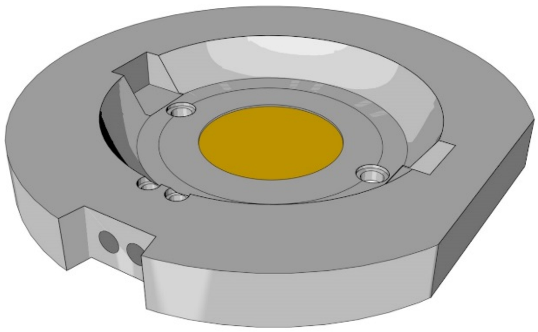
Zhaga Interface Specification

Book 17
Edition 1.0
March 2017

Integrated Spot LED Light Engine



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Zhaga Interface Specification Book 17

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 it is easy to replace one product with another, even if they have been made by different manufacturers.

Contents
This Book 17 defines the LED Spot Light Engines with integrated Electronic Control Gear, intended to be used in a Luminaire. The shape of maximum height 15mm and maximum diameter 81mm allows variants of light emitting surface and variants of flux output.

This Book should be read together with Zhaga Book 1.

Intended Use
The LED Spot Light Engine intended to be screwed to the heat sink base of a Luminaire by an OEM Luminaire manufacturer.

The light output is essentially Lambertian to allow the Luminaire Optics to have a defined input to shape the light distribution to the needs of the application.

The LED light engines defined in this Book 17 are primarily intended for use in LED Spot Light Luminaires. They are intended to be installed and replaced by luminaire manufacturers only.

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 17 defines the LED Spot Light Engines with integrated Electronic Control Gear, intended to be used in a Luminaire. The shape of maximum height 15mm and maximum diameter 81mm allows variants of light emitting surface and variants of flux output.

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 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 References

For references that are not listed in this section, see [Book 1]. For undated references, the most recently published edition applies.

[Book 1] Zhaga Interface Specification, Book 1: Overview and Common Information.

1.4 Definitions

This section defines terms that have a specific meaning in the context of this Book 17. Terms that have a specific meaning across all Zhaga Books are defined in [Book 1].

Book-17 LED Light Engine LED Light Engine according to the specifications in this book.

1.5 Acronyms

Acronyms that have a specific meaning across all Zhaga Books are defined in [Book 1].

1.6 Symbols

Symbols that have a specific meaning across all Zhaga Books defined in [Book 1].

1.7 Conventions

This section defines the notations and conventions used in the Zhaga Interface Specifications.

1.7.1 Precedence

In the case of any perceived discrepancy between the definitions provided in Part 1 of this document, Interface Definition and the definitions provided in Part 2 of this document, Compliance Testing, the definitions provided in Part 2 take precedence over the definitions provided in Part 1.

1.7.2 Cross references

Unless indicated otherwise, cross references to sections include the sub sections contained therein.

1.7.3 Informative text

Informative text is set in italics, unless the whole section is marked as informative.

1.7.4 Terms in capitals

Terms that have a specific meaning in the context of this Book 17 are capitalized. See section 1.4.

1.7.5 Units of physical quantities

Physical quantities are expressed in units of the International System of Units. All lengths that omit an explicit unit indication are in millimeters.

1.7.6 Decimal separator

The decimal separator is a comma.

1.7.7 Limits

Values that are indicated as typical, as well as values between parentheses, are informative.

2 Overview (Informative)

2.1 General

General information with respect to the Zhaga Interface Specifications and certification of products that comply with this Book 17 can be found in [Book 1], section 2.

2.2 Description of the LED Light Engine

This Book 17 defines a LED Light Engine (LLE) typically applied in spot lighting applications. The LLE is to be mounted to or into a Luminaire by an OEM Luminaire manufacturer typically by means of M3 screws.
The LLE defined in this Book 17 has a circular Light Emitting Surface. Figure 2-1 shows informative 3D-drawing of the LLE. These screw holes allow the application of screws that do not protrude above the surface of the OCA (OCA is defined in section 3.5).

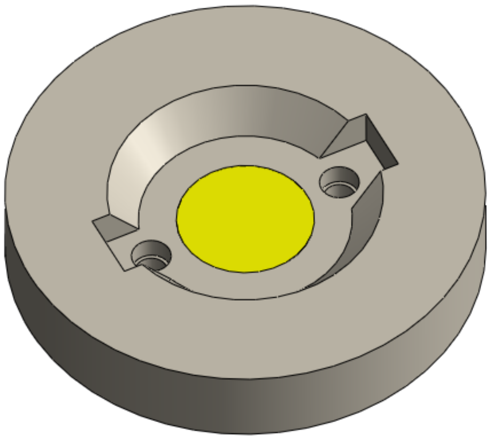

Figure 2-1: Schematic overview of the Book 17 LLE.

The Luminaire typically comprises means to guide the heat away from the LLE and keep the temperature of the LLE at a level that is necessary to reach the performance and lifetime specified by the LLE manufacturer.
The light output of the LLE itself does not have a ‘spot light’ distribution but a general distribution (defined in section 4) which can be tailored into a specific distribution by means of Luminaire Optics. The photometric interface of the LLE is specified here in such a way that using suitable Luminaire Optics, similar Luminaire performance in spot applications is to be expected using different LLEs with the same LES category. The specification has been carefully evaluated to yield as similar performance as possible without restricting the inner structure of the LLE or the LED technology used inside. This has been done to leave as much room as possible for technical innovation on this field.

2.3 Outline of this Book

This Book 17 consists of two parts:

Part 1, Interface Definition, defines the LLE-Luminaire interface in terms of the five sub interfaces:

- The mechanical interface (section 3).
- The photometric interface (section 4).
- The electrical interface (section 5).
- The thermal interface (section 6).
- The control interface (section 7).

Part 2, Compliance Tests, defines:

- Specific tools, which are used for testing compliance of a LLE or a Luminaire (section 8).
- The LLE tests (section 9).
- The Luminaire tests (section 10)

The Annexes to this Book 17 provide the following additional information:

- Requirements on the information that shall be part of the Product Data Set (Annex A).
- Guideline for LES and Luminance measurement (Annex B).

Part 1: Interface Definition

3 Mechanical interface

3.1 General

For the purpose of this section, the provisions in [Book 1] - section 3.1, apply.

3.2 Mechanical references

The reference plane and the reference point of a LLE (including TIM) are defined in Figure 3-1. The reference point is the point where the LLE symmetry axis crosses the reference plane. Heights are specified relative to the reference plane unless otherwise specified. Moreover, dimensions are specified to include the thickness of the TIM (if present).

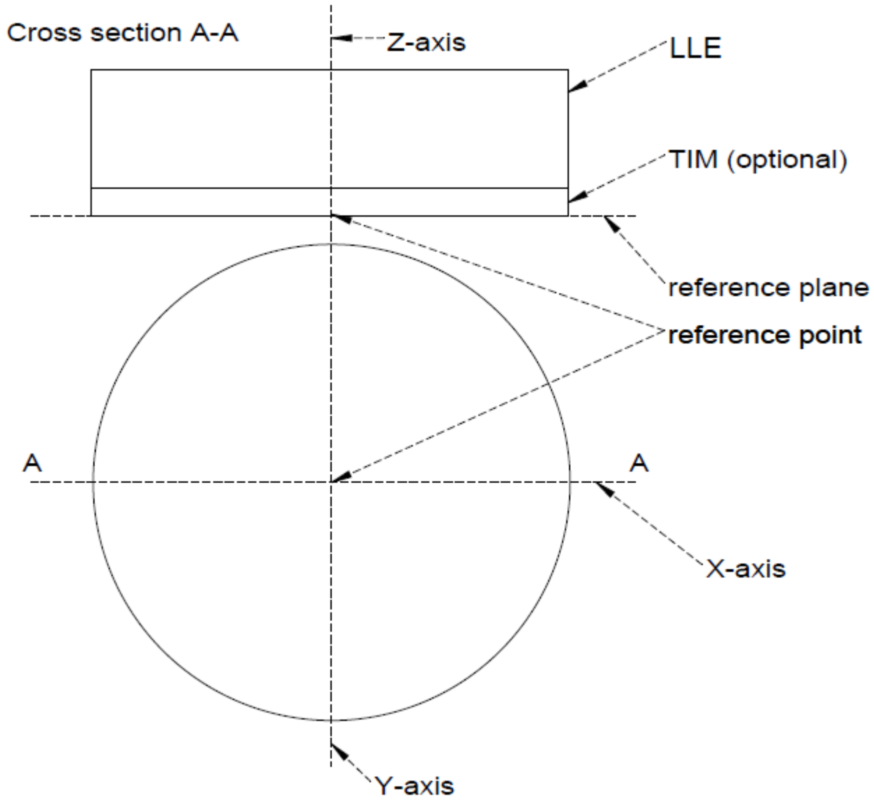

Figure 3-1: Mechanical references

3.3 Outline and common geometry

The LLEs specified in this document share the same outlines: they may preferably be round with a diameter specified in Figure 3-2 and Table 3-1. Note that the parameters given with only one-sided tolerance define the maximum/minimum outlines, meaning that the LLE may also be smaller/bigger if technically feasible. It is explicitly not required to even follow the shape indicated here as long as the maximum/minimum outlines are kept. Further parameters indicated in Figure 3-2 (Øc, Ød, Øe, b) are related to the OCA and defined in section 3.5.

Notes to Figure 3-2

- (RP) Reference plane
- (X) Reference X-axis.
- (Y) Reference Y-axis.
- (Z) Reference Z-axis

- (P) Reference point

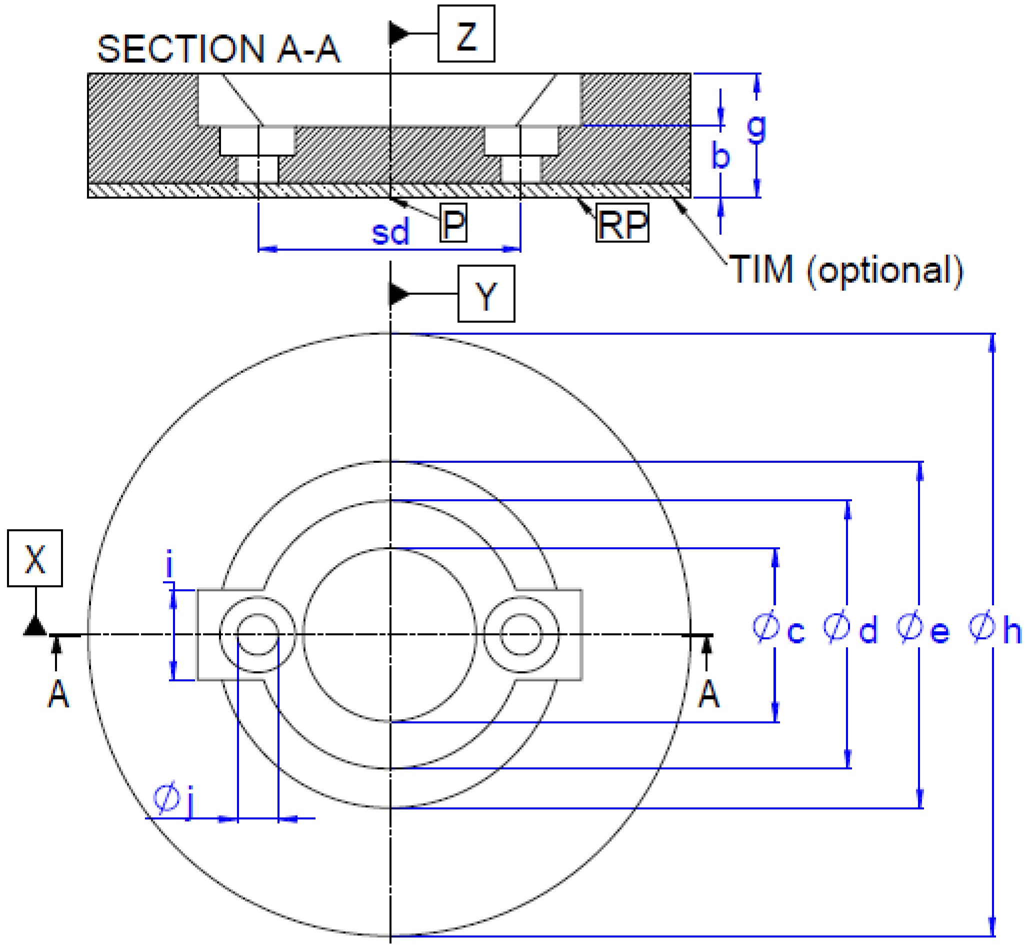

Figure 3-2: Drawing of mechanical dimensions.

	Min.	Typ.	Max.
g	--	--	15
Øh	--	--	81
sd	34,85	35,00	35,15
i	6.4	--	--
j	3,1	3,3	--

Table 3-1: Mechanical dimensions

3.4 LED Light Engine connection

The electrical interconnect(s) can be placed according to technical feasibility but they shall not exceed the maximum outline given in Figure 3-3 and Table 3-2. (Dimension ⌀h is defined in Table 3-1). The electrical interconnect(s) shall be inside the LLE.

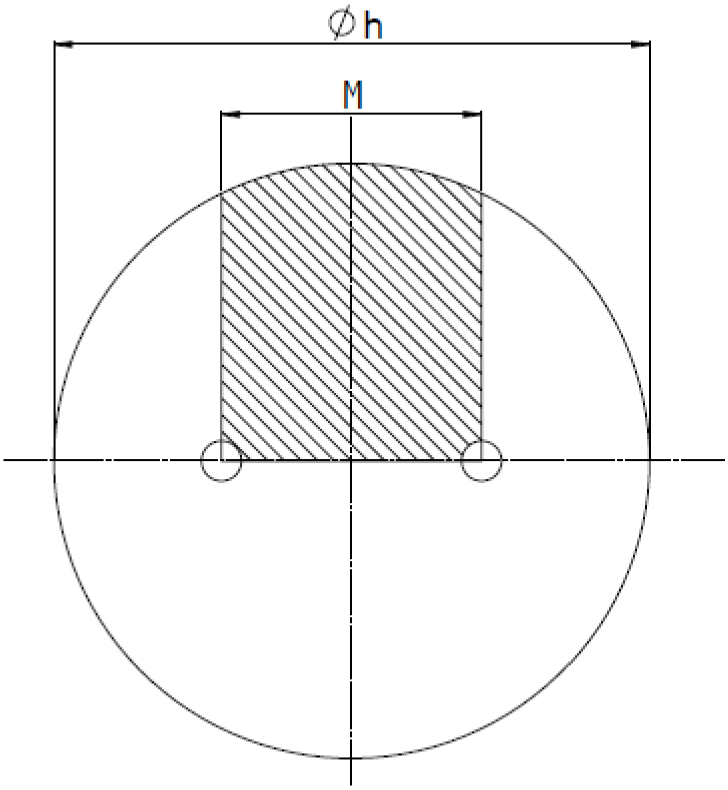

Figure 3-3: Mechanical dimension for electrical interconnect.

	Min.	Typ.	Max.
M	--		35

Table 3-2: Mechanical dimension for electrical interconnect

3.5 Optics Contact Area

The dimensions Øc, Ød, Øe and b are related to the OCA. They have been defined in Figure 3-2. The surface of LLE with a diameter ⌀d excluding center hole is intended to be used as Optics Contact Area. The position and dimensions of OCA are specified in Figure 3-2, Figure 3-4, Table 3-1 and Table 3-3.

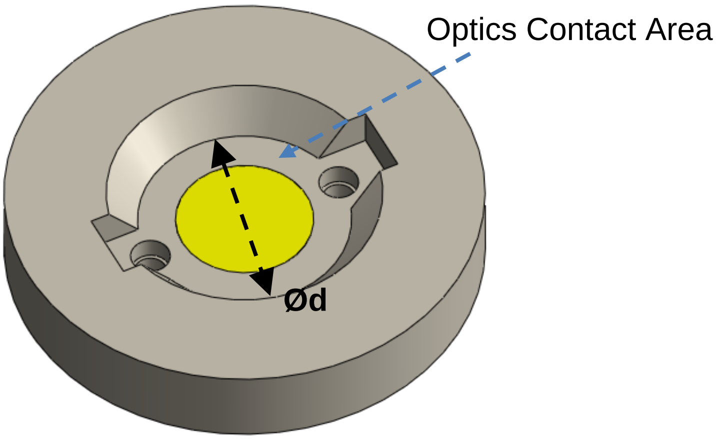

Figure 3-4: Optics Contact Area

	Min.	Typ.	Max.
b	--	--	7,5
Ød	32	--	--
Øe	2*(g-b)+ Ød	--	--

Table 3-3: Mechanical dimension for OCA

The inner diameter of the OCA (Øc) shall be less or equal than $ØOCA_{max}$ with $ØOCA_{max}$ depending on the LES category (defined in section 4.1) according to Table 3-4.

LES category	$ØOCA_{max}$
LES9	13,67
LES13.5	19,17
LES19	23.2
LES23	26.2

Table 3-4: Maximum inner OCA diameter.

3.6 Requirements on screw holes

The Book 17 LLE shall have either counterbored screw holes or countersunk screw holes. In either case, the LLE maker shall specify in the PDS the screw type for which the LLE has been designed by referencing a public standard (for example a DIN standard).
The geometry of the screw holes shall be such that a screw compliant with the specification in the PDS fits in the screw hole and the screws do not protrude above the surface of OCA.

4 Photometric interface

4.1 Light Emitting Surface

For the purpose of this section, the provisions in [Book 1] - section 4.1, apply. The LES for Book 17 LLE shall be described by a circular flat plane parallel to the reference plane defined in section 3.2. It has a physical boundary or it is a virtual surface in the surrounding area of the LLE.
The LES shall have the smallest possible diameter while complying with the following conditions:

- When seen from above, all light emitting parts (LED, diffuse cover and / or mixing chamber) are covered by the LES.
- It encircles all pixels in the luminance image of the LLE that have a value >10% of the maximum (See Annex B).

The height of the LES shall be as small as possible while complying with the condition that all light emitting parts are behind the LES, when seen in a top view. The typical height of the LES is 2 mm. This height should be taken as a reference by the Luminaire manufacturer in designing Luminaire Optics.
The center of the LES should not be off from the Z-axis of the LLE by more than 1 mm in any direction.
Book 17 LLE shall have a LES in one of the categories LES9, LES13, LES19 or LES23, as defined in [Book 1] - section 4.1.

4.2 Operating conditions

For the LLE defined in this Book 17, the operating conditions defined in [Book 1], section 4.2 apply.

4.3 Luminance Flux

For the purpose of this section, the provisions in [Book 1] - section 4.3 apply. The luminous flux of a LLE shall be measured under the conditions specified in section 4.2.

4.4 Luminous intensity distribution

For the purpose of this section, the provisions in [Book 1] - section 4.4 apply. The luminous intensity distribution of a LLE shall be measured under the conditions specified in section 4.2 with the exception that the Reference Temperature may be stabilized at any temperature as only relative values are considered for the luminous intensity distribution.
It is recommended that the LLE has a luminous intensity distribution that is as close as possible to a lambertian intensity distribution. There is no requirement regarding FWHM of the luminous intensity distribution. Relative Partial Luminous Fluxes for the polar angle regions as defined in [CIE 52] ("CIE cumulative flux zones") shall be within the limits defined in Table 4-1.

γ_1	γ_2	Relative Partial Luminous	
		Minimum	Maximum
0°	41,40°	39%	56%
41,40°	60,00°	31%	37%
60,00°	75,50°	11%	22%
75,50°	90°	0%	7%

Table 4-1: Relative partial luminous flux requirements.

4.5 Luminance uniformity

The luminance uniformity of a LLE should be measured under the conditions specified in section 4.2 with the exception that the Reference Temperature may be stabilized at any temperature as only relative values are to be considered for the luminance uniformity.

The luminance of the LLE should be symmetric with respect to the reference Z-axis. Using the definition of the five segments A_i (i=1…5) of the LES as shown in Figure 4-1, the following symmetry parameters are defined as follows:

1. Luminance rotational symmetry
   The luminance rotational symmetry parameter S is calculated from the average luminance L_i in forward direction in each of the four segments A_i (i=1…4) as $\frac{\min(L_i)}{\max(L_i)}$. Note that the definition of segments as defined in Figure 4-1 does not have a coupling with the orientation of the LLE. For that reason, $\frac{\min(L_i)}{\max(L_i)}$ is calculated for different orientation (see Annex B) and luminance rotational symmetry (S) is defined as $S = \max\left(\frac{\min(L_i)}{\max(L_i)}\right)$. The value of S should not be lower than 0,5.
2. Luminance center balance
   The Luminance center balance is defined as: $B = \frac{L_5}{\text{Average}(L_1 \,..L_4\,)}$. The value of B should not be higher than 4.
3. Luminance uniformity
   The luminance uniformity U is defined as $U = \frac{L_{avg}}{L_{RMS}}$ with

   L_{avg} : the average luminance over the actual LES area [1].

   $L_{RMS} = \sqrt{\frac{1}{N}\Sigma L_j^2}$: the RMS luminance values over every pixel in the actual LES area.

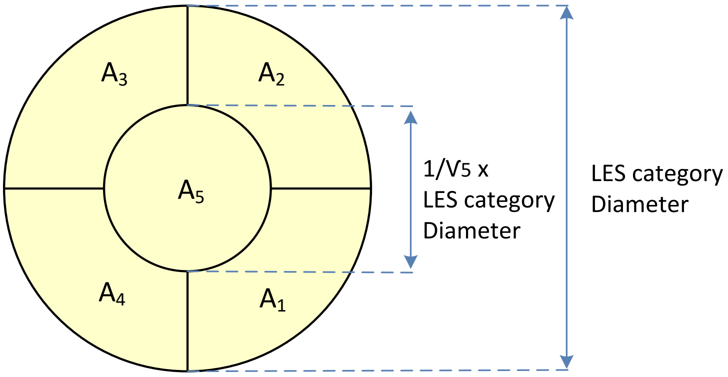

Figure 4-1: Luminance property evaluation areas

4.6 Correlated color temperature

For the purpose of this section, the provisions in [Book 1] - section 4.6 apply. The correlated color temperature of a LLE shall be measured under the conditions specified in section 4.2.

4.7 Color rendering index

For the purpose of this section, the provisions in [Book 1] - section 4.7 apply. The color rendering index of a LLE shall be measured under the conditions specified in section 4.2.

[1] For this requirement, not the LES category diameter but the actual LES diameter determined in 9.2.5 shall be used.

4.8 Luminaire Optics (Informative)

Luminaire Optics (e.g., reflectors) should be designed in such a way, that the nominal values of LES diameter and height with a lambertian emission pattern result in the desired performance.
Luminaire Optics may be mounted in contact with the OCA corresponding to the LES diameter category it is designed for according to section 3.5.
Note: Due to the compound nature of many LLE solutions, it is expected that Luminaire Optics designed for Zhaga compliant Spot LLEs takes into account the structure of LED clusters, e.g. by using frosted surfaces or facetted structures to achieve the comparable light output with all kinds of module technologies enabled by the Zhaga Specifications. The luminance uniformity factor U of the LLE can give a hint on the degree of effort necessary to achieve properly distributed light with Luminaire Optics.

5 Electrical interface

5.1 Mains power

LLE Mains Power input shall follow one of the categories given in Table 5-1.

Categories	Input voltage range [V]	Rated frequency [Hz]
A	100…120	50 or 60
B	220…240	50 or 60
C	100…240	50 or 60

Table 5-1: Mains power characteristics of the LLE.

5.2 Electrical insulation

For the purpose of this section, the provisions in [Book 1] - section 5.1 apply.

6 Thermal interface

6.1 Background information (informative)

For the purpose of this section, the provisions in [Book 1] - section 6.1 apply.

6.2 Generic thermal interface model

6.2.1 General case

For the purpose of this section, the provisions in [Book 1] - section 6.2.1 apply. The position of the measurement point for the Reference Temperature for the LED Light Engine defined in this Book 17 is the same as the mechanical reference point defined in Figure 3-1.

6.2.2 Rated Operating Temperature and safety (informative)

For the purpose of this section, the provisions in [Book 1] - section 6.2.3 apply.

6.2.3 Thermal overload protection

For the purpose of this section, the provisions in [Book 1] - section 6.2.4 apply.

6.2.4 Thermal compatibility check

In order to determine whether a particular LED Light Engine is thermally compatible with a particular Luminaire, it should be verified that the LED Light Engine -Luminaire combination will operate at $t_r \le t_{r,max}$. The value of $t_{r,max}$ is listed in the LED Light Engine Product Data Set. Using the generic thermal model as defined in [Book 1] - section 6.2.1, the operating temperature tr can be determined by:

EQ. 6-1: $t_r = t_a + R_{th} \cdot P_{th,rear}$

The ambient temperature t_a is determined by the application of the LED Light Engine -Luminaire combination. The value of R_{th} is a characteristic of the heat sink. Both t_a and R_{th} should be chosen appropriately by a skilled person.

The value of $P_{th,rear}$ is not listed in the LED Light Engine Product Data Set. However, it can be estimated, using the Rated value of P_{th} in the LED Light Engine Product Data Set.

(Informative)

Depending on the required accuracy of the estimation of $P_{th,rear}$, the following methods may be used.

Method 1 - Ignore $\boldsymbol{P}_{th,front}$

In this case $P_{th,rear} = P_{th}$

Method 2 – Estimate $\boldsymbol{P}_{th,front}$ using a thermal simulation.

In this case, $P_{th,rear}$ is calculated using: $P_{th,rear} = P_{th} - P_{th,front}$ and $P_{th,front}$ is estimated using a thermal simulation of the LED Light Engine in the specific application. This allows the characteristics of the Luminaire also to be taken into account.

6.2.5 Thermal Interface Material

For the purpose of this section, the provisions in [Book 1] - section 6.2.9 apply.

6.2.6 Surface planarity and roughness

For the purpose of this section, the provisions in [Book 1] - section 6.2.10 apply. It is recommended that the surface in the Luminaire which serves as a thermal interface has a surface planarity smaller than 0,1 mm and a surface roughness smaller than 3,2 µm.

6.2.7 Aging of LED Light Engine (informative)

For the purpose of this section, the provisions in [Book 1] - section 6.2.11 apply.

7 Control Interface

For the purpose of this section, the provisions in [Book 1] - section 7 apply.

Part 2: Compliance Tests

8 Compliance test tools

8.1 LED Light Engine test tools

8.1.1 Test Fixture PETF (photometric and electrical)

The PETF for Book 17 LLE is a temperature controlled heat sink that allows for mounting the LLE-under-test and that can be attached to the photometric measurement system.
The Thermal Interface Material to be used shall be supplied by the LLE manufacturer when submitting the LLE for compliance test to the ATC.

9 LED Light Engine Compliance Tests

9.1 LED Light Engine mechanical interface tests

9.1.1 Test of the mechanical interface of the LED Light Engine

The purpose of this test is to verify that the LLE under test meets the requirements as defined in section 3.3 and section 3.4.

9.1.1.1 Test equipment

- (Semi) automated 3D measuring equipment like a non-contact optical measuring system. The measurement accuracy shall be at least ±0,05 mm.
- Caliper

9.1.1.2 Test conditions

The mechanical interface shall be verified at a temperature in the range of 25±5℃.

9.1.1.3 Pass criteria

The LLE under test passes if the verified dimensions are within the minimum and maximum limits defined in Section 3.

9.1.2 Test OCA of the LED Light Engine

The first purpose of this test is to verify that the LLE under test meets the requirements on the OCA as defined in section 3.5. The second purpose of this test is to verify whether the LLE under test meets the requirements on the screw holes as defined in section 3.6.

9.1.2.1 Test equipment

- (Semi) automated 3D measuring equipment like a non-contact optical measuring system. The measurement accuracy shall be at least ±0,05 mm.
- Caliper
- Flat metal ring with an outer-diameter of Ød, inner-diameter equal to Øc and a known thickness, constant within ±0,05 mm.

9.1.2.2 Test conditions

The mechanical interface shall be verified at a temperature in the range of 25±5°C. The LLE under test shall be tested in combination with TIM and screws which shall be provided with the test sample. The LLE – TIM combination shall be tested with the TIM in compressed state with a contact pressure or torque as defined in the PDS.

9.1.2.3 Test procedure

- Determine the designation of the LES category from the Product Data Set of the LLE under test.
- Measure the diameter related to OCA of the LLE (Øc, Ød and Øe).
- Mount the LLE on a plate by means of the supplied screws with a contact pressure or torque according to the specification in the PDS.
- Position the ring on the OCA of LLE such that the center of the ring coincides with the center of the LLE.
- Verify that there is visual clearance between the top of the screws and the ring.
- Measure the height of OCA surface at 4 positions: 0°, 90°, 180° and 270°, on a concentric circle with a diameter of (Øc+ Ød)/2.
- Calculate the average height of the OCA <b> as the average height of the 4 measurement points minus the thickness of the ring.

9.1.2.4 Pass criteria

The LLE under test passes if the following conditions are met:

- The verified dimensions are within the minimum and maximum limits defined
- There is visual clearance between the top of the screws and the ring.

9.2 LED Light Engine photometric interface tests

9.2.1 Test on luminous flux

For the purpose of this section, the provisions in [Book 1] - section A.1.2.1 apply. The Test Fixture PETF is defined in section 8.1.1. The test conditions are defined in section 4.2.

9.2.2 Test on relative partial luminous flux and beam angle.

For the purpose of this section, the provisions in [Book 1] - section A.1.2.2 apply. The Test Fixture PETF is defined in section 8.1.1. The test conditions are defined in section 4.2. The relative partial luminous flux shall meet the requirements defined in section 4.4. This Book 17 does not define requirements for beam angle.

9.2.3 Test on correlated color temperature (CCT)

For the purpose of this section, the provisions in [Book 1] - section A.1.2.3 apply. The Test Fixture PETF is defined in section 8.1.1. The test conditions are defined in section 4.2.

9.2.4 Test on color rendering index

For the purpose of this section, the provisions in [Book 1] - section A.1.2.4 apply. The Test Fixture PETF is defined in section 8.1.1. The test conditions are defined in section 4.2.

9.2.5 Test on luminance uniformity & LES (Informative)

The recommended measurement procedures for luminance related parameters are described in Annex B.

9.3 LED Light Engine Electrical interface tests

This edition of Book 17 of the Zhaga Interface Specification does not contain compliance tests for the Electrical interface of the LLE. Note that the electrical interface is implicitly tested by performing the photometric tests as defined in section 9.2.

9.4 LED Light Engine thermal interface tests

9.4.1 Test on thermal power (P_{th})

For the purpose of this section, the provisions in [Book 1] - section A.1.3.1 apply. The Test Fixture PETF is defined in section 8.1.1.

9.4.2 Temperature stabilization

For the purpose of this section, the provisions in [Book 1] - section A.1.3.5 apply.

9.4.3 Position of measurement point for the Reference Temperature

For the purpose of this section, the provisions in [Book 1] - section A.1.3.6 apply.

9.5 LED Light Engine Product Data Set test

For the purpose of this section, the provisions in [Book 1] - section A.1.5 apply.

10 Luminaire compliance tests

10.1 Luminaire mechanical interface tests

10.1.1 Test on the mechanical interface of the Luminaire for mounting the LLE

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

10.1.1.1 Test equipment

- (Semi) automated 3D measuring equipment like a non-contact optical measuring system. The measurement accuracy shall be at least ±0,05 mm.
- Caliper

10.1.1.2 Test conditions

The mechanical interface shall be verified at a temperature in the range of 25 $\pm$ 5 °C.

10.1.1.3 Test procedure

Verify that the Luminaire-under-test, including mounting means such as screws does not cross the LLE as defined in section 3.3..

10.1.1.4 Pass criteria

The Luminaire-under-test passes if the result of the LLE verification is positive for all LLE positions in the Luminaire.

Annexes

Annex A Product Data Set requirements

In this section the requirements with respect to the Product Data Sets of Zhaga products defined in this Book 17 are listed.

A.1 LED Light Engine Product Data Set

The LLE Product Data Sets shall contain the following information:

- The Luminous Flux category at the Rate Operating Temperature $t_{r,max}$
- The CCT and CRI category at the Rated Operating Temperature $t_{r,max}$ using the three digit code as defined in [IEC 62732]. Only the nominal CCT categories as specified in [ANSI C78.377] shall be used
- The LES category
- The Luminance rotational symmetry (S)
- The Luminance uniformity (U)
- The Rated Operating Temperature $t_{r,max}$
- The thermal power P_{th}
- The properties or type of TIM to be used with this LED Light Engine
- The contact pressure or torque required for mounting the LED Light Engine
- The type of screw to be used for mounting the LED Light Engine by referencing an international standard

Annex B Guidelines for LES and Luminance measurements (informative)

The Light Emitting Surface and the LES diameter for a Book 17 LLE are defined in section 4.1 while the luminance uniformity parameters B, S and U are defined in section 4.5. This annex provides guidance on how to measure these parameters. Note that this section is informative only. Other methods to determine the value of these parameters may also be used. As an example one may calculate these values from ray-set data of the device under test.

B.1 Test equipment

The luminance uniformity and the LES diameter can be measured using a setup as depicted in Figure B-1. The luminance camera should have sufficient resolution to measure at least 500 pixels over the actual LES area. The measurement uncertainty for the luminance value should be +/- 10% or less[2].

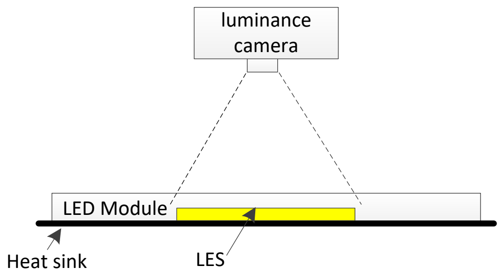

Figure B-1: Set-up for measurement of luminance uniformity and LES diameter.

B.2 Test conditions

See section 4.2.

B.3 Test procedure

- Perform a suitable geometrical calibration to relate the size of the luminance image to the geometrical dimension of the LES. This should be done at least after any modification of the test setup.
- Mount the LLE-under-test on a suitable heat sink. The luminance camera should measure the luminance directly looking at the LLE-under-test along the Z-axis (Figure 3-1). Ensure that the whole LLE-under-test is in the field of vision of the luminance camera.
- Choose the focus of the luminance camera to be in the plane of the OCA, not on the LEDs.
- Turn on the LLE-under-test.
- As only relative data is to be taken, it is not necessary to wait for thermal stabilization if the duration of the measurement is less than 1 s. Otherwise, wait for stabilization of the temperature t_r (see [book 1], section A.0.3.2).
- Measure the luminance image of the LLE-under-test. Trim the image in such a way that the LLE is in the center of the image, and that it fills at least 80% of height and width of the image.

[2] Evaluation of measurements is always relative in this specification. Thus, the tolerance for the luminance rotational symmetry, center balance and uniformity parameter is expected to be much lower.

- Determine the center of gravity of the luminance image. The "center of gravity" of a luminance image is by definition the point which has the least summed distance to all pixels in the image. Use only pixels above the background noise level for this determination. A typical threshold level is 10% of the maximum intensity. Shift the center of the evaluation areas (section 4.5) such that it coincides with the "center of gravity".
- Evaluate the average luminances L_i in the areas A_i as defined in section 4.5. Note that the LES category diameter shall be taken for this evaluation.
- Determine the actual LES diameter as the minimum diameter of the circle around the center of gravity of the luminance image that encloses all pixels with >10% of the maximum L_i (i=1..5).
- Rotate the orientation of the segments diagram defined in section 4.5 with respect to the luminance image by 90° in steps of 5°. For every step, evaluate the rotational symmetry parameter (S) as defined in section 4.5. The maximum shall be taken as value for S.
- Evaluate center balance (B) as defined in section 4.5.
- Evaluate the average luminance L_{avg} over the actual LES area.
- Calculate the luminance uniformity (U) as defined in section 4.5. The number of pixels N shall not be less than 500.