Zhaga Interface Specification

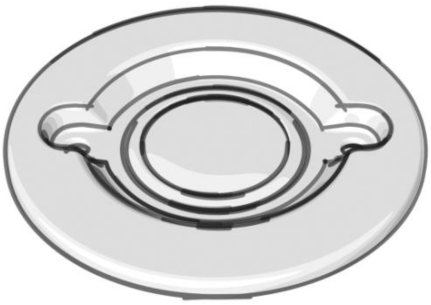
Book 3

Edition 1.3
October 2013

LED LIGHT ENGINE

TYPE D:
NON-SOCKETABLE WITH SEPARATE
CONTROL GEAR 7,2MM x 50MM

LES 9MM – 23MM ROUND



Zhaga Interface Specification Book 3

Summary (informative)

Background
The Zhaga Consortium is a worldwide organization that aims to define LED Light Engines (LLE), which are interchangeable in the sense that LED Light Engines designed by different manufacturers can be exchanged without complications.

Each specification defines at least the Mechanical, Photometric, Electrical, Thermal and Control interfaces between the LED Light Engine and the Luminaire.

The individual Specifications of the Zhaga Interface Specification are approved by the general assembly of the Zhaga Consortium and published in the form of technical 'Zhaga Interface specifications'.

They are catagorized into generic types to help understanding;
A) Socketable with integrated control gear
B) Socketable with separate control gear
C) Non-socketable with integrated control gear
D) Non-socketable with separate control gear

Contents
This Specification Book 3 defines the interfaces between a type D non-socketable LLE with separate control gear and a luminaire. It is a round disc shape of 7.2mm maximum height and 50mm typical diameter. It allows for various Light emitting surface dimensions categorized as LES 9, LED 13.5, LES 19 & LES 23mm (diameter round).

This Specification Book 3 must be read together with Specification Book 1 on general requirements.

Intended Use
An LED module intended to be screwed to the heat sink base of a Luminaire by an OEM Luminaire manufacturer and to be controlled by separate electronic control gear.
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.
It is primarily intended for use in LED spot light luminaires so is described this way in the specification.

An optional accessory included in this specification is a locking ring to allow screwless mounting of the LED module.

Conformance
All provisions in the Zhaga Interface Specification are mandatory, unless specifically indicated as recommended, optional or informative.

Zhaga Interface Specification

LED Light Engine Type D:

Non-socketable with separate control gear

7.2mm x 50mm

Edition 1.3

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DISCLAIMER

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CLASSIFICATION

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1 General

1.1 Introduction

The Zhaga Consortium is a worldwide organization that aims to define LED Light Engines, which are interchangeable—in the sense that products designed by different manufacturers can be exchanged without complications. A LED Light Engine (LLE) is a light source for general lighting that is based on solid state technology, and typically consists of one or more LEDs combined with stabilization and control electronics (Electronic Control Gear).

Different types of LED Light Engines are defined in different books of the Zhaga Interface Specification. Each book defines at least the following set of interfaces that are connected with interchangeability:

- Mechanical interface.
- Optical interface.
- Electrical interface.
- Thermal interface.
- Control Interface.

The individual books of the Zhaga Interface Specification are approved by the General Assembly of the Zhaga Consortium and published in the form of technical specifications.

1.2 Scope (informative)

This Book 3 defines the interfaces between a "Spot LED Light Engine with separate Electronic Control Gear" and a Luminaire.

1.3 Main features (informative)

A Spot LED Light Engine includes at least one LED Module intended to be screwed to the heat sink base of a Luminaire by an OEM Luminaire manufacturer. Light output is essentially Lambertian, so Luminaire Optics has a defined input to shape the light distribution to the needs of the application. This document defines:

- A set of LED Modules with mechanical, thermal and photometric interfaces to be used in a suitable Luminaire.
- The mechanical outlines and the electrical interface to mains of the separate Electronic Control Gear necessary to operate the individual LED Module
- A Luminaire that provides the appropriate environment for the LED Light Engine to operate correctly.
- A marking scheme for LED Light Engines as well as for Luminaires that allows users to select LED Light Engines that can be operated safely and satisfactorily in the corresponding Luminaire.
- Testing procedures to ensure mechanical, photometric, thermal and electrical interchangeability between different LED Light Engines used in the same Luminaire.

1.4 Conformance and References

1.4.1 Conformance

All provisions in the Zhaga Interface Specification are mandatory for an LLE or Luminaire to be certified as "Zhaga compliant", unless specifically indicated as recommended or optional or informative. Verbal expression of provisions in the Zhaga Interface Specification follows 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 Specification, 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 Specification. The word "**can**" indicates a possibility or capability, whether material, physical or causal.

1.4.2 Normative references

In addition to the provisions in this Book 3 of the Zhaga Interface Specification, product implementations shall also conform to the provisions in the System Descriptions as well as the relevant parts[1] of the International Standards listed below or in section 1.3.2. of [Book 1] of the Zhaga Interface Specification. For undated references, the applicable revision is the one most recently published at the release date of this Book 3, of the Zhaga Interface Specification. As an exception, a reference to [Book 1] always refers to the most recent edition of [Book 1] unless explicitly stated otherwise.

[Book 1]	Zhaga Interface Specification, Book 1: Overview and Common Information.
[IEC 60598]	Luminaires—Part 1: General requirements and tests, IEC 60598-1.
[IEC 61347-1]	Lamp controlgear - Part 1: General and safety requirements: IEC 61347-1
[IEC 61347-2-13]	Lamp controlgear - Part 2-13: Particular requirements for d.c. and a.c. supplied electronic controlgear for LED modules: IEC 61347-2-13
[IEC 62031]	LED modules for general lighting—Safety specifications, IEC 62031.
[IEC 62384]	DC or AC supplied electronic control gear for LED modules – Performance requirements
[IEC /PAS 62717]	PAS LED modules for general lighting—performance requirements, IEC / PAS 62717.
[ISO 262]	ISO general purpose metric screw threads—Selected sizes for screws, bolts and nuts, ISO 262

In addition to the measurement techniques defined in this document, measurement techniques used to characterize product implementations shall conform to the provisions in the International Standards listed below or in section 1.3.2. of [Book 1] of the Zhaga Interface Specification. For undated references, the applicable revision is the one most recently published at the release date of this Book 3 of the Zhaga Interface Specification.

[CIE 52]	Calculations for interior lighting – Applied Method, CIE 52
[IEC/TR 61341]	Method of measurement of centre beam intensity and beam angle(s) of reflector lamps, IEC/TR 61341.
[IES LM-79-08]	IES Approved Method for the Electrical and Photometric Measurements of Solid-State Lighting Products, IES LM-79-08.
[ISO 17025]	General requirements for the competence of testing and calibration laboratories, ISO / IES 17025
[EN 13032-2]	Light and lighting - Measurement and presentation of photometric data of lamps and luminaires - Part 2: Presentation of data for indoor and outdoor work places
[UL 1598]	Safety of Luminaires

1.4.3 Informative references

In addition to the references given in section 1.3.3. of [Book 1], the following references provide additional information that may be relevant to the provisions in this Book 3 of the Zhaga Interface Specification.

[CIE 84]	The measurement of luminous flux, CIE 84.

[1]As referenced in the subsequent sections of this document.

[CIE 121]	The photometry and goniophotometry of Luminaires, CIE 121.
[CIE 177]	Colour rendering of white LED light sources, CIE 177.
[IEC 60061-d]	Designation of Lamp Caps and Holders, IEC 60061 standard sheet 7007-1.
[ASTM D5470]	Standard Test Method for Thermal Transmission Properties of Thermally Conductive Electrical Insulation Materials - ASTM D5470

1.5 Definitions

Definitions common to all books of the Zhaga Interface Specification are given in section 1.4 of [Book 1]. The following additional definitions apply for this Book. In case of conflicts, the definitions given here overrule the definitions from [Book 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.
LED Light Engine	A combination of an Electronic Control Gear and one or more LED Modules. An LED Light Engine may have an integrated control gear or a control gear in separate housing. In Book 3: Spot LED Light Engine with Separated Electronic Control Gear, the LLE consists of the LED Module, the ECG and all means of connecting them.
Light Emitting Surface	Surface of a LED Light Engine or LED Module with the function of light emission. In Book 3, it is the basis entity for Luminaire Optics designs. Here, it is a virtual surface which shall be used for a simplified description of the optical emission of the LED Module. It might, but need not coincide with a physical surface of the module.
Plug	Part of an electrical connection that is attached to wires.
Spot Application	Application of a Luminaire, in which light is to be focussed to a beam with FWHM of typically <40°.
Receptacle	Part of electrical connection that is usually mounted to a rigid structure like the LED Module.
Thermal Test Engine	A device that is used to determine the thermal properties of a Luminaire. A Thermal Test Engine is also used for compliance verification with respect to the thermal properties of the Luminaire.
Luminous Flux	Quantity derived from radiant flux by evaluating the radiation according to its action upon the CIE standard photometric observer

1.6 Acronyms

Acronyms common to all books of the Zhaga Interface Specification are given in section 1.5 of [Book 1] . The following additional acronyms apply for this Book.

NMI	national metrology institute
TUTF-Spot	Thermal Uniformity Test Fixture for Spot LED Modules
TTE-Spot	Thermal Test Engine for Spot LED Modules

TPTF-Spot	thermal power Test Fixture for Spot LED Modules
TUTF-Spot	thermal uniformity Test Engine for Spot LED Modules

1.7 Symbols

Symbols commonly used in all books of the Zhaga Interface Specification are given in section 1.5 of [Book 1]. The following additional symbols are used in this Book.

β	Inverse calibration parameter of the heat flux sensor (unit: W/V)
L_i	Average Luminance in Area i (unit: W/m^{2}sr)
N	Number of Luminaire camera pixels within LES
N_{bright}	Number of pixels that are brighter than a reference value
P_{thCH}	electrical power applied to the correction heater of TPTF (unit: W)
$P_{th, max}$	Maximum thermal power generated by LED Module (unit: W)
$P_{th, rear, max}$	Maximum thermal power transferred by LED Module to the Luminaire heat sink via its Thermal Interface Surface. In this Book 3 of the Zhaga Interface Specification the value is to be specified in the Product Data Set by the LLE manufacturer. (unit: W).
R_{th}	Thermal resistance of the Luminaire (unit: K/W)
$R_{th, rear}$	Thermal resistance at Thermal Interface Surface for power generated by either LED Module or TTE (unit: K/W)
$R_{th, max}$	Value of thermal resistance from the Thermal Interface Surface to the environment for which holds $t_r = t_{t,max}$ (unit: K/W)
R_{sp}	Thermal spreading resistance between specified measurement points (unit: K/W)
$R_{sp, lum}$	Thermal spreading resistance between specified measurement points at the Luminaire (unit: K/W)
S	Luminance rotational symmetry parameter
U	Luminance uniformity parameter
V_{HFS}	Voltage response from the heat flux sensor (unit: V)

1.8 Conventions

For the purpose of this section, [Book 1] section 1.7 applies.

2 System Overview (informative)

For a general overview of the Zhaga Interface Specification, please see Chapter 2 of [Book 1].

This Book 3 of the Zhaga Interface Specification defines a Spot LED Light Engine consisting of one or more LED Modules and an Electronic Control Gear physically separated from each other. The LED Module is to be mounted to or into a Luminaire by an OEM Luminaire manufacturer by the means defined here. The ECG may be mounted to or into the Luminaire. The connection between them is not defined here and has to be done according to the prescription of the LED Light Engine manufacturer.

The Luminaire typically comprises means to guide the heat away from the LED Module and keep the temperature of the LED Module at a level tolerable to reach the performance and lifetime specified by the LLE manufacturer. To ensure this capability, LLE as well as Luminaire testing procedures and certification and marking specifications are given in this document.

The Luminaire may incorporate optical elements, which shape the light output of the Spot LLE (Luminaire Optics). The output of the Spot LLE itself has not a 'Spot Light' distribution but a general distribution (which is defined in section 4) which can be tailored into a specific distribution by means of Luminaire Optics. The photometric interface of the Spot LLE is specified here in such a way that using suitable Luminaire Optics (reflectors, preferably), 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 much as possible similar performance without restricting the inner structure of the LLE nor the LED technology used inside[2]. This has been done to leave as much room as possible for technical innovation on this field.

Figure 1 below illustrates the arrangement

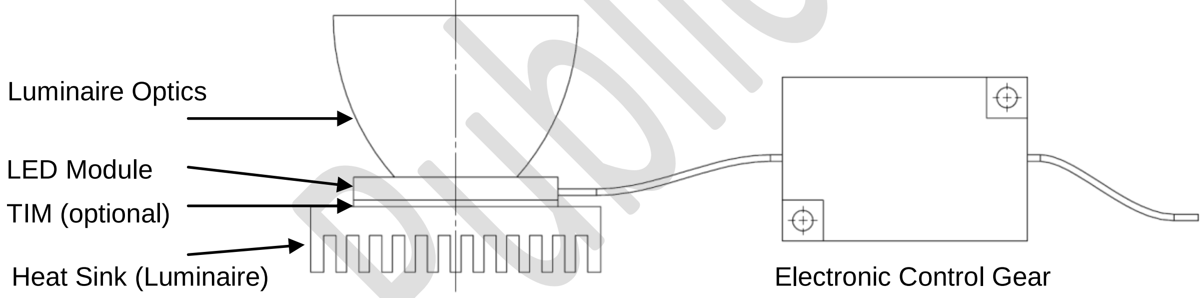

Figure 1: Schematic view of the assembly of LED Module, Luminaire with heat sink and Luminaire Optics, and Electronic Control Gear

Section 3 defines the mechanical interface. Section 4 defines the optical interface, which is characterized by the size and shape of the Light Emitting Surface of the Socketable LLE, the Luminous Flux, the luminous intensity distribution, color temperature, and the color rendering index (CRI). Section 5 defines the electrical interface to mains power.

Section 6 defines the thermal interface. This Book 3 of the Zhaga Interface Specification does neither limit the amount of heat that an LLE may generate, nor the amount of heat a Luminaire should drain away. However, does give a procedure for compatibility assessment to fit the thermal properties of the Luminaire to the heat load generated by the LLE.

[2] Definition of photometric interface has been done aiming at a maximum deviation in both FWHM and central beam intensity of Luminaires with (non specular) spot reflectors of +/- 12,5 % from sample average. Testing of the standard with reference parts has shown that these criteria could be met. However, it cannot be guaranteed for any combination of Luminaire Optics and LLEs. Please see also Annex D.

Section 7 defines the control interface in terms of generic functionalities. This Book 3 of the Zhaga Interface Specification does not require a specific method to implement a generic functionality. Instead, relevant information is to be made available from the Product Data Set. This Book 3 of the Zhaga Interface Specification does not require control functionality other than mains power on/off.

Annex A defines a set of compliance testing procedures for both LED Light Engines and Luminaires. Products have to pass these tests in order to obtain the Zhaga logo, as a sign of compatibility between LED Light Engines and a Luminaire, now and in the future. The tests defined in Annex A verify compliance with the provisions that are specific to Book 3 of the Zhaga Interface Specification only. Products may be subject to additional testing as well, e.g. to show compliance with (local) regulations. However, such additional testing is outside the scope of this document.

More information on compliance testing can be found in section 2.5 of [Book 1].

3 Mechanical Interface

3.1 General

The LED Module may consist of several parts, which have to be assembled by the OEM Luminaire manufacturer. The completely assembled LLE shall fulfill the requirements in this specification.

3.2 Drawing principles

The drawing principles defined in Section 3.1 of [Book 1] apply.

The Reference Plane is the backplane of the LED Module as provided by the LLE manufacturer (not including TIM material), the reference point is the point where the LED Module symmetry axis crosses the reference plane. Diameters are centered around the symmetry axis unless otherwise specified. Heights are specified relative to the reference plane unless otherwise specified. The positions of the reference entities are sketched in Figure 2. [3]

Mechanical tolerances in this book are standard molded plastics tolerances and originate from DIN 16901 group 140 set b.

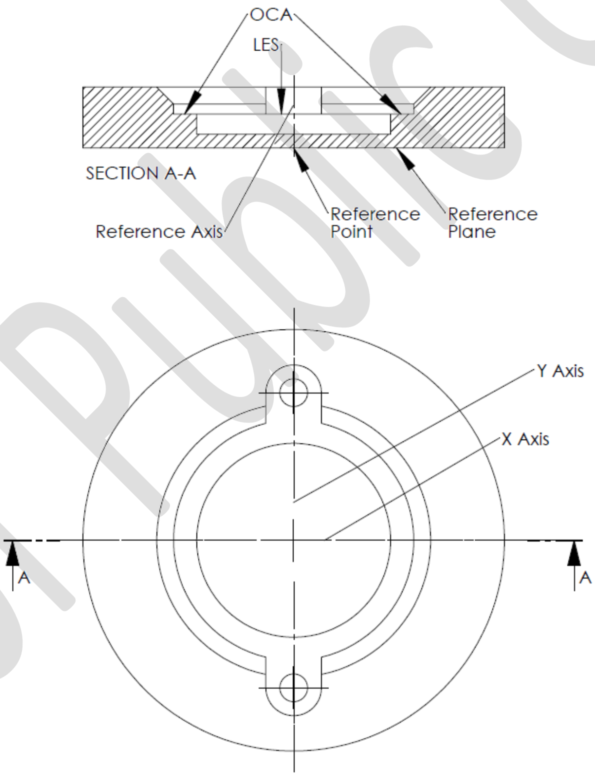

Figure 2: Positions of the reference point, plane and axis in a sketch of the LED Module.

[3] The Z Axis is identical with the "Reference Axis" throughout this document.

3.3 LED Module Outlines and common geometry

All Spot LED Modules specified in this document share the same outlines: They shall preferably be round with a diameter specified below. Note that the parameters given with only one-sided tolerance define the maximum module outlines, meaning that the LED Module may also be smaller if technically feasible. It is explicitly not required to even follow the shape indicated here as long as the maximum outlines are kept. Only the features relevant to interchangeability like the screw holes and their positions and the Optics Contact Area are specified with both-sided tolerances. The drawing is found in Figure 3. All parameters relevant for the common geometry are found in Table 1. [4,5] Further parameters indicated in this drawing (øc, d, ha) relate to the Optics Contact Area defined in section 3.6.[6]

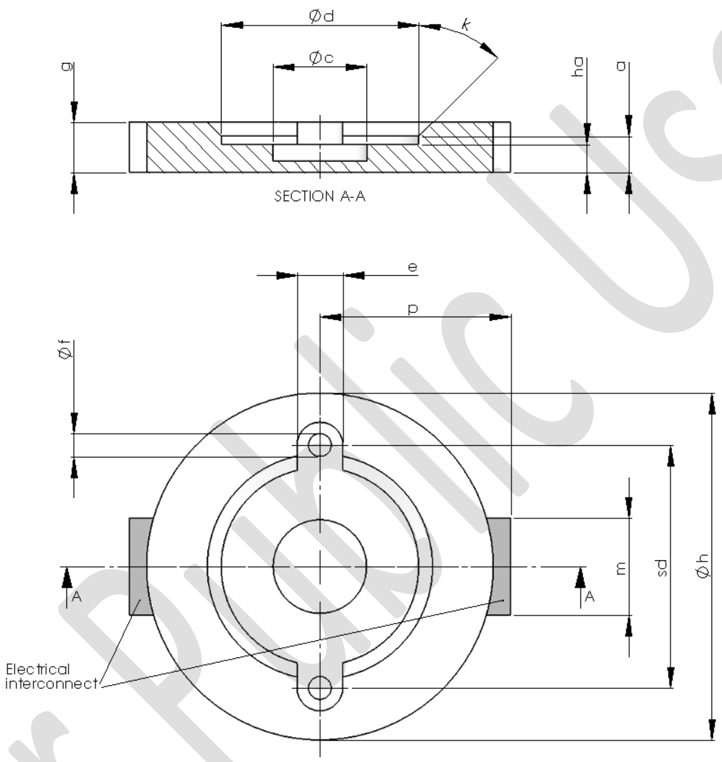

Figure 3: Drawing of mechanical dimensions of the LED Module

[4] Rounding of the edge at diameter d is assumed to be maximum 0,3 mm.
[5] All dimensions exclude TIM dimensions.
[6] In order to guarantee a minimum (external) reflector design freedom for luminaire makers, the parameters a and k have been defined in this standard. The height parameter a is thereby defined at diameter d, as shown in Figure 3. Consequently, the minimum reflector design freedom corresponds to the maximum value for parameter a in combination with minimum values for parameters d and k. Reflectors which require larger design freedom (e.g. larger starting angle) will not be compliant with this Zhaga standard as they potentially interfere with the module outer dimensions.

dimension	min	typ	max
a	NA	NA	5,2
e	6,4	6,6	NA
f	3,1	3,3	3,4
g	NA	NA	7,2
øh	49,75	50	50,25
sd	34,85	35	35,15
k	45°	NA	NA
m	NA	NA	15
p	NA	NA	27,5

Table 1: Mechanical dimensions of Spot LED Module

LED Modules including the electrical interconnect shall be within the dimension specified in Figure 3 and Table 1. LED Modules should be round with a diameter designated by the parameter h. Deviations from a perfect circle are allowed. However, at least 2 opposing points or at least 3 non-opposing points on the outer diameter shall be located on the diameter h.[7]

The stability of the LED Module should be sufficient to withstand screwing with M3 screws into a metric thread with a torque of 0,8 Nm. [8,9]

3.4 LED Module Connection

An electrical interconnect[10] should be placed symmetrically at the LED Module X axis (see Figure 2).

The interconnect should not exceed the maximum outline given in Figure 3. If a Plug is used it should have a width of maximum 14 mm and a length (in plugging direction) of maximum 8 mm.

Any wires exiting the module should be within the dimension m.

3.5 Luminaire keepouts for interconnect

The Luminaire should foresee space for a connection as specified in section 3.4.

Note: In addition to these connection keepouts, the thickness of connection wires needs to be taken into account.

3.6 Optics Contact Area

The LED Module shall have a physical surface of the housing denoted as Optics Contact Area (OCA)[11]. The position and dimensions of this OCA are specified in Figure 4, Table 2 and Table 3.

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[7] This is to ensure that Luminaire optics may be centered around the LED Module.
[8] It is expected that, to ensure proper thermal contact, a screwing torque of 0,4-0,6 Nm is necessary. The stability of the LED Module shall be chosen such, that this torque including tolerance can be sustained without damage to the LED Module.
[9] Although this specification is written in the metric system, the use of such LLEs is not limited to metric screws only. Also other screw sizes may be used provided they deliver similar mounting stability and pressure on the thermal interface.
[10] e.g. by means of a Receptacle / Plug system or a set of wires
[11] This is to ensure that a Luminaire Optics mounted at the Luminaire will fit without strain and with a maximum air gap of 0,5 mm when designed for an OCA height of 4 mm. The OCA needs to be a continuous surface. No notches or similar are allowed within this surface not to have light “escaping” through them.

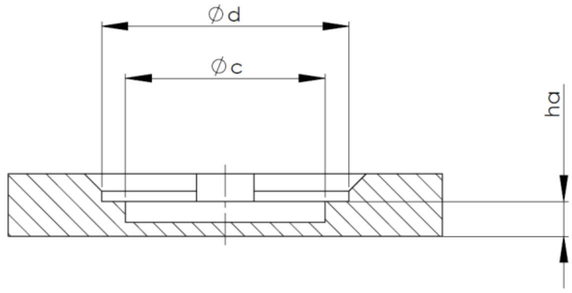

Figure 4: Dimensions of OCAs

dimension	min	typ	max
ød	28,4	28,5	NA
h_a	3,5	4	4

Table 2: Common dimensions of OCAs

There are 4 different variants of OCA dimensions, designated by the letters A, B, C, and D.

The dimension *øc* of the OCA shall be associated to the OCA designation as defined in Table 3.[12]

OCA category	*øc* min	*øc* typ	*øc* max
OCA A	NA	13,5	13,67
OCA B	NA	19	19,17
OCA C	NA	23	23,2
OCA D	NA	26	26,2

Table 3: *øc* dimensions and tolerances for different OCA categories

3.7 Inner Feature

Within the diameter *øc* defined in section 3.6, the LED Module may contain any kind of mechanical "inner feature" like light mixing elements, mechanical holding elements, electrical insulation elements, etc., provided they do not exceed the height b as defined in Table 4. In particular, the inner feature may contain an extension of the OCA or even an OCA of smaller size (e.g. an OCA C module may contain OCA B as an inner feature).

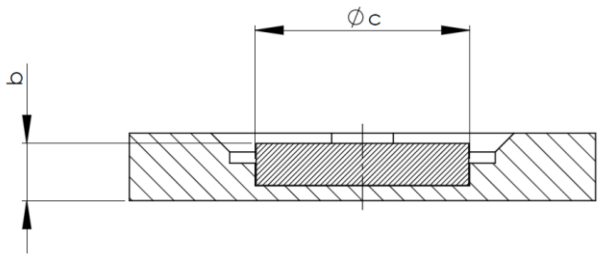

Figure 5: Maximum Inner Feature outlines (hatched area)

[12] From the definition it can be seen that OCA A includes B, C and D; OCA B includes C, D and OCA C includes D.

OCA category	*b* max
OCA A	5,0
OCA B	5,5
OCA C	6,4
OCA D	7,2

Table 4: maximum inner feature heights *b* for different OCA categories.

A dome or cover above one or more LEDs shall be allowed to exceed the height b max, if optical behaviour is not changed from a similar LES without dome or cover (See section 4.2). The maximum height of the dome or cover shall not exceed 20 mm (measured from the Reference Plane).

3.8 Optional "locking ring feature"

The LED Module may contain features described in this section in order to enable toolless mounting by means of a holder ("locking ring").

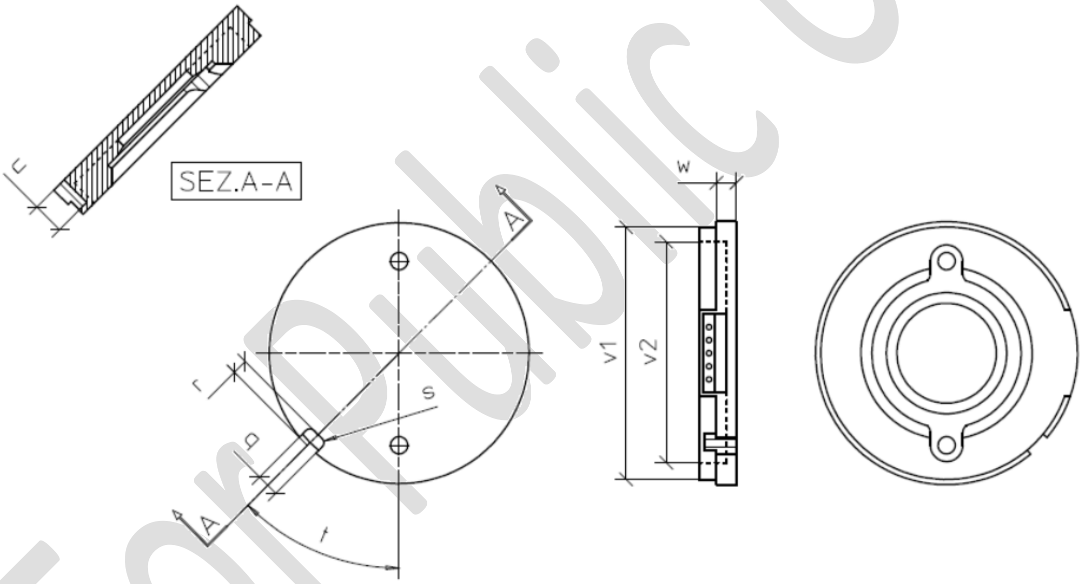

Figure 6: Drawing of optional features necessary for "locking ring"

	min	typ	max
q	4,3	4,4	4,5
r	2,8	2,9	3,0
s	NA	NA	1,1
t	NA	45°	NA
u	6,1	NA	NA
v1	48	NA	NA
v2	NA	NA	42
w	3,85	NA	NA

Table 5: Dimensions for "locking ring features"

Parameter q shall be maintained within tolerances from the module backside up to a height of 4 mm.

If the notch indicated in Figure 6 is used, the following features shall be used as well (to enable the notch as a “coding” for “locking ring suited”)

- Module height g between diameters v1 and v2 shall be 7,2 mm+0-0,45 mm at minimum 75% of the circle (equally balanced on the circumference).
- Module can withstand 50 N of force by the holder. It should be expected that the holder exerts at least 25 N of force to the LED Module.

3.9 Luminaire mechanical properties

The Module mounting surface of the Luminaire shall have a diameter of more than 50,5 mm, with means for screwing the LED Module (e.g. M3 threads or holes for self-cutting screws) at points corresponding to the LED Module geometry as defined in section 3.3.[13]

As the heat path is the most critical interface between LED Module and Luminaire, special demands apply to the Luminaire heat sink. Figure 7 shows a basic structure. The Module mounting surface of the Luminaire should be equivalent to or better than the defined features of the Test Fixture TUTF (flatness and material thickness, see section A.2.3.5).

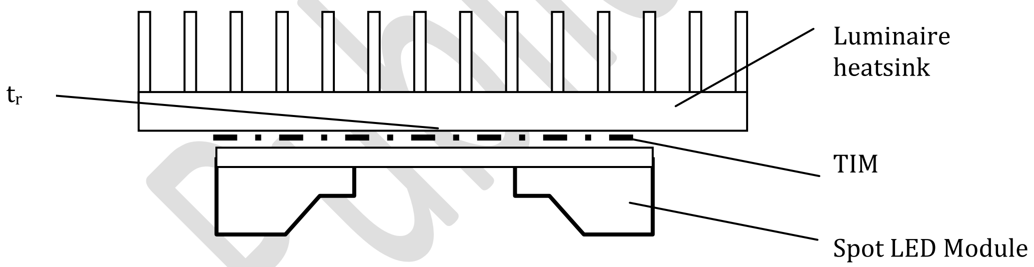

Figure 7: Basic structure of Luminaire heat sink part

3.10 Mechanical dimensions of ECG

The mechanical dimensions of the ECG shall comply with section 3.2. of [Book 1].

3.11 Luminaire ECG mounting surface

If the Luminaire contains mounting features for an ECG, at least one of the ECGs defined in section 3.2. of [Book 1] shall be accommodated. The Luminaire Product Data Set shall contain the information which ECG sizes are suitable as described in Annex B.2.

3.12 Optional “Locking Ring System” (LRS)

The Locking Ring System (LRS) is an optional accessory that enables toolless mounting of the module. In Figure 8, the concept of Locking Ring System is shown.

[13] The LLE mounting surface does not necessarily have a circular boundary. However, a circular area of minimum size shall be present and fulfill the requirements.

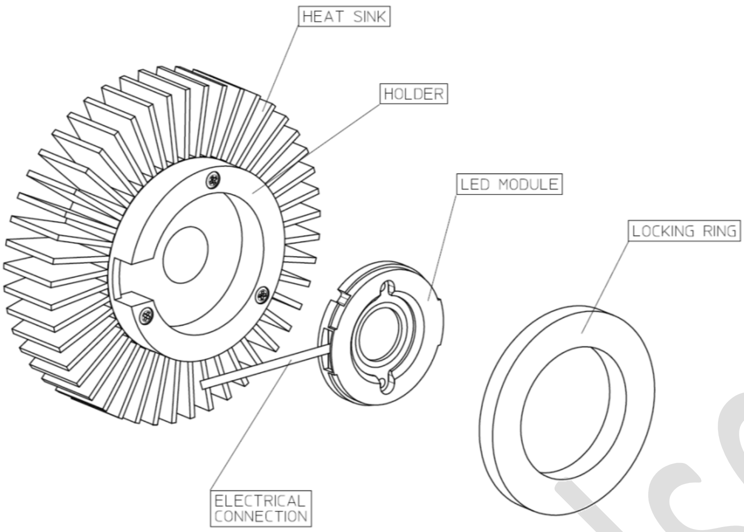

Figure 8: Example of Locking Ring System

To ensure the level of exchangeability aimed for Zhaga, the Locking Ring System ("Holder") shall comply with the following dimensions:

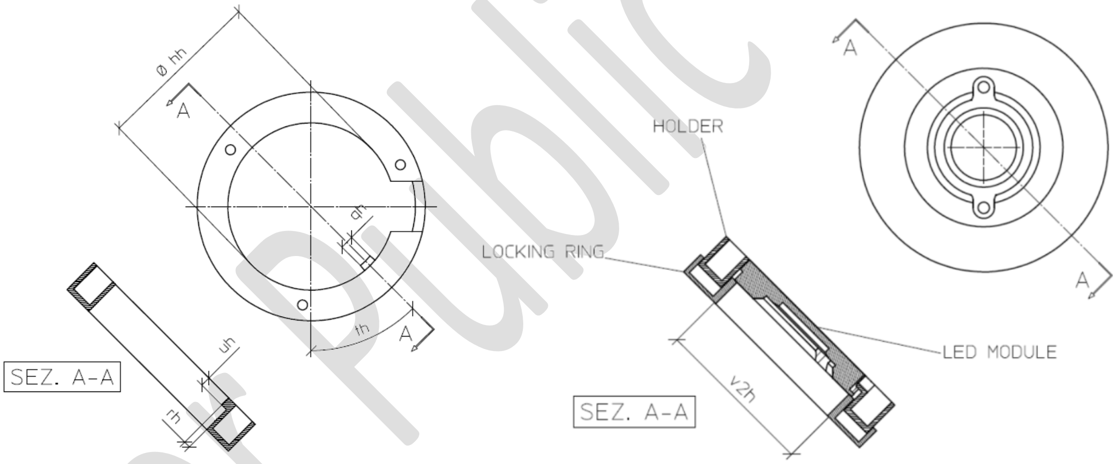

Figure 9a/b: Drawing of Locking Ring System

	min	typ	max
Ø hh	50,35	50,6	50,85
qh	3,95	4,1	4,3
rh	2,65	2,8	2,95
th	NA	45°	NA
uh	2	4	6
v2h	42	44	46

Table 6: Locking Ring System dimensions[14]

In case a Locking Ring System is used, the following requirements shall apply:

- A suitable Thermal Interface Material shall be used, preferably attached to the LED Module: It is recommended that the TIM material is easy removable when using the LRS.
- The holder shall provide a homogeneous pressure between 25 and 50 N to the rim of the LED Module
- The anti-rotation notch shall be used by a suitable pin in the holder to prevent rotation.
- The holder shall not influence or change the means of electrical connection between LED Module and ECG.

As the Locking Ring System is an optional accessory, Luminaire tests need to be conducted without the holder. This means that the holder needs to be removable. The Luminaire without the Locking Ring System shall comply with this specification.

[14] The maximum value of dimensions *qh* and *rh* is applicable only for rigid construction of the key, In case of “elastic” key, *qh,* max and *rh*, max could be higher.

4 Photometric Interface

4.1 General

The LED Module shall emit light of a Lambertian distribution in the direction of the module's reference axis. Associated to the specific light emission of the LED Module is a Light Emitting Surface characterized by its height and diameter. There are 4 different diameter categories specified here. Categories are also specified for Luminous Flux and Correlated Color Temperature.

4.2 Light Emitting Surface

The LES for spotlight applications shall be described by a 2-dimensional circle having the smallest possible diameter to fulfill the following principles. The LES shall be parallel to the reference surface defined in section 3.2. It has a physical boundary or is a virtual surface in the surrounding area of the LED Module.

The Light Engine manufacturer specifies the Rated diameter of the LES according to the following principles:

1. The horizontal position of the centre of the LES is the photometric centre of the light emission
2. When seen from above, all parts of the light emitting area (LED Chip, diffuse cover and / or mixing chamber) are covered by the LES.
3. Inside the circular shaped LES, the LEDs could be placed in a rectangular arrangement. The aspect ratio of this rectangle shall be >= 0,8 to produce almost rotational symmetric light distributions even with reflectors for small beam angles. Within any direction mechanical parts of the LEDs may exceed the diameter of the OCA as long as top surface of the OCA is not intersected and all light emitting parts are within the diameter c of the OCA. The area of the light emission shall be equal to the area of a circle with the diameter of the LES.
4. The position in height (*hp*) of the LES shall be chosen in that way, that all light emitting parts are behind the LES, when seen from top view and a substantial amount of the emitted Luminous Flux is expected to pass the LES.
5. A dome or cover above one or more LEDs shall be allowed to exceed the LES height *hp*, keeping the mechanical limits laid down in 3.7. This dome / cover should have mainly hemispherical shape.

Examples for defining LES diameters:

a) LES is located around the domed cover of a multichip, phosphor covered LED.

b) LES is located around the Silicone domes of single LEDs in the LED Module. The LES diameter is large enough to encircle all LED domes completely.

c) In case the LEDs are encircled by the nearly vertical walls of a light guiding, mixing or diffusing element, the LES should be described by the opening of this element.

d) In the case of a diffuse cover covering the LEDs, the LES shall be described by the functional area of the diffuse cover.

As a reference, a procedure for determination of the LES by means of a luminance measurement is given in annex A.3.2.4.

Regarding the LES, the following requirements apply:

The center of the LES shall not vary from the symmetry axis of the module by more than 1 mm in any direction.

The typical height *hp* of the LES shall be 4 mm. This height should be taken as a reference by the Luminaire manufacturer in designing Luminaire Optics. Maximum value of *hp* is the *b* value of the associated OCA as defined in Table 4.

LES diameters are categorized in four groups designated as LES 9, LES 13,5, LES 19, LES 23. Boundaries for these categories are found in Table 7.

	min LES diameter	max LES diameter
LES 9	6,3	9
LES 13,5	9	13,5
LES 19	13,5	19
LES 23	19	23

Table 7: Categorization of LES diameter

4.3 LES diameter vs. OCA

In order to guarantee mechanical interchangeability for LED Modules with the same LES diameter, the following relations shall be kept: (Please see also Footnote 12 in Section 3.6)

LES 9 shall have at least OCA A

LES 13,5 shall have at least OCA B

LES 19 shall have at least OCA C

LES 23 shall have at least OCA D

4.4 Operating conditions

For operating conditions for photometric tests see [Book 1], Section 4.2. In addition, the mounting position of a Spot LED Module is not considered to have a significant influence on the photometric properties and can thus be chosen arbitrarily.

4.5 Luminous Flux

The Luminous Flux of an LLE measured under the conditions specified in section 4.4 shall be in one of the categories listed in Table 8. For reporting the Luminous Flux on the Product Data Set of the LLE, the flux category name shall be used.

Flux category	Luminous Flux [lm]	
	Minimum	Maximum
C006	540	800
C008	720	1100
C011	990	1500
C015	1350	2000
C020	1800	2500
C025	2250	3000
C030	2700	4000
C040	3600	5000
C050	4500	NA

Table 8: Luminous Flux categories

4.6 Luminous intensity distribution

4.6.1 Measurement

The luminous intensity distribution of an LLE shall be measured under the conditions specified in section 4.4, with C-slices[15] every 15° and polar angles every 2,5°. C-Slices shall be given with respect to module x axis (see Figure 2).

4.6.2 Relative Partial Luminous Flux

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 determined from the measurement and rounded to full percent numbers. For each of these regions, the tolerances in Table 9 apply.

CIE cumulative flux zone	γ-angles (all C-planes)	min of relative partial Luminous Flux	max of relative partial Luminous Flux
FC1	0°- 41,4°	39%	56%
FC2 – FC1	41,4° - 60°	31%	37%
FC3 – FC2	60° - 75,5°	11%	22%
FC4 – FC3	75,5° - 90°	0%	7%

Table 9: Relative Partial Luminous Flux Tolerances

[15] For definition of "C-Slices" see [CIE 121].

4.6.3 Rotational Symmetry

The Luminous Intensity Distribution shall be substantially rotational symmetric.

The average Luminous Intensity curve (Luminous Intensity versus polar angle) is calculated as the average of Luminous Intensities in all C-slices for polar angles between -60° and 60°. For polar angles outside this range, the C-Slices between 60° and 120° shall be ignored for the average. [16, 17]

The deviation from the average curve has the limits shown in Table 10.

Polar Angle	C-slices (azimuth angle)	max. deviation from average curve
-60° to 60°	all	+/-20%
-75° to -62,5° and 62,5° to 75°	0° to 45° and 135° to 165°	+/-40%
-75° to -62,5° and 62,5° to 75°	60° to 120°	NA[19]

Table 10: Limits for Rotational Symmetry

4.7 Luminance properties

Luminance of the LLE should be symmetric with respect to the reference axis. The minimum symmetry requirements are defined as follows:

The LES category circle shall be divided into five segments A_i (i=1…5) as shown in Figure 10.

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 $S = \min(L_i)/\max(L_i)$. The value of S shall not be lower than 0.5. It shall be reported in the datasheet.

2. Luminance center balance

The average luminance L_i in forward direction in segment A_5 with respect to the average of the four segments $A_1 - A_4$ shall fulfill the criterion $L_5/\mathrm{average}(L_{1\text{-}4})<4$.

3. Luminance uniformity

The uniformity parameter U shall be stated in the datasheet. Details on how to determine U can be found in Annex A.3.2.[18, 19]

[16] This exception honors the observation that the screw cutout in the housing may have a significant influence on light output in these angles, which has no impact on performance with a reflector starting at the OCA.
[17] Please notice that for determination of Relative Partial Luminous Flux, all C-slices and polar angles shall be taken.
[18] For this requirement, not the LES category diameter but the actual LES diameter determined in 4.2 shall be used.
[19] Uniformity parameter U is only sensitive to brightness uniformity. Color uniformity in case of modules consisting of differently colored LEDs may introduce additional inhomogenities. This should be mentioned in the LLE datasheet. Further elaboration for U will be done for a later edition.

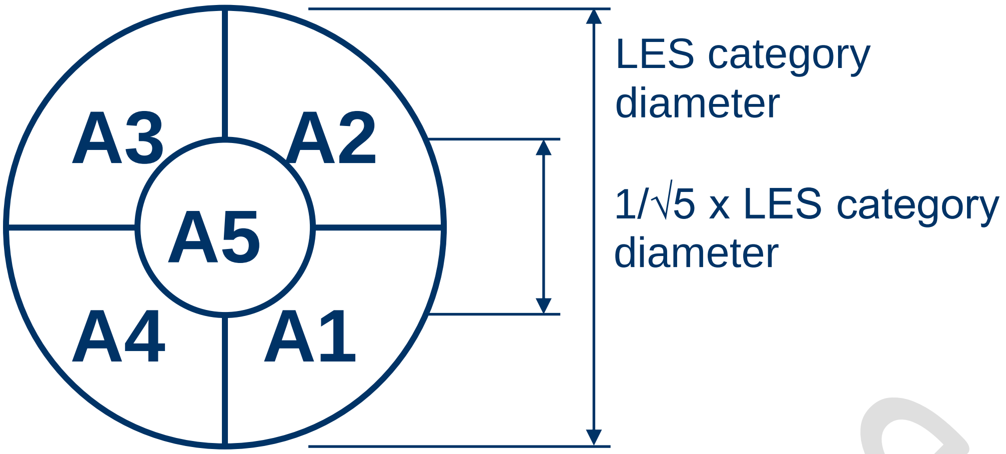

Figure 10: Luminance property evaluation areas

4.8 Correlated color temperature

For the purpose of this Section, [Book 1] Section 4.6 applies.

4.9 Color rendering index

For the purpose of this Section, [Book 1] Section 4.7 applies.

4.10 Luminaire Optics

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 4.3.

Note: (informative) Due to the compound nature of many LED Module 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 LED Module can give a hint on the degree of effort necessary to achieve properly distributed light with Luminaire Optics.

5 Electrical Interface

5.1 General

The spot LLE consists of one or more LED Modules and accompanying ECG. The ECG is intended to be driven primarily by mains power.

5.2 Mains input

5.2.1 Spot LLE mains power requirements

If a range of operating conditions is possible (e.g. 200V-277V for the ECG), the LLE manufacturer shall define a preferred operating point in the LLE documentation.

5.2.2 Insulation requirements for LLE

Reference is made to [Book 1] Section 5.1.

This specification does not require specific means of insulation for the LLE. Implemented electrical insulation according to applicable standard(s) shall be stated in the LLE datasheet.

6 Thermal Interface

6.1 Thermal Interface Model

For general information to the thermal interface models used in the Zhaga Interface Specification, please refer to chapter 6 in [Book 1].

Figure 11 illustrates the model for the thermal interface defined for an LED Module. During development of the specification, most spot reference modules consisted of LEDs mounted on a metal-core PCB, but this specification is not restricted solely to this setup. Typically it is assembled to a Luminaire by screws which realize a sufficient contact pressure on the bottom side of the LED Module towards the Luminaire heat sink. For improving the heat transfer via the Thermal Interface Surface, a Thermal Interface Material can be applied.

The LED Module generates an amount of heat, which is represented by the total thermal power $P_{th} = P_{th,rear} + P_{th,front}$. The major portion $P_{th,rear}$ is transferred via the Thermal Interface Surface by heat conduction. The $P_{th,front}$ portion is transferred by means of IR radiation and convection into direction of light and can heat up additionally the Luminaire´s environment. This portion is assumed to be minor.

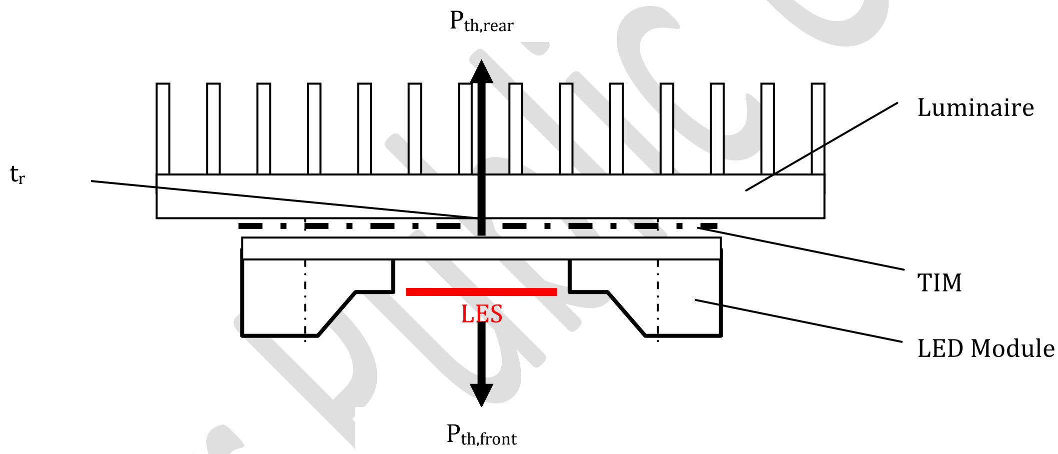

Figure 11: Thermal Model

The thermal power is mainly produced within the region of the Light Emitting Surface (LES) by LEDs. But also some additional electronics for controlling, steering and sensing the light output, which can be located around the Light Emitting Surface, contributes to the total thermal power P_{th}.

The thermal power from both the LEDs and the electronics is mainly conducted into the PCB where it is spread non-uniformly towards the thermal interface of the Luminaire. The amount of heatspreading done by the module can vary on the module construction. Low amount of module spreading will increase the requirements on luminaire heat spreading. The testing conditions and procedures in this Book 3 of the Zhaga Interface Specification have taken into account typical module constructions available at the time of development.

t_r is the reference temperature of the Thermal Interface Surface. t_r is measured at the luminaire side of the TIM, at the position that is closest to the reference point. A temperature $t_{r,max}$ is to be defined by the LLE manufacturer as the maximum temperature of t_r at which Rated LLE performance is specified.[20]

[20] $t_{r,max}$ is equivalent to the temperature $t_{p,max}$ in [IEC/PAS 62717], with the difference that here the position is specified to be at the mechanical reference point.

Then, t_r can be calculated according to $t_r = t_a + R_{th} \cdot P_{th,rear}$

where R_{th} is the thermal resistance a Luminaire offers to a Spot LED Module.

6.2 Luminaire Thermal requirements

The Luminaire shall contain heat sinking features that enable the heat generated by the LED Module to be conducted to the ambient. The Rated thermal resistance of the Luminaire shall be marked according to Annex B.2.

The Module mounting surface serves as thermal interface and should have a surface planarity smaller than 0,1 mm and a surface roughness smaller than 3,2 µm. It is recommended to use Aluminum alloy with a good thermal conductivity and a thickness of at least 2 mm.[21]

For Luminaires intended for use with multiple LED Modules and / or multiple LLEs, marking has to be done for every mounting position explicitly or with the highest value for the thermal resistance. The provisions in [Book 1], section 6.2.6 and subsections therein apply.

6.3 TIM Materials

In order to guarantee good thermal contact between the LLE and the heat sink, a Thermal Interface Material (TIM) is typically applied to this interface. The TIM is defined to be part of the LED Module and the Thermal Interface Surface is at the interface of the LLE and the TIM as depicted in Figure 12.

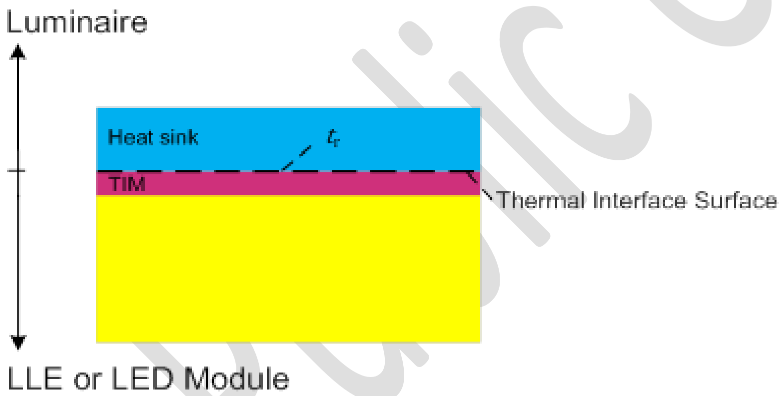

Figure 12: TIM assignment

- The LED Module manufacturer shall list in the Product Data Set the properties or type of TIM to be used with this LED Module[22]. The TIM may be already attached to the LED Module or delivered together with the LLE.
- The LLE shall be tested with the TIM prescribed by the LED Module manufacturer, and the manufacturer shall provide the prescribed TIM to the Zhaga authorized test center (ATC) when offering the LLE for Zhaga certification.
- The Luminaire shall be tested with a Thermal Test Engine using the “average performance TIM” as defined in Annex A.2.3.2.

6.4 Compatibility check

The thermal compatibility check including an example is described in section 6.2.7 of [Book 1]

Note: (Informative) In case of a closed Luminaire design, the maximum total thermal power P_{th} should be used instead of the maximum thermal power applied at the Thermal Interface Surface $P_{th,rear}$.

Note: (Informative) The thermal power generated by the ECG is not considered in this edition 1.2 of the specification. It has to be evaluated whether it needs to be considered with a safety margin.

[21] See also Annex A.4.4.2
[22] It is allowed that the Product Data Set holds the prescription to use no TIM.

6.5 Ambient temperature and thermal resistance (Rth).

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.

The thermal resistance of the Luminaire ($R_{th,lum}$) 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 ($R_{th,lum}$) depends on the application of the Luminaire. The Luminaire manufacturer defines in the PDS (generally in the mounting instructions) how the Luminaire shall be applied. Next to that, the Luminaire manufacturer defines 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.

7 Controls

For the purpose of this section, Chapter 7 of [Book 1] applies.

Annex A Compliance Testing (Normative)

A.1 General

All compliance tests shall be done by a Zhaga Authorized Testing Center (ATC) on new samples. Preconditioning (Burn-In) shall not be done.

In case of LLEs containing multiple LED Modules, tests shall be for each LED module separately.

In case of Luminaires intended for use with multiple LED Modules, mechanical tests shall be done for each LED module mounting position. Thermal tests shall be done according to the provisions given in [Book 1], Section 6.2.6, and subsections thereof.

A.2 Specific testing tools

A.2.1 Mechanical dimensions testing equipment

The mechanical dimensions may be tested with a hand gauge or (semi-)automated 3D measuring equipment. Measurement accuracy of better than +/- 0,05 mm shall be achieved. The tool for measuring the diameter of the LLE mounting surface in the Luminaire shall have an accuracy better than +/-0,25 mm.

A.2.2 Photometric testing equipment

- An integrating sphere-spectroradiometer system, 25 cm diameter minimum, 2Pi geometry. If 4Pi geometry is used, the sphere diameter should be at least 1m. This system shall be calibrated against spectral radiant flux standards traceable to an NMI.[23]
- A goniophotometer system with measurement distance of at least 0,5 m. This system shall be calibrated against illuminance or luminous intensity standards traceable to an NMI.[24]
- A system to measure luminance with sufficient resolution to measure at least 500 pixels over the actual LES area (Imaging luminance measurement device – ILMD). Measurement uncertainty for the luminance value shall be +/- 10% or less[25]

A.2.3 Thermal testing equipment

A.2.3.1 Thermocouples

All thermal tests shall be conducted with thermocouples as specified in [UL 1598] section 19.7 or in Annex K of [IEC 60598]. Measurement uncertainty shall be +/- 1°C or less. All thermocouples in Test Fixture TUTF-Spot shall have an uncertainty of no more than +/-0,5°C.

A.2.3.2 Thermal Interface Materials

All tests with Luminaires shall be conducted with an “average performance TIM”. For an “average performance TIM”, preferably silicone-based Keratherm 86/82 should be used. If not available, a comparable material with a thermal conductivity of 6,5 W/mK and thermal impedance of 35 Kmm^2/W (determined according to [ASTM D5470]) may be taken.

Tests with LLEs shall be conducted with the TIM specified or supplied by the LED Module manufacturer.

[23] *See [IES LM-79-08], section 9.1 and sub sections therein for additional information with respect to measurements with integrating sphere photometers. See also [CIE 84]. It is expected that uncertainty for Luminous Flux measurement is below +/- 5%*

[24] *See [IES LM-79-08], section 9.3 and sub sections therein for additional information with respect to measurements with goniophotometers. See also [CIE 121].*

[25] 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.

Please be aware that some TIMs are not suited for multiple use. Repeated tests should be done with a fresh TIM in this case.

When using a TIM foil, use of additional thermal grease is considered unnecessary.

A.2.3.3 Ambient Temperature determination

Ambient Temperature shall be measured by thermocouple at a draught-free location 20 cm away, at the same height as the device under test. A different location may be chosen if similar results are obtained there. Special care has to be taken if actively cooled devices are tested as they may produce airflow that can interfere with the Ambient Temperature measurement.

A.2.3.4 Test Fixture TPTF – Spot

Figure 13 illustrates Test Fixture TPTF - Spot schematically. The thickness of the heat flow elements shall be such that a 1-dimensional heat flow through the heat flux sensor is guaranteed.

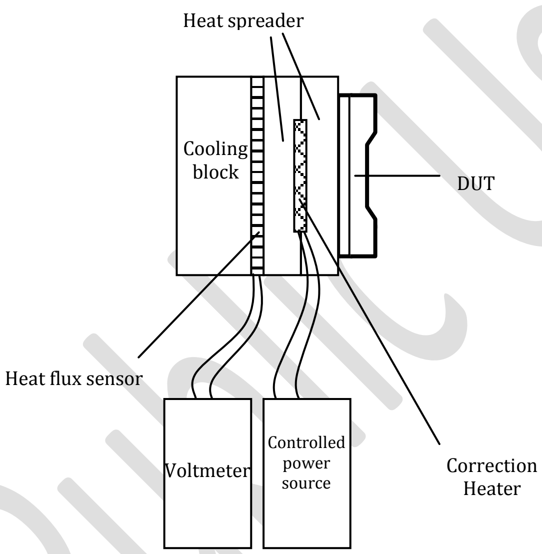

Figure 13: Test Fixture TPTF-Spot

A.2.3.5 Test Fixture TUTF – Spot

The thermal properties of the system LLE-Luminaire are strongly affected by the heat sink part directly beneath the Thermal Interface Surface. Thus, the Thermal Uniformity Test Fixture TUTF is designed to resemble a real Luminaire heat sink. Vice versa, the Luminaire counterpart should have equal or better properties than the Test Fixture.

The material shall be an Aluminum alloy with a thermal conductivity in the range 120-140 W/ mK.[26]

Thickness shall be 2 +/- 0,1 mm at the Module mounting surface of the Test Fixture. The surface shall have a surface planarity smaller than 0,1 mm and a surface roughness smaller than 3,2 µm.

At the center (t_r)[27] and at the 4 points t_{S1}…t_{S4} indicated in, thermocouples shall be placed and fixed with tight thermal contact at the end of the holes. The thermocouple wires may be placed in a slit at the backside that must be in the axial direction not to hinder heat flow. All thermocouples in Test Fixture TUTF-Spot shall be of type T with uncertainty +/-0,5°C.

[26] During Phase B testing, AlCu4PbMg (EN AW-2007) was used. Other suitable materials include AlCu4Mg1 (EN AW-2024) and AlMg3 (EN AW-5754).
[27] To facilitate testing, in TUTF-Spot t_r can be measured at the end of the hole. It has been checked that the difference between a measurement directly at the TIM and a measurement at the end of the hole is minimal.

Figure 14 shows the basic structure of the Test Fixture TUTF – Spot

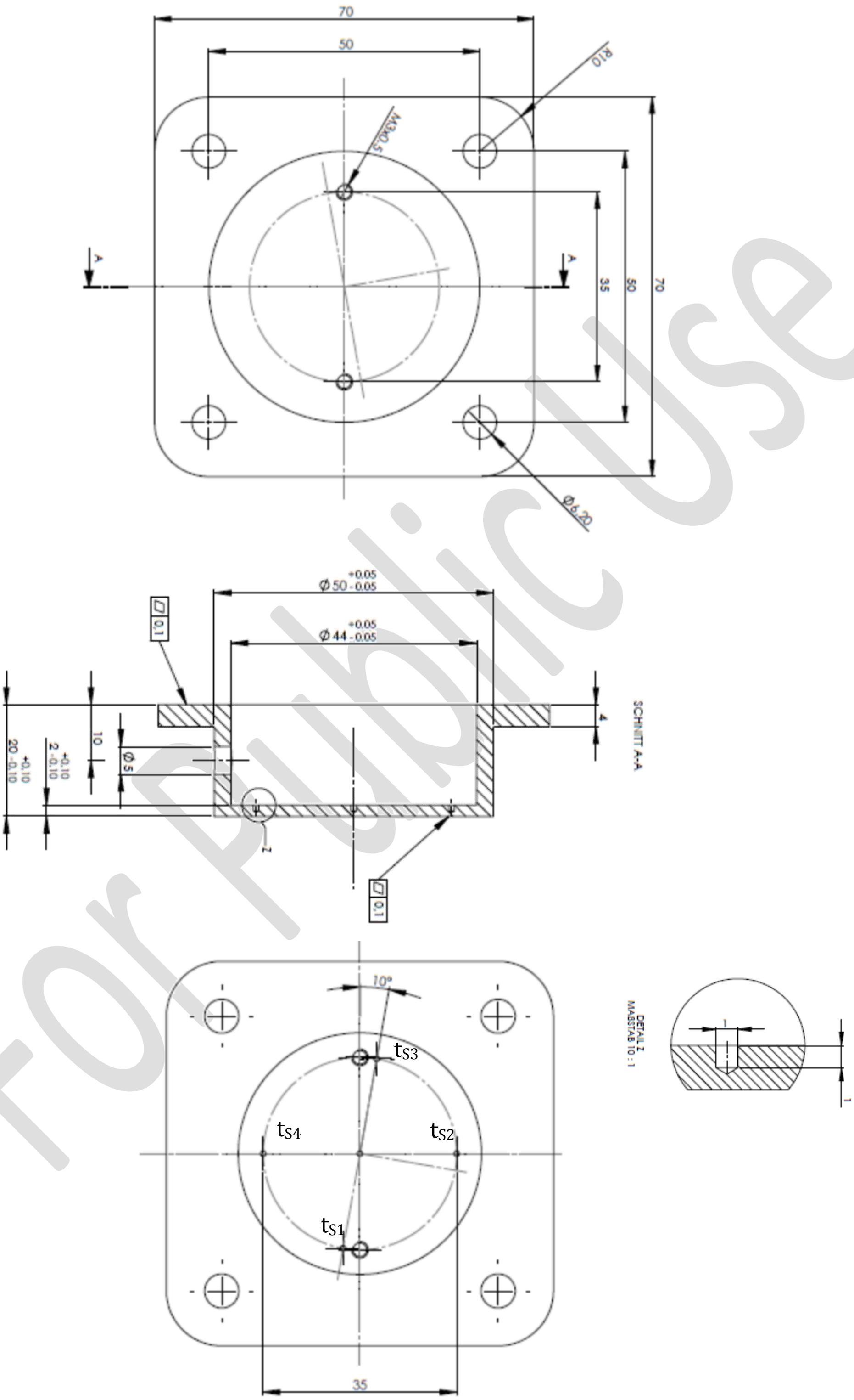

Figure 14: Test Fixture TUTF-Spot

A.2.3.6 Thermal Test Engine TTE – Spot

Thermal Test Engine TTE-Spot is shown schematically in Figure 15. A technical drawing of the Aluminium part is shown in Figure 16. As a heater, preferably Vishay LTO 100 should be used. If not available, another heater with sufficient power capability and heat transfer area of approximately 11,5 mm x 14 mm shall be used. The heater shall be in good thermal contact, for example by use of thermal grease.

The material shall be the same as for TUTF-Spot defined in Annex A.2.3.5.

TTE-Spot shall always be mounted with M3 screws, using a screw torque of 0,3 Nm

The thermocouple shall be placed at the end of the radial hole shown in Figure 16.

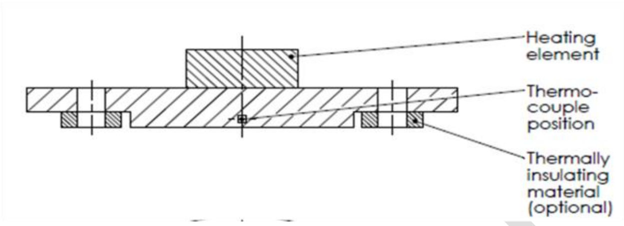

Figure 15: Thermal Test Engine TTE-Spot schematic

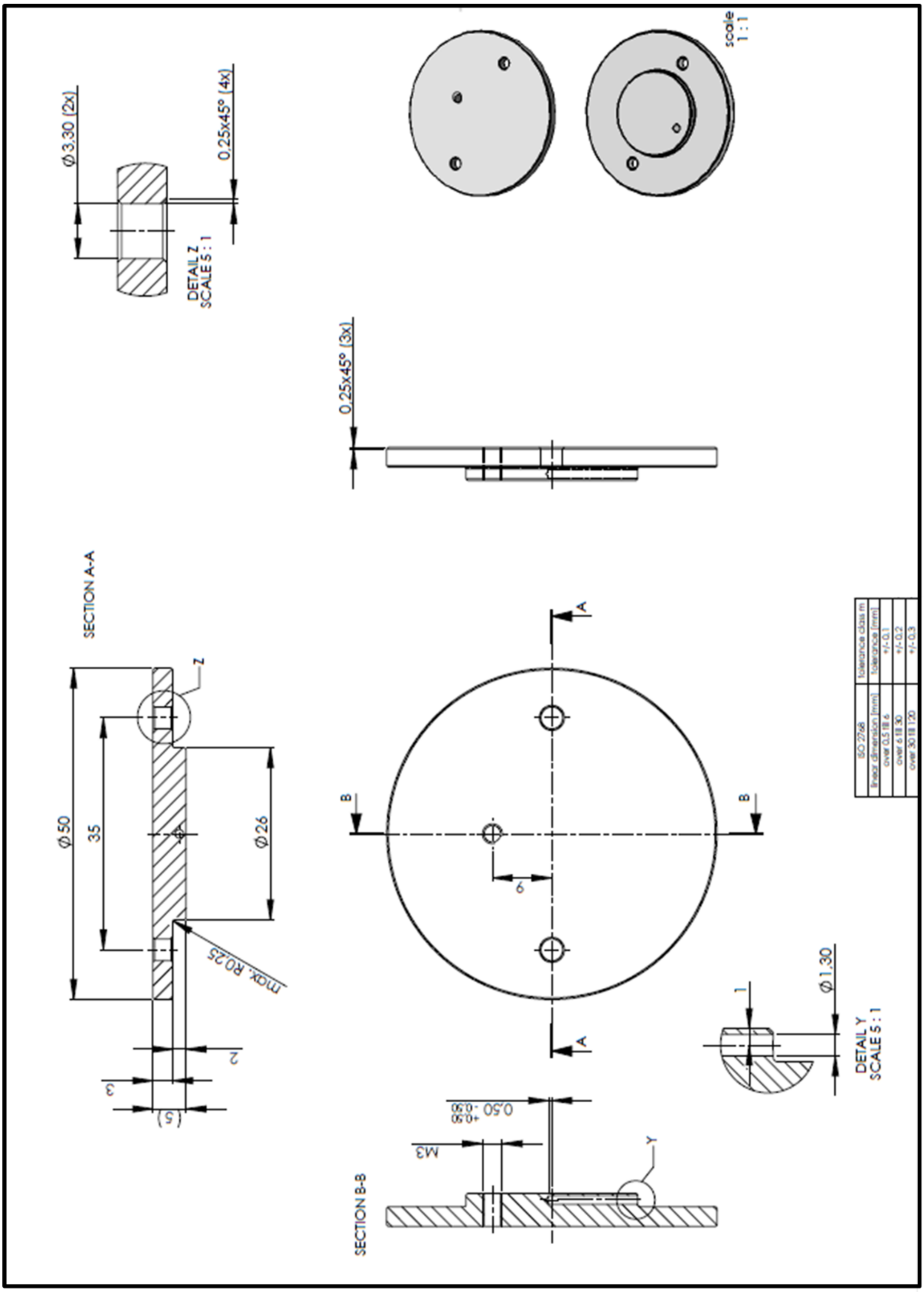

Figure 16: Thermal Test Engine TTE-Spot – technical drawing of the aluminum part

A.3 LLE tests

A.3.1 Mechanical interface tests

A.3.1.1 Tested parameters

It shall be verified that the maximum module outlines defined in section 3.3 are kept. Parameters f, sd and h as well as mandatory parameters[28] in sections 3.6 to 3.8 shall be verified explicitly to be within the borders specified. All these tests shall be done at room temperature. It shall be verified that the OCA dimensions fit to the Rated LES diameter according to section 4.3.

LES diameter shall also be measured mechanically as defined in section 4.2.

In case the LED module can be deformed during the mounting process, the test shall be conducted in mounted state. ECG outlines and screw hole positions as defined in [Book 1] shall be verified at room temperature.

If TIM is attached to the LED Module, an additional sample without TIM shall be submitted for testing or the TIM may be removed for mechanical tests based on manufacturer recommendations. No further tests shall be conducted on the sample as soon as the TIM is removed.

A.3.1.2 Test result

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

For the ECG screw hole distances (parameters denoted as B and D in Section 3 of [Book 1]), the following allowances apply[29]:

- In case the dimension is above 30 mm up to 120 mm: allowance +/- 0,3 mm
- In case the dimension is above 120 mm up to 400 mm: allowance +/- 0,5 mm
- In case the dimension is above 400 mm: allowance +/- 0,8 mm

A.3.2 Photometric interface tests

A.3.2.1 Test conditions

Testing conditions defined in section 4.4 apply for all photometric measurements. The ECG shall not influence the test results. This is expected to be the case if the ECG is positioned at a distance more than 25 cm to the side of the LED Module or test fixture. In case of a thermal shielding or a 4 Pi integrating sphere is used, the ECG shall be positioned outside the shielding or sphere.

If only relative values are to be determined (as for luminous intensity distribution (Goniometer) or luminance (ILMD)), t_r may be allowed to stabilize at any temperature (not necessarily next to $t_{r,max}$), unless any absolute values (like Luminous Flux) are to be measured in the same measurement.

A.3.2.2 Test procedure Integrating Sphere

- Mount the LED Module to a suitable heat sink. This may also be actively temperature-controlled. The LES shall be tightly connected to the opening of the integrating sphere by means of a suitable mechanical adapter. The ECG shall be mounted in due distance to the LED Module.
- Turn on the LLE
- Wait until the temperature at the t_r point is stable, as defined in section 4.4.

[28] As defined in section 1.4.1, mandatory requirements are introduced using the word "shall".
[29] These allowances originate from [DIN ISO 2768-1] – medium tolerances for linear measures. These are slightly larger than the corresponding tolerances for plastic moulded parts in [DIN 16910] to account for different housing materials.

- Perform the test as described in [IES LM-79-08], section 9.1.
- Data collected from this measurement are Luminous Flux, CCT, CRI, and Spectral Power Distribution ((λ)).
- From SPD(λ), calculate CCT according to [ANSI C78.377] and CRI simulating a color plate measurement according to [CIE 13.3]
- This test may also be done during the thermal measurement described in section A.3.3.1.2.1.

A.3.2.3 Test procedure Goniophotometer

- Mount the LED Module to a suitable heat sink on the goniophotometer, using a suitable TIM[30]. This may also be actively temperature-controlled. The LES shall be open and not obscured by any objects, cables etc.. The ECG shall be mounted in due distance to the LED Module.
- Turn on the LLE
- Wait until the temperature at the t_r point is stable, as defined in section 4.4. If no absolute Luminous Flux values are to be determined, the t_r temperature may differ from $t_{r,max}$.
- Perform the test as described in [IES LM-79-08], section 9.3 with C-slices every 15°, and Azimuth angles every 2,5°, using the LED Module x-axis as C-slice 0°.

A.3.2.4 Test procedure Luminance measurement

- 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 LED Module on a suitable heat sink. The ILMD shall measure the luminance directly looking at the LED Module along the symmetry axis. Ensure that the whole LED Module is in the field of vision of the ILMD.
- Choose the focus of the ILMD to be in the plane of the OCA, not on the LEDs.
- Turn on the LLE
- As only relative data is to be taken, it is not necessary to wait for thermal stabilization if the duration of the measurement is below 1 s. Otherwise, wait until the temperature at the t_p point is stable, as defined in section 4.4.
- Measure the luminance image of the LED Module. Trim the image in such a way that the LED Module is in the center of the image, and that it fills at least 80% of height and width of the image.
- .Determine the center of gravity of the luminance image. Use only pixels above background noise level for this determination. A typical threshold level is 10% of maximum intensity. Shift the center of the evaluation crosshair (Figure 10) such that both coincide.
- Evaluate the average luminances L_i in the areas A_i as defined in section 4.7. Note that the LES category diameter shall be taken for this evaluation. Rotate the crosshair by 90° in steps of 5°. For every step, evaluate the rotational symmetry parameter S as described in section 4.3. The maximum shall be taken as value for S.
- Determine the actual LES area as the minimum circle around the center of gravity of the luminance image that encircles all pixels with >10% of the maximum L_i (i=1..5).
- Evaluate the average luminance L_{ave} over the actual LES area.
- Calculate the RMS (root mean sq$_{uar}$e) of the luminances L_j of every pixel j inside the LES: $RMS = \sqrt{\sum L_j^{\ 2} / N}$ The number of pixels N shall not be less than 500. The uniformity parameter shall be calculated U = L_{avg} / RMS [31].

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[30] Please notice that the C-Plane with 0° is to be oriented along the Module X axis, which is perpendicular to the axis though the screw holes, see Figure 2 and section 4.6.

A.3.2.5 Test result

The LLE under test passes if all verified parameters are within the minimum and maximum limits defined / applicable to their Rated category.

Parameters to be verified include:

- LES diameter is within boundaries of the Rated LES category according to section 4.2
- OCA fits to LES category according to section 4.3.
- Measured Luminous Flux fits to Flux category according to section 4.5, allowing for variances of up to 5%.
- Partial Luminous Flux for Flux Zones FC1, (FC2-FC1), (FC3-FC2), (FC4-FC3) is within defined limits (section 4.6) Interpolation of goniophotometer data is allowed in this test.
- Rotational symmetry of Luminous Intensity fulfills criterion defined in 4.6.
- U deviates not more than +/-5 percentage points from rated Uniformity U (e.g. Rated 70% allows for a range 65%...75%)
- Luminance Rotational Symmetry shall comply with the limits given in section 4.7.
- Luminance Center Balance comply with the limits given in section 4.7.
- Correlated color temperature complies with the provisions of [ANSI C78.377], and both the measured correlated color temperature and Rated correlated color temperature are in the same quadrangle as defined in [ANSI C78.377], with these quadrangles being extended by 0.002 in each chromaticity direction.
- CRI is not more than 3 units below Rated CRI
- A measurement procedure for LES height hp will be defined in a later edition of this specification.

A.3.3 Thermal interface tests

A.3.3.1 Thermal Power Testing

A.3.3.1.1 Total thermal power

The purpose of this test is to verify the total thermal power P_{th}, which is produced within the Spot LED Module under test.

P_{th} can be determined by following equation: $P_{th} = P_{el,\,mod} - P_{vis}$

where

$P_{el,\,mod}$ is determined by measuring the electrical input power of the LED Module

and

P_{vis} is determined by measuring the spectral radiant flux. This can be done by evaluating the SPD(λ) measured during the photometric measurement in section A.3.2.2. Usually, evaluating a wavelength range between 380 and 780 nm is sufficient. If the LLE emits significant radiation outside this range, the range may be extended.

A.3.3.1.2 Thermal power through thermal Interface

The purpose of this test is to verify the thermal power $P_{th\,rear}$ that is produced within the Spot LED Module under test and directly transferred via the defined thermal interface to the Luminaire heat sink by heat

[31] For this requirement, not the LES category diameter but the Rated LES diameter acc. to 4.2 shall be used.

conduction. If the LLE manufacturer states identical values for $P_{th,rear,max}$ and $P_{th,max}$, this test may be omitted.

A.3.3.1.2.1 Thermal power test procedure

A.3.3.1.2.2 Required tools

- Test Fixture TPTF – Spot. It is recommended to shield the Test Fixture from air convection by a suitable isolation. It is also allowed but not mandatory to combine TPTF-Spot and the integrating sphere spectroradiometer specified in A.2.2 as shown in Figure 17.

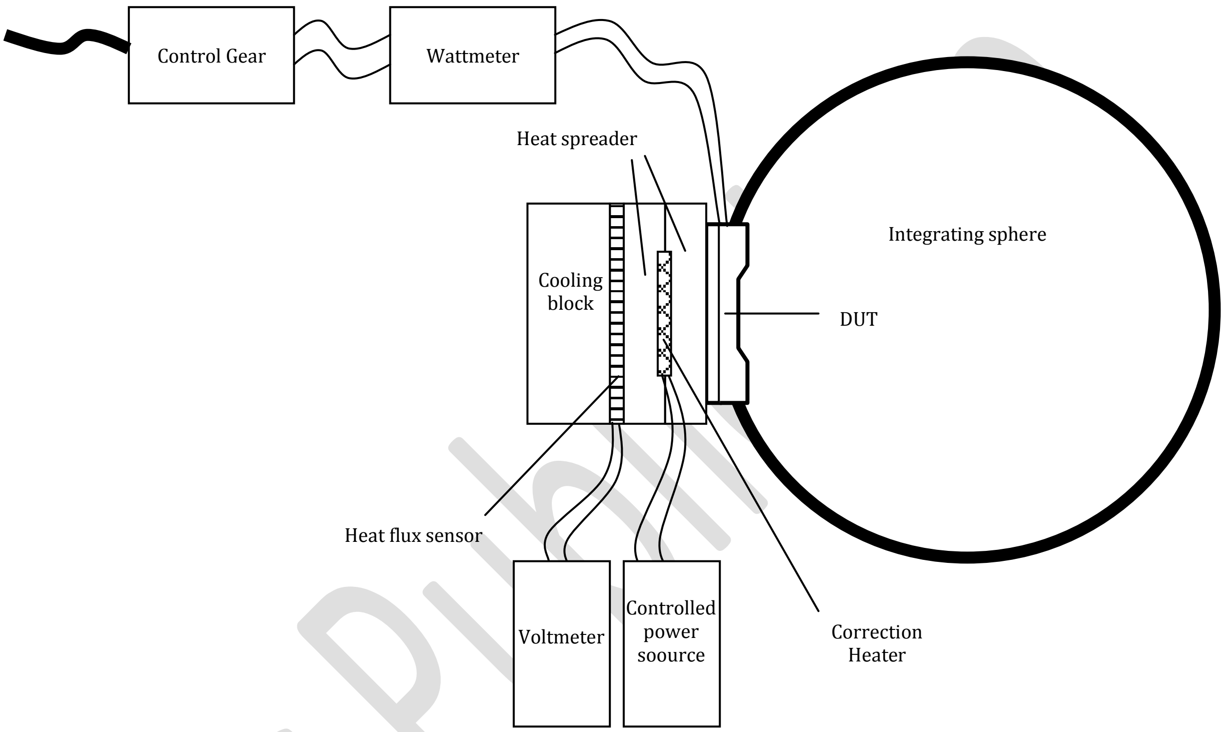

Figure 17: Test setup for combined power measurement

A.3.3.1.2.3 Test condition

For operating conditions for LLE thermal interface tests see [Book 1], Section A.1.3.2.2. A typical ambient temperature of 25°C is assumed.

A.3.3.1.2.4 Test procedure[32]

For the calibration of the $P_{th,rear}$ test setup see [Book 1], Section A.1.3.2.3. and use the following instructions in addition:

- To determine the cooling temperature ($t_{cooling}$), use $P_{th,rear,max}$ if given in LLE product data set, $P_{th,max}$ otherwise.
- Power settings for the correction heater are P_1=10W, P_2=20W, P_3=30W, P_4=40W, P_5=50W.

Measurement of the Spot LED Module

[32] This LLE test procedure is done in a temperature range which covers typical Luminaire ambient temperature of 25°C. If a Luminaire is to be operated at different ambient temperature, this LLE characterization stays valid, only Luminaire R_{th} will change.

For the measurement of the $P_{th,rear}$ see [Book 1], Section A.1.3.2.4. and use the following instructions in addition:

- Attach the Spot LED Module via its mounting features to the TPTF-Spot using an average Thermal Interface Material as defined in A.2.3.2.
- Assemble the structure to the integrating sphere. The optical output of the Spot LED Module shall not be affected in any way by objects.
- Connect a power meter in between the separated control gear and the Spot LED Module[33]
- Measure radiant flux (Φ_e) in an integrating sphere and calculate P_{vis} in [W]. This measurement may also be done in a separate setup under the same conditions.
- Measure electrical power $P_{el,mod}$ to the LED Light Engine.
- Determine $P_{th,\ rear}$ according to [Book 1], Equation A-3 in Section A.1.3.2.4.

$$P_{th} = P_{el,mod} - P_{vis}$$

$$P_{th,front} = P_{th} - P_{th,\ rear}$$

A.3.3.1.3 Test results

The Spot LED Module under test passes if the following conditions are fulfilled:

- The measured total thermal power $P_{th,}$ does not exceed the Rated maximum thermal power $P_{th,max}$ as given in the LLE Product Data Set (cf. Annex C) by more than 5%.

- The measured thermal power conducted through the thermal interface $P_{th,\ rear}$, does not exceed the Rated maximum thermal power values $P_{th,rear,max}$ as given in the LLE Product Data Set by more than 5%

A.3.3.2 Thermal uniformity test

A.3.3.2.1 Thermal uniformity test of Spot LED Module

The purpose of this test is to make sure that the LLE has sufficient internal means to spread the heat generated by the LEDs to be represented by the Thermal Test Engine TTE-Spot. In case differences are seen, a correction term is calculated as defined in this section.

A.3.3.2.2 Test procedure

- Attach Test Fixture TUTF – Spot to a cooling block
- Attach Spot LED Module under test to the TUTF – Spot with the standard Thermal Interface Material on the Thermal interface
- Increase cooling block temperature until t_r is within the interval [$t_{r,max}$-5°C, $t_{r,max}$]
- Measure t_r , as well as the temperatures t_{S1}-t_{S4}
- Calculate the spreading resistance R_{sp} = max [$(t_r - t_{Sx})$ / $P_{th,\ rear}$] using the $P_{th,rear}$ measured in A.3.3.1.2.4. In case $P_{th,,rear}$ test is omitted because $P_{th,max}$ is not specified by the manufacturer (see A.3.3.1.2), take P_{th} determined in A.3.3.1.1 instead.

A.3.3.2.3 Test results

R_{sp} is to be used for determination of $R_{th,max}$ in section A.3.3.2.4.

A.3.3.2.4 Verification of maximum allowed thermal resistance

The maximum allowed thermal resistance $R_{th,max}$ given in the datasheet shall be verified as follows:

- Calculate $R_{th,\ rear} = (t_{r,max}-t_a) / P_{th,rear}$. t_a shall be taken as 25°C[34].
- Calculate $R_{th,max}$ as follows:

$$R_{th,max}=R_{th,rear}-R_{sp}+0,3\ K/W$$ [35]

[33] The LLE manufacturer has to provide instructions to Test Labs on Request, which describe how to determine $P_{el,mod}$ with a given LLE. These might also include a special test ECG.
[34] In the calculation of $R_{th,\ rear}$, the values for $t_{r,max}$ and t_a shall be taken from the product data set. The values present during the test shall not be used for this calculation. $P_{th,\ rear}$ shall be taken from the result of the test described in A.3.3.1.

The LLE under test passes if the following condition is fulfilled:

$R_{th,max}$ is >90% of the Rated $R_{th,max}$ as given in the LLE Product Data Set.

A.3.4 ECG tests

In this edition 1.3 of the Zhaga Spot LLE specification, no electrical tests of the ECG are required. The mechanical outlines defined in [Book 1] shall be checked with the allowance defined there.

A.4 Luminaire Compliance tests (Normative)

A.4.1 General

All tests defined in this section A.4 shall be performed on 1 specimen of a Luminaire. In case the Luminaire is intended to be used with more than one LLE/LED Module, the appropriate number of Thermal Test Engines TTE-Spot is to be used for the thermal interface tests.

A.4.2 Mechanical interface tests

A.4.2.1 Tested parameters

All mechanical dimensions specified in section 3.9 and section 3.11 shall be verified at room temperature.

A.4.2.2 Test result

The Luminaire under test passes if the verified dimensions are within the minimum and maximum limits defined.

A.4.3 Electrical interface tests

The electrical interface of a Luminaire is identical to the electrical interface of the LLE. Thus, no electrical interface tests are to be performed.

A.4.4 Thermal interface tests

A.4.4.1 Thermal Resistance of Luminaire heatsink

The purpose of this test is to verify the Rated thermal resistance(s) R_{th} of the Luminare under test in the test conditions specified by the manufacturer.

A.4.4.1.1 Required tools

- Thermal Test Engine TTE – Spot.
- Test setup as specified by the manufacturer

A.4.4.1.2 Test conditions

The Luminaire shall be mounted in the test setup as specified by the manufacturer. The assembly shall be installed in a draught free room.

The Ambient Temperature shall be 25 +/- 1°C, unless indicated otherwise in the product data sheet. If it can that be shown that results are equivalent, also different Ambient Temperatures in the range 20-30°C may be used.

Multiple LED Modules have all to be replaced by TTE-Spot. All of these shall be operated at powers intended to be used, even if only one position is to be tested at once.

[35] This is the $R_{th,sp}$ of TTE-Spot, to be confirmed by further, independent measurements

A.4.4.1.3 Test procedure

- Assemble the Thermal Test Engine TTE – Spot into the Luminaire under test and apply a typical Thermal Interface Material on the Thermal Interface.
- Mount the Luminaire in test setup as specified by the manufacturer. Install the assembly in a draught free room.
- Configure the Thermal Test Engine TTE – Spot to generate 10W of electrical power
- Wait until the temperature t_r at the Thermal Interface Surface of the Thermal Test Engine TTE - Spot is stable. The temperature t_r shall be deemed stable if the difference between two consecutive temperature measurements, taken at least 15 min apart, is less than 0,5% of the absolute temperature rise
- Measure the temperature t_r.
- Determine the thermal resistance as

  $$R_{th(10W)} = (t_r - t_a) / P_{th},$$

  where P_{th} is the thermal power generated in Thermal Test Engine TTE – Spot (equal to electrical power).
- Repeat the procedure with the Thermal Test Engine TTE - Spot configured to consume 20W, 30W, 40W and 50Wof electrical power, yielding in $R_{th\ (20W)}$, $R_{th\ (30W)}$, $R_{th\ (40W)}$, $R_{th,\ (50W)}$. If the Luminaire is intended to a limited power range, parts of this test may be skipped and the limited power range needs to be marked in the datasheet.

A.4.4.1.4 Test result

The Luminaire under test passes if the the measured R_{th} does not exceed the Rated $R_{th,lum}$ by more than 10% for all stated power levels.

A.4.4.2 Thermal uniformity of Luminaire heatsink

A.4.4.2.1 General

If the thermal interface of the Luminaire is consisting of Aluminium alloy (thermal conductivity of 130 W/mK or better) of at least 2 mm thickness, this test may be skipped. If thickness is lower or a less thermally conductive material is chosen, the test shall be conducted.

The purpose of this test is to verify that thermal spreading of the Luminaire is sufficient.

A.4.4.2.2 Required tools

- Thermal Test Engine TTE – Spot

A.4.4.2.3 Test conditions

The Luminaire shall be mounted in a draught free room, with an orientation that is according to the "intended use" as indicated in the Product Data Set of the Luminaire under test. Multiple LED Modules shall all be replaced by TTE-Spot. All of these shall be operated at powers intended to be used, even if only one position is to be tested at once.

If an active cooling device is part of the Luminaire, it shall be powered by a suitable power supply during test. In case the cooler is regulated, it shall run at maximum cooling performance during the test.

A.4.4.2.4 Test procedure

- Place thermocouples in the Luminaire at the testing points t_{S1} to t_{S4} indicated in
- Figure 14. They also may be moved to a different position on the 35 mm diameter circle indicated in
- Figure 14.

- Assemble the Thermal Test Engine TTE – Spot into the Luminaire under test and apply a typical Thermal Interface Material on the Thermal Interface Surface.
- Configure the Thermal Test Engine TTE – Spot to generate 10W of electrical power
- Wait until the temperature t_r at the Thermal Interface Surface of the Thermal Test Engine TTE - Spot is stable. The temperature t_r shall be deemed stable if the difference between two consecutive temperature measurements, taken at least 15 min apart, is less than 0,5% of the absolute temperature rise
- Measure t_r, as well as the temperatures t_{S1}-t_{S4}
- Calculate the spreading resistance $R_{sp,lum} = \max [(t_r - t_{Sx}) / P_{th}]$
- Repeat the procedure with the Thermal Test Engine TTE - Spot configured to consume 20W, 30W, 40W and 50W of electrical power, yielding in $R_{th\ (20W)}$, $R_{th\ (30W)}$, $R_{th\ (40W)}$, $R_{th,\ (50W)}$. If the Luminaire is intended to a limited power range, parts of this test may be skipped and the limited power range needs to be marked in the datasheet.

A.4.4.2.5 Test result

The Luminaire under test passes if the measured $R_{sp,lum}$ does not exceed 0,4 K/W for all stated power levels.

Annex B Product Data Set requirements (Normative)

B.1 LLE

In addition to the marking requirements imposed by national or international standards, the following marking shall be done at the product or in the accompanying documentation:

For each LLE:

- The operating mains voltage and frequency.
- The ECG designation acc. to [Book 1] Chapter 3.
- Implemented electrical insulation according to applicable standard(s).

For each LED Module in case the LLE consists of more than one Module:

- The Luminous Flux category according to section 4.5.
- The Rated LES diameter as specified in section 4.2.
- The LES category according to section 4.2.
- The Luminance rotational symmetry S according to section 4.7.
- The Luminance uniformity parameter U according to section 4.7.
- The correlated color temperature according to section 4.8.
- The color rendering index according to section 4.9.
- The maximum total thermal power $P_{th,max}$ [W].
- The maximum thermal power applied at the Thermal Interface $P_{th,rear,max}$ [W]. The LLE manufacturer may choose to specify the value of $P_{th,max}$.
- The maximum allowable thermal resistance of the Luminaire $R_{th,max}$ [W/K]. The Ambient Temperature for which this maximum applies is 25 °C, unless explicitly indicated otherwise.[36]
- The temperature $t_{r,max}$.
- The Thermal Interface Material that should be used. In case several TIMs are suggested, one shall be indicated as preferred for testing purposes.
- If the LED Module is suited for use with the Locking Ring System: The statement "This LLE is suited for use with a Locking Ring System according to Book 3 of the Zhaga Interface Specification".

B.2 Luminaire

In addition to the marking requirements imposed by national or international standards, the following information shall be given in the Product Data Set:

- Number of LLEs / LED Modules if greater than 1.
- The intended operating conditions specifying Luminaire orientation and t_a.
- Description of test setup and test conditions for R_{th} testing. This may be a known standardized setup or a setup specific to the luminaire manufacturer and intended use.
- The Rated values of the Luminaire thermal resistance R_{th} for all LLE power levels $P_{th,rear,max}$ it is suited for, at least in steps of 10 W. These shall be given for all LED Module mounting positions. The ambient temperature for which these thermal resistances apply should be 25° C, unless explicitly indicated otherwise.

[36] $R_{th,mod,max}$ for different ambient temperatures t_a can be calculated by the formula $R_{th,mod,max}=(t_{r,max}-t_a)/P_{th,rear})$.

- As it is expected that the Luminaire is only suited up to a maximum LLE power $P_{th,rear,max}$, this maximum shall be stated in the datasheet.
- Maximum outlines of ECG.
- ECG designation(s) acc. to [Book 1] Chapter 3 that can be mounted into the Luminaire.

B.3 Designation scheme

The LLE and probably also the Luminaire will be classified and marked with a designation. The designation scheme will be worked out and laid down in [Book 1] of the Zhaga System Description. As soon as this part is implemented in [Book 1], marking shall be done according to the rules laid down there.

Annex C Safety Requirements (Informative)

C.1 General

This Specification of a Spot LED Light Engine with Separate Electronic Control Gear shall ensure exchangeability of LED Light Engines. Safety issues are not assessed nor checked in the certification procedure. LLE and Luminaire manufacturers are responsible for safety of their products.

C.2 LED Module

Safety provisions with respect to a LED Module comprise – amongst others – [IEC 62031]

C.3 Electronic Control Gear

Safety provisions with respect to an ECG comprise – amongst others – [IEC 61347-1] and [IEC 61347-2-13]

C.4 Luminaire requirements

Safety provisions with respect to a Luminaire/LLE comprise – amongst others – [IEC 60598]

Annex D Remarks (Informative)

D.1 Photometric interchangeability

The main objective of the Zhaga Interface Specification is to promote interchangeability of LED Light Engines while allowing maximum design freedom, especially regarding LED technology. The consequence of this is that the light emission cannot be defined in the very last detail, especially the luminance distribution over the Light Emitting Surface cannot be tightly toleranced.

The definitions in this book have been carefully balanced in order to make the best compromise between freedom in LED technology and a secure platform for Luminaire Optics design.

This compromise has been found using a set of test reflectors with target beam angles of 20 and 40°, using both specular and frosted surface. These reflectors have been optimized for LES 19. Parameters in this specification have been set such that variations in beam angle and center beam intensity are not larger than 12,5%. This has been verified with all available LES 19 LLEs during phase B testing.

However, it cannot be foreseen whether in a specific reflector design the 12,5% criterion will be met automatically. Specific optics design for interchangeability is recommended.

As LED technology evolves, there may be solutions that have not been foreseen during drafting this specification. They should be reviewed regularly by the Zhaga Workgroup and implemented to newer editions of this specification if they fulfill the 12,5% criterion.

D.2 Color effects

Current LED technology at the time of finalization of this specification comes in many technical realizations. Some of them show effects of color variation over the emission angle or / and also in the luminance distribution. Both effects have not been taken into account in this edition of the specification, as the effects can be managed by proper light mixing properties of the Luminaire Optics. However, it is always recommended to evaluate the performance of a Luminaire Optics using multi-color rayfiles and / or real samples of LLEs to ensure the intended performance is met in a specific combination of LLE and Luminaire Optics.