13500	15000	20000
20000	18000	20000	30000
30000	27000	30000	40000
40000	36000	40000	60000
60000	54000	60000	80000
80000	72000	80000	100000

Table 4-2: Definition of luminous flux categories

4.4 Luminous intensity distribution

For each type of LLE or LED Module, the required luminous intensity distribution may be defined in the respective Book. In case of a LLE with multiple LED Modules, the luminous intensity distribution is defined per LED Module.

The luminous intensity distribution may be defined in terms of Relative Partial Luminous Fluxes. The Relative Partial Luminous Flux is the percentage of the total luminous flux emitted into the rotationally symmetric solid angle bounded by the polar angles γ_1 and γ_2, as shown in Figure 4-1.

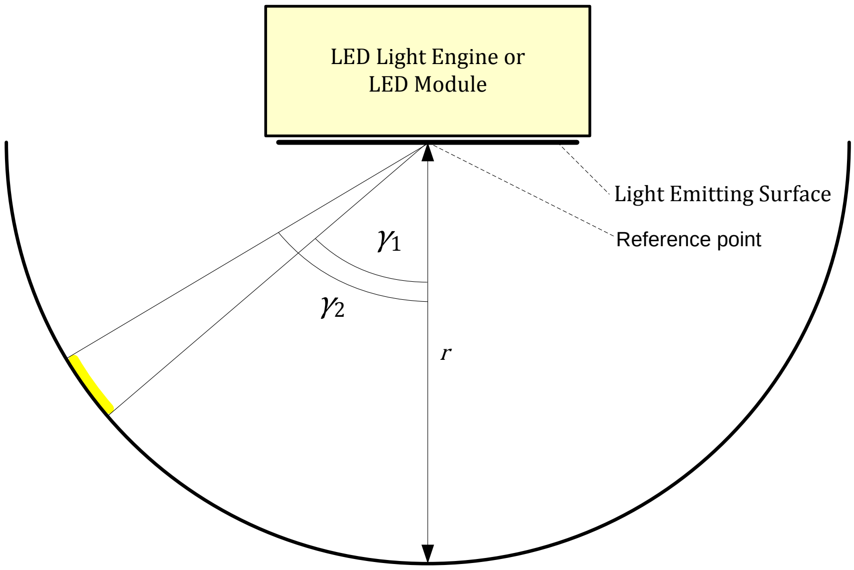


Figure 4-1: Rotationally symmetric solid angle bounded by the polar angles γ_1 and γ_2 which is used to define the Relative Partial Luminous Flux

4.4.1 Beam angle and beam angle categories

The beam angle shall be defined as in [IEC61341:2010] and the beam angle categories shall be defined as in Table 4-3.

Beam angle category	Minimum beam angle (°)	Maximum beam angle (°)
6	3	9
12	9	15
17,5	15	21
25	21	29
35	29	41
55	41	70
90	70	110
120	110	150

Table 4-3: Definition of beam angle categories.

4.5 Luminance uniformity

For each type of LLE or LED Module, the required luminance characteristics may be defined in the respective Book. In case of a LLE with multiple LED Modules, luminance characteristics are defined per LED Module.

4.6 Correlated color temperature (CCT)

The CCT category of an LLE or LED Module shall comply with the provisions of [ANSI C78.377], with the exception that the target color points may be chosen freely within the quadrangles defined therein. Only the nominal CCT categories as specified in [ANSI C78.377] shall be used. The value, in combination with the CRI value shall be expressed using the three-digit code as defined in [IEC 62732]. In case of an LLE with multiple LED Modules, CCT is defined per LED Module.

4.7 Color rendering index (CRI)

The CRI value of the LLE or LED Module is defined in [CIE 13.3]. The value, in combination with the CTT value shall be expressed using the three-digit code as defined in [IEC 62732]. In case of an LLE with multiple LED Modules, CRI is defined per LED Module.

4.8 Luminaire Optics (informative)

The Luminaire Optics (e.g. reflectors, refractors or diffusers) are not defined in the Zhaga interface specifications. It is recommended to design Luminaire Optics in such a way, that the nominal parameter values of the LES and luminous intensity distribution result in the desired photometric characteristics of the LLE-Luminaire Optics combination.

Note: Due to the compound nature of many LED Module solutions, it is expected that Luminaire Optics designed for Zhaga compliant LLEs takes into account the structure of LED clusters, e.g. by using frosted surfaces or facetted structures to achieve comparable light output with all kinds of module technologies enabled by the Zhaga interface specifications. The luminance uniformity of the LED Module can provide information on the measures that need to be taken to achieve proper light distributed with Luminaire Optics. The larger the uniformity the more simple the measures are that need to be taken for a proper light distribution.

5 Electrical interface

5.1 Electrical insulation (informative)

International and national regulations require that products on the market have to be compliant with product safety standards (for example UL standards in the USA, EN standards in Europe and JIS-Standard and PSE-Law in Japan) and individual manufacturers are responsible for this.

The electrical insulation of a complete LLE-Luminaire system is a safety item and depends on the electrical insulation implemented in the LLE, in associated components and in the Luminaire. Like all other safety requirements, electrical insulation is explicitly out of scope of the Zhaga interface specifications and it is the sole responsibility of the manufacturer that brings the product to the market.

6 Thermal interface

6.1 Background information (informative)

One of the most challenging issues in LED lighting is related to the temperature of the LED. On the one hand this component is made of a semiconductor material and therefore it is sensitive to operating temperature, both in terms of performance and lifetime. On the other hand the operating temperature of the LED is not only determined by the design of the LLE or the LED Module but also by the design of the Luminaire. Manufacturers of Zhaga LLEs or LED Modules have no knowledge in which Luminaire the LLE or LED Module will be used. In order to effectively cope with this situation, a model of LLE-Luminaire or LED Module-Luminaire combination with respect to thermal behavior is defined in this section. This thermal interface model allows prediction of the Reference Temperature of a specific LLE - Luminaire combination or LED Module – Luminaire combination.

6.2 Generic thermal interface model

6.2.1 General case

In the thermal interface model, the light generating (and heat generating) component can be any one of the following devices:

1. A LLE with Integrated ECG. In this case the thermal interface is defined as the contact surface of the LLE and the Luminaire.
2. A LED Module. In this case the thermal interface is defined as the contact surface of the LED Module and the Luminaire.
3. A LLE with Separate ECG. In this case the thermal interface is defined as the contact surface of the LED Module and the heat sink the Luminaire and it is assumed that the ECG does not influence the thermal behavior of the Luminaire – LLE combination (See also section 6.1.12). In case of an LLE with multiple LED Modules, each LED Module has its thermal interface with the Luminaire.

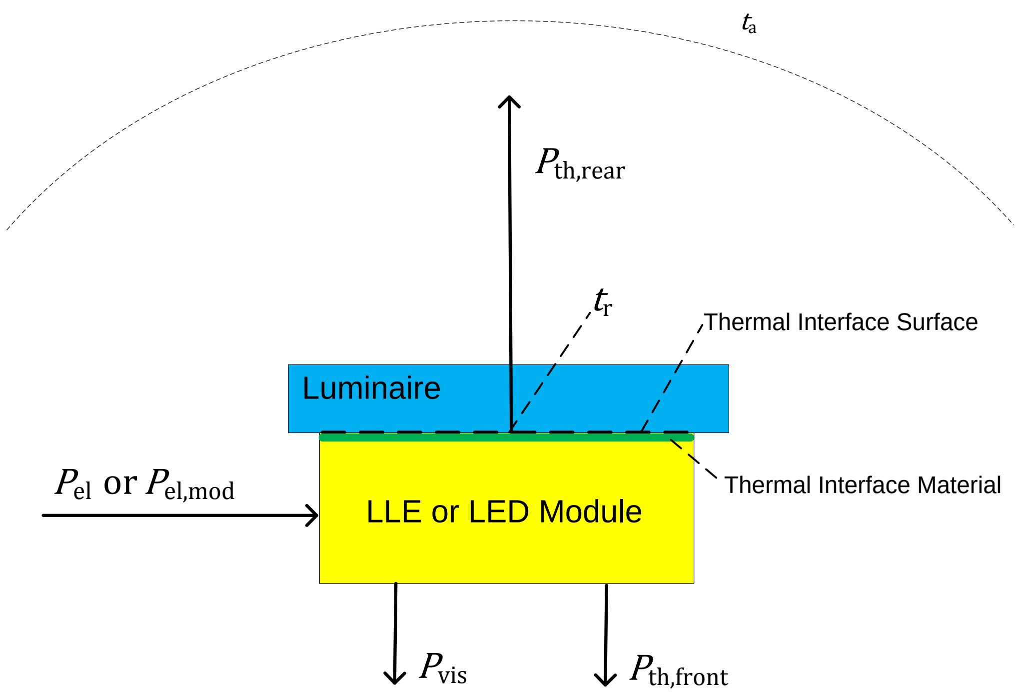


Figure 6-1: Thermal model of a LLE - Luminaire or a LED Module – Luminaire combination

Figure 6-1 illustrates the model of the thermal interface between the LLE or LED Module and the Luminaire. The LLE or LED Module consumes an amount of electrical power P_{el} and $P_{el,mod}$ respectively. This power is converted into visible light and heat:

EQ. 6-1: $\boldsymbol{P}_{el} = \boldsymbol{P}_{vis} + \boldsymbol{P}_{th}$ or

EQ. 6-2: $P_{el,mod} = P_{vis} + P_{th}$

Here, P_{vis} is defined as the radiant flux in the visible light spectrum (380 nm< λ < 780 nm)[3].

[3] IR radiation is not included in P_{vis} and it is assumed that radiation in the range λ < 380 nm is negligible.

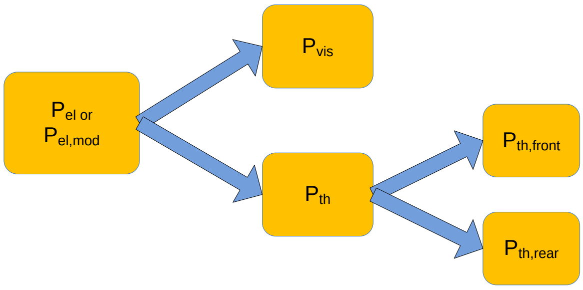


Figure 6-2: Power conversion

Some of the thermal power P_{th} is drained by convection and infra-red radiation. The sum of the thermal power drained by convection and IR radiation is denoted by $P_{th,front}$[4]. Typically a substantial part of the thermal power will be drained through the Thermal Interface Surface to the heat sink of the Luminaire[5]. This portion is denoted by $P_{th, rear}$.

EQ. 6-3: $$P_{th} = P_{th,rear} + P_{th,front}$$

The Thermal Interface Surface is defined as the surface of the LLE or LED Module that makes physical contact with the surface of the heat sink of the Luminaire. The Reference Temperature t_r is defined as the temperature at a specified position on the Thermal Interface Surface under steady state operating conditions[6]. The exact position of this temperature point is defined for each type of LLE or LED Module in the respective Book.

The Zhaga defines the Rated Operating Temperature ($t_{r,max}$) and the value of $t_{r,max}$ shall be such that if $t_r = t_{r,max}$, a sample of the LLE or LED Module at zero burning hours shows photometric values equal to the Rated values within tolerances defined in the compliance test specifications of the Zhaga interface specifications.

The Reference Temperature t_r depends on the Ambient Temperature (t_a), the thermal resistance of the heat sink of the Luminaire (R_{th}) and the thermal power that is transferred through the Thermal Interface Surface ($P_{th,rear}$). Using a simple 1-dimensional model, the following relation is obtained:

EQ. 6-4: $$t_r = t_a + R_{th} \cdot P_{th,rear}$$

For performance equal to or better than the Rated values, the LLE or LED Module should be operated under the condition

$$t_r \leq t_{r,max} \quad \text{Or:}$$

EQ. 6-5: $$R_{th} \leq R_{th,max} \qquad \text{with} \quad R_{th,max} = \frac{t_{r,max} - t_a}{P_{th,rear}}$$

6.2.2 Test Fixture TPTF

The relation between the thermal power drained by convection and IR radiation ($P_{th,front}$) on the one hand and the thermal power drained via the heat sink ($P_{th,rear}$) on the other hand depends on the geometry of the LLE-Luminaire system or the LED Module–Luminaire system. For each type of LLE or LED Module a

[4] $P_{th,front}$ is defined to be the thermal power that is drained by convection and IR radiation to the environment and not re-absorbed by the LLE, the LED Module or the heat sink.
[5] Heat transfer via conduction through other parts of the system is assumed to be negligible.

[6] “steady state” is defined in section A.1.3.4.

Test Fixture TPTF may be defined in the respective Book. This Test Fixture TPTF shall be used to measure $P_{th,rear}$.

6.2.3 Rated Operating Temperature and safety (informative)

The Rated Operating Temperature ($t_{r,max}$) is used to define the conditions for the measurement of the temperature dependent parameters of the LED Light Engine or LED Module. In practical applications the Reference Temperature may be higher or lower than the Rated Operating Temperature. Also, the Rated Operating Temperature is not the absolute maximum Reference Temperature related to safety.

In order to comply with safety regulations, the LLE manufacturer has to make sure that the LLE or LED Module operates safely under normal operating conditions. However, this is not mandated by Zhaga and will not be verified by the ATC. In typical products, the maximum Reference Temperature related to safety will be considerably higher than the Rated Operating Temperature ($t_{r,max}$). This maximum Reference Temperature related to safety may be listed in the Product Data Set of the LLE or the LED Module. Alternatively the LLE or LED Module manufacturer may specify the maximum thermal resistance related to safety in the Product Data Set.

6.2.4 Thermal overload protected LED Light Engine (Informative)

The Reference Temperature in a specific LLE-Luminaire or LED Module – Luminaire combination depends on many characteristics of the LLE or the LED Module, the Luminaire and the mounting (for example the TIM and the contact pressure). Zhaga does not mandate a protection in the LLE or LED Module that guarantees the Reference Temperature not to exceed an upper limit (for example by reducing power or shut down).

6.2.5 Ambient Temperature

As indicated in EQ. 6-5, the maximum thermal resistance of the LLE or LED Module ($R_{th,max}$) depends on the Ambient Temperature. With increasing Ambient Temperature $R_{th,max}$ decreases. This effect can be significant and shall be taken into account in the thermal compatibility check (section 6.2.7).

The LLE or LED Module manufacturer may list values of $R_{th,max}$ for several values of the Ambient Temperature. For each type of LLE or LED Module, Product Data Set requirements with respect to $R_{th,max}$ are defined in the respective Book. In case the Ambient Temperature is not listed in the Product Data Set, a value of 25 °C shall be used.

For each type of LLE or LED Module it is defined in the respective Book whether the Ambient Temperature shall be listed on the Luminaire Product Data Set or not.

In case the Ambient Temperature is listed in the Product Data Set of the Luminaire this value shall be used in the thermal compatibility check (section 6.2.7) to determine the corresponding $R_{th,max}$ of the LLE or the LED Module.

In case the Ambient Temperature is not listed in the Product Data Set of the Luminaire an independent judgment of the Ambient Temperature shall be made by the non-professional end-user or professional lighting expert and this value shall be used in the thermal compatibility check (section 6.2.7) to determine the corresponding $R_{th,max}$ of the LLE or LED Module.

6.2.6 Luminaires with multiple LLEs or multiple LED Modules

Within Zhaga a Luminaire is a lighting fixture which provides an appropriate environment for one or more LED Light Engines. Each LED Light Engine is a combination of one Electronic Control Gear and one or more LED Modules. In this section two cases for Luminaires with multiple LLEs or Multiple LED Modules are described.

6.2.6.1 Separate heat sinks

In case a Luminaire contains more than one LLE or more than one LED Module and these LLEs or LED Modules are mounted on separate heat sinks, it is assumed that the LLEs or LED Modules do not influence each other from a thermal point of view. The general model described in section 6.2.1 can be applied to each LLE or LED Module individually.

6.2.6.2 One heat sink

In case a Luminaire contains more than one LLE or more than one LED Module and these LLEs or LED Modules are mounted on a single heat sink, all LLEs or LED Modules shall be identical[7]. For such systems, the thermal resistance of the Luminaire is defined as:

EQ. 6-6:
$$R_{\mathrm{th}} = \frac{MAX\ (t_{\mathrm{r,i}}) - t_{\mathrm{a}}}{P_{\mathrm{th,rear}}}$$

with $t_{\mathrm{r,i}}$: Reference Temperature of a LLE_i or LED $Module_i$

$P_{\mathrm{th,rear}}$: Thermal power per LLE or LED Module

6.2.7 Thermal compatibility check

In general, the thermal resistance of a heat sink depends on the thermal power applied to the Thermal Interface Surface ($P_{\mathrm{th,rear}}$). For that reason several values of $P_{\mathrm{th,rear}}$ and corresponding values of R_{th} are listed on the Product Data Set of the Luminaire.

In order to determine whether a particular LLE or LED Module is thermally compatible[8] with a particular Luminaire, the user should verify that the applicable thermal resistance R_{th} specified in the Product Data Set of the Luminaire is less than or equal to the applicable maximum thermal resistance $R_{\mathrm{th,max}}$ specified in the Product Data Set of the LLE or LED Module. Here, the applicable thermal resistance can be linearly approximated from thermal resistances corresponding to thermal powers above and below the actual LED Module thermal power. In cases of doubt or incomplete data, the thermal resistance of a power lower than the actual LED Module power shall be chosen for evaluation. The applicable maximum thermal resistance $R_{\mathrm{th,max}}$ is the maximum thermal resistance that corresponds with the Ambient Temperature.

As an example (Informative), consider the information listed in the Product Data Sets of particular LLEs and Luminaires:

Data sheet of LLE #1				
$t_{r,max}$ (°C)	65			
$P_{th,rear}$ (W)	18			
ta (°C)		30	40	50
$R_{th,max}$ (K/W)		1.9	1.4	0.8

Data sheet of LLE #2				
$t_{r,max}$ (°C)	80			
$P_{th,rear}$ (W)	35			
ta (°C)		30	40	50
$R_{th,max}$ (K/W)		1.4	1.1	0.9

Data sheet of Luminaire #1				
Max. ta (°C)		30		
R_{th} at $P_{th,rear}$ = 10 W (K/W)		1.8		
R_{th} at $P_{th,rear}$ = 20 W (K/W)		1.6		
R_{th} at $P_{th,rear}$ = 30 W (K/W)		1.5		
R_{th} at $P_{th,rear}$ = 40 W (K/W)		1.4		

Data sheet of Luminaire #2				
Max. ta (°C)		40		
R_{th} at $P_{th,rear}$ = 10 W (K/W)		0.9		
R_{th} at $P_{th,rear}$ = 20 W (K/W)		0.8		
R_{th} at $P_{th,rear}$ = 30 W (K/W)		0.7		
R_{th} at $P_{th,rear}$ = 40 W (K/W)		0.6		

From these numbers it can be concluded that

[7] In case a Luminaire contains more than one LLE or more than one LED Module and these LLEs or LED Modules are mounted on the same heat sink the Reference Temperature of each LLE or LED Module depends on the characteristics of all LLEs or LED Modules and on the geometry of the system. In general this will result in a complex dependency matrix that cannot be translated into a simple model characterized by one thermal resistance (R_{th}). For that reason the model has been restricted to Luminaires with identical LLEs or LED Modules. In later editions of the document the model may be expanded to other configurations.

[8] "thermally compatible" means that the LLE-Luminaire or LED Module-Luminaire combination will operate at $t_{\mathrm{r}} \leq t_{\mathrm{r,max}}$

- *LLE #1 is thermally compatible with Luminaire #1 as* R_{th} *at* $P_{th,rear} = 10\ W$ *(1,8 K/W) is less than* $R_{th,max}$ *at 30 ºC (1,9 K/W)*
- *LLE #1 is thermally compatible with Luminaire #2 as* R_{th} *at* $P_{th,rear} = 10\ W$ *(0,9 K/W) is less than* $R_{th,max}$ *at 40 ºC (1,4 K/W)*
- *LLE #2 is not thermally compatible with Luminaire #1 as* R_{th} *at* $P_{th,rear} = 30\ W$ *(1,5 K/W) is more than* $R_{th,max}$ *at 30 ºC (1,4 K/W)*
- *LLE #2 is thermally compatible with Luminaire #2 as* R_{th} *at* $P_{th,rear} = 30\ W$ *(0,7 K/W) is less than* $R_{th,max}$ *at 40 ºC (1,1 K/W)*

6.2.8 Thermal uniformity

The thermal interface model defined in section 6.2.1 is a one-dimensional model. Implicitly it is assumed that the temperature across the Thermal Interface Surface is independent of the position. In typical applications this is not exactly the case. When replacing the LED Light Engine or LED Module by a Thermal Test Engine, the thermal interface model can only be used to predict the Reference Temperature if the temperature non-uniformity of the LED Light Engine or LED Module and the Thermal Test Engine are limited. The non-uniformity of the temperature distribution across the Thermal Interface Surface depends on:

- the construction of the LLE, TTE or LED Module and
- the construction of the heat sink of the Luminaire.

The non-uniformity of the temperature distribution across the Thermal Interface Surface is expressed in a set of thermal spreading resistance values. Here, the thermal spreading resistance between two measurement points i and j is defined as:

EQ. 6-7:
$$R_{\mathrm{sp}}(i,j) = \frac{t_i - t_j}{P_{\mathrm{th,rear}}}$$

Here t_i and t_j are the temperatures at the measurement points i and j located on the Thermal Interface Surface. For each type of LLE or LED Module the positions of these measurement points may be defined in the respective Book.

The parameter $R_{\mathrm{sp}}^{\max}$ is defined as the maximum value of all spreading resistance values:

EQ. 6-8:
$$R_{\mathrm{sp}}^{\max} = MAX(R_{\mathrm{sp}}(i,j))$$

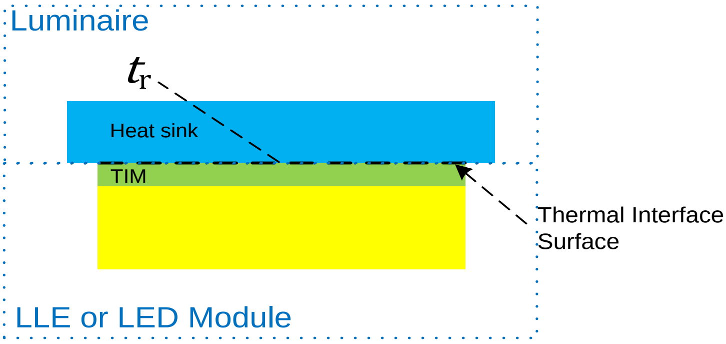
The Zhaga interface specifications may restrict the thermal non-uniformity in the case of a LLE or LED Module being operated in a Test Fixture TUTF. For each type of LLE or LED Module the Test Fixture TUTF and the requirements for thermal uniformity in this test case may be defined in the respective Book.

The Zhaga interface specifications may contain minimum requirements for the construction of the Luminaire. If so, these requirements are defined in the respective Book. If these requirements are not defined or not fulfilled, the Zhaga interface specifications may restrict the thermal non-uniformity in the case of a Thermal Test Engine being operated in a Luminaire. For each type of Luminaire the Thermal Test Engine and the requirements for thermal uniformity in this test case may be defined in the respective Book.

6.2.9 Thermal Interface Material

In order to guarantee good thermal contact between the LLE or LED Module and the heat sink, a Thermal Interface Material (TIM) is typically applied to this interface. The TIM is defined to be part of the LLE or

LED Module and the Thermal Interface Surface is at the interface of the Luminaire and the TIM as depicted



in Figure 6-3.

Figure 6-3: Position of the Thermal Interface Surface in case of a configuration with TIM

The LLE or LED Module shall be tested with the TIM prescribed by the LLE or LED Module manufacturer, and the LLE or LED Module manufacturer shall provide the prescribed TIM to the Zhaga Authorized Testing Center (ATC) when offering the LLE or LED Module for Zhaga certification. The Luminaire shall be tested with a TIM that is specified in the test specification of the respective Book.

6.2.10 Surface planarity and roughness

In order to guarantee good thermal contact between the LLE or LED Module and the heat sink of the Luminaire, both the surface of the LLE or LED module and the surface of the heat sink shall meet planarity and roughness requirements. For each type of LLE or LED Module these requirements may be defined in the respective Book.

6.2.11 Aging of LED Light Engine or LED Module (informative)

Due to aging of the LED, the radiated power (P_{vis}) will decrease over time and consequently the thermal power will increase. Although this effect is relatively weak it is recommended that the Luminaire manufacturer takes it into account in the design of the Luminaire.

6.2.12 Influence of the Electronic Control Gear on the thermal interface (informative)

In case of an LLE with Separate ECG, the thermal model described in section 6.2.1 does not take into account the influence of the thermal power of the ECG on the thermal interface. In this section guidelines are provided on how to deal with this simplification.

Due to the marginal influence of the ECG in most of the luminaires, Zhaga interface specifications do not specify a test for measuring the influence of the thermal power of the ECG on the thermal interface.

In case of a Luminaire with an expected relatively high influence of the ECG on the thermal interface it is recommended to list in the Product Data Set a value of R_{th} which is 110% of the measured R_{th} . This will ensure that the Rated values of photometric parameters of Zhaga LLEs are met in all realistic circumstances.

Guideline for detecting Luminaires with a relatively high influence of the ECG on the thermal interface:

- LED Module and ECG are mounted on the same heat sink
- LED Module and ECG are mounted on different heat sinks but still influence each other by heating up the inner temperature of the Luminaire

6.2.13 Ambient Temperature and thermal resistance (R_{th}).

The Ambient Temperature is defined as the average temperature of the air in the environment where the Luminaire (or Test Fixture) is applied. A few typical examples are:

- In case of an outdoor Luminaire or a suspended indoor Luminaire, the Ambient Temperature is the temperature of the air in the vicinity of the Luminaire.
- In case of a recessed Luminaire, the Ambient Temperature is the temperature of the air in the room, below the ceiling and in the vicinity of the Luminaire.

In section 6.2.1, the thermal resistance of the Luminaire (R_{th}) is defined as the thermal resistance from the Thermal Interface Surface to the environment. The environment corresponds to the position where the Ambient Temperature is defined.

As a consequence of these definitions, the thermal resistance of the Luminaire (R_{th}) depends on the mounting conditions of the Luminaire. The Luminaire manufacturer defines in the PDS (generally in the mounting instructions) how the Luminaire shall be mounted. Next to that, the Luminaire manufacturer shall define a setup for measuring the thermal resistance of the Luminaire. This setup should be a good model for the actual application of the Luminaire. Note that this measurement setup can be anything ranging from a free air setup to measurement boxes as defined by, for example UL and IEC for safety tests. It is recommended to use the same test setup for R_{th} measurement as for safety measurement. The ATC will use the setup as defined by the Luminaire manufacturer to measure the thermal resistance of the Luminaire.

7 Control interface

This edition Book 1 does not define means to control the light output characteristics of the LED Light Engine or the LED Module.

Annex A Compliance tests

A.0 LED Module compliance tests

The compliance tests defined in this section A.0 are applicable if the device-under-test is a LED Module.

A.0.1 LED Module mechanical interface test

The purpose of this test is to verify the dimensions of the mechanical interface of the LED-Module-under-test.

A.0.1.1 Test equipment

The mechanical dimensions may be tested with (semi-)automated 3D measuring equipment like a non-contact optical measuring system. Measurement accuracy of +/- 0,01 mm shall be achieved.

A.0.1.2 Test conditions

All mechanical dimensions shall be verified at an Ambient Temperature in the range 25 $\pm$ 5 °C.

A.0.1.3 Test procedure

Measure all relevant dimensions of the mechanical interface of the LED-Module-under-test.

A.0.1.4 Pass criteria

The LED-Module-under-test passes if all requirements with respect to the mechanical dimensions as defined in the appropriate Book are met.

A.0.2 LED Module photometric interface tests

A.0.2.1 Test on Luminous Flux

The purpose of this test is to verify the Rated luminous flux category of the LED-Module-under-test.

A.0.2.1.1 Test equipment

- Test Fixture PETF. For each type of LED Module, the Test Fixture PETF is defined in the respective Book.
- A photometric measurement system as defined in [IES LM-79-08], section 9.1.

A.0.2.1.2 Test conditions

The test conditions for the LED-Module-under-test shall be according to the operating conditions as defined in the respective Book.

A.0.2.1.3 Test procedure

- Attach the LED-Module-under-test to the Test Fixture PETF using torque, Thermal Interface Material and the fixation means as specified by the LED Module manufacturer.
- Connect the Test Fixture PETF to the photometric measurement system.
- Connect the LED Module to a power source and turn on the power.
- Adjust the Ambient Temperature and the Reference Temperature such that, after stabilization (see section A.0.3.2), all test conditions are met.
- Perform the test as described in [IES LM-79-08], section 9.1.

A.0.2.1.4 Pass criteria

The LED-Module-under-test passes if the measured luminous flux value complies with the Rated luminous flux category as defined in the respective Book, extended with 5% on either side.

Example: if the Rated luminous flux category is defined from 500 to 1000 lm, the LED Module passes if the measured value is in the range from 475 to 1050 lm. The LED Module fails if the measured value is less than 475 lm or more than 1050 lm.

A.0.2.2 Test on Relative Partial Luminous Flux and beam angle.

The purpose of this test is to verify Relative Partial Luminous Flux and/or Rated beam angle of the LED-Module-under-test.

A.0.2.2.1 Test equipment

- Test Fixture PETF. For each type of LED Module, the Test Fixture PETF is defined in the respective Book.
- A goniophotometer as defined in [IES LM-79-08], section 9.3.

A.0.2.2.2 Test conditions

The test conditions for the LED-Module-under-test shall be according to the operating conditions as defined in the respective Book.

A.0.2.2.3 Test procedure

- Attach the LED-Module-under-test to the Test Fixture PETF using torque, Thermal Interface Material and the fixation means as specified by the LED Module manufacturer.
- Connect the Test Fixture PETF in the photometric center of the goniophotometer.
- Connect the LED Module to a power source and turn on the power.
- Adjust the Ambient Temperature and the Reference Temperature such that, after stabilization (see section A.1.3.2), all test conditions are met.
- Perform the test as described in [IES LM-79-08], section 9.3.
- Calculate the Relative Partial Luminous Flux according to [CIE 52].
- Calculate the beam angle according to [IEC 61341:2010].

A.0.2.2.4 Pass criteria

The LED-Module-under-test passes if for all CIE cumulative flux zones holds that the measured Relative Partial Luminous Flux values comply with the Relative Partial Luminous Flux zone as defined in the respective Book, extended with 5% on either side.

Example: if the CIE cumulative flux zone is defined by Relative Partial Luminous Flux from 40% to 50%, the LED Module passes if the measured value is in the range from 38% to 52,5%. The LED Module fails if the measured value is less than 38% or more than 52,5%.

The LED-Module-under-test passes if the measured beam angle complies with the Rated beam angle category as defined in section 4.4. For the comparison, the boundaries of the beam angle category shall be extended with 5% on either side.

Example: if the Rated beam angle category is defined from 40° to 80°, the LED Module passes if the measured value is in the range from 38° to 84°. The LED Module fails if the measured value is less than 38° or more than 84°.

A.0.2.3 Test on correlated color temperature (CCT)

The purpose of this test is to verify the Rated CCT category of the LED-Module-under-test.

A.0.2.3.1 Test equipment

- Test Fixture PETF. For each type of LED Module, the Test Fixture PETF is be defined in the respective Book.
- A sphere-spectroradiometer system as defined in [IES LM-79-08], section 9.1.

A.0.2.3.2 Test conditions

The test conditions for the LED-Module-under-test shall be according to the operating conditions as defined in the respective Book.

A.0.2.3.3 Test procedure

- Attach the LED-Module-under-test to the Test Fixture PETF using torque, Thermal Interface Material and the fixation means as specified by the LED Module manufacturer.
- Connect the Test Fixture PETF tightly to the opening of the integrating sphere.
- Connect the LED Module to a power source and turn on the power.
- Adjust the Ambient Temperature and the Reference Temperature such that, after stabilization (see section A.1.3.2), all test conditions are met.
- Perform the test as described in [IES LM-79-08], section 9.1.
- Calculate CCT according to [ANSI C78.377].

A.0.2.3.4 Pass criteria

The LED-Module-under-test passes if the calculated CCT is within the quadrangle that is associated with the Rated CCT category, extended with 0.002 in each direction.

Example: if the quadrangle that is associated with the Rated CCT category is defined by the coordinates (0,5/0,5), (0,6/0,5), (0,5/0,6) and (0,6/0,6), then LED Module passes if the measured value is in the quadrangle defined by the coordinates (0,5-0.002/0,5-0.002), (0,6+0.002/0,5-0.002), (0,5-0.002/0,6+0.002) and (0,6+0.002/0,6+0.002). The LED Module fails if the measured value is outside the quadrangle defined by the coordinates (0,5-0.002/0,5-0.002), (0,6+0.002/0,5-0.002), (0,5-0.002/0,6+0.002) and (0,6+0.002/0,6+0.002).

A.0.2.4 Test on color rendering index

The purpose of this test is to verify the Rated CRI of the LED-Module-under-test.

A.0.2.4.1 Test equipment

- Test Fixture PETF. For each type of LED Module, the Test Fixture PETF is be defined in the respective Book.
- A sphere-spectroradiometer system as defined in [IES LM-79-08], section 9.1.

A.0.2.4.2 Test conditions

The test conditions for the LED-Module-under-test shall be according to the operating conditions as defined in the respective Book.

A.0.2.4.3 Test procedure

- Attach the LED-Module-under-test to the Test Fixture PETF using torque, Thermal Interface Material and the fixation means as specified by the LED Module manufacturer.
- Connect the Test Fixture PETF tightly to the opening of the integrating sphere.
- Connect the LED Module to a power source and turn on the power.
- Adjust the Ambient Temperature and the Reference Temperature such that, after stabilization (see section A.1.3.2), all test conditions are met.
- Perform the test as described in [IES LM-79-08], section 9.1.
- Calculate CRI simulating a color plate measurement according to [CIE 13.3].

A.0.2.4.4 Pass criteria

The LED-Module-under-test passes if the measured CRI ≥ Rated CRI – 3. The LED Module fails if the measured CRI < Rated CRI – 3.

A.0.2.5 Test on Luminance Uniformity

This edition of Book 1 does not contain compliance tests on the luminance uniformity of the LED Module.

A.0.3 LED Module thermal interface tests

A.0.3.1 Test on thermal power (P_{th})

The purpose of this test is to verify the Rated thermal power (P_{th}) of the LED-Module-under-test.

Using EQ. 6-2, P_{th} can be determined by the equation:

EQ. A-1: $$\boldsymbol{P}_{\text{th}} = \boldsymbol{P}_{\mathbf{el}} - \boldsymbol{P}_{\text{vis}}$$

A.0.3.1.1 Test equipment

See section A.0.2.1.1.

A.0.3.1.2 Test conditions

The test conditions for the LED-Module-under-test shall be according to the operating conditions as defined in the respective Book.

A.0.3.1.3 Test procedure

- Perform the measurement as described in section A.0.2.1.
- Measure electrical power $P_{\text{el,mod}}$
- Calculate P_{vis} using the $SPD(\lambda)$ results from the luminous flux measurement as described in section A.0.2.1.
- Use equation A.1 to calculate P_{th}.

A.0.3.1.4 Pass criteria

The LED-Module-under-test passes if the measured thermal power (P_{th}) does not exceed the Rated thermal power + 5%.

Example: if the Rated value of the thermal power (P_{th}) is 20W, the LED Module passes if the measured value is less than 21W. The LED Module fails if the measured value is more than 21W.

A.0.4 LED Module electrical interface tests

This edition of Book 1 does not contain compliance tests for the electrical interface of the LED Module.

A.0.5 LED Module Product Data Set test

A.0.5.1 Test

Inspect the Product Data Set of the LED-Module-under-test and check whether the requirements on the Product Data Set in the corresponding Book are met.

A.0.5.2 Pass criteria

This test passes if all requirements on the Product Data Set are met.

A.1 LLE compliance tests

The compliance tests defined in this section A.1 are applicable if the device-under-test is a LED Light Engine.

A.1.1 LLE mechanical interface tests

If the device-under-test is an Integrated LLE the mechanical interface shall be tested according to the test specification in this section A.1.1.1. If the device-under-test is a non-Integrated LLE the mechanical interfaces of the LED Module and the ECG shall be tested separately according to the test specification in the corresponding Zhaga books.

A.1.1.1 Test of the mechanical interface of the Integrated LLE

The purpose of this test is to verify the dimensions of the mechanical interface of the Integrated LLE-under-test.

A.1.1.1.1 Test equipment

The mechanical dimensions may be tested with (semi-)automated 3D measuring equipment like a non-contact optical measuring system. Measurement accuracy of +/- 0,01 mm shall be achieved.

A.1.1.1.2 Test conditions

All mechanical dimensions shall be verified at an Ambient Temperature in the range 25 $\pm$ 5 °C.

A.1.1.1.3 Test procedure

Measure all relevant dimensions of the mechanical interface of the LLE-under-test.

A.1.1.1.4 Pass criteria

The LLE-under-test passes if all requirements with respect to the mechanical dimensions as defined in the respective Book are met.

A.1.2 LLE photometric interface tests

A.1.2.1 Test on Luminous Flux

The purpose of this test is to verify the Rated luminous flux category of the LLE-under-test.

A.1.2.1.1 Test equipment

- Test Fixture PETF. For each type of LLE, the Test Fixture PETF is defined in the respective Book.
- A photometric measurement system as defined in [IES LM-79-08], section 9.1.

A.1.2.1.2 Test conditions

The test conditions for the LLE-under-test shall be according to the operating conditions as defined in the respective Book.

A.1.2.1.3 Test procedure

- Attach the LLE-under-test or LED Module of the LLE-under-test to the Test Fixture PETF using torque, Thermal Interface Material and the fixation means as specified by the LLE manufacturer.
- Connect the Test Fixture PETF to the photometric measurement system.
- In case of an LLE with more than one LED Module, the LED Module(s)-not-under-test shall also be operated. The LED Module(s)-not-under-test shall be mounted on temperature controlled Test Fixture(s), not connected to the photometric measurement system.
- Turn on the power supply.
- Adjust the Ambient Temperature and the Reference Temperature such that, after stabilization (see section A.1.3.4), all test conditions are met.
- Perform the test as described in [IES LM-79-08], section 9.1.

A.1.2.1.4 Pass criteria

The LLE-under-test passes if the measured luminous flux value complies with the Rated luminous flux category as defined in the respective Book, extended with 5% on either side.

Example: if the Rated luminous flux category is defined from 500 to 1000 lm, the LLE passes if the measured value is in the range from 475 to 1050 lm. The LLE fails if the measured value is less than 475 lm or more than 1050 lm.

A.1.2.2 Test on Relative Partial Luminous Flux and beam angle.

The purpose of this test is to verify Relative Partial Luminous Flux and/or Rated beam angle of the LLE-under-test.

A.1.2.2.1 Test equipment

- Test Fixture PETF. For each type of LLE, the Test Fixture PETF is defined in the respective Book.
- A goniophotometer as defined in [IES LM-79-08], section 9.3.

A.1.2.2.2 Test conditions

The test conditions for the LLE-under-test shall be according to the operating conditions as defined in the respective Book.

A.1.2.2.3 Test procedure

- Attach the LLE-under-test or LED Module of the LLE-under-test to the Test Fixture PETF using torque, Thermal Interface Material and the fixation means as specified by the LLE manufacturer.
- Connect the Test Fixture PETF in the photometric center of the goniophotometer.
- In case of an LLE with more than one LED Module, the LED Module(s)-not-under-test shall also be operated. The LED Module(s)-not-under-test shall be mounted on temperature controlled Test Fixture(s), not connected to the photometric measurement system.
- Turn on the power supply.
- Adjust the Ambient Temperature and the Reference Temperature such that, after stabilization (see section A.1.3.4), all test conditions are met.
- Perform the test as described in [IES LM-79-08], section 9.3.
- Calculate the Relative Partial Luminous Flux according to [CIE 52].
- Calculate the beam angle according to [IEC 61341:2010].

A.1.2.2.4 Pass criteria

The LLE-under-test passes if for all CIE cumulative flux zones holds that the measured Relative Partial Luminous Flux values comply with the Relative Partial Luminous Flux zone as defined in the respective Book, extended with 5% on either side.

Example: if the CIE cumulative flux zone is defined by Relative Partial Luminous Flux from 40% to 50%, the LLE passes if the measured value is in the range from 38% to 52,5%. The LLE fails if the measured value is less than 38% or more than 52,5%.

The LLE-under-test passes if the measured beam angle complies with the Rated beam angle category as defined in section 4.4. For the comparison, the boundaries of the beam angle category shall be extended with 5% on either side.

Example: if the Rated beam angle category is defined from 40° to 80°, the LLE passes if the measured value is in the range from 38° to 84°. The LLE fails if the measured value is less than 38° or more than 84°.

A.1.2.3 Test on correlated color temperature (CCT)

The purpose of this test is to verify the Rated CCT category of the LLE-under-test.

A.1.2.3.1 Test equipment

- Test Fixture PETF. For each type of LLE, the Test Fixture PETF is be defined in the respective Book.
- A sphere-spectroradiometer system as defined in [IES LM-79-08], section 9.1.

A.1.2.3.2 Test conditions

The test conditions for the LLE-under-test shall be according to the operating conditions as defined in the respective Book.

A.1.2.3.3 Test procedure

- Attach the LLE-under-test or LED Module of the LLE-under-test to the Test Fixture PETF using torque, Thermal Interface Material and the fixation means as specified by the LLE manufacturer.
- Connect the Test Fixture PETF tightly to the opening of the integrating sphere.
- In case of an LLE with more than one LED Module, the LED Module(s)-not-under-test shall also be operated. The LED Module(s)-not-under-test shall be mounted on temperature controlled Test Fixture(s), not connected to the photometric measurement system.
- Turn on the power supply.
- Adjust the Ambient Temperature and the Reference Temperature such that, after stabilization (see section A.1.3.4), all test conditions are met.
- Perform the test as described in [IES LM-79-08], section 9.1.
- Calculate CCT according to [ANSI C78.377].

A.1.2.3.4 Pass criteria

The LLE-under-test passes if the calculated CCT is within the quadrangle that is associated with the Rated CCT category, extended with 0.002 in each direction.

Example: if the quadrangle that is associated with the Rated CCT category is defined by the coordinates (0,5/0,5), (0,6/0,5), (0,5/0,6) and (0,6/0,6), then LLE passes if the measured value is in the quadrangle defined by the coordinates (0,5-0.002/0,5-0.002), (0,6+0.002/0,5-0.002), (0,5-0.002/0,6+0.002) and (0,6+0.002/0,6+0.002). The LLE fails if the measured value is outside the quadrangle defined by the coordinates (0,5-0.002/0,5-0.002), (0,6+0.002/0,5-0.002), (0,5-0.002/0,6+0.002) and (0,6+0.002/0,6+0.002).

A.1.2.4 Test on color rendering index

The purpose of this test is to verify the Rated CRI of the LLE-under-test.

A.1.2.4.1 Test equipment

- Test Fixture PETF. For each type of LLE, the Test Fixture PETF is be defined in the respective Book.
- A sphere-spectroradiometer system as defined in [IES LM-79-08], section 9.1.

A.1.2.4.2 Test conditions

The test conditions for the LLE-under-test shall be according to the operating conditions as defined in the respective Book.

A.1.2.4.3 Test procedure

- Attach the LLE-under-test or LED Module of the LLE-under-test to the Test Fixture PETF using torque, Thermal Interface Material and the fixation means as specified by the LLE manufacturer.
- Connect the Test Fixture PETF tightly to the opening of the integrating sphere.
- In case of an LLE with more than one LED Module, the LED Module(s)-not-under-test shall also be operated. The LED Module(s)-not-under-test shall be mounted on temperature controlled Test Fixture(s), not connected to the photometric measurement system.

- Turn on the power supply.
- Adjust the Ambient Temperature and the Reference Temperature such that, after stabilization (see section A.1.3.4), all test conditions are met.
- Perform the test as described in [IES LM-79-08], section 9.1.
- Calculate CRI simulating a color plate measurement according to [CIE 13.3].

A.1.2.4.4 Pass criteria

The LLE-under-test passes if the measured CRI ≥ Rated CRI – 3. The LLE fails if the measured CRI < Rated CRI – 3.

A.1.2.5 Test on Luminance Uniformity

This edition of Book 1 does not contain compliance tests on the luminance uniformity of the LLE.

A.1.3 LLE thermal interface tests

A.1.3.1 Test on thermal power (P_{th})

The purpose of this test is to verify the Rated thermal power (P_{th}) of the LLE-under-test.

In case of an Integrated LLE, P_{th} is the thermal power of the complete LLE. Using EQ. 6-1, P_{th} can be determined by following equation:

EQ. A-2: $$\boldsymbol{P}_{\mathrm{th}} = \boldsymbol{P}_{\mathbf{el}} - \boldsymbol{P}_{\mathrm{vis}}$$

In case of an LLE with Separate ECG, P_{th} is the thermal power of the LED Module. Using EQ. 6-2, P_{th} can be determined by following equation:

EQ. A-3: $$\boldsymbol{P}_{\mathrm{th}} = \boldsymbol{P}_{\mathbf{el,mod}} - \boldsymbol{P}_{\mathrm{vis}}$$

A.1.3.1.1 Test equipment

See section A.1.2.1.1.

A.1.3.1.2 Test conditions

The test conditions for the LLE-under-test shall be according to the operating conditions as defined in the respective Book.

A.1.3.1.3 Test procedure

- Perform the measurement as described in section A.1.2.1.
- Measure electrical power P_{el} (in case of an Integrated LLE) or $P_{\mathrm{el,mod}}$ (in case of an LLE with Separate ECG)
- Calculate P_{vis} using the $SPD(\lambda)$ results from the luminous flux measurement as described in section A.1.2.1.
- Use EQ. A-2 or EQ. A-3 to calculate P_{th}.

A.1.3.1.4 Pass criteria

The LLE-under-test passes if the measured thermal power (P_{th}) does not exceed the Rated thermal power + 5%.

Example: if the Rated value of the thermal power (P_{th}) is 20W, the LLE passes if the measured value is less than 21W. The LLE fails if the measured value is more than 21W.

A.1.3.2 Test on Thermal power through the Thermal Interface Surface ($P_{th,rear}$)

The purpose of this test is to verify the Rated thermal power ($P_{th,rear}$) through the Thermal Interface Surface of the LLE-under-test.

A.1.3.2.1 Test equipment

- Test Fixture TPTF. For each type of LLE, the Test Fixture TPTF is defined in the respective Book.
- Heat flux setup. A schematic overview of such a setup is shown in Figure A-1. In order to minimize the effect of draft and temperature fluctuations, the heat flux setup shall be thermally insulated with minimum of 20mm foam with conductivity of smaller than 0,2W/m·K. The mounting plate of the Test Fixture shall be mounted on the heat flux setup with an appropriate TIM like silicone oil based thermal grease.

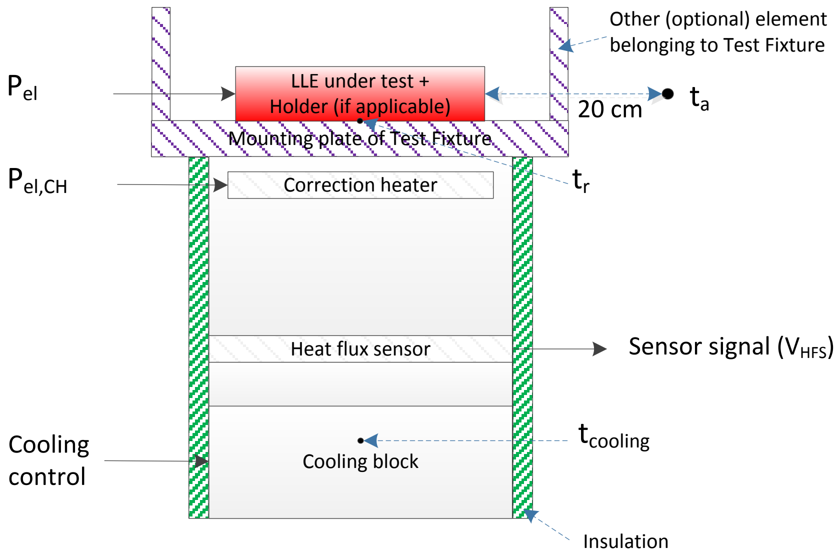


Figure A-1: Heat sensor equipment with Test Fixture and LLE-under-test

A.1.3.2.2 Test conditions

- For each type of LLE the test shall be conducted with the LLE mounted in the Test Fixture TPTF defined in the respective Book and in the orientation as defined in the respective Book.
- The Ambient Temperature (t_a) shall be measured at the same height as the LLE-under-test and at a distance of 20 cm from the LLE-under-test.
- The cooling temperature ($t_{cooling}$) shall be controlled at the position indicated in Figure A-1.
- The Reference Temperature (t_r) shall be measured at the position defined in A.1.3.6.
- The Ambient Temperature (t_a) during calibration and measurement shall be between 20 °C and 30 °C. Moreover the Ambient Temperature (t_a) during calibration shall be equal to the Ambient Temperature during measurement within a range of +/-1 °C.
- The cooling temperature ($t_{cooling}$) during calibration shall be equal to the cooling temperature during measurement within a range of +/-1 °C.
- For each type of LLE, the Thermal Interface Material to be used for mounting the LLE in the Test Fixture is defined in the respective Book.
- In case of an LLE with Separate ECG, the ECG shall be mounted at a distance from the LED Module such that the ECG does not influence the results of the measurement.

- The optical output of the LLE-under-test shall not be affected in any way, by object(s)—reflectors, glass or plastic windows, heat sink features, etcetera—that are exterior to the LLE-under-test and Test Fixture TPTF.

A.1.3.2.3 Calibration of $P_{th,rear}$ test setup

The heat flux measurement setup shall be calibrated according to the procedure described in this section. A schematic overview of the setup during calibration is shown in Figure A-2. In order to minimize the heat flux to the front and to minimize the effect of draft and temperature fluctuations, the heat flux setup (including the Mounting plate[9] of the Test Fixture, but excluding the Holder) shall be thermally insulated with minimum of 20mm foam with conductivity of smaller than 0,2W/m·K. The mounting plate shall be mounted on the heat flux setup with an appropriate TIM like silicone oil based thermal grease.

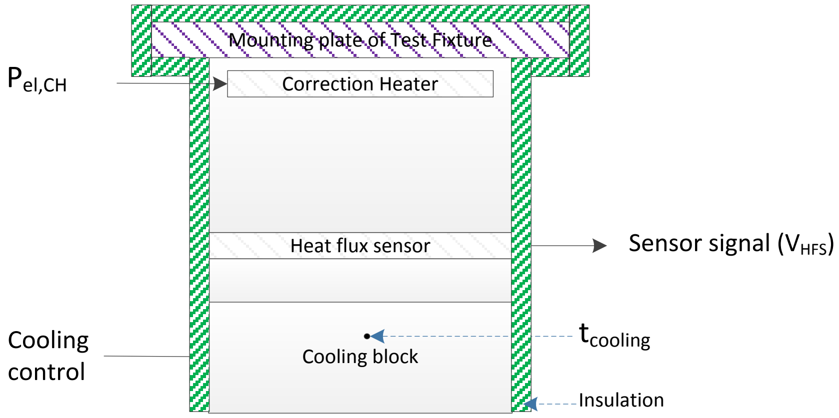


Figure A-2: Calibration of the heat flux measurement setup.

- Mount thermocouples for measuring t_a and $t_{cooling}$ at the positions defined in A.1.3.2.2.
- Keep the cooling temperature ($t_{cooling}$) at 45 °C in case (1) the Rated $t_{r,max}$ of the LLE ≥ 70 °C and (2) the Rated $P_{th,rear}$ of the LLE ≤ 20 W (both conditions shall be met).
- Keep the cooling temperature ($t_{cooling}$) at 25 °C in all other cases. Keep the cooling temperature constant within a range of +/- 1 °C during the complete calibration process.
- Keep the Ambient Temperature (t_a) at a predefined value between 20 °C and 30 °C and keep this value constant within a range of +/- 1 °C during the complete calibration process.
- Configure the internal correction heater of the heat flux sensor equipment to consume no electrical power.
- Wait until stabilization of the heat flux sensor signal (V_{HFS}). The heat flux sensor signal is deemed stable if the difference between two consecutive measurements, taken at least 15 minutes apart, is less than 1 mV.
- Measure the heat flux sensor voltage. Take 6 readings of the heat flux sensor voltage, at intervals of at least 1 min. The average of these 6 readings is the response $V_{HFS}(0)$.

[9] The term 'Mounting plate of the test fixture' is the same as 'Holder mount' use in some of the other Zhaga specifications.

- Configure the internal correction heater of the heat flux sensor equipment to consume electrical power P_1 W[10]. For each type of LLE, the value of P_1 is defined in the respective Book.
- Wait until stabilization of the heat flux sensor signal (V_{HFS}). The heat flux sensor signal is deemed stable if the difference between two consecutive measurements, taken at least 15 minutes apart, is less than 1 mV.
- Measure the heat flux sensor voltage. Take 6 readings of the heat flux sensor voltage, at intervals of at least 1 min. The average of these 6 readings is the response $V_{\mathrm{HFS}}(P_1)$.
- Repeat the above two steps with the internal correction heater configured to consume P_2, P_3.... P_n of electrical power yielding $V_{\mathrm{HFS}}(P_2), V_{\mathrm{HFS}}(P_3), \dots, V_{\mathrm{HFS}}(P_n)$ respectively. For each type of LLE, the values of P_2, P_3,...., P_n are defined in the respective Book.
- Plot V_{HFS} on the X-Axis and power supplied to the system ($P_{\mathrm{th,sys}}$) on the Y-Axis and fit data with a second order equation curve. Each term shall have at least 3 significant digits. An example of such a curve fit is:

$$P_{\mathrm{th,sys}}(V_{\mathrm{HFS}}) = -1.06 * 10^{-1} + 1.30 * 10^{-1} * V_{\mathrm{HFS}} + 5.15 * 10^{-6} * V_{\mathrm{HFS}}^2$$

A.1.3.2.4 Measurement of $P_{\mathrm{th,rear}}$ of the LLE

The measurement of $P_{\mathrm{th,rear}}$ shall be conducted using a setup as depicted in Figure A-1 and the procedure described below:

- If the setup is modified (for example for measuring different LLE types), the heat flux setup shall be re-calibrated.
- Mount thermocouples for measuring t_{a}, t_{cooling} and t_{r} at the positions defined in A.1.3.2.2.
- Build up the measurement setup with the orientation as defined in the appropriate Book.
- Attach the LLE to the Test Fixture via its mounting features. For each type of LLE, the TIM to be used is defined in the respective Book.
- In case of an LLE with Separate ECG, connect the ECG to the LED module according to LLE datasheet instructions.
- Connect external power. The voltage and frequency of the external power source shall be within 0.2% of the Rated voltage and Rated frequency.
- Keep the cooling temperature (t_{cooling}) at the same average value as during calibration within a range of +/-1˚C during the complete measurement process.
- Keep the Ambient Temperature (t_{a}) at the same average value as during calibration within a range of +/-1˚C during the complete measurement process.
- Turn on the LLE and measure the Reference Temperature and adjust the power to the correction heater such that, after stabilization (see section A.1.3.5), t_r is within the interval $t_{\mathrm{r,max}} \pm 1$ °C
- Wait until stabilization of the heat flux sensor signal (V_{HFS}). The heat flux sensor signal is deemed stable if the difference between two consecutive measurements, taken at least 15 min apart, is less than 1 mV.
- Measure the heat flux sensor output. Take 6 readings of the heat flux sensor voltage, at intervals of at least 1 min. The average of these 6 readings is the response V_{HFS}. Plug the V_{HFS} value into the calibration second order fit equation to determine $P_{\mathrm{th,sys}}$ of the system. Then calculate $P_{\mathrm{th,rear}}$ using the formula:

  EQ. A-4: $$P_{\mathrm{th,rear}} = P_{\mathrm{th,sys}} - P_{\mathrm{el,CH}}$$

[10] In order to measure the electrical power to the correction heater as accurately as possible it is recommended to mount wires for measuring the voltage over the correction heater as close as possible to the device and use separated wires for this measurement.

A.1.3.2.5 Pass criteria

The LLE-under-test passes if $P_{th,rear}$ does not exceed the Rated value of $P_{th,rear}$ + 5%.

Example: if the Rated value of $P_{th,rear}$ is 20W, the LLE passes if the measured value is less than 21W. The LLE fails if the measured value is more than 21W.

A.1.3.3 Test on maximum thermal resistance ($R_{th,max}$)

The purpose of this test is to verify the Rated maximum thermal resistance ($R_{th,max}$) of the LLE-under-test.

A.1.3.3.1 Test equipment

See section A.1.3.2.1.

A.1.3.3.2 Test conditions

See section A.1.3.2.2.

A.1.3.3.3 Test procedure

See sections A.1.3.2.3 and A.1.3.2.3. Then calculate $R_{th,max}$ using the formula:

EQ. A-5:

$$R_{th,max} = \frac{t_{r,max} - t_a}{P_{th,rear}}$$

With $P_{th,rear}$: the measured value of $P_{th,rear}$ (section A.1.3.2.4)

t_a : the ambient temperature for which the $R_{th,max}$ is specified by the LLE manufacturer

A.1.3.3.4 Pass criteria

The LLE-under-test passes if $R_{th,max}$ does not exceed the Rated value of $R_{th,max}$ +10%.

Example: if the Rated value of $R_{th,max}$ is 1 K/W, the LLE passes if the measured value is less than 1,1 K/W. The LLE fails if the measured value is more than 1,1 K/W.

A.1.3.4 Test on thermal uniformity

The purpose of this test is to verify the temperature uniformity of the Thermal Interface Surface of the LLE-under-test.

A.1.3.4.1 Test equipment

- Test Fixture TUTF that is defined for each type of LLE in the respective Book.

A.1.3.4.2 Test conditions

The test conditions for a specific type of LLE shall be according to the operating conditions as defined in the respective Book.

A.1.3.4.3 Test procedure

- Attach the LLE-under-test or LED Module of the LLE-under-test via its mounting features to the Test Fixture TUTF using a Thermal Interface Material as specified by the manufacturer.
- Turn on the power supply.
- Adjust Ambient Temperature and Reference Temperature such that, after stabilization (see section A.1.3.5), all test conditions are met.

- Measure the temperatures t_i, $i = 0,1, \ldots$ on the TUTF (See definition of TUTF in the respective Book).
- Use EQ. 6-7, and the value of $P_{\mathrm{th,rear}}$ from the measurement in A.1.3.2 to determine the thermal spreading resistance $R_{\mathrm{th}}(i, j)$ for each combination of measurement points i and j.
- Use EQ. 6-8 to determine the maximum thermal spreading resistance $R_{\mathrm{sp}}^{\max}$.
- The thermocouples used for this measurement shall have an accuracy of ± 1°C.

A.1.3.4.4 Pass criteria

For each type of LLE, the pass-fail criteria for thermal uniformity are defined in the respective Book.

A.1.3.5 Temperature stabilization

The temperature shall be deemed stable if the difference between two consecutive temperature measurements, taken at least 15 min apart, is less than 1 °C.

A.1.3.6 Position of measurement point for the Reference Temperature

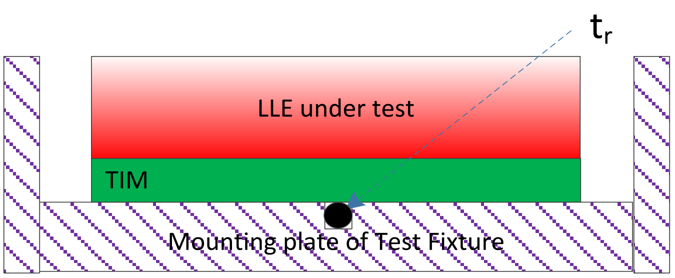


Figure A-3: Position of measurement point for the Reference Temperature

When mounting a LLE to the mounting plate, generally a TIM is applied. The thermocouple for measuring the Reference Temperature shall be mounted in the mounting plate rather than in the TIM[11]. See Figure A-3.

A.1.4 LLE electrical interface tests

This edition of Book 1 does not contain compliance tests for the electrical interface of the LLE.

A.1.5 LLE control interface tests

This edition of Book 1 does not contain compliance tests for the control interface of the LLE.

A.1.6 LLE Product Data Set test

A.1.6.1 Test

Inspect the Product Data Set of the LLE-under-test and check whether the requirements on the Product Data Set in the corresponding Book are met.

A.1.6.2 Pass criteria

This test passes if all requirements on the Product Data Set are met.

[11] The thermal conductivity of a typical TIM is low relative to the thermal conductivity of the mounting plate. Because of that, the temperature gradient across the TIM may be considerable and mounting the thermocouple in the TIM may give unpredictable results.

A.2 Luminaire compliance tests

A.2.1 Luminaire mechanical interface tests

A.2.1.1 Test of the mechanical dimensions of the Luminaire

The purpose of this test is to verify the dimensions of the mechanical interface of the Luminaire-under-test.

A.2.1.1.1 Test equipment

The mechanical dimensions may be tested with (semi-)automated 3D measuring equipment like a non-contact optical measuring system. Measurement accuracy of +/- 0,01 mm shall be achieved.

A.2.1.1.2 Test conditions

All mechanical dimensions shall be verified at an Ambient Temperature in the range 25 ± 5 °C.

A.2.1.1.3 Test procedure

Measure all relevant dimensions of the mechanical interface of the Luminaire-under-test.

A.2.1.1.4 Pass criteria

The Luminaire-under-test passes if all requirements with respect to the mechanical dimensions as defined in the respective Book are met.

A.2.2 Luminaire photometric interface tests

This edition of Book 1 does not contain compliance tests for the photometric interface of the Luminaire.

A.2.3 Luminaire thermal interface tests

A.2.3.1 Test on thermal resistance (R_{th})

The purpose of this test is to verify the Rated thermal resistance (R_{th}) of the Luminaire-under-test in the test setup as specified by the manufacturer.

A.2.3.1.1 Test equipment

- Thermal Test Engine. For each type of LLE the Thermal Test Engine is defined in the respective Book.
- Test setup as specified by the Luminaire manufacturer.

A.2.3.1.2 Test conditions

The Luminaire shall be mounted in the test setup as specified by the Luminaire manufacturer. The assembly shall be installed in a draught free room. The Ambient Temperature shall be 25 ± 5 °C.

A.2.3.1.3 Test procedure

- Mount the Thermal Test Engine in the Luminaire-under-test[12]. For each type of LLE the Thermal Interface Material to be applied is defined in the respective Book.
- Mount the Luminaire in the test setup as specified by the Luminaire manufacturer and install the assembly in a draught free room.
- Connect the TTE to an electrical power source and adjust the consumed electrical power (P_{el}) to a value P_1. For each type of LLE, the value of P_1 is specified in the respective Book.

[12] In case the Luminaire accommodates more than one identical LLEs, all LLE positions shall be equipped with a TTE and all TTEs shall be configured to consume the same electrical power. For the rest the test procedure for multi-TTE case is the same as for the one-TTE case.

- Measure the Reference Temperature (t_r) at the position indicated in section 6.2.9 and wait until this temperature is stabilized (see section A.1.3.4).
- Measure the temperature t_a [13].
- Determine the thermal resistance of the Luminaire-under-test according to:

  EQ. A-6: $$R_{th} = \frac{t_r - t_a}{P_1}$$

- Repeat the above four steps with electrical powers $P_2, P_3, \ldots\ldots P_n$. For each type of LLE, $P_2 \ldots . P_n$ are specified in the respective Book.

A.2.3.1.4 Pass criteria

The Luminaire-under-test passes if for all values $P_1, P_2, \ldots\ldots P_n$ of electrical power holds that the measured thermal resistance does not exceed the Rated thermal resistance + 10%.

Example: if the Rated value of the thermal resistance (R_th) is 2,0 K/W, the Luminaire passes if the measured value is less than 2,2 K/W. The Luminaire fails if the measured value is more than 2,2 K/W.

A.2.4 Luminaire electrical interface tests

This edition of Book 1 does not contain compliance tests for the electrical interface of the Luminaire.

A.2.5 Luminaire control interface tests

This edition of Book 1 does not contain compliance tests for the control interface of the Luminaire.

A.2.6 Luminaire Product Data Set test

A.2.6.1 Test

Inspect the Product Data Set of the Luminaire and check whether the requirements on Product Data Set in the corresponding Book are met.

A.2.6.2 Pass criteria

This test passes if all requirements on the Product Data Set are met.

[13] In case the measurement setup is box, t_a is the room temperature outside the box.

Annex B History of changes

Location	Old	New	Reason
Throughout document		Wording related to definition and tests of LLE replaced by LED Module and/or ECG.	New Zhaga positioning enabling exchange of LED Modules and Drivers.
Summary		Zhaga has created a set of interface specifications, known as Books.	
1		Define 'Zhaga product': LLE, associated component or Luminaire.	
1		Define 'associated products': Holder, LED Module, ECG.	
1		Define Zhaga Consumer Product.	
1		Define Zhaga Professional Product.	
1		Removed several references that are not used anymore.	
1		Added reference to ECG book.	
1		Modified definition of Compatibility and Interchangeability.	
1		Modified definition of Holder.	
1		Removed definition of Mounting hole and Mounting slot.	
2		Updated text on compatibility and interchangeability.	
2		Updated text on product data set.	
2		Updated text on compliance tests and compatibility check.	
3.2 and Annex B		Definition of ECG dimensions removed.	Moved to separate ECG book.
4		New text on operating conditions for LED Modules	
5.1		Text on electrical insulation updated.	Making Zhaga position on electrical insulation more clear.
4.6		Remove explicit list of CCT categories	Follow updates of [ANSI C78.377]
6		Updated text to allow for LED modules as device-under-test.	
7		PDS requirements removed	
Annex A.0		Added test descriptions for LED Modules.	New Zhaga positioning allows for certification of LED Modules.

Table C-1: Changes from Edition 1.6 to Edition 1.7

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