Zhaga

Zhaga Interface Specification

Book 2
Edition 1.3
June 2013

LED LIGHT ENGINE

TYPE A: SOCKETABLE WITH INTEGRATED CONTROL GEAR 70 MM × 45 MM

LES 57 MM MINIMUM ROUND

Zhaga Interface Specification Book 2

Summary (informative)

Background
The Zhaga Consortium is a worldwide organization that aims to standardize LED light engines.

The Zhaga Interface Specification consists of a series of books, which have been approved by the general assembly of the Zhaga Consortium. Each book defines a LED light engine by means of its mechanical, photometric, electrical, thermal, and control interfaces to a luminaire. This makes the LED light engines interchangeable in the sense that is easy to replace one LED light engine with another, even if they have been made by different manufacturers.

Each LED light engine belongs to one of the following categories:
Type A: socketable with integrated electronic control gear.
Type B: socketable with separate electronic control gear.
Type C: non-socketable with integrated electronic control gear.
Type D: non-socketable with separate electronic control gear.

Contents
This book 2 of the Zhaga Interface Specification defines a type A socketable LED light engine with integrated control gear. It has a round drum shape with maximum dimensions of 70.2 mm diameter and 45 mm height. It has a light emitting surface dimension of (typically) 59 mm diameter round and a PHJ65d type base.

This book must be read together with book 1 of the Zhaga Interface Specification.

Intended Use
The light engine can be locked into a luminaire by means of a twisting motion. Mechanical fit keying is present to ensure that the luminaire provides the correct mains voltage.

The light output is essentially lambertian, which enables the luminaire optics to shape the light distribution to the needs of the application.

The light engine is primarily intended for use in LED downlighting luminaires.

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

Zhaga Interface Specification

Book 2: LED Light Engine Type A:

socketable with integrated control gear

70 mm × 45 mm

Edition 1.3

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DISCLAIMER

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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.

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

This Book 2, LED Light Engine Type A: socketable with integrated control gear 70 mm × 45 mm, of the Zhaga Interface Specification defines the interfaces for LED Light Engines with integrated Electronic Control Gear that have a typical diameter of 70 mm, a typical height of 45 mm, and a PHJ65d type Base.

1.3 Main features

A Socketable LED Light Engine, which can be locked into a Luminaire by means of a twisting motion. This document defines:

- A Socketable LED Light Engine with integrated Electronic Control Gear, which is operated on mains power.
- Variants of the Socketable LED Light Engine, which use mechanical fit Keying to ensure that operation is possible at the Rated mains voltage only.
- An appropriate environment inside the Luminaire for the Socketable LED Light Engine to operate correctly.

1.4 Conformance and references

1.4.1 Conformance

All provisions in the Zhaga Interface Specification are mandatory, unless specifically indicated as recommended or optional or informative. Verbal expression of provisions in the Zhaga Interface Specification follow the rules provided in Annex H of ISO/IEC Directives, Part 2. For all clarity, the word "**shall**" indicates a requirement that is to be followed strictly in order to conform to the Zhaga Interface 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 References

The documents listed in this Section 1.4.2 provide information that supports or adds to the requirements and procedures provided in this Book 2 of the Zhaga Interface Specification.

[ANSI C78.377] American National Standard for electric lamps—Specifications for the Chromaticity of Solid State Lighting Products, ANSI NEMA ANSLG C78.377.

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

[CIE 121] The photometry and goniophotometry of luminaires, CIE 121.

[CIE 13.3] Method of measuring and specifying colour rendering properties of light sources, CIE 13.3.

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

[IEC 60061] Lamp caps and holders together with gauges for the control of interchangeability and safety—Part 4: Guidelines and general information, IEC 60061-4.

[IEC 60061-a] New cap (base)/holder fits; requirements for increased safety, IEC 60061-4 standard sheet 7007-4.

[IEC 60061-b] Creepage distances and clearances for caps on finished lamps, IEC 60061-4 standard sheet 7007-6.

[IEC 60061-c] Guidelines for the retention of caps in holders, IEC 60061-4 standard sheet 7007-8.

[IEC 60061-d] Designation of Lamp Caps and Holders, IEC 60061-4 standard sheet 7007-1.

[IEC 60598] Luminaires—Part 1: General requirements and tests, IEC 60598-1.

[IEC 60838] Miscellaneous lampholders—Part 1: General requirements and tests, IEC 60838-1.

[IEC 62031] LED modules for general lighting—Safety specifications, IEC 62031.

IEC/PAS 62717] LED modules for general lighting—Performance requirements, IEC/PAS 62717.

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

[ISO 128], [ISO 128-*x*] Technical Drawings—General principles of presentation—Part *x,* ISO 128-*x* (all parts).

[IES LM-79-08] IES Approved Method for the Electrical and Photometric Measurements of Solid-State Lighting Products, IES LM-79-08.

[NEMA SSL 7A] Phase Cut Dimming for Solid State Lighting: Basic Compatibility, NEMA SSL 7A-2013.

1.5 Definitions

For the purpose of this Book 2 of the Zhaga Interface Specification, the following definitions apply:

Base — The part of a Socketable LLE that fits in the Holder.

Electronic Control Gear — A unit that is located between the mains power supply and a LED Module to provide the LED Module with an appropriate voltage or current. It may consist of one or more separate components, and may include additional functionality, such as means for dimming, power factor correction, radio interference suppression, etcetera.

Holder — The part of a Luminaire that locks the Socketable LLE in a clear, stable, and functional position.

Keying — Differentiation—usually mechanical—to distinguish between options that are non-interchangeable (for example different mains voltage ranges). Keying is a safety feature.

LED Light Engine — A light source that combines one or more LED Modules and a single Electronic Control Gear. The LED Modules and Electronic Control Gear are not necessarily integrated into a single housing.

LED Module	A light source that is supplied as a single unit, but which cannot normally be operated without additional components, such as Electronic Control Gear, an enclosure, etcetera.
Light Emitting Surface	The surface of a LED Light Engine through which the light is emitted. The Light Emitting Surface may be a virtual surface (i.e. not a solid surface such as a cover).
Luminaire	A lighting fixture, which consists of one or more light sources, one or more reflectors, one or more apertures, an enclosure, a connection to a power source, optional Electronic Control Gear, and one or more optional Holders.
Mechanical Force Pin	An extrusion of the Socketable LLE, which has the purpose for a Holder to apply an axial force thereon, such that the Thermal Interface Surface is firmly pressed against the heat sink of the Luminaire.
Rated *<parameter>*	The value of the *<parameter>* as listed on the data sheet of the Socketable LLE, respectively Luminaire. Examples: the Rated voltage, the Rated frequency, etcetera.
Socketable LLE	A LED Light Engine that contains one or more LED Modules and the associated Electronic Control Gear in a single enclosure, and which can be inserted into or removed from a Holder by means of a twisting motion.
Test Fixture	A Luminaire that is used to define the optical or thermal properties of a Socketable LLE. This edition 1.3 of Book 2 of the Zhaga Interface Specification defines several Test Fixtures.
Thermal Interface Material	Substance at the Thermal Interface Surface, which has the purpose to improve the heat transfer from the Socketable LLE to the heat sink of the Luminaire.
Thermal Interface Surface	The surface of the Socketable LLE or Thermal Test Engine that makes physical contact with the surface of the heat sink of the Luminaire.
Thermal Test Engine	A device that is used to define the thermal properties of a Luminaire. This edition 1.3 of Book 2 of the Zhaga Interface Specification defines a single Thermal Engine.

1.6 Acronyms

AWG	American Wire Gauge
CCT	correlated color temperature
CIE	Commission Internationale de l'Eclairage
CRI	color rendering index
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
LED	light emitting diode
LLE	LED Light Engine
MFG	Mechanical Force Gauge
MTG	Mechanical Test Gauge
NA	not applicable
NMI	National Metrology Institute
OETF	optical/electrical Test Fixture
RMS	root mean square
TIM	Thermal Interface Material

TPTF	Thermal power Test Fixture
TTE	Thermal Test Engine
TUTF	thermal uniformity Test Fixture
UL	Underwriters Laboratories

1.7 Symbols

P_{el}	total effective electrical power consumed by the Socketable LLE [W]
P_{rad}	total optical power radiated by the Socketable LLE [W]
P_{th}	total thermal power generated in the Socketable LLE [W]
$P_{\mathrm{th,front}}$	thermal power flowing through the front side of the Socketable LLE [W]
$P_{\mathrm{th,rear}}$	thermal power flowing through the rear side of the Socketable LLE [W]
$R_{i,j}$	thermal spreading resistance between measurement points i and j [K/W]
$R_{\mathrm{sp}}^{\mathrm{max}}$	measured maximum spreading resistance [K/W]
$R_{\mathrm{th,rear}}$	thermal resistance from the Thermal Interface Surface to the environment [K/W]
r	distance for luminous intensity distribution measurement [m]
t_{a}	ambient temperature [°C]
t_{grad}	temperature difference between measurement points i and j [°C]
t_i	temperature at measurement point i [°C]
t_{r}	highest of the temperatures at the predefined measurement points [°C]
t_{r}'	temperature of the Thermal Test Engine close to the TIM [°C]
Δt_{TIM}	temperature drop over the TIM [°C]
γ_1, γ_2	polar angles (for defining the luminous intensity distribution)

1.8 Conventions

This Section 1.8 defines the notations and conventions used in the Zhaga Interface Specification.

1.8.1 Cross references

Unless indicated otherwise, cross references to Sections in either this document or documents listed in Section 1.4, refer to the referenced Section as well as the sub Sections contained therein.

1.8.2 Informative text

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

1.8.3 Terms in capitals

All terms that start with a capital are defined in Section 1.5.

1.8.4 Units of physical quantities

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

1.8.5 Decimal separator

The decimal separator is a comma.

2 System Overview (Informative)

The Zhaga Interface Specification consists of a series of books, which define the interfaces between various kinds of LED Light Engines (LLE) and the Luminaires in which these LED Light engines can be applied. A LED Light Engine is a light source that complies with the provisions in one or more of the books in the Zhaga Interface Specification. Typically, a LED Light Engine consists of one or more LED Modules, associated Electronic Control Gear, and additional mechanical and/or optical components, which may be distributed across several separate enclosures. In the context of the Zhaga Interface Specification, a Luminaire is a lighting fixture, which is designed to operate with a LED Light Engine. Interchangeability of a LED Light Engine and a Luminaire can be recognized from the Zhaga logo, which is applied to the product and/or its associated documentation.

This Book 2 of the Zhaga Interface Specification defines a Socketable LLE with integrated Electronic Control Gear. This is a particular kind of LED Light Engine, which contains both the light source—typically one or more LED Modules—and the necessary Electronic Control Gear in a single enclosure. A Socketable LLE can be easily inserted into and removed from a Luminaire, without requiring the use of a special or general-purpose tool.[1] In particular, the Socketable LLE defined in this Book 2 of the Zhaga Interface Specification can be locked into position by means of a twisting motion. For this purpose, this Book 2 of the Zhaga Interface Specification also defines a Holder, which is mounted inside the Luminaire to lock the Socketable LLE into a clear, stable, and functional position.

A Luminaire typically comprises a Holder to lock the Socketable LLE into position, a heat sink to carry away the heat generated in the Socketable LLE, a reflector to reshape the optical output of the Socketable LLE, means to supply electrical power to the Socketable LLE, and means to attach the Luminaire to a wall, ceiling, stand, etcetera.

Figure 2-1 below illustrates the arrangement of Socketable LLE, Holder, and Luminaire schematically. From this diagram, it is clear that there are several interfaces between these three components that affect interchangeability, namely:

- The mechanical interface, which defines the fit of the Socketable LLE in the Luminaire.
- The optical interface, which defines the light output characteristics from the Socketable LLE.
- The electrical interface, which define the mains power requirements of the Socketable LLE.
- The thermal interface, which defines the heat management between the Socketable LLE and the Luminaire.
- The control interface, which defines the functionality to adjust the light output characteristics from the Socketable LLE.

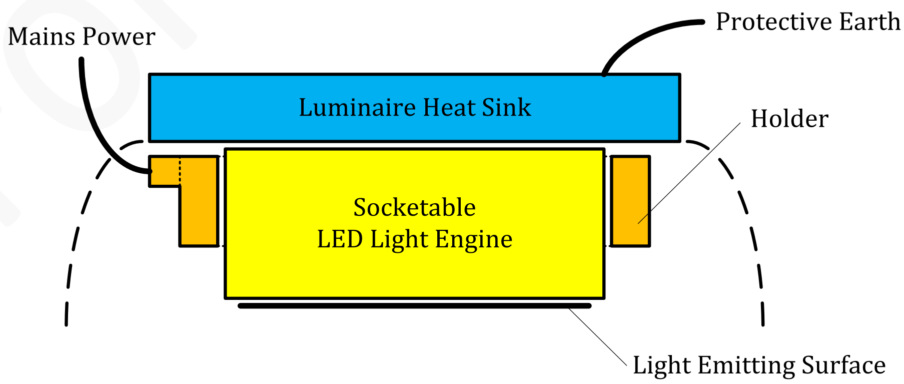

Figure 2-1: Schematic view of the assembly of a Socketable LLE, Holder and Luminaire

[1]However, note that depending on the industrial design of the Luminaire, it may be necessary to use a tool to open the Luminaire in order to reach the Socketable Led Light Engine.

Section 3 defines the mechanical interface. The enclosure of a Socketable LLE consists of a Base and a top construction. The Base is the part of the enclosure that locks in the Holder, and includes the electrical contacts and the mechanical fit Keying to distinguish between different mains voltages. Section 3 defines the maximum outline of the complete enclosure—including Base and top construction—as well as details of the Base (including three variants for high, low and universal mains power). In addition, Section 3 defines the Holder (including two variants for high and low mains power) that locks the Socketable LLE in the Luminaire.

Section 4 defines the photometric 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 4 defines a number of discrete ranges for the total luminous flux.

Section 5 defines the electrical interface. The mains power interface of the Socketable LLE includes the mains voltage ranges for different regions as well as safety features such as insulation and protective earth.

Section 6 defines the thermal interface. This edition 1.3 of Book 2 of the Zhaga Interface Specification does neither limit the amount of heat that a Socketable LLE may generate, nor the amount of heat a Luminaire should drain away.

Section 7 defines the control interface in terms of generic functionalities.[2] This edition 1.3 of Book 2 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's data sheet. This edition 1.3 of Book 2 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 guaranteed interchangeability between LED Light Engines, now and in the future. The tests defined in Annex A verify compliance with the provisions that are specific to Book 2 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.

[2]An example of such a generic functionality is "dimmable to 10% of the maximum light output."

3 Mechanical Interface

3.1 Drawing principles

All technical drawings that define the mechanical interfaces in Section 3 are made according to the principles defined in [ISO 128]. In general, the drawings use the first angle projection method defined in [ISO 128-30].

The minimum and maximum values provided in tables that accompany the drawings represent absolute limits, without any implied tolerance (neither positive, nor negative); typical values as well as values between parentheses are informative, unless indicated otherwise.

3.2 Socketable LLE

This Section 3.2 defines the mechanical properties of the Socketable LLE, which has a PHJ65d Base [IEC 60061-d]. Two mechanically non-interchangeable variants are defined for operation with different mains voltages. An additional variant is defined for operation with any mains voltage. (See Section 5.1 for the relation of the mechanical fit Keying and the mains voltage).

3.2.1 Maximum outline

Figure 3-1 and Table 3-1 define the maximum outline of the Socketable LLE, in the case that it is not locked into a Holder. The demarcation line divides the Socketable LLE into a Base and a top construction. The Base is defined in detail in Section 3.2.2. The top construction shall provide for a Light Emitting Surface that complies with the provisions of Section 4.1. Moreover, the extent of the top construction shall not exceed the volume defined by the diameter AA and the height BB above the demarcation line. (Informative) *Note that a Socketable LLE product does not need to have a clearly visible indication of the position of the demarcation line.*

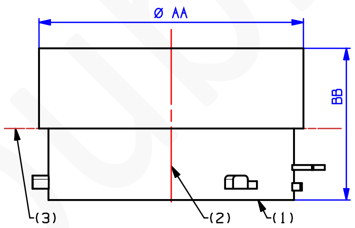

Figure 3-1: Maximum outline of the Socketable LLE

Notes to Figure 3-1:

(1) The reference plane corresponds to the Thermal Interface Surface. The Thermal Interface Surface shall consist of Thermal Interface Material (TIM), which may be compressible..

(2) The reference Z-axis is at the center of the diameter AA.

(3) Demarcation line between the Base and top construction of the Socketable LLE.

Table 3-1: Maximum outline of the Socketable LLE

Dimension	Minimum	Typical	Maximum	Notes
AA	NA	NA	70,20	
BB	(35,00)	NA	45,00	(4)

Notes to Table 3-1:

(4) The minimum value for the height BB is due to the position of the LES (see Section 4.1).

3.2.2 Common Base dimensions

Figure 3-2 and Table 3-2 define the common dimensions of the Base. The Base typically has a cylindrical shape, and contains the following features:

- Three Mechanical Force Pins, which a Holder shall use to apply an axial force—parallel to the reference Z-axis—to the Socketable LLE, in order to press the Thermal Interface Surface to the heat sink of the Luminaire (enabling proper thermal contact to be established).
- An electrical contact carrier, which contains both a line and a neutral contact on each side. See Figure 3-3 for details.
- A protection tab underneath the electrical contact carrier.
- Mechanical fit Keying features, which ensure that Socketable LLEs having different Rated mains voltages are not interchangeable. See Section 3.2.3 for the specific combinations of Keying features that may be present.

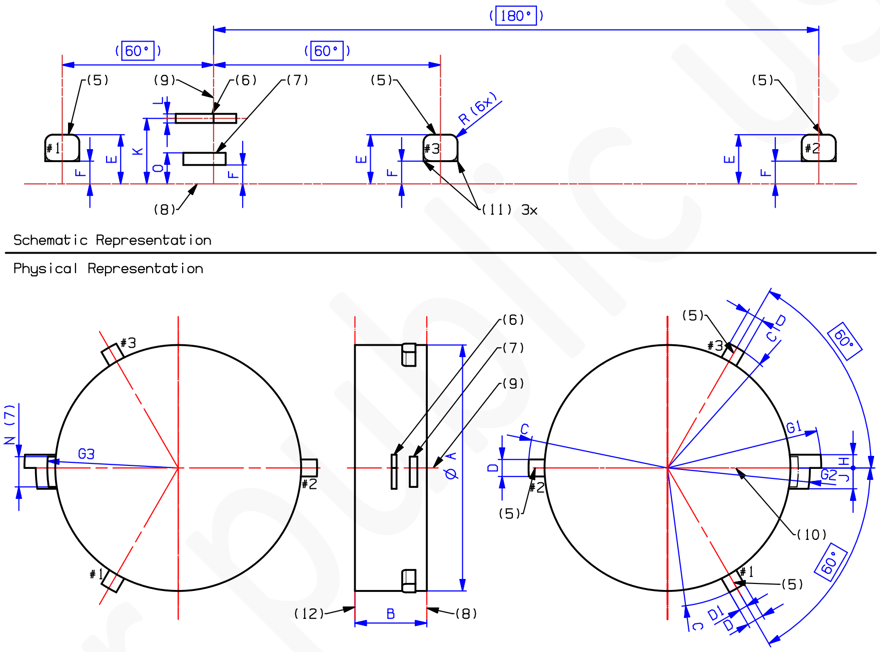

Figure 3-2: Dimensions of the Base

Notes to Figure 3-2:

(5) Mechanical Force Pins, numbered clockwise (top view; shown at the right-hand side of Figure 3-2) starting from the reference X-axis. (Informative) *In Section 3.3.2 it is required that a Holder uses mechanical force pin #1 to stop any twisting motion for locking the Socketable LLE. Dimension D1 fixes the stopping edge of this mechanical force pin relative to the reference X-axis.*

(6) Electrical contact carrier.

(7) Protection tab. See also note (18) to Table 3-2 below.

(8) The reference plane corresponds to the Thermal Interface Surface (see also note (1) to Figure 3-1 in Section 3.2.1).

(9) The reference Z-axis is at the center of the diameter A.

(10) The reference X-Axis corresponds to the central edge of the electrical contact carrier (see also Figure 3-3).

(11) The corners shall be slightly chamfered or rounded as with a dimension $R < 0{,}2$ mm, in accordance with [IEC 60061].

(12) Demarcation line between the Base and top construction of the Socketable LLE.

Table 3-2: Dimensions of the Base

Dimension	Minimum	Typical	Maximum	Notes
A	65,20	65,30	65,80	(13)
B	20,00	NA	(45,00)	(14)
C	36,30 (∅ 72,60)	36,65 (∅ 73,30)	37,00 (∅ 74,00)	
D	4,35	4,50	4,95	(15)
D1	2,18	2,25	2,33	
E	5,70	6,00	6,10	(14)
F	1,00	3,00	NA	(14), (16), (17)
G1	40,45	40,65	40,85	
G2	37,45	37,65	37,85	
G3	34,30	34,60	34,90	
H	3,35	3,50	3,65	
J	5,35	5,50	5,65	(18)
K	8,25	8,60	8,85	(14)
L	1,10	1,30	1,50	(19)
N	8,00	8,50	9,00	(18)
O	3,70	4,250	4,50	(14)
R	0,80	1,00	1,50	

Notes to Table 3-2:

(13) Exceptions to the minimum value of dimension A are permitted where necessary for (a) the construction of a Base that consists of multiple components (such as the electrical contact carrier, Mechanical Force Pins, and keying elements), and for (b) ease of insertion into a Holder.

(14) The minimum value shall not be violated due to any compression of the TIM. Moreover, the dimension E should not decrease by more than 0,2 mm (including any compression of the TIM), if a force of 20 N or less is applied parallel to the reference Z-axis in the direction of the Thermal Interface Surface, and at most 1 mm from the tip of the Mechanical Force Pin.

(15) This is the width of the mechanical force pin.

(16) Dimension F is provides pre-guidance during insertion of the Socketable LLE into the Holder, and should be the same for all Mechanical Force Pins as well as the protection tab.

(17) The minimum value of dimension R shall not be violated in the case of thin Mechanical Force Pins.

(18) The protection tab shall not extend beyond the electrical contact carrier in either direction.

(19) The thickness of the electrical contact carrier includes any additional electrical contact material. The conductive surface of the electrical contacts shall be elevated above any non-conducting surface of the electrical contact carrier.

Figure 3-3 and Table 3-3 define the electrical contacts of the Base.

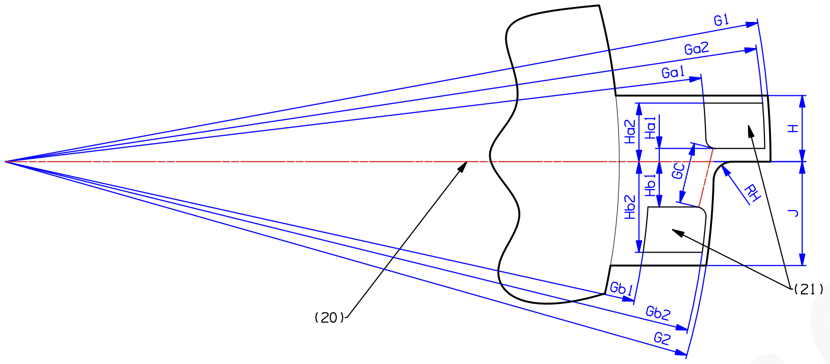

Figure 3-3: Base electrical contact definition

Notes to Figure 3-3:

(20) The reference X-Axis corresponds to the central edge of the electrical contact carrier.

(21) Electrical contact outlines. Within an electrical contact outline, the shortest distance from an arbitrary point to the nearest conductive part of the electrical contact surface shall be at most 0,2 mm. The conductive surface shall extend up to or beyond the boundary of the minimum electrical contact outline. Both sides of the contact carrier shall have electrical contacts of the same polarity within the defined electrical contact outlines.

Table 3-3: Base electrical contact definition

Dimension	Minimum	Typical	Maximum	Notes
G1	(40,45)	(40,65)	(40,85)	(22)
G2	(37,45)	(37,65)	(37,85)	(22)
Ga1	NA	NA	37,10	
Ga2	40,20	NA	NA	
Gb1	NA	NA	34,10	
Gb2	37,20	NA	NA	
GC	3,00	NA	NA	(23)
H	(3,35)	(3,50)	(3,65)	(22)
Ha1	NA	NA	0,70	(23)
Ha2	3,10	NA	NA	
Hb1	NA	NA	2,40	(23)
Hb2	4,80	NA	NA	
J	(5,35)	(5,50)	(5,65)	(22)
RH	NA	NA	0,90	

Notes to Table 3-3:

(22) See Table 3-2.

(23) Dimension GC defines the minimum distance between the electrical contacts.

3.2.3 Keying-specific dimensions

Figure 3-4 and Table 3-4 define the Keying for the mechanical fit of the Base. The Keying enables the design of Luminaires and Holders that ensure that a Socketable LLE can be operated at its Rated mains voltage only. The mechanical fit Keying features consist of the following set:

- A tab directly adjacent in the counter-clockwise direction (top view) to either Mechanical Force Pin #1 or Mechanical Force Pin #2.
- A tab at different positions in between Mechanical Force Pins #2 and #3.
- An L-shaped slot, which runs in the counter-clockwise direction (top view) from the reference plane at a position in between the electrical contact carrier and Mechanical Force Pin #3. (Informative) *The L-shaped slot is functional only during the axial insertion of the Socketable LLE into a Holder , and allows for additional Keying combinations to be made in future editions of Book 2 of the Zhaga Interface Specification.*

As shown in Figure 3-4, the mechanical fit Keying features shall be used in specific combinations only.

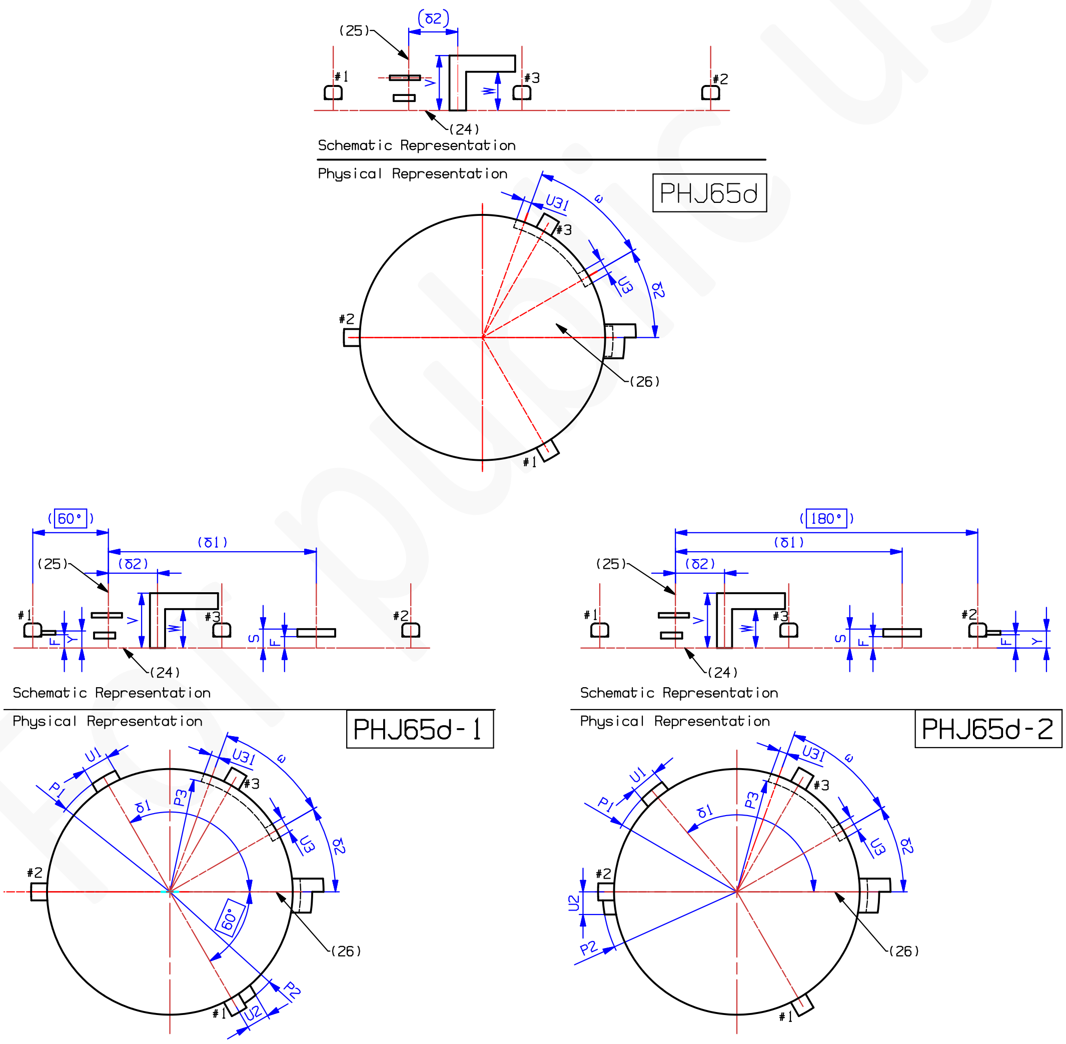

Figure 3-4: Base mechanical fit Keying definition (top view)

Notes to Figure 3-4:

(24) The reference plane corresponds to the Thermal Interface Surface (see also note (1) to Figure 3-1 in Section 3.2.1).

(25) The reference Z-axis is at the center of the reference plane.

(26) The reference X-Axis corresponds to the central edge of the electrical contact carrier.

Table 3-4: Base mechanical fit Keying definition

Dimension	Minimum	Typical	Maximum	Notes
F	(1,00)	(3,00)	(NA)	(27), (28)
P1	34,90	35,10	35,30	(29)
P2	34,80	35,10	37,00	(30)
P3	NA	NA	30,50	
S	4,30	5,00	5,50	(28)
U1	6,80	7,15	7,30	(29)
U2	5,70	6,10	6,50	(30)
U3	4,20	4,40	4,60	(31)
U31	2,10	2,20	2,30	(32)
V	14,15	14,55	NA	(28)
W	7,80	10,25	10,50	(28)
Y	3,80	5,00	5,35	(28)
$\delta 1$	NA	120°	NA	(33)
	NA	130°	NA	(34)
$\delta 2$	NA	30°	NA	
ω	25,50°	NA	NA	(35)

Notes to Table 3-4:

(27) See Table 3-2 in Section 3.2.2.

(28) The minimum value shall not be violated due to any compression of the TIM. See also note (14) to Table 3-2 in Section 3.2.2.

(29) Dimensions P1 and U1 define the maximum and minimum outline of the tab between Mechanical Force Pin #2 and #3.

(30) Dimensions P2 and U2 define the maximum and minimum outline of the tab directly adjacent to either Mechanical Force Pin#1 or #2.

(31) This is the width of the vertical part of the L-shaped slot.

(32) This is the position of the clockwise edge (top view) of the L-shaped slot relative to the angle $\delta 2$.

(33) Base PHJ65d-1.

(34) Base PHJ65d-2.

(35) The length of the L-shaped slot enables rotational motion between Base and Holder.

3.2.4 Mass

The mass of the Socketable LLE shall not exceed 0,2 kg.

3.3 Holder PHJ65d

This Section 3.3 defines the mechanical properties of a Holder for a Socketable LLE with a PHJ65d Base [IEC 60061-d]. Two mechanically non-interchangeable variants are defined for use with different mains voltages. (See Section 5.1 for the relation of the mechanical fit Keying and the mains voltage).

3.3.1 Maximum outline

Figure 3-5 and Table 3-5 define the maximum outline of the Holder (both with and without a Socketable LLE locked therein). Some of the details shown in Figure 3-5 apply to a PHJ65d-1 Holder only, see Section 3.3.3. The Holder shall be mounted on a heat sink of a Luminaire.

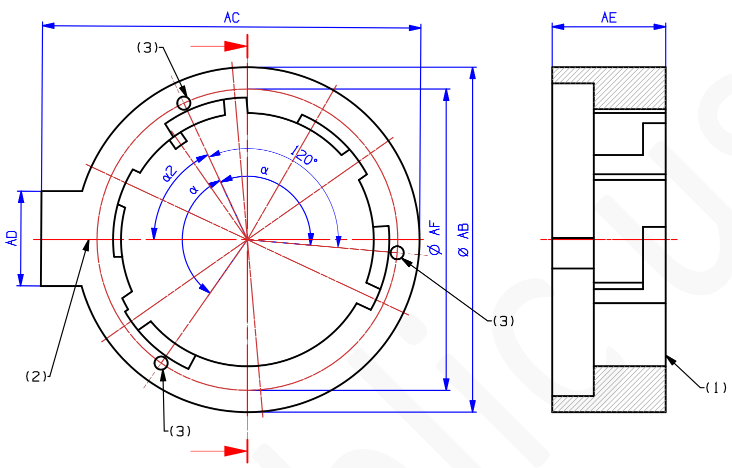

Figure 3-5: Maximum outline of a Holder (bottom view on the left)

Notes to Figure 3-5:

(1) The reference plane corresponds to the surface of the heat sink on which the Holder is mounted. Part or all of the Holder may be lifted if a Socketable LLE is locked into the Holder. In that case, the (lifted part of the) bottom of the Holder is not located at the reference plane any more.

(2) Reference X-Axis.

(3) Holes for attaching the Holder to a heat sink using M3 screws. It is recommended that the heat sink provides screw holes of at least 4,50 mm depth. Fixing screws that may be part of the Holder are allowed to extend beyond the maximum outline of the Holder.

Table 3-5: Maximum outline of a Holder

Dimension	Minimum	Typical	Maximum	Notes
AB	NA	95,00	96,00	
AC	NA	100,00	120,00	(4)
AD	NA	20,00	40,00	(4)
AE	NA	19,00	35,00	(4)
AF	79,20	79,50	79,70	(5)
α	NA	(120°)	NA	(5)
$\alpha 2$	50,00°	65,00°	75,00°	(5)

Notes to Table 3-5:

(4) The Holder shall provide mains wire connection terminals within the outline defined by dimensions AC, AD, and AE, as shown in Figure 3-5. Instead of a dedicated connection box, the section between the two mounting holes on either side of the electrical contact opening can be used for connecting means.

(5) Pitch circle of the holes for screwing the Holder down to a heat sink. The spacing of the holes is equidistant along the pitch circle, with the first hole located at an angle $\alpha 2$ from the reference X-axis in clockwise direction (bottom view).

3.3.2 Common Holder dimensions

Figure 3-6 and Table 3-6 define the common dimensions of the Holder. Some of the details in Figure 3-6 apply to a PHJ65d-1 Holder only, see Section 3.3.3. The Holder has a circular opening to receive the Socketable LLE, and contains the following features:

- Cut-outs for the Mechanical Force Pins and electrical contact carrier, such that the Socketable LLE can be inserted in a single orientation only.
- Guides for rotating the Socketable LLE to a stable and functional (locked) position, during which pressure between the Thermal Interface Surface and the heat sink gradually increases.
- Line and neutral contacts for the top side as well as the bottom side of the electrical contact carrier of a Socketable LLE that is locked into the Holder
- Mechanical fit Keying features, which ensure that the Holder can receive a Socketable LLE of the appropriate Rated mains voltage only. See Section 3.3.3 for the specific combination of Keying features that may be present.

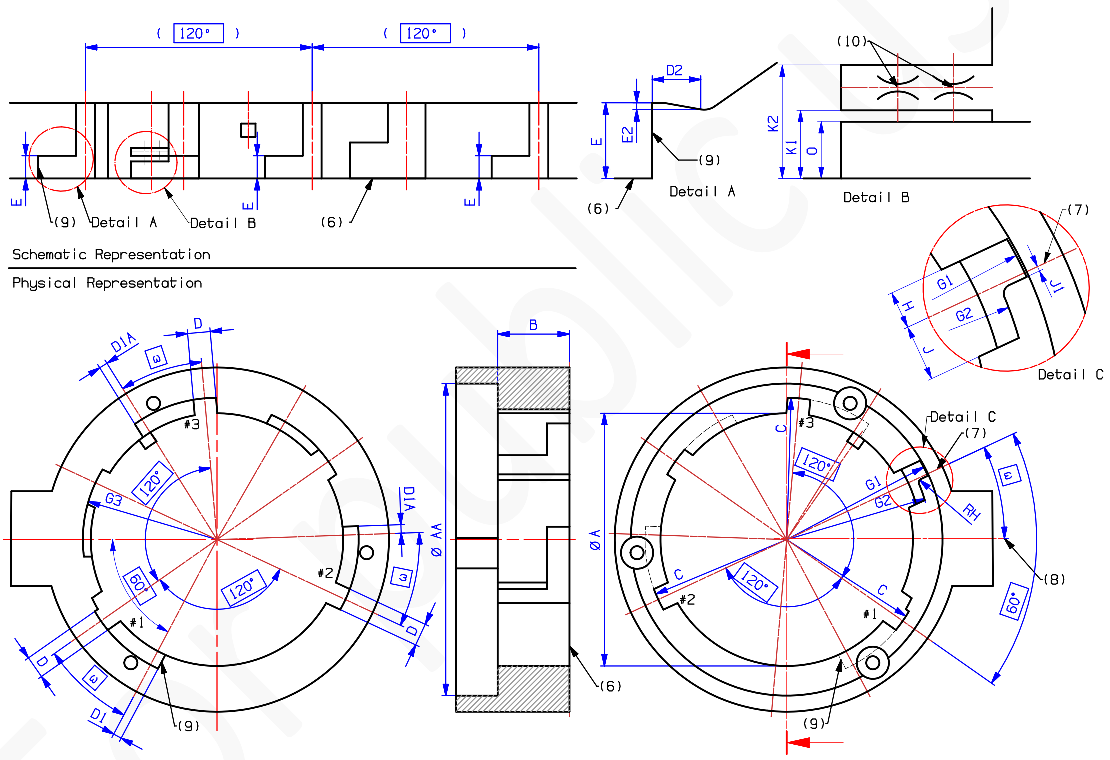

Figure 3-6: Dimensions of Holder (containing some details of a PHJ65d-1 Holder)

Notes to Figure 3-6:

(6) The reference plane corresponds to the surface of the heat sink on which the Holder is mounted.

(7) In the case of an empty Holder, this is the reference X-axis.

(8) In the case that a Socketable LLE is locked in the Holder, this is the reference X-axis.

(9) The end face of the guide for Mechanical Force Pin #1 of the Socketable LLE shall stop the rotation when locking a Socketable LLE into the Holder.

(10) The top and bottom electrical contacts of the Holder shall be constructed such that the Holder can make electrical contact with the Socketable LLE, if the Socketable LLE is locked into the Holder.

Table 3-6: Dimensions of Holder PHJ65d

Dimension	Minimum	Typical	Maximum	Notes
A	66,10	66,40	66,50	(11)
AA	70,50	NA	NA	
B	(12,90)	19,00	19,30	(11), (12)
C	37,25	37,50	37,75	(11)
D	5,10	5,20	5,50	
D1	2,33	2,40	2,45	
D1A	2,45	NA	NA	
D2	NA	4,70	NA	
E	5,70	6,00	6,10	(12), (13)
E2	NA	0,2	NA	(12), (13)
G1	41,30	41,50	42,50	
G2	38,30	38,50	39,50	
G3	35,10	35,25	NA	
H	3,70	3,80	5,00	
J	5,70	5,80	7,00	
J1	NA	0,20	NA	(14)
K1	NA	NA	7,40	
K2	9,70	NA	NA	
O	4,60	5,00	NA	(12)
RH	1,00	NA	NA	
ω	24,50°	25,00°	25,50°	(15)

Notes to Table 3-6:

(11) The minimum and maximum dimensions for diameters A and C apply along height B; the diameter A does not have to be continuous over the circumference.

(12) Dimensions B, E, K1, K2 and O apply with a Socketable LLE locked into the Holder.

(13) The Holder shall apply a force to the Mechanical Force Pins that is locked into the Holder, such that the Thermal Interface Surface applies a force of at least 25 N, and at most 50 N to the heat sink on which the Holder is mounted. These limits to the force are independent of the orientation of the system.

(14) This is the play that enables insertion of the Socketable LLE into the Holder.

(15) This is the twisting angle for locking the Socketable LLE into the Holder.

Figure 3-7 and Table 3-7 define the electrical contact outlines of the Holder.

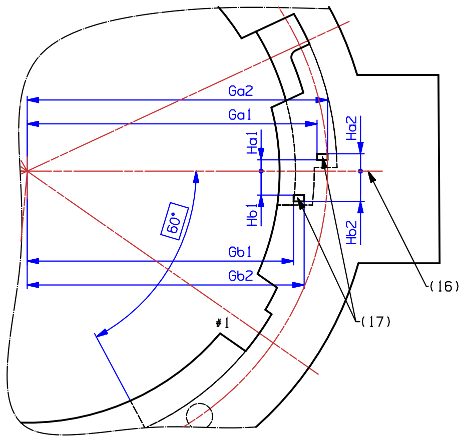

Figure 3-7: Holder electrical contact definition

Notes to Figure 3-7:

(16) The reference X-axis corresponds to the central edge of the electrical contact carrier of Socketable LLE that is locked into the Holder.

(17) Electrical contact outlines. The Holder shall be able to make electrical contact to the Socketable LLE at any location within the electrical contact outlines, at two positions—the top and bottom sides of the electrical contact carrier of the Socketable LLE—along the combined dimensions K and L; it is recommended that the Holder employs line-shaped contacts for this purpose. In addition, the Holder should be designed in such a way that it does not apply an axial remaining force to the electrical contact carrier of the Socketable LLE.

Table 3-7: Holder electrical contact definition

Dimension	Minimum	Typical	Maximum	Notes
Ga1	NA	NA	38,55	
Ga2	39,95	NA	NA	
Gb1	NA	NA	35,05	
Gb2	36,45	NA	NA	
Ha1	NA	NA	1,50	
Ha2	2,80	NA	NA	
Hb1	NA	NA	3,20	
Hb2	4,50	NA	NA	
ω	(24,50°)	(25,00°)	(25,50°)	(18)

Notes to Table 3-7:

(18) See Table 3-6.

3.3.3 Keying-specific dimensions

Figure 3-8 and Table 3-8 define the Keying of the mechanical fit of Holder PHJ65d. The Keying enables a Holder to discriminate between Socketable LLEs that have different Rated mains voltage requirements. The mechanical fit Keying features consist of the following set:

- An additional cut-out directly adjacent in the counter-clockwise direction (top view) to either the Mechanical Force Pin #1 or the Mechanical Force Pin #2 cut-out.
- A cut-out at different positions in between the cut-outs for Mechanical Force Pins #2 and #3.
- A tab in between the cut-outs for the electrical contact carrier and Mechanical Force Pin #3. (Informative) *This tab allows for additional Keying combinations to be made in future editions of Book 2 of the Zhaga Interface Specification.*

As shown in Figure 3-8, the mechanical fit Keying features shall be used in specific combinations only.

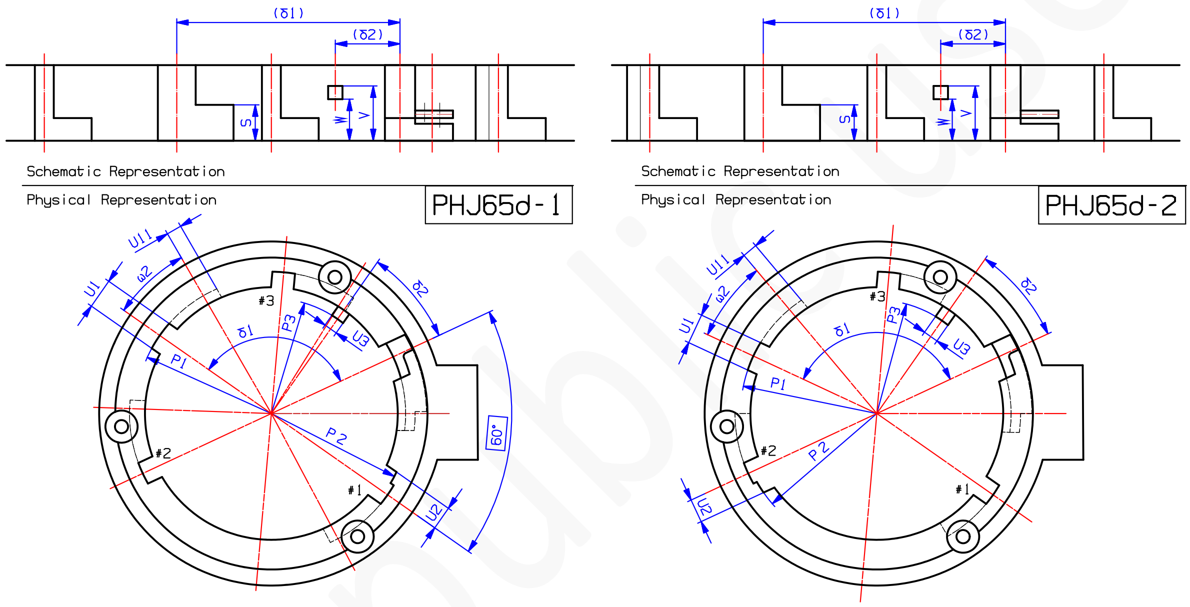

Figure 3-8: Holder mechanical fit Keying definition (top view)

Table 3-8: Holder mechanical fit Keying definition

Dimension	Minimum	Typical	Maximum	Notes
P1	35,40	35,60	35,80	
P2	37,25	37,50	37,75	
P3	30,70	31,05	31,30	
S	5,60	6,00	NA	(19)
U1	7,70	7,80	7,95	
U11	3,85	NA	NA	
U2	6,80	7,00	7,20	
U3	3,00	3,70	3,80	
V	12,50	14,00	14,10	(19)
W	10,80	11,00	11,50	(19)
$\delta 1$	NA	120°	NA	(20)
	NA	130°	NA	(21)
$\delta 2$	NA	30°	NA	
$\omega 2$	25,50°	NA	NA	(22)

Notes to Table 3-8:

(19) Dimensions S, T, V and W apply with a Socketable LLE locked into the Holder.

(20) Holder PHJ65d-1.

(21) Holder PHJ65d-2.

(22) The length of the keying slot shall exceed the twisting angle.

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4 Photometric Interface

4.1 Light Emitting Surface

As shown in Figure 4-1 and Table 4-1, the dimensions AO and BO define the size, shape and position of the Light Emitting Surface relative to the Thermal Interface Surface.

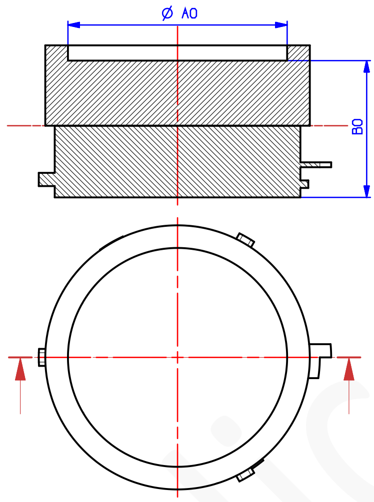

Figure 4-1: Definition of Light Emitting Surface

Table 4-1: Definition of Light Emitting Surface

Dimension	Minimum	Typical	Maximum	Notes
AO	57,00	59,00	(70,20)	
BO	35,00	36,00	40,00	(1)

Notes to Figure 4-1:

(1) Neither the minimum nor the maximum value of the height BO shall be violated due to any compression of the TIM.

4.2 Operating conditions

In general, the optical output of a Socketable LLE depends on the operating conditions. For example, the total luminous flux depends on the applied mains power and the temperature of the Thermal Interface Surface. This Section 4.2 defines the operating conditions that shall apply for the provisions of the optical interface as defined in Section 4 of this Book 2 of the Zhaga Interface Specification. If the Socketable LLE is operated under different conditions, the optical properties of the Socketable LLE may differ from the provisions defined in Section 4.

If a Socketable LLE is operated under the conditions listed below,[3] the Socketable LLE shall comply with the provisions in Section 4:

- The Socketable LLE shall be locked into position in the Holder of Test Fixture OETF.[4] The orientation of Test Fixture OETF-PHJ65d-*x* shall be vertical base up, unless the data sheet of the Socketable LLE indicates otherwise.

[3](Informative) *These conditions closely follow the operating conditions specified in [IES LM-79-08].*
[4]See Annex A.1.1.2 for a definition of Test Fixture OETF-PHJ65d-*x*.

- Test Fixture OETF-PHJ65d-*x* shall be mounted in a draught free room. The ambient air temperature in the room shall be stable at (25 ± 5) °C. Motion of the ambient air in the closed room shall be limited to air flow caused by the operation of the Socketable LLE in Test Fixture TUTF-PHJ65d-*x*.
- Test Fixture OETF-PHJ65d-*x* shall be connected to mains power. The mains voltage and frequency shall be within 0,2% of the Rated voltage and Rated frequency. The RMS summation of the harmonic components in the mains voltage shall not exceed 3% of the fundamental frequency.
- Test Fixture OETF-PHJ65d-*x* shall actively regulate the temperature at the Thermal Interface Surface (t_{r} point, see Section 6.3.1) to be stable within 1 °C of the appropriate Rated value. The temperature shall be deemed stable if the difference between two consecutive temperature measurements, taken at least 15 min apart, is less than 0,5%.
- The optical output of the Socketable LLE shall not be affected in any way, by object(s)—reflectors, glass or plastic windows, heat sink features, etcetera—that are exterior to the Socketable LLE and Test Fixture OETF-PHJ65d-*x*.

4.3 Luminous flux

The luminous flux of a Socketable LLE shall be in one of the flux categories listed in Table 4-2. For reporting the luminous flux on the data sheet of the Socketable LLE, the flux category name shall be used.

Table 4-2: Luminous flux categories

Flux category name	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

4.4 Luminous intensity distribution

The partial relative luminous flux (i.e. percentage of the total luminous flux) emitted into the rotationally symmetric solid angle bounded by the polar angles γ_1 and γ_2, as shown in Figure 4-2, shall be as defined in Table 4-3. Measurements of the partial relative luminous flux shall be made at a distance of at least $r =$ 1 m from the center of the Light Emitting Surface.[5]

In addition, it is recommended that the Socketable LLE has a luminous intensity distribution that is as close as possible to a lambertian intensity distribution.

[5]See [CIE 121], Section 6.2.1.4.

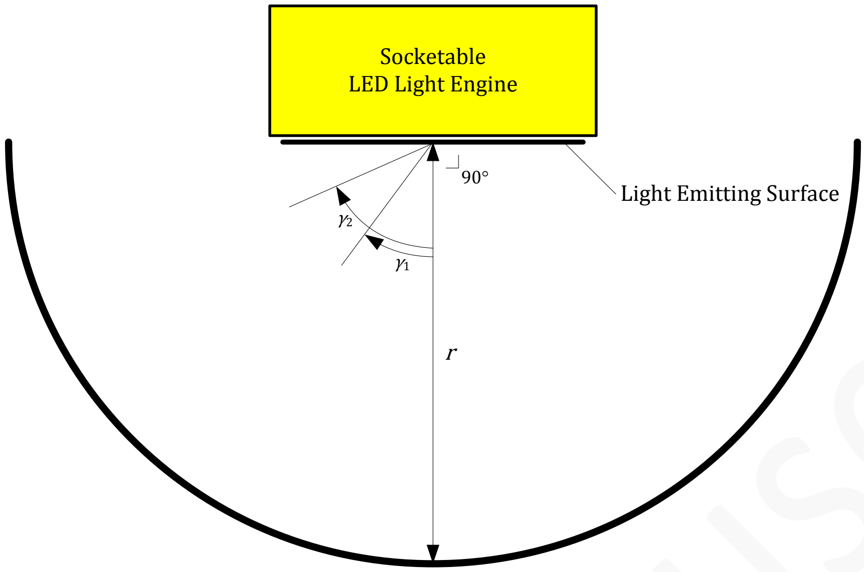

Figure 4-2: Luminous intensity distribution

Table 4-3: Luminous intensity distribution

γ_1	γ_2	Partial relative luminous flux [%]		
		Minimum	Nominal	Maximum
0°	41,4°	35		55
41,4°	60°	25		40
60°	75,5°	10		30
75,5°	90°	0		10

4.5 Luminance uniformity

This edition 1.3 of Book 2 of the Zhaga Interface Specification does not define limits on the uniformity of the luminance of a Socketable LLE.

4.6 Correlated color temperature

The correlated color temperature (CCT) of a Socketable LLE shall comply with the provisions of [ANSI C78.377], with the exception that the target color points may be chosen freely within the quadrangles defined therein.[6] It is recommended to use the nominal CCT values specified in [ANSI C78.377] only.

4.7 Color rendering index

This edition 1.3 of Book 2 of the Zhaga Interface Specification does not define limits on the color rendering index of a Socketable LLE. However, this edition 1.3 of Book 2 of the Zhaga Interface Specification does require the data sheet of a Socketable LLE to provide the color rendering index at the Rated operating temperature (see Annex B.1).

[6]Note that notwithstanding this exception, a Socketable LLE shall have a CCT that is within the quadrangle of the Rated CCT.

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5 Electrical Interface

5.1 Mains input

5.1.1 Socketable LLE mains power requirements

Table 5-1 lists the relation of the Keying of the mechanical fit to the appropriate mains power sources. In addition, Table 5-1 defines the maximum amount of power that a Socketable LLE shall consume.

Table 5-1: Mains power mechanical fit codes Socketable LLE

Fit code	Rated Voltage [V]	Rated Frequency [Hz]	Maximum Power [W]
PHJ65d	100…277	50 or 60	50
PHJ65d-1	100…127	50 or 60	50
PHJ65d-2	200…277	50 or 60	50

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6 Thermal Interface

6.1 Thermal interface model

Figure 6-1 illustrates the model for the thermal interface. The Socketable LLE is locked into position in the Holder and makes thermal contact with the heat sink of the Luminaire. The Socketable LLE generates an amount of heat, which is represented by the total thermal power $P_{th} = P_{th,rear} + P_{th,front}$. The $P_{th,front}$ part of the heat is transferred to the environment of the Luminaire through the front side of the Socketable LLE by means of radiation and/or convection. The $P_{th,rear}$ part of the heat is transferred to the environment of the Luminaire through the Thermal Interface Surface.

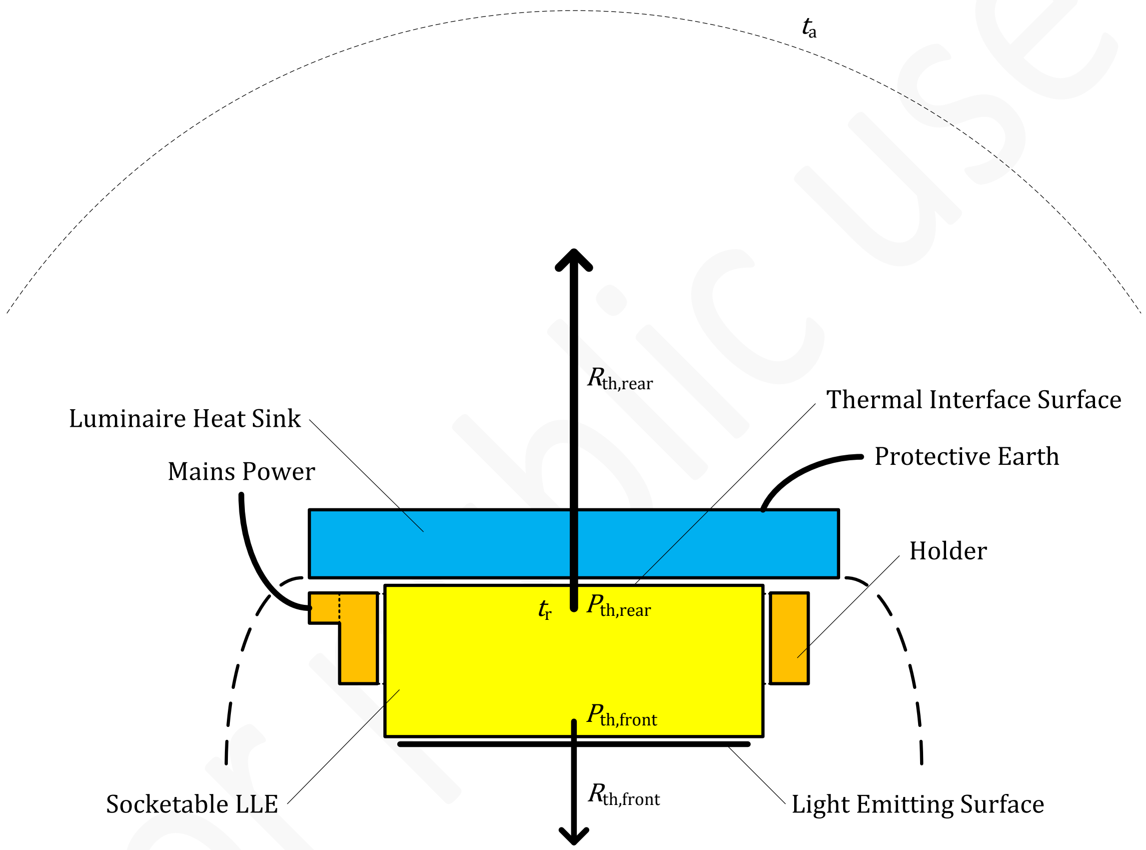

Figure 6-1: Thermal model

After switching on the Socketable LLE, the temperature of the Thermal Interface Surface starts to rise. In the steady state—with the Socketable LLE switched on—the Thermal Interface Surface reaches a temperature t_r (see Section 6.3.1 for the location of the measurement point). This temperature t_r depends on the temperature t_a of the environment of the Luminaire, the thermal resistance of the Luminaire, and the amount of heat generated in the Socketable LLE. Using a simple 1-dimensional model, the following relation is obtained:

$$t_r = t_a + R_{th,rear} \cdot P_{th,rear}$$

Here, $R_{th,rear}$ is the thermal resistance, which the Luminaire presents to the Socketable LLE. Note that in general the temperature distribution across the Thermal Interface Surface is not uniform. See also Section 6.3.

This edition 1.3 of Book 2 of the Zhaga Interface Specification does neither define a maximum for the thermal resistance of the Luminaire, nor a maximum for the amount of heat generated in the Socketable LLE. Instead, this edition 1.3 of Book 2 of the Zhaga Interface Specification requires a Socketable LLE manufacturer characterize the thermal performance—in terms of P_{th} and $P_{th,rear}$—of the Socketable LLE under the condition that the Socketable LLE is operated in Test Fixture TUTF-PHJ65d-*x*,[7,8] and provide the results on the data sheet of the Socketable LLE. See Annex B.1. Similarly, this edition 1.3 of Book 2 of the Zhaga Interface Specification requires a Luminaire manufacturer characterize the thermal performance—in terms of $R_{th,rear}$—of the Luminaire under the condition that the Luminaire is operated with Thermal Test Engine TTE-PHJ65-d locked into position,[9] and provide the results on the data sheet of the Luminaire. See Annex B.

In order to determine if—from a thermal point of view—a particular Socketable LLE can be used reliably in a particular Luminaire, it shall be verified that the applicable thermal resistance specified in the data sheet of the Luminaire is less than or equal to the maximum thermal resistance specified in the data sheet of the Socketable LLE. Here, the applicable thermal resistance is the thermal resistance in the case of a power that is greater than or equal to the maximum thermal power applied at the Thermal Interface Surface listed in the data sheet of the Socketable LLE. (Informative) *In case of a closed Luminaire design, the maximum total thermal power should be used instead of the maximum thermal power applied at the Thermal Interface Surface.*

(1) (Informative) *As an example of an open Luminaire, consider the information listed in the data sheets of particular Socketable LLEs and Luminaires (note that the numbers in this example are not necessarily realistic):*

Socketable LLE data sheets:	*data sheet#1*	*data sheet #2*
• *Maximum total thermal power [W]*	*23*	*38*
• *Maximum thermal power applied at the Thermal Interface [W]*	*18*	*35*
• *Maximum allowable thermal resistance of the Luminaire [K/W]*	*2*	*1*
Luminaire data sheets	*data sheet #1*	*data sheet #2*
• *Thermal Resistance at 10 W [K/W]*	*2,2*	*1,5*
• *Thermal Resistance at 20 W [K/W]*	*1,9*	*1,4*
• *Thermal Resistance at 30 W [K/W]*	*1,7*	*1,2*
• *Thermal Resistance at 40 W [K/W]*	*1,6*	*0,9*

From these numbers is can be seen that Socketable LLE #1 can be used reliably in both Luminaire #1 and #2 (because $1{,}9 < 2$*, and* $1{,}4 < 2$*), whereas Socketable LLE #2 can be used reliably in Luminaire #2 only (because* $1{,}6 > 1$ *and* $0{,}9 < 1$*).*

6.2 Luminaire heat sink

The heat sink surface to which the Socketable LLE is mounted shall extend to a diameter of at least 65 mm.

6.3 Temperature uniformity

6.3.1 Thermal interface temperature uniformity requirement

The non-uniformity of the temperature distribution across the Thermal Interface Surface depends on the details of the construction of both the Socketable LLE and the Luminaire. This edition 1.3 of Book 2 of the Zhaga Interface Specification does not restrict this non-uniformity in the case of a arbitrary Socketable LLE being operated in an arbitrary Luminaire. Instead, this edition 1.3 of Book 2 of the Zhaga Interface Specification restricts the non-uniformity in the case of an arbitrary Socketable LLE being operated in Test Fixture TUTF-PHJ65d-*x*:

[7]Note that $P_{th,rear}$ can be determined from the heat flow through the heat sink of the Luminaire to the environment. In addition, P_{th} can be determined from the electrically consumed power P_{el} and radiated optical power P_{rad} using the relation $P_{th} = P_{el} - P_{rad}$. See Annex A.2.4 for details on specific measurement methods.
[8]See Annex A.1.1.3 for a definition of Test Fixture TUTF-PHJ65d-*x*.
[9]See Annex A.1.3.1 for a definition of Thermal Test Engine TTE-PHJ65d.

The non-uniformity of the temperature distribution across the Thermal Interface Surface shall be such that the thermal spreading resistance $R_{i,j}$ between any pair of the measurement points shown in Figure 6-2 is at most 0,2 K/W. Here, the thermal spreading resistance between two measurement points i and j is defined as:

$$R_{i,j} = \frac{t_i - t}{P_{\text{th,rear}}}$$

Here t_i and t_j are the temperatures at the measurements points i and j, located on the heat sink surface of Test Fixture TUTF-PHJ65d-x that makes physical contact with the Thermal Interface Surface, and $P_{\text{th,rear}}$ is the amount of heat that is transferred through the Thermal Interface Surface (see Section 6.1). Measurement point 0 is at the center of the Thermal Interface Surface (i.e. at the center of dimension A of the Socketable LLE, see Figure 3-2 and Table 3-2 in Section 3.2.2. Measurement points $i = 1,2, \ldots ,6$ are located equidistantly on a circle, which is centered on measurement point 0 and has a diameter of $(48 \pm 0{,}1)$ mm. Moreover, the orientation of the measurement points is such that measurement points 1 and 4 are located on the reference X-axis of the Socketable LLE (see Figure 3-2 in Section 3.2.2), with measurement point 1 closest to the mechanical force pin that is parallel to the reference X-axis. The highest temperature value t_i, $i = 0, 1, 2, \ldots ,6$, at these measurement points shall be used as the temperature t_r defined in Section 6.1.

The exact operating conditions for the above restriction are listed in Sections 6.3.2 below.

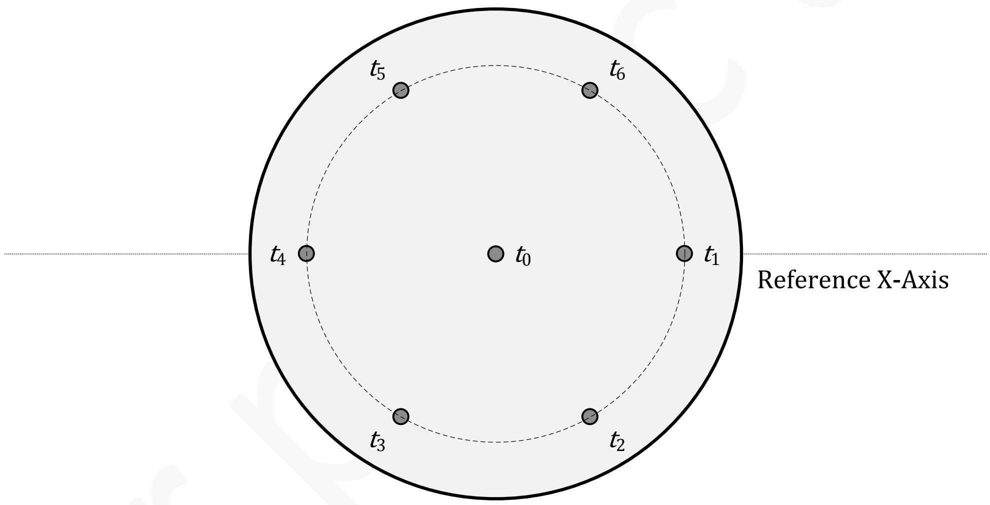

Figure 6-2: Temperature distribution at the thermal interface

6.3.2 Socketable LLE operating conditions

The temperature non-uniformity in the case of an arbitrary Socketable LLE being operated in Test Fixture TUTF-PHJ65d-*x* shall be determined under the conditions listed below:[10]

- The Socketable LLE shall be locked into position in the Holder of Test Fixture TUTF-PHJ65d-*x*. The orientation of Test Fixture TUTF-PHJ65d-*x* shall be vertical base up, unless the data sheet of the Socketable LLE indicates otherwise.
- Test Fixture TUTF-PHJ65d-*x* shall be mounted in a draught free room. The ambient air temperature in the room shall be stable at (25 ± 5) °C. Motion of the ambient air in the closed room shall be limited to air flow caused by the operation of the Socketable LLE in Test Fixture TUTF-PHJ65d-*x*.
- Test Fixture TUTF-PHJ65d-*x* shall be connected to mains power. The mains voltage and frequency shall be within 0,2% of the Rated voltage and Rated frequency. The RMS summation of the harmonic components in the mains voltage shall not exceed 3% of the fundamental frequency.

[10](Informative) *These conditions closely follow the operating conditions specified in [IES LM-79-08].*

- The temperature of the Thermal Interface Surface shall be stable. The temperature shall be deemed stable if the difference between two consecutive temperature measurements at the same measurement point (all measurement points $i = 0,1,2,\ldots,6$), taken at least 15 min apart, is less than 0,5% of the average of the two measured temperatures.

6.4 Maximum temperature (informative)

Under normal operating conditions, the maximum temperature at any position of the Thermal Interface Surface should not exceed 110 °C.

7 Control Interface

7.1 Dimming (optional)

If a Socketable LLE supports dimming functionality, such dimming functionality shall comply with the provisions of [NEMA SSL 7A].

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Annex A Compliance Testing (Normative)

A.1 Specific testing tools

A.1.1 Socketable LLE testing tools

Each Socketable LLE testing tool includes a Holder. This Holder may be exchangeable in order to enable a single physical realization of a Socketable LLE testing tool to be used for any Socketable LLE under test. If the Holder is permanently attached, two variants of that tool are necessary.

A.1.1.1 Gauges

Unless specified otherwise, all sharp angles should be chamfered or rounded with a dimension $R <$ 0,2 mm, in accordance with [IEC 60061]. In addition, unless specified otherwise, the gauges shall be manufactured from stainless steel, which is hardened to at least 55 HRC and should have a surface finish of $Ra = 0{,}4$ µm.

No undue force shall be used to fit a Socketable LLE under test to any of the gauges.

A.1.1.1.1 Gauges MTG-B1 and MTG-B2

Figure A-1 and Table A-1 define gauges MTG-B1 and MTG-B2. The purpose of gauges MTG-B1 and MTG-B2 is to verify the maximum of Base dimensions A, C, D, G1, G2, H, J, P1, RH, U1, and U2; as well as the minimum of Base dimension B. The Base of a PHJ65d-1 Socketable LLE under test shall fit into gauge MTG-B1; the Base of a PHJ65d-2 Socketable LLE under test shall fit into gauge MTG-B2.

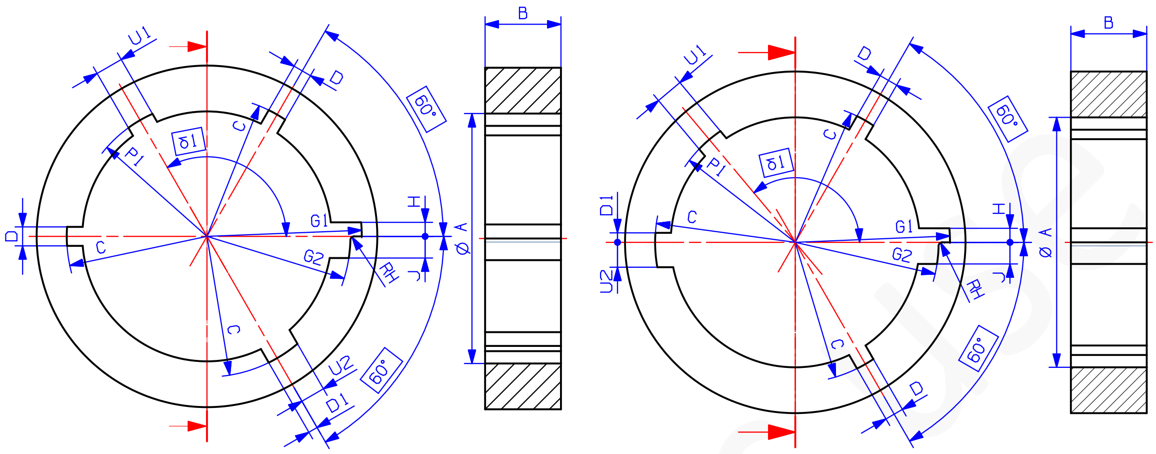

Figure A-1: Dimensions of MTG-B1 (left) and MTG-B2 (right)

Table A-1: Dimensions of MTG-B1 (left) and MTG-B2 (right)

Dimension	Nominal	Tolerance	Notes
A	65,85	−0,02	
B	19,95	−0,02	
C	37,05	−0,02	
D	5,00	−0,02	
D1	2,50	−0,01	
G1	40,90	−0,02	
G2	37,90	−0,02	
H	3,70	−0,02	
J	5,70	−0,02	
P1	35,35	−0,02	
RH	0,95	−0,02	
U1	7,35	−0,02	
U2	6,55	−0,02	
$\delta 1$	120°	±0°5’	(1)
	130°	±0°5’	(2)

Notes to Table A-1:

(1) MTG-B1

(2) MTG-B2

A.1.1.1.2 Gauge MTG-B3

Figure A-2 and Table A-2 define gauge MTG-B3. The purpose of gauge MTG-B3 is to verify the minimum of Base dimension A. The Base of a Socketable LLE under test shall not fit into gauge MTG-B3.

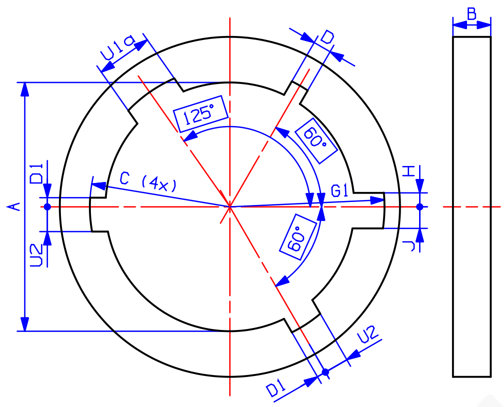

Figure A-2 : Dimensions of MTG-B3

Table A-2: Dimensions of MTG-B3

Dimension	Nominal	Tolerance	Notes
A	65,15	+0,02	
B	8,10	±0,10	
C	38,00	±0,10	
D	5,80	±0,10	
D1	2,90	±0,10	
G1	41,85	±0,10	
H	4,65	±0,10	
J	6,65	±0,10	
U1a	14,60	±0,10	
U2	7,00	±0,10	

A.1.1.1.3 Gauge MTG-B4

Figure A-3 and Table A-3 define gauge MTG-B4. The purpose of gauge MTG-B4 is to verify the minimum of Base dimensions C, D, U1, and the combination of D1 and U2. The Base of a Socketable LLE under test shall not fit through gauge MTG-B4, with the Socketable LLE under test and gauge MTG-B4 in axial alignment. Mechanical Force Pin #1 and the adjacent tab of a PHJ65d-1 Socketable LLE under test shall not fit in the slot of gauge MTG-B4 labeled DU2; Mechanical Force Pin #2 and the adjacent tab of a PHJ65d-2 Socketable LLE under test shall not fit in the slot of gauge MTG-B4 labeled DU2. The tab between Mechanical Force Pins #2 and #3 of a Socketable LLE under test shall not fit in the slot of gauge MTG-B4 labeled U1. Mechanical Force Pins #2 and #3 of a PHJ65d-1 Socketable LLE under test shall not fit in the slot of gauge MTG-B4 labeled D; Mechanical Force Pins #1 and #3 of a PHJ65d-2 Socketable LLE under test shall not fit in the slot of gauge MTG-B4 labeled D.

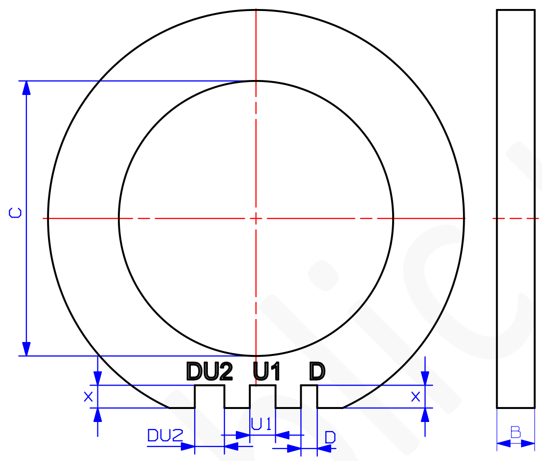

Figure A-3: Dimensions of MTG-B4

Table A-3: Dimensions of MTG-B4

Dimension	Nominal	Tolerance	Notes
B	10,00	±0,10	
C	72,55	+0,02	
D	4,30	+0,02	
U1	6,75	+0,02	
DU2	7,83	+0,02	
x	6,00	±0,10	

A.1.1.1.4 Gauges MTG-B5a, MTG-B5b, and MTG-B5c

Figure A-4 and Table A-4 define gauge MTG-B5a. Figure A-5 and Table A-5 define gauge MTG-B5b. Figure A-6 and Table A-6 define gauge MTG-B5c. The purpose of gauges MTG-B5a, MTG-B5b, and MTG-B5c is to verify the minimum of Base dimensions E, K, and L; as well as the maximum of Base dimensions E, K, L, and O.

Gauges MTG-B5a, MTG-B5b, and MTG-B5c shall be used in three configurations:

- Configuration A: The Socketable LLE under test rests on its Thermal Interface Surface.
- Configuration B: As configuration A. In addition, gauge MTG-B5a rests on the Mechanical Force Pins of the Socketable LLE under test. Gauge MTG-B5b rests on top of gauge MTG-B5a.
- Configuration C: See configuration B. In addition, a mass of (2,5 ± 0,03) kg shall be positioned on top of gauge MTG-B5b.

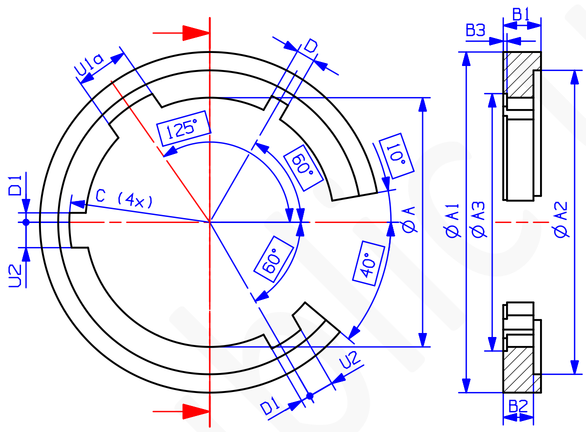

Figure A-4: Dimensions of MTG-B5a

Table A-4: Dimensions of MTG-B5a

Dimension	Nominal	Tolerance	Notes
A	65,85	−0,02	
A1	90,00	±0,10	
A2	80,20	±0,20	
A3	68,00	±0,05	
B1	10,00	±0,10	
B2	8,00	±0,10	
B3	1,00	±0,10	
C	38,00	±0,10	
D	5,80	±0,10	
D1	2,90	±0,10	
U1a	14,60	±0,10	
U2	7,00	±0,10	

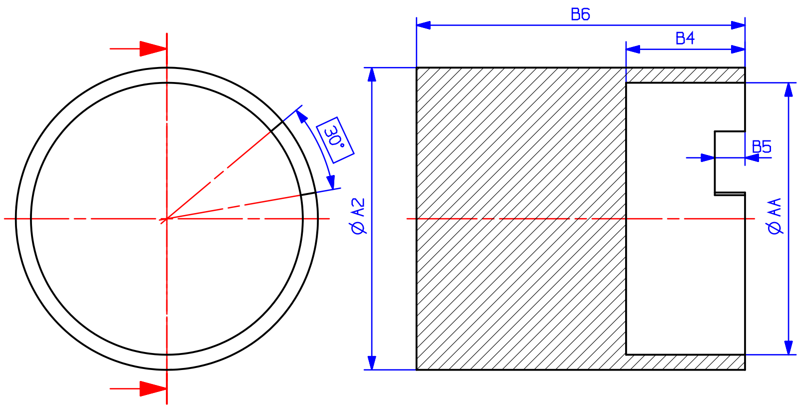

Figure A-5: Dimensions of MTG-B5b

Table A-5: Dimensions of MTG-B5b

Dimension	Nominal	Tolerance	Notes
AA	70,50	+0,20	
A2	80,00	−0,20	
B4	32,00	+0,20	
B5	8,00	+0,20	
B6	(90,00)	—	(1)

Notes to Table A-5:

(1) Dimension B6 shall be adjusted such that the combined mass of gauges MTG-B5a and MTG-B5b is 2,55 ± 0,03 kg.

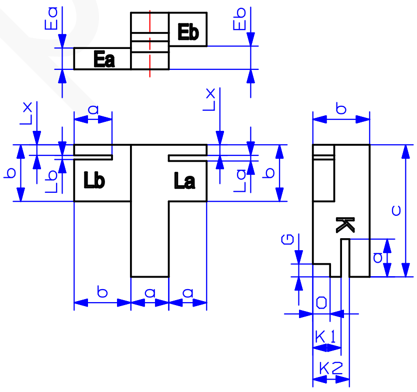

Figure A-6: Dimensions of MTG-B5c

Table A-6: Dimensions of MTG-B5c

Dimension	Nominal	Tolerance	Notes
a	10,00	±0,20	
b	15,00	±0,20	
c	35,00	±0,20	
Ea	5,65	+0,02	
Eb	6,15	−0,02	
G	3,40	±0,20	
K1	7,45	−0,02	
K2	9,65	+0,02	
La	1,50	+0,02	
Lb	1,10	−0,02	
Lx	2,80	±0,10	
O	4,55	−0,02	

- Configuration A
    - The mechanical Force Pins of the Socketable LLE under test shall fit underneath the blade labeled Eb of gauge MTG-5c, with gauge MTG-5c resting on the support for the Thermal Interface Surface of the Socketable LLE under test (this verifies the maximum of dimension E).
    - The electrical contact carrier of the Socketable LLE under test shall fit into the slot labeled K of gauge MTG-5c, such that gauge MTG-5C touches the main body of the Socketable LLE under test, with gauge MTG-5C resting on the support for the Thermal Interface Surface of the Socketable LLE under test (this verifies the maximum of dimension K combined with the maximum of dimension L, as well as the maximum of dimension O).
    - The electrical contact carrier of the Socketable LLE under test shall fit in the slot labeled La and shall not fit in the slot labeled Lb (this verifies the minimum and maximum of dimension L).
- Configuration B:
    - The blade labeled Ea of gauge MTG-5c shall fit underneath gauge MTG-5a at any position (this verifies the minimum of dimension E), with gauge MTG-5c resting on the support for the Thermal Interface Surface of the Socketable LLE under test.
- Configuration C:
    - The blade labeled Ea of gauge MTG-5c shall fit underneath gauge MTG-5a at any position (this verifies the minimum of dimension E), with gauge MTG-5c resting on the support for the Thermal Interface Surface of the Socketable LLE under test.
    - The electrical contact carrier of the Socketable LLE under test shall fit into the slot labeled K of gauge MTG-5c, such that gauge MTG-5C touches the main body of the Socketable LLE under test, with gauge MTG-5C resting on the support for the Thermal Interface Surface of the Socketable LLE under test (this verifies the minimum of dimension K combined with the maximum of dimension L, as well as the maximum of dimension O).

A.1.1.1.5 Gauge MTG-B6

Figure A-7 and Table A-7 define gauge MTG-B6. The purpose of gauge MTG-B6 is to verify the minimum of Base dimensions Ga2, Gb2, Ha2, and Hb2; as well as the maximum of Base dimensions G1, Ga1, Gb1, Ha1, and Hb1.

Gauge MTG-B6 shall be used as follows: The Socketable LLE under test shall be inserted into the gauge, and twisted until a stop is reached. In the end position, the electrical contacts of the Socketable LLE under test shall be visible through the windows of the gauge (see detail A in Figure A-7). It shall be verified that the electrically conductive material of the electrical contacts extends to all edges of the windows.

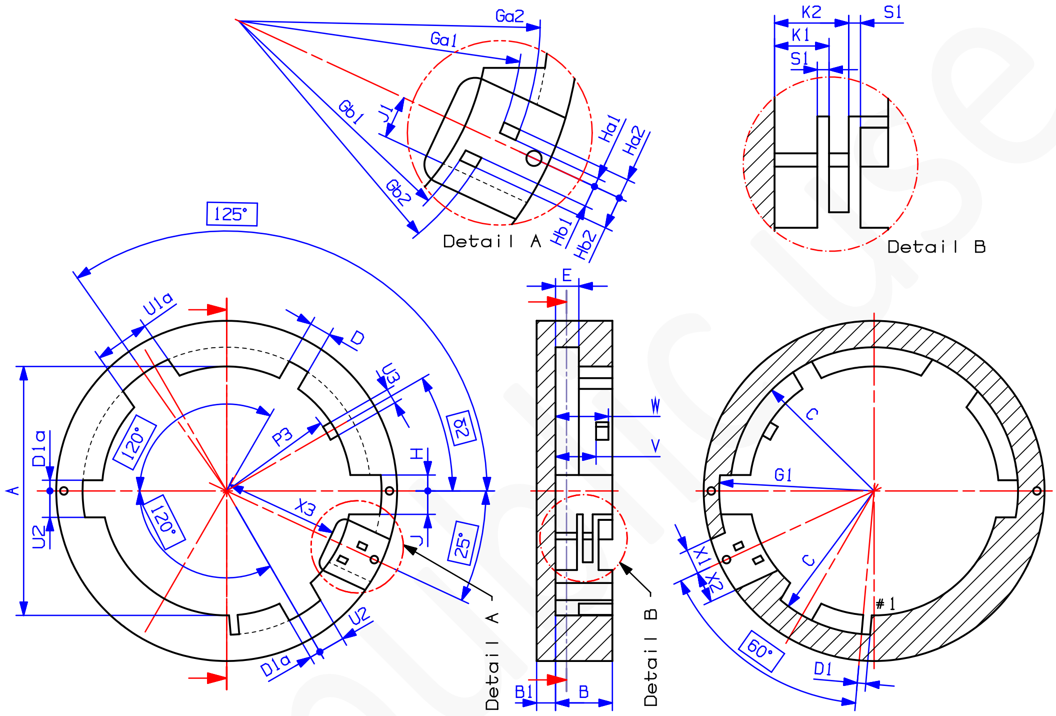

Figure A-7 : Dimensions of MTG-B6

Table A-7: Dimensions of MTG-B6

Dimension	Nominal	Tolerance	Notes
A	65,85	−0,02	
B	15,00	±0,10	
B1	5,00	±0,10	
C	38,00	+0,20	
D	5,65	+0,20	
D1	2,25	±0,01	
D1a	2,83	±0,10	
E	6,15	−0,02	
G1	40,90	−0,02	
Ga1	37,50	±0,01	
Ga2	39,80	±0,01	
Gb1	34,50	±0,01	
Gb2	36,80	±0,01	
H	4,15	+0,20	
Ha1	1,15	±0,01	
Ha2	2,65	±0,01	
Hb1	2,85	±0,01	
Hb2	4,35	±0,01	
J	6,15	+0,20	
J1	5,70	−0,02	
K1	7,20	±0,10	
K2	9,80	±0,10	
P3	30,55	+0,02	
S1	1,50	+0,20	
U1a	14,60	±0,10	
U2	7,00	±0,10	
U3	4,00	+0,02	
V	14,00	−0,10	
W	10,65	+0,10	
X1	6,60	±0,20	
X2	8,30	±0,20	
X3	30,00	±0,20	
$\delta 2$	30,00°	+10′	

A.1.1.2 Test Fixture OETF-PHJ65d-*x* (optical and electrical)

Figure A-8 illustrates Test Fixture OETF-PHJ65d-*x* schematically. The Holder used in a physical realization of Test Fixture OETF-PHJ65d-*x* shall comply with the provisions of Section 3.3. The temperature controlled heat sink shall be constructed to have a surface planarity of 0,05 mm / ∅65 mm, a surface roughness R_a < 3,2 µm, a thickness of at least 8 mm across the Thermal Interface Surface, and a heat conductivity of at least 160 W/m·K.

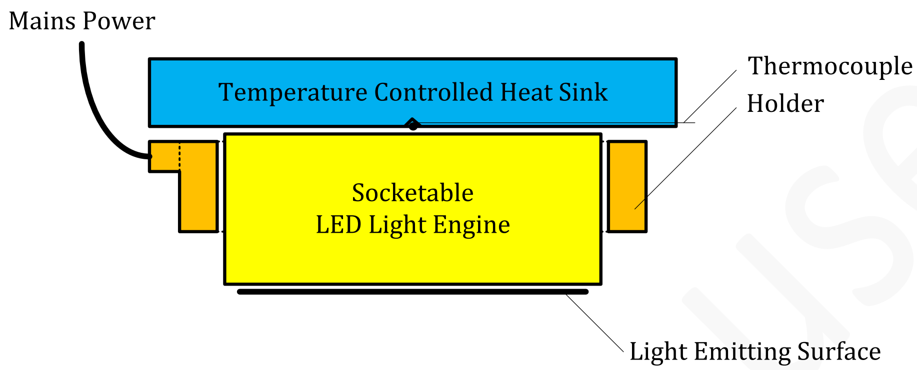

Figure A-8: Definition of Test Fixture OETF-PHJ65d-*x*

A.1.1.3 Test Fixture TUTF-PHJ65d-*x* (temperature uniformity)

Figure A-9, Figure A-10, and Table A-8 define Test Fixture TUTF-PHJ65d-*x*. In Figure A-9, $T_0 ... T_6$ represent thermocouple positions for measuring the temperature at the measurement points defined in Section 6.3.1 with an accuracy of ± 1 K. The wire thickness shall not affect the measurement result.

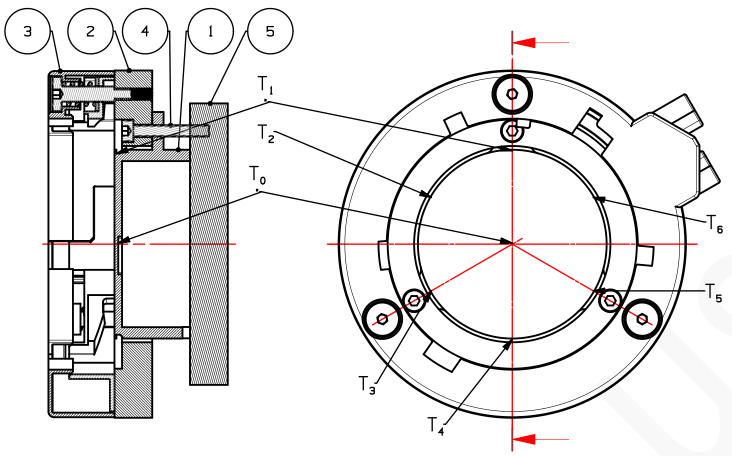

Figure A-9: Definition of Test Fixture TUTF-PHJ65d-*x* — composition

Components in Figure A-9:

(1) Heat sink, AlMgSiMn 100HV (AA6082) or equivalent.

(2) Mounting ring, 30% glass-filled PBT or equivalent.

(3) Holder PHJ65d-1 respectively Holder PHJ65d-2.

(4) Screw M3×20, stainless steel.

(5) Cooling device (schematic).

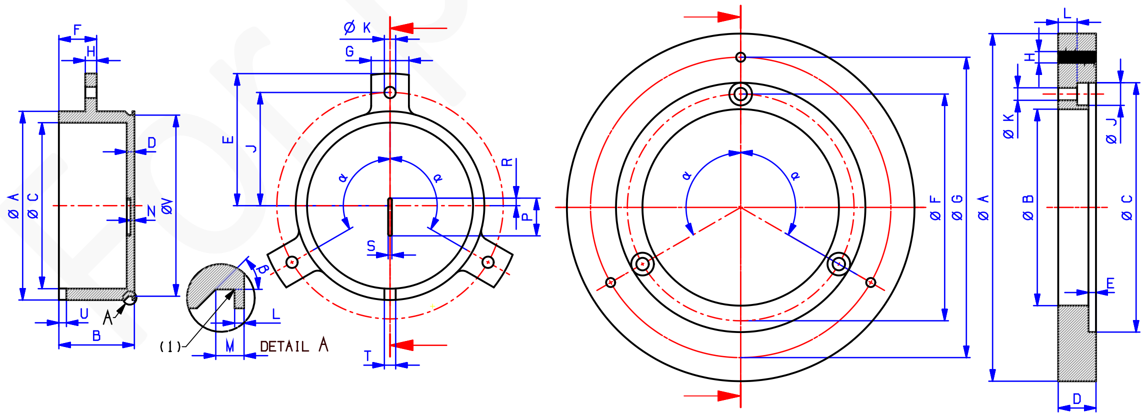

Figure A-10: Test Fixture TUTF-PHJ65d-*x* — heat sink (left) and mounting ring (right)

Notes to Figure A-10 (above):

(1) Position of a thermocouple in the groove.

Table A-8: Heat sink (top) and mounting ring (bottom) dimensions

Dimension	Nominal	Tolerance	Notes
A	50,00	±0,05	
B	20,00	±0,1	
C	44,00	±0,05	
D	2,00	±0,1	
E	35,00	±0,1	
F	10,00	±0,1	
G	10,00	±0,1	
H	3,00	±0,1	
J	30,00	±0,1	
K	3,20	±0,1	
L	0,50	±0,05	
M	1,50	±0,1	
N	1,00	±0,1	
P	10,00	±0,1	
R	2,00	±0,1	
S	1,00	±0,1	
T	3,00	±0,1	
U	2,00	±0,1	
V	48,00	±0,1	
α	120°	±1°	
β	45°	±1°	
A	92,00	±0,2	
B	52,00	±0,2	
C	66,00	±0,2	
D	10,00	±0,2	
E	2,00	±0,2	
F	60,00	±0,2	
G	79,50	±0,2	
H	M3	NA	
J	6,00	±0,1	
K	3,30	±0,1	
L	5,00	±0,1	
α	120°	±1°	

A.1.1.4 Test Fixture TPTF-PHJ65d-*x* (thermal power)

Figure A-11 illustrates Test Fixture TPTF-PHJ65d-*x* schematically. The Holder used in a physical realization of Test Fixture TPTF-PHJ65d-*x* shall comply with the provisions of Section 3.3.

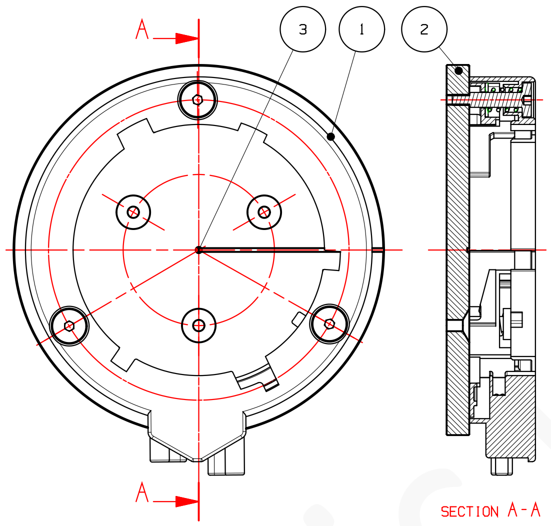

Figure A-11: Definition of Test Fixture TPTF-PHJ65d-*x* — composition

Components in Figure A-11:

(1) Holder PHJ65d-1 respectively Holder PHJ65d-2.

(2) Holder mount, AlMgSiMn 100HV (AA6082) or equivalent.

(3) Thermocouple, which enables temperature measurements with an accuracy of ±1 K. It shall be ensured that the wire thickness does not affect the measurement result.

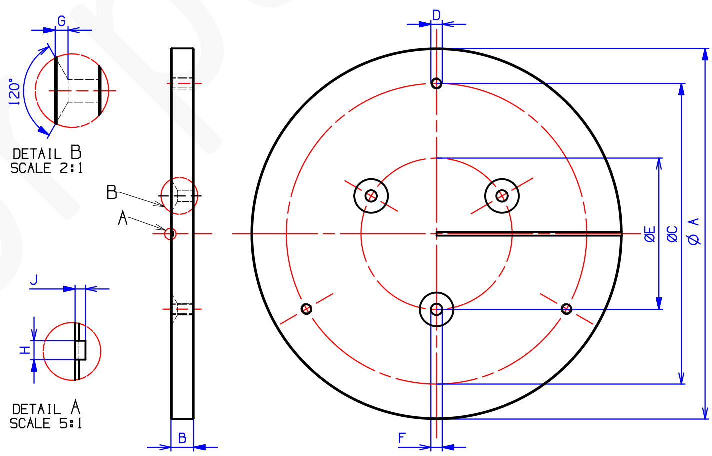

Figure A-12: Holder mount dimensions

Table A-9: Holder mount dimensions

Dimension	Nominal	Tolerance	Notes
A	98,00	±0,1	
B	6,00	±0,1	
C	79,50	±0,1	
D	M3	NA	
E	41,60	±0,1	
F	3,20	±0,1	
G	1,80	±0,1	
H	1,00	±0,1	
J	0,55	±0,05	

A.1.2 Holder testing tools

A.1.2.1 Gauges

Unless specified otherwise, all sharp angles should be chamfered or rounded with a dimension $R <$ 0,2 mm, in accordance with [IEC 60061]. In addition, unless specified otherwise, the gauges shall be manufactured from stainless steel, which is hardened to at least 55 HRC and should have a surface finish of $Ra = 0{,}4$ µm.

The Holder under test shall be mounted on a flat surface prior to applying the gauges. No undue force shall be used to fit any of the gauges to the Holder under test.

A.1.2.1.1 Gauges MTG-H1a, MTG-H1b, MTG-H2a, and MTG-H2b

Figure A-13 and Table A-10 define gauges MTG-H1A, MTG-H1B, MTG-H2A, and MTG-H2B. The purpose of these gauges is to verify the minimum of Holder dimensions C, G1, G2, G3, H, J, P1, and S; as well as the maximum of Holder dimensions B and E. It shall be possible to fully insert gauges MTG-H1A and MTG-H1B into a PHJ65d-1 Holder under test, and rotate these gauges to the stop position in a clockwise direction. It shall be possible to fully insert gauges MTG-H2A and MTG-H2B into a PHJ65d-2 Holder under test, and rotate these gauges to the stop position in a clockwise direction.

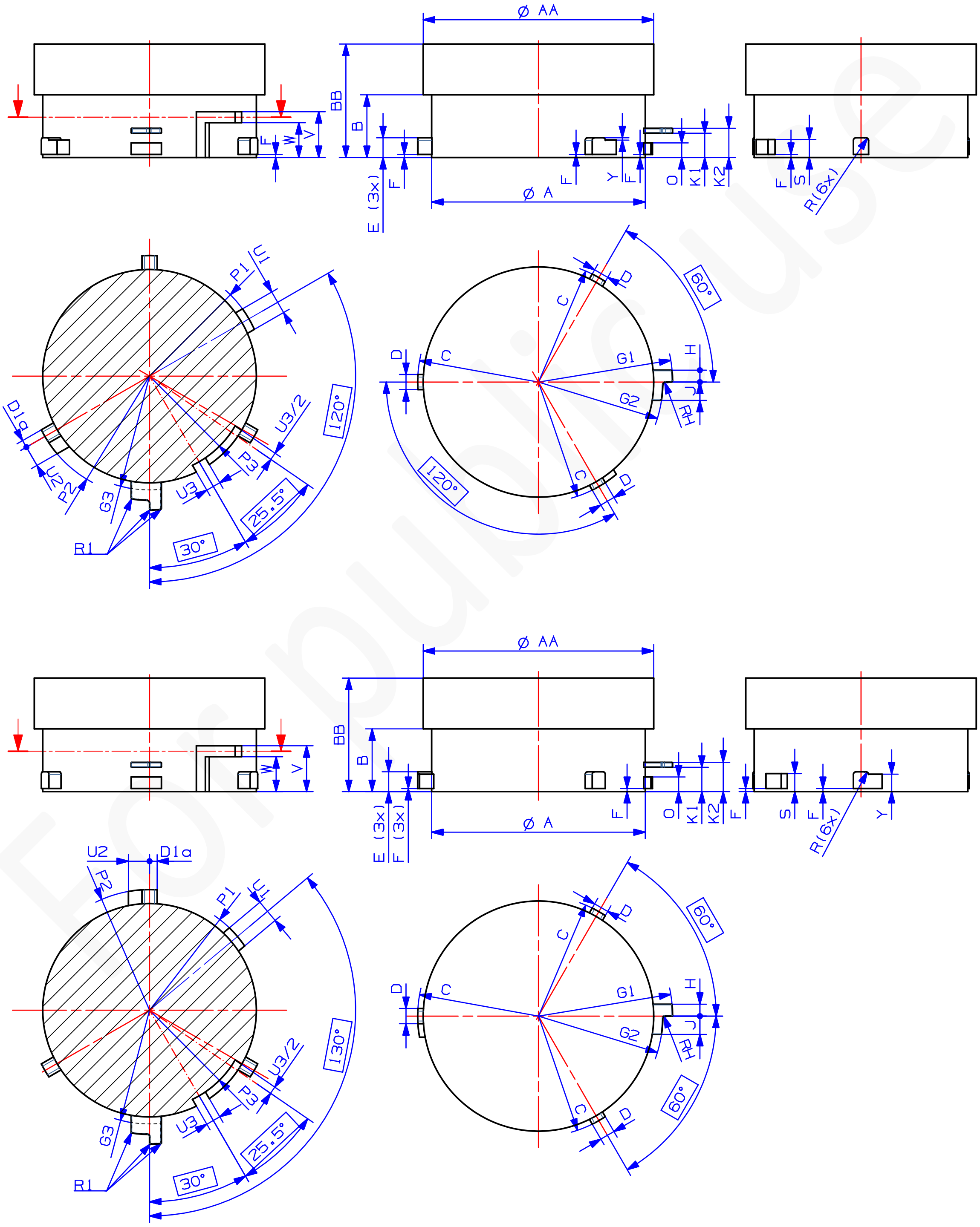

Figure A-13: Dimensions of MTG-H1A, MTG-H1B (top), MTG-H2A and MTG-H2B (bottom)

Table A-10: Dimensions of MTG-H1A, MTG-H1B, MTG-H2A, and MTG-H2B

Dimension	Nominal	Tolerance	Notes
A	65,80	+0,02	
AA	71,00	±0,10	
B	19,35	−0,02	
BB	35,00	±1,00	
C	37,20	+0,02	
D	4,65	+0,02	
D1a	2,33	+0,01	
E	6,10	+0,02	
F	0,95	+0,02	
G1	41,30	+0,02	
G2	38,30	+0,02	
G3	35,10	+0,02	
H	3,65	+0,02	
J	5,65	+0,02	
K1	8,10	−0,02	(1)
	7,50	−0,02	(2)
K2	9,60	+0,02	(1)
	9,00	+0,02	(2)
O	4,50	+0,02	
P1	35,35	+0,02	
P2	37,20	+0,02	
P3	30,50	+0,02	
R	0,80	+0,02	
RH	0,90	+0,02	
R1	0,50	+0,10	
S	5,55	+0,02	
U1	7,30	+0,02	
U2	6,50	+0,02	
U3	4,60	+0,02	
V	14,15	−0,02	
W	10,75	−0,02	
Y	5,35	+0,02	

Notes to Table A-10:

(1) MTG-H1A and MTG-H2A

(2) MTG-H1B and MTG-H2B

A.1.2.1.2 Gauge MTG-H3

Figure A-14 and Table A-11 define gauge MTG-H3. The purpose of gauge MTG-H3 is to verify the maximum of Holder dimension A. The gauge MTG-H3 shall not fit into the Holder under test.

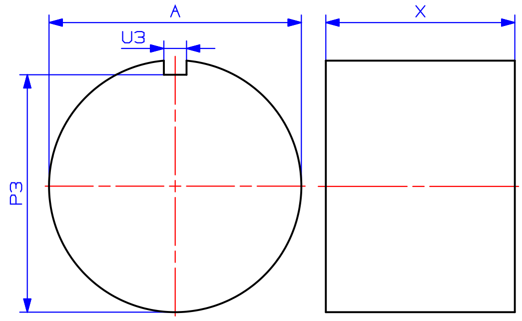

Figure A-14 : Dimensions of MTG-H3

Table A-11: Dimensions of MTG-H3

Dimension	Nominal	Tolerance	Notes
A	66,55	−0,02	
P3	62,80	±0,10	
U3	6,00	±0,10	
X	50,00	±1,00	

A.1.2.1.3 Gauge MTG-H4

Figure A-15 and Table A-12 define gauge MTG-H4. The purpose of gauge MTG-H4 is to verify the functionality of the keying tab (defined by dimensions P3 and U3, Figure 3-8 in Section 3.3.3) in the Holder, taking into account tilted insertion of the gauge. The gauge MTG-H4 shall not fit into the Holder under test.

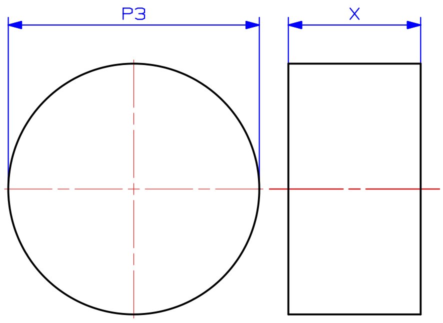

Figure A-15 : Dimensions of MTG-H4

Table A-12: Dimensions of MTG-H4

Dimension	Nominal	Tolerance	Notes
P3	64,40	−0,02	
X	35,00	±1,00	

A.1.2.1.4 Gauges MTG-H5 and MTG-H6

Figure A-16 and Table A-13 define gauges MTG-H5 and MTG-H6. The purpose of these gauges is to verify the minimum of Holder dimensions A, D, D1, G1, G2, G3, H, J, P3, RH, U1, and U2. Gauge MTG-H5 shall fit axially into a PHJ65d-1 Holder under test, and shall not fit into a PHJ65d-2 Holder under test. Gauge MTG-H6 shall fit axially into a PHJ65d-2 Holder under test, and shall not fit into a PHJ65d-1 Holder under test.

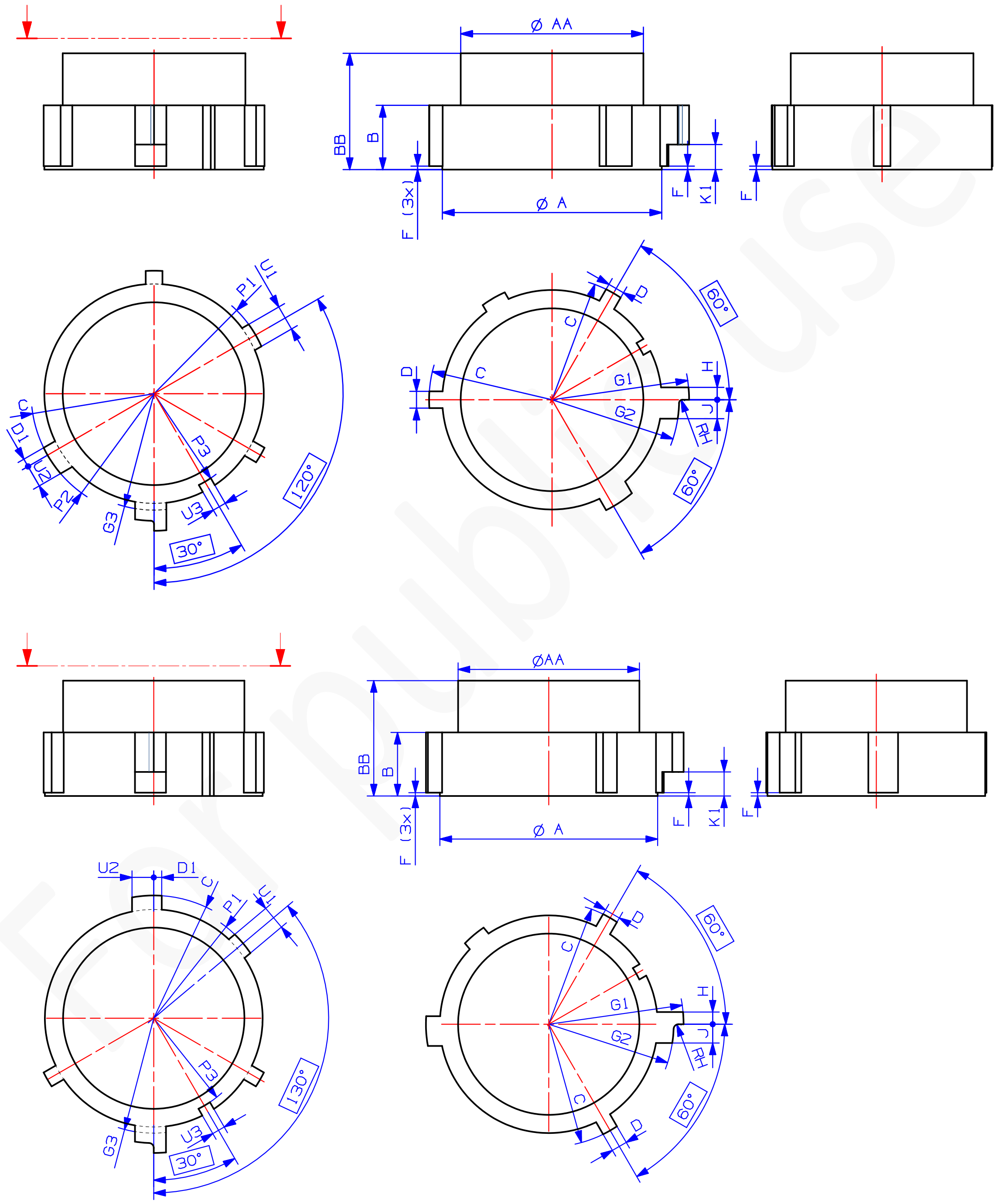

Figure A-16 : Dimensions of MTG-H5 (top) and MTG-H6 (bottom)

Table A-13: Dimensions of MTG-H5 and MTG-H6

Dimension	Nominal	Tolerance	Notes
A	66,05	+0,02	
AA	55,00	±1,00	
B	19,35	±0,10	
BB	35,00	±1,00	
C	37,00	+0,02	
D	5,05	+0,02	
D1	2,53	+0,01	
F	1,00	+0,10	
G1	41,25	+0,02	
G2	38,25	+0,02	
G3	35,05	+0,02	
H	3,70	+0,02	
J	5,70	+0,02	
K1	7,50	+0,10	
P1	35,30	+0,02	
P2	37,00	+0,02	
P3	30,65	+0,02	
RH	1,00	−0,02	
U1	7,65	+0,02	
U2	6,75	+0,01	
U3	4,13	+0,02	

A.1.2.1.5 Gauge MTG-H7

Figure A-17 and Table A-14 define gauge MTG-H7. The purpose of gauge MTG-H7 is to verify the contact making properties of the Holder. Therefore, gauge MTG-H7 shall be manufactured from one of the materials listed in [IEC60838], Annex B. It shall be possible to fully insert gauge MTG-H7 into a Holder under test, and rotate this gauge to the stop position in a clockwise direction. In addition, with gauge MTG-H7 in the stop position, the measured electrical resistance between the two mains terminals of the Holder under test shall be at most 0,1 Ω.

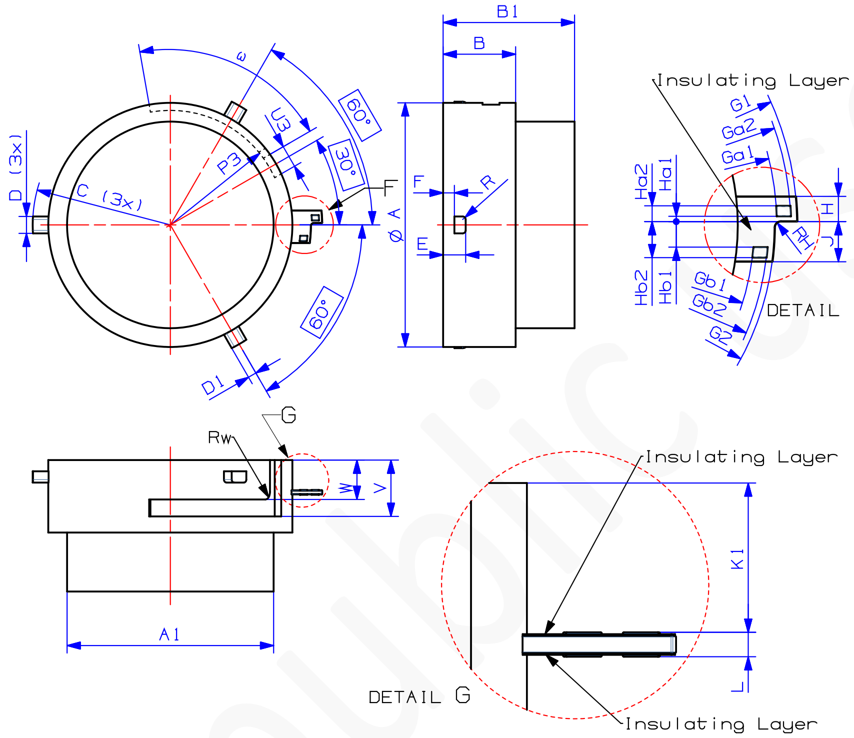

Figure A-17 : Dimensions of MTG-H7

Table A-14: Dimensions of MTG-H7

Dimension	Nominal	Tolerance	Notes
A	65,20	+0,02	
A1	55,00	±0,10	
B	20,00	±0,10	
B1	35,00	±0,10	
C	36,30	±0,1	
D	4,50	+0,02	
D1	2,25	+0,01	
E	6,00	−0,10	
F	1,00	+0,10	
G1	40,45	+0,02	
G2	37,45	+0,02	
Ga1	37,10	±0,02	
Ga2	40,22	±0,02	
Gb1	34,10	±0,02	
Gb2	37,22	±0,02	
H	3,35	+0,02	
Ha1	0,70	±0,02	
Ha2	3,12	±0,02	
Hb1	2,40	±0,02	
Hb2	4,82	±0,02	
J	5,35	+0,02	
K1	8,05	−0,02	
L	1,06	±0,06	
P3	30,50	−0,20	
R	1,00	±0,10	
RH	0,90	+0,02	
Rw	2,00	±0,20	
U3	4,60	±0,10	
V	15,00	±0,10	
W	10,00	±0,10	
ω	26,00°	+60,00°	

A.1.2.1.6 Gauge MTG-H8 and MTG-H9

Figure A-16 (shown in Section A.1.2.1.4) and Table A-15 define gauges MTG-H8 and MTG-H9.[11] The purpose of these gauges is to verify the minimum of Holder dimensions A, D, D1, G1, G2, G3, H, J, P3, RH, U1, and U2. Gauge MTG-H8 shall fit axially into a PHJ65d-1 Holder under test, and shall not fit into a PHJ65d-2 Holder under test. Gauge MTG-H9 shall fit axially into a PHJ65d-2 Holder under test, and shall not fit into a PHJ65d-1 Holder under test.

Table A-15: Dimensions of MTG-H8 and MTG-H9

Dimension	Nominal	Tolerance	Notes
A	65,15	+0,02	
AA	55,00	±1,00	
B	19,30	±0,10	
BB	35,00	±1,00	
C	36,25	+0,02	
D	4,30	+0,02	
D1	2,15	+0,01	
F	1,00	+0,10	
G1	40,40	+0,02	
G2	37,40	+0,02	
G3	34,25	+0,02	
H	3,30	+0,02	
J	5,30	+0,02	
K1	7,50	+0,10	
P1	34,85	+0,02	
P3	30,55	−0,02	
RH	0,90	−0,02	
U1	6,75	+0,02	
U2	5,65	+0,01	
U3	4,65	+0,02	

[11]Note that the drawings of gauges MTG-H8 respectively MTG-H9 are identical to the drawings of gauges MTG-H5 respectively MTG-H6.

A.1.2.1.7 Gauge MFG type A and type B

Figure A-18 and Table A-16 define gauges MFG type A and type B. The purpose of these gauges is to verify the minimum and maximum forces applied by the Holder under test to a Socketable LLE.

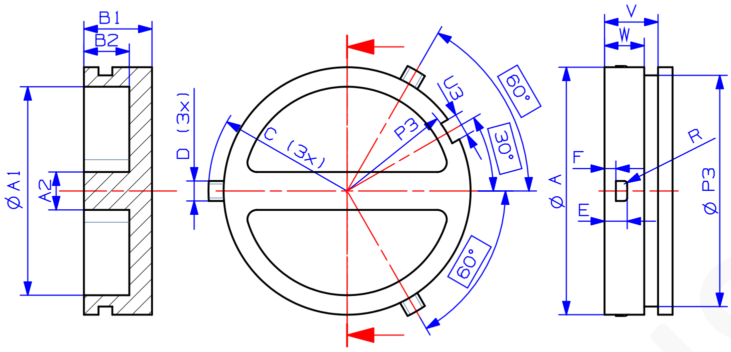

Figure A-18 : Dimensions of MFG type A and type B

Table A-16: Dimensions of MFG type A and type B

Dimension	Nominal	Tolerance	Notes
A	65,30	±0,05	
A1	55,00	±0,10	
A2	10,00	±0,10	
B1	18,00	±0,10	
B2	12,00	±0,10	
C	36,65	±0,10	
D	4,50	+0,02	
E	6,10	+0,02	(1)
	5,70	−0,02	(2)
F	2,00	±0,10	
P3	29,00	−0,20	
R	0,80	±0,10	
U3	6,00	±0,10	
V	15,00	±0,05	
W	7,80	±0,05	

Note to Table A-16:

(1) Type A

(2) Type B

Figure A-19 and Table A-17 define a mounting platform for the Holder under test. Figure A-20 shows the assembly of the mounting platform, a force transducer, and the Holder under test.

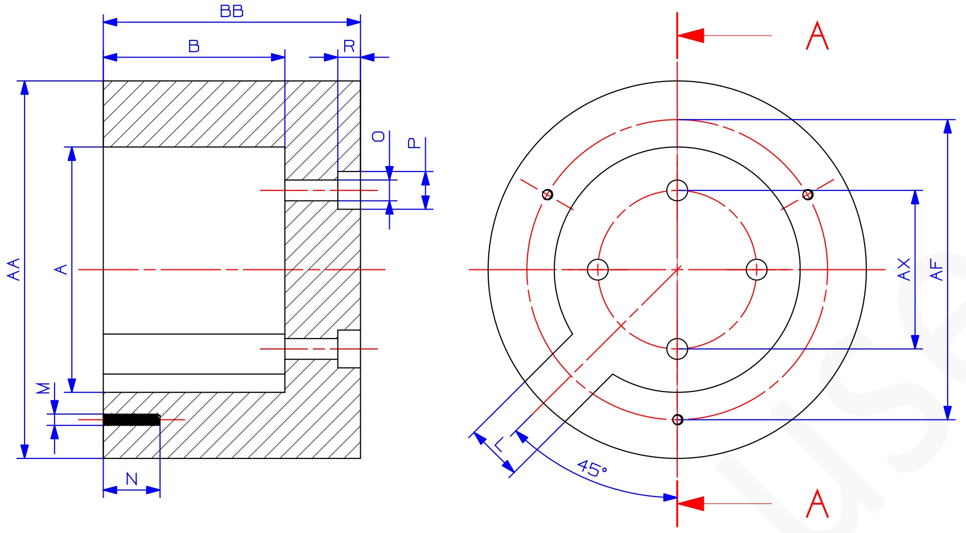

Figure A-19 : Mounting platform

Table A-17: Mounting platform

Dimension	Nominal	Tolerance	Notes
A	66,00	±0,10	
AA	100,00	±0,10	
AF	79,50	±0,10	
AX	42,00	±0,10	
B	48,00	±0,10	
BB	68,00	±0,10	
L	15,00	±0,10	
M	M3	NA	
N	15,00	±0,10	
O	5,50	±0,10	
P	10,00	±0,10	
R	6,00	±0,10	

Gauges MFG type A and type B shall be used as follows:

(1) Mount the force transducer into mounting platform, using four hexagonal socket head cap screws.

(2) Assemble the Holder under test onto the mounting platform.

(3) Put the calibration disc on top of the force transducer.

(4) Insert gauge MFG type A into the Holder, set the read-out unit to zero, and subsequently rotate gauge MFG type A to the locked position, and verify that the measured force does not exceed 50 N.

(5) Insert gauge MFG type B into the Holder, set the read-out unit to zero, and subsequently rotate gauge MFG type B to the locked position, and verify that the measured force exceeds 25 N.

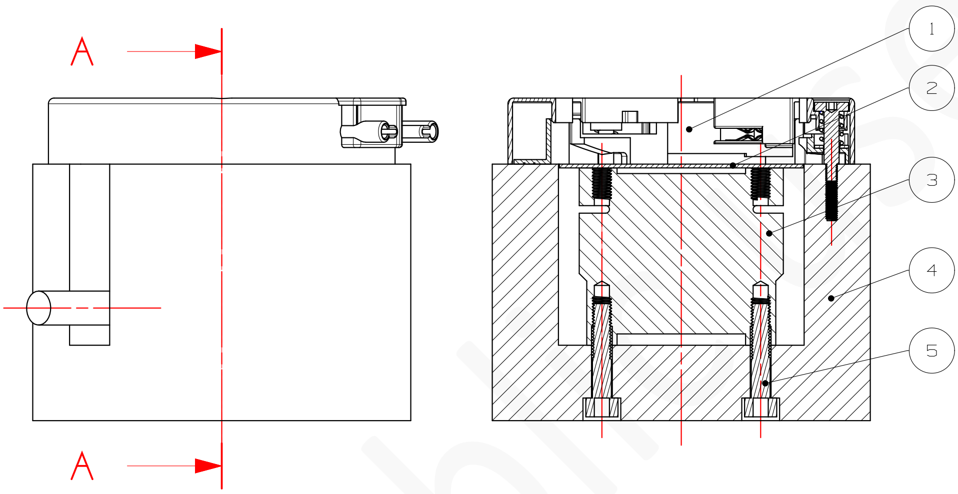

Figure A-20 : Assembly of mounting platform, force transducer and Holder under test

Components in Figure A-20:

(1) Holder under test.

(2) Calibration disc. This disc has a diameter of 65,50 ± 0,10 mm, and thickness that is adjusted such that the top surface of this disc is aligned with an accuracy of ±0,01 mm to the top surface of the housing for MFG type A and type B (component 4).

(3) Force transducer according to VDI/VDE 2638—e.g. Hottinger Baldwin Messtechnik GmbH (Germany), product U93/1—in combination with a suitable readout unit (not shown)—e,g, . Hottinger Baldwin Messtechnik GmbH (Germany), product MVD2555.

(4) Housing for MFG type A and type B.

(5) Screw M5×25 hexagonal socket head cap screw, stainless steel (4×).

A.1.3 Luminaire testing tools

A.1.3.1 Thermal Test Engine TTE-PHJ65d (thermal engine)

Figure A-21, Figure A-22, and Table A-18 define Thermal Test Engine TTE-PHJ65d.

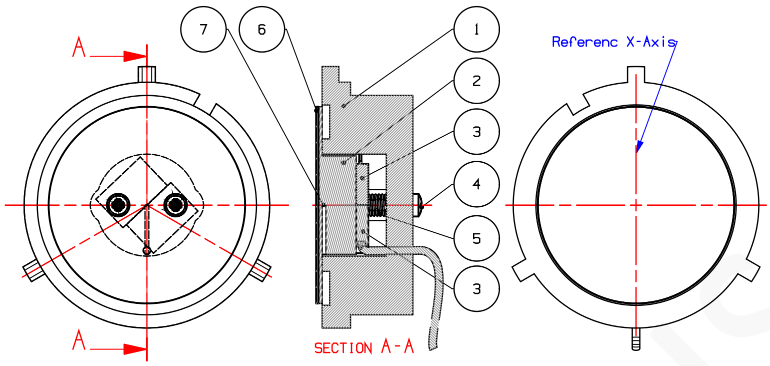

Figure A-21: Thermal Test Engine TTE-PHJ65d — composition

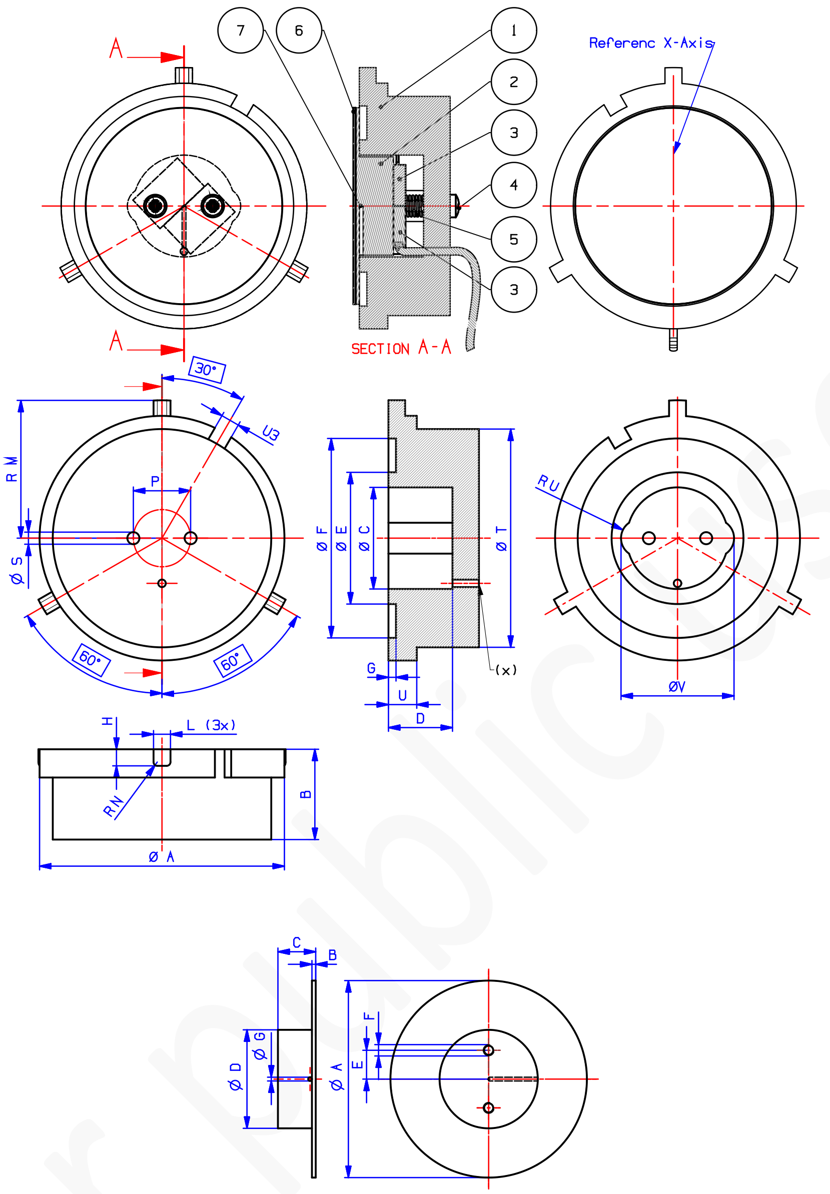

Figure A-22: Thermal Test Engine TTE-PHJ65d — force inducer (top) and power inducer (bottom)

Components in Figure A-21:

(1) Force inducer, see Figure A-22 left, 30% glass-filled PBT or equivalent.

(2) Power inducer, see Figure A-22 right, AlMgSiMn 100HV (AA6082) or equivalent.

(3) Power resistors, type Vishay-LTO-30 or equivalent. Alternatively, a single power resistor (Vishay LTO-100 or equivalent) may be used, if a proper thermal and mechanical balance is ensured.

(4) Screw M3×18, stainless steel.

(5) Helical compression spring, 1…10 N in compressed state.

(6) Laird Technologies HR620 TIM plus liner (maximum thickness: 0,60 mm).

(7) Thermocouple for measuring the temperature t_r' of the Thermal Test Engine TTE-PH65d with an accuracy of ± 1 K. The wire thickness shall not affect the measurement result.

Table A-18: Force inducer (top) and power inducer (bottom) dimensions

Dimension	Nominal	Tolerance	Notes
A	65,00	±0,1	
B	24,00	±0,1	
C	27,00	±0,1	
D	17,00	±0,1	
E	35,00	±0,1	
F	53,00	±0,1	
G	2,00	±0,1	
H	4,40	±0,05	
L	4,50	±0,1	
P	15,20	±0,1	
RN	1,00	±0,1	
RM	36,65	±0,1	
RU	5,00	±0,1	
S	3,20	±0,1	
T	58,00	±0,1	
U	7,50	±0,1	
U3	5,00	±0,1	
V	30,00	±0,1	
A	52,00	±0,1	
B	1,00	±0,05	
C	10,00	±0,1	
D	26,00	±0,1	
E	7,60	±0,1	
F	M3	NA	
G	1,00	±0,1	

A.2 Socketable LLE tests

All tests defined in this Annex A.2 shall be performed on 1 specimen of a Socketable LLE.

A.2.1 Mechanical interface tests

The mechanical dimensions of the Socketable LLE under test shall be verified using the mechanical test gauges defined in Annex A.1.1.1. Note that in addition to the dimensions of these mechanical test gauges, Annex A.1.1.1 also defines the usage of these mechanical test gauges.

A.2.1.1 Mass

A.2.1.1.1 Test Purpose (informative)

The purpose of this test is to verify that the mass of the Socketable LLE under test does not exceed the maximum allowed value.

A.2.1.1.2 Required tools

- Balance. The accuracy of the balance shall be ±1 g.

A.2.1.1.3 Test conditions

Not applicable

A.2.1.1.4 Test Procedure

Determine the mass of the Socketable LLE.

A.2.1.1.5 Test result

The Socketable LLE under test passes if the mass of the Socketable LLE is less than or equal to 201 g.

A.2.2 Photometric Interface tests

A.2.2.1 Total luminous flux

A.2.2.1.1 Test purpose (informative)

The purpose of this test is to verify the Rated total luminous flux of the Socketable LLE under test.

A.2.2.1.2 Required tools

- Test Fixture OETF-PHJ65d-*x*.
- A sphere-spectroradiometer system, 1 m diameter minimum, 2π geometry.[12] This system shall be calibrated against total spectral radiant flux standards traceable to a NMI. The accuracy of this system shall be $\pm$5%.

A.2.2.1.3 Test conditions

See Section 4.2. Test Fixture OETF-PHJ65d-*x* shall regulate the temperature of the Thermal Interface Surface of the Socketable LLE under test to within $\pm$1 °C of the Rated operating temperature.

A.2.2.1.4 Test procedure

- Lock the Socketable LLE under test into position in Test Fixture OETF-PHJ65d-*x*, and connect to mains power as appropriate for the Socketable LLE under test.
- Wait until the temperature at the Thermal Interface Surface is stable, as defined in Section 4.2 (see Annex A.2.2.1.3).
- Perform the test as described in [IES LM-79-08], Section 9.1.

A.2.2.1.5 Test result

The Socketable LLE under test passes if the measured total luminous flux lies within the range listed in Table A-19 that is appropriate for the Rated total luminous flux.

Table A-19: Luminous flux categories

Flux category name	Luminous flux [lm]		
	Minimum		Maximum
C006	513,0		840,0
C008	684,0		1155,0
C011	940,5		1575,0
C015	1282,5		2100,0
C020	1710,0		2625,0
C025	2137,5		3150,0
C030	2565,0		4200,0
C040	3420,0		5250,0
C050	4275,0		NA

[12] See [IES LM-79-08], Section 9.1 and sub Sections therein. (Informative) *For additional information with respect to measurements with integrating sphere photometers see [CIE 84].*

A.2.2.2 Luminous intensity distribution

A.2.2.2.1 Test purpose (informative)

The purpose of this test is to verify the—approximate—lambertian character of the luminous intensity distribution of the Socketable LLE under test.

A.2.2.2.2 Required tools

- Test Fixture OETF-PHJ65d-*x*.
- A goniophotometer system. The accuracy of the goniophotometer system shall be ±2%.

A.2.2.2.3 Test conditions

See Section 4.2. Test Fixture OETF-PHJ65d-*x* shall regulate the temperature of the Thermal Interface Surface of the Socketable LLE under test to within ±1 °C of the Rated operating temperature.

A.2.2.2.4 Test procedure

- Lock the Socketable LLE under test into position in Test Fixture OETF-PHJ65d-*x*, and connect to mains power as appropriate for the Socketable LLE under test.
- Wait until the temperature at the Thermal Interface Surface is stable, as defined in Section 4.2 (see Annex A.2.2.2.3).
- Perform the test as described in [IEC/TR 61341], Sections 5 and 6.[13]

A.2.2.2.5 Test result

The Socketable LLE under test passes if the measured luminous intensity satisfies the distribution defined in Table A-20.

Table A-20: Luminous intensity distribution

γ_1	γ_2	Partial relative luminous flux [%]		
		Minimum	Nominal	Maximum
0°	41,4°	35		55
41,4°	60°	25		40
60°	75,5°	10		30
75,5°	90°	0		10

[13](Informative) *For additional information with respect to measurements with a goniophotometer see [CIE 121].*

A.2.2.3 Correlated color temperature

A.2.2.3.1 Test purpose (informative)

The purpose of this test is to verify the Rated correlated color temperature of the Socketable LLE under test.

A.2.2.3.2 Required tools

- Test Fixture OETF-PHJ65d-*x*.

A.2.2.3.3 Test conditions

See Section 4.2. Test Fixture OETf-PHJ65d-*x* shall regulate the temperature of the Thermal Interface Surface of the Socketable LLE under test to within ±1 °C of the Rated operating temperature.

A.2.2.3.4 Test procedure

- Lock the Socketable LLE under test into position in Test Fixture OETF-PHJ65d-*x*, and connect to mains power as appropriate for the Socketable LLE under test.
- Wait until the temperature at the Thermal Interface Surface is stable, as defined in Section 4.2 (see Annex A.2.2.3.3).
- Perform the test as described in [ANSI C78.377], with an accuracy of 0,002 for the chromaticity coordinates.[14]

A.2.2.3.5 Test result

The Socketable LLE under test passes if the measured 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.

[14](Informative) *For additional information with respect to color rendering of white LED light sources see [IES LM-79-08].*

A.2.2.4 Color rendering index

A.2.2.4.1 Test purpose (informative)

The purpose of this test is to verify the Rated color rendering index of the Socketable LLE under test.

A.2.2.4.2 Required tools

- Test Fixture OETF-PHJ65d-*x*.
- Test color samples as specified in [CIE 13.3].

A.2.2.4.3 Test conditions

See Section 4.2. Reference OT shall regulate the temperature of the Thermal Interface Surface of the Socketable LLE under test to within ±1 °C of the Rated operating temperature.

A.2.2.4.4 Test procedure

- Lock the Socketable LLE under test into position in Test Fixture OETF-PHJ65d-*x*, and connect to mains power as appropriate for the Socketable LLE under test.
- Wait until the temperature at the Thermal Interface Surface is stable, as defined in Section 4.2 (see Annex A.2.2.4.3).
- Perform the test as described in [CIE 13.3], with an accuracy of 0,5 point.[15]

A.2.2.4.5 Test result

The Socketable LLE under test passes if the measured color rendering index is not less than the Rated color rendering index minus 3 points.

[15](Informative) *For additional information with respect to color rendering of white LED light sources see [IEC/PAS 62717].*

A.2.3 Electrical interface tests

A.2.3.1 Power use

A.2.3.1.1 Test purpose (informative)

The purpose of this test is to verify the Rated power usage of the Socketable LLE under test.

A.2.3.1.2 Required tools

- Test Fixture OETF-PHJ65d-*x* or Test Fixture TPTF-PHJ65d-*x*.
- Power meter. The accuracy of the power meter shall be ±0,5%.

A.2.3.1.3 Test conditions

See Section 4.2. The Test Fixture shall regulate the temperature of the Thermal Interface Surface of the Socketable LLE under test to within ±1 °C of the Rated operating temperature. The orientation of the Test Fixture shall be vertical base up, unless the data sheet of the Socketable LLE under test indicates otherwise.

A.2.3.1.4 Test procedure

- Lock the Socketable LLE under test into position in the Test Fixture—either Test Fixture OETF-PHJ65d-*x* or Test Fixture TPTF-PHJ65d-*x*—and connect to mains power as appropriate for the Socketable LLE under test.
- Wait until the temperature at the Thermal Interface Surface is stable, as defined in Section 4.2 (see Annex A.2.3.1.3).
- Use the wattmeter to determine the power usage of the Socketable LLE under test.

A.2.3.1.5 Test result

The Socketable LLE under test passes if the measured value is below 100,5% of the maximum power specified in Table 5-1.

A.2.4 Thermal interface tests

A.2.4.1 Temperature uniformity

A.2.4.1.1 Test purpose (informative)

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

A.2.4.1.2 Required tools

- Test Fixture TUTF-PHJ65d-*x*.

A.2.4.1.3 Test conditions

See Section 6.3.2. Test Fixture TUTF-PHJ65d-*x* shall regulate the temperature of the Thermal Interface Surface of the Socketable LLE under test to within ± 1 °C of the Rated operating temperature. The orientation of Test Fixture TUTF-PHJ65d-*x* shall be vertical base up, unless the data sheet of the Socketable LLE under test indicates otherwise.

A.2.4.1.4 Test procedure

- Lock the Socketable LLE under test into position in Test Fixture TUTF-PHJ65d-*x*, and connect to mains power as appropriate for the Socketable LLE under test.
- Wait until the temperature at the Thermal Interface Surface is stable, as defined in Section 6.3.2 (see Annex A.2.4.1.4).
- Measure the temperatures t_i, $i = 0,1, \dots ,6$.
- Determine the maximum temperature difference $t_{\text{grad}} = \max(t_i) - \min(t_j)$, $i, j = 0,1, \dots ,6$, where $\max(t_i)$ means to take the maximum of the measured temperatures, and $\min(t_j)$ means to take the minimum of the measured temperatures.
- Determine the maximum thermal spreading resistance $R_{\text{sp}}^{\text{max}} = t_{\text{grad}}/P_{\text{th,rear}}$, where $P_{\text{th,rear}}$ is the thermal power as determined from the test defined in Annex A.2.4.3). The maximum thermal spreading resistance shall be determined with an accuracy of at least $\pm 80\%$.

A.2.4.1.5 Test result

The Socketable LLE under test passes in $R_{\text{sp}}^{\text{max}} \leq 0{,}36$ K/W.

A.2.4.2 Maximum total thermal Power generated

A.2.4.2.1 Test Purpose (informative)

The purpose of this test is to verify the Rated maximum total thermal power of the Socketable LLE under test.

A.2.4.2.2 Required Tools

See Annex A.2.2.1.2 and Annex A.2.3.1.2.

A.2.4.2.3 Test conditions

See Annex A.2.2.2.3 and Annex A.2.3.1.3

A.2.4.2.4 Test procedure

- Lock the Socketable LLE under test into position in Test Fixture OETF-PHJ65d-*x*, and connect to mains power as appropriate for the Socketable LLE under test.
- Wait until the temperature at the Thermal Interface Surface is stable, as defined in Section 4.2 (see Annex A.2.2.1.3).
- Determine the total spectral radiant flux P_{rad} as described in [IES LM-79-08], Section 9.1.
- Use the power meter to determine the power usage P_{el} of the Socketable LLE under test.
- Determine the total thermal power as $P_{\text{th}} = P_{\text{el}} - P_{\text{rad}}$, with an accuracy of at least $\pm 10\%$.

A.2.4.2.5 Test result

The Socketable LLE under test passes if the measured total thermal power P_{th} shall not exceed the Rated maximum total thermal power by more than 10%.

A.2.4.3 Maximum thermal power at the Thermal Interface Surface

The Rated maximum thermal power at the Thermal Interface Surface ($P_{\mathrm{th,rear}}$) of the Socketable LLE under test shall be verified according to the test and pass criteria defined in [Book 1], Annex A.1.3.2 and Annex A.1.3.3. For this purpose:

- The test shall be performed using test fixture TPTF-PHJ65d-*x*, as defined in Annex A.1.1.4, with the LLE under test mounted Base down, such that convective air flow is not obstructed.
- The Reference Temperature shall be measured using the thermocouple provided in the test fixture.
- Only the TIM that is part of, or supplied with the LLE under test shall be used.
- For calibration of the test setup, the electrical power applied to the correction heater of the test set up shall be $P_n = n \cdot 10$ W, with $n = 1, \ldots, 9$.

A.2.5 Control interface tests

A.2.5.1 Dimming

This test applies only if the data sheet of the Socketable LLE under test indicates that dimming functionality is supported.

A.2.5.2 Test purpose (informative)

The purpose of this test is to verify the dimming functionality of the Socketable LLE under test.

A.2.5.3 Required Tools

See [NEMA SSL 7A] Section 4.9 and [NEMA SSL 7A] Section 4.10

A.2.5.4 Test conditions

See [NEMA SSL 7A] Section 4.9 and [NEMA SSL 7A] Section 4.10

A.2.5.5 Test procedure

See [NEMA SSL 7A] Section 4.9 and [NEMA SSL 7A] Section 4.10

A.2.5.6 Test result

The Socketable LLE under test passes if the requirements of [NEMA SSL 7A] Section 4.9.2 and [NEMA SSL 7A] Section 4.10.2 are satisfied.

A.3 Holder tests

All tests defined in this Annex A.3 shall be performed on 1 specimen of a Holder.

A.3.1 Mechanical interface tests

The mechanical dimensions of the Holder under test shall be verified using the mechanical test gauges defined in Annex A.1.2.1. Note that in addition to the dimensions of these mechanical test gauges, Annex A.1.2.1 also defines the usage of these mechanical test gauges.

A.3.2 Photometric Interface tests

This edition 1.3 of Book 2 of the Zhaga Interface Specification does not define optical interface tests for the Holder.

A.3.3 Electrical interface tests

This edition 1.3 of Book 2 of the Zhaga Interface Specification does not define electrical interface tests for the Holder.

A.3.4 Thermal interface tests

This edition 1.3 of Book 2 of the Zhaga Interface Specification does not define thermal interface tests for the Holder.

A.3.5 Control interface tests

This edition 1.3 of Book 2 of the Zhaga Interface Specification does not define control interface tests for the Holder.

A.4 Luminaire tests

All tests defined in this Annex A.4 shall be performed on 1 specimen of a Luminaire.

A.4.1 Mechanical interface tests

The mechanical interface tests of a Luminaire are identical to the mechanical interface tests of a Holder. See Annex A.3. As an exception, there is no need to apply the tests defined in Annex A.1.2.1.7.

A.4.2 Photometric Interface tests

This edition 1.3 of Book 2 of the Zhaga Interface Specification does not define tests for the optical interface of a Luminaire.

A.4.3 Electrical interface tests

The electrical interface tests of a Luminaire are identical to the electrical interface tests of a Holder. See Annex A.3.

A.4.4 Thermal interface tests

A.4.4.1 Thermal resistance

A.4.4.1.1 Test purpose (informative)

The purpose of this test is to verify the Rated thermal resistance of the Luminaire under test.

A.4.4.1.2 Required tools

- Thermal Test Engine TTE-PHJ65d.

A.4.4.1.3 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 data sheet of the Luminaire under test. The ambient air temperature in the room, at a distance of at most 1 m from the edge of the Luminaire, shall be (25 ± 5) °C. Motion of the ambient air throughout the closed room shall not exceed 15 cm/s, unless caused by the operation of the Luminaire.

A.4.4.1.4 Test procedure

- Lock Thermal Test Engine TTE-PHJ65d into position in the Luminaire under test, and configure Thermal Test Engine TTE-PHJ65d to generate 10 W of thermal power.
- Wait until the temperature t_r' of the Thermal Test Engine TTE-PHJ65d 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%.
- Measure the temperature t_r' with an accuracy of at least $\pm$0,5 °C.
- Measure the temperature t_a with an accuracy of at least $\pm$1,0 °C.
- Determine the thermal resistance of the Luminaire under test as

  $$R_{\text{th,rear}} = \frac{t_r' - \Delta t_{\text{TIM}}(P_{\text{th}}) - t_a}{P_{\text{th}}}$$

  where P_{th} is the thermal power generated in Thermal Test Engine TTE-PHJ65d, $\Delta t_{\text{TIM}}(P_{\text{th}})$ is a correction for the temperature drop over the TIM as defined in Table A-21, and t_a is the temperature of the ambient air (see also Section 6.1).
- Repeat the above four steps with Thermal Test Engine TTE-PHJ65d configured to consume respectively 20 W, 30 W, and 40 W of electrical power, insofar as these do not exceed any Rated maximum thermal power of the Luminaire under test.

Table A-21: Correction for temperature drop over TIM

P_{th} [W]	Δt_{TIM} [°C]
10	4,9
20	9,7
30	14,4
40	19,1

A.4.4.1.5 Test result

The Luminaire under test passes if

- the thermal resistance $R_{\text{th,rear}}$ as determined in the test using a 10 W load from the Thermal Test Engine does not exceed the Rated thermal resistance at 10 W thermal power applied to the heat sink by more than 10%; and

- (if applicable) the thermal resistance $R_{\mathrm{th,rear}}$ as determined in the test using a 20 W load from the Thermal Test Engine does not exceed the Rated thermal resistance at 20 W thermal power applied to the heat sink by more than 10%; and
- (if applicable) the thermal resistance $R_{\mathrm{th,rear}}$ as determined in the test using a 30 W load from the Thermal Test Engine does not exceed the Rated thermal resistance at 30 W thermal power applied to the heat sink by more than 10%; and
- (if applicable) the thermal resistance $R_{\mathrm{th,rear}}$ as determined in the test using a 40 W load from the Thermal Test Engine does not exceed the Rated thermal resistance at 40 W thermal power applied to the heat sink by more than 10%.

A.4.5 Control interface tests

A.4.5.1 Dimming

This test applies only if the data sheet of the Luminaire under test indicates that dimming functionality is built-in.

A.4.5.2 Test purpose (informative)

The purpose of this test is to verify the dimming functionality of the Luminaire under test.

A.4.5.3 Required Tools

See [NEMA SSL 7A] Section 3.10. (Informative) *It may be necessary to modify one or more commercially available LLEs in order to construct the test circuit defined in [NEMA SSL 7A].*

A.4.5.4 Test conditions

See [NEMA SSL 7A] Section 3.10.

A.4.5.5 Test procedure

See [NEMA SSL 7A] Section 3.10.

A.4.5.6 Test result

The Luminaire under test passes if the requirements of [NEMA SSL 7A] Section 3.10.2 are satisfied.

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Annex B Product Data Sheet Requirements (Normative)

B.1 Socketable LLE

The data sheet of a Socketable LLE product shall contain at least the following information:

- The mechanical fit (PHJ65d, PHJ65d-1 or PHJ65d-2).
- The Rated operating temperature.
- The total luminous flux at the Rated operating temperature (a flux category name from Table 4-2).
- The color rendering index at the Rated operating temperature.
- The correlated color temperature at the Rated operating temperature.
- The operating mains voltage and frequency.
- The maximum mains power consumed.
- The maximum total thermal power and the maximum thermal power applied at the Thermal Interface Surface.
- The maximum allowable thermal resistance of the Luminaire. The ambient temperature for which this maximum applies is 25 °C, unless explicitly indicated otherwise.
- If dimming functionality is supported, the information required by [NEMA SSL 7A] Section 5.

B.2 Holder

The data sheet of a Holder product shall contain at least the following information:

- The mechanical fit (PHJ65d-1 or PHJ65d-2).

B.3 Luminaire

The data sheet of a Luminaire shall contain at least the following information:

- The mechanical fit (PHJ65d-1 or PHJ65d-2).
- The thermal resistance at 10 W, 20 W, 30 W, and 40 W thermal power applied to the heat sink, insofar as applicable if the Luminaire has a Rated maximum thermal power. The ambient temperature for which these thermal resistances apply is 25 °C, unless explicitly indicated otherwise.
- If dimming functionality is built-in, the information required by [NEMA SSL 7A] Section 5.

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Annex C Safety Requirements (Informative)

International and local regulations require both a Socketable LLE and a Luminaire to comply with several standards for product safety. This Annex C list a number of the most relevant of such standards.

C.1 Socketable LLE requirements

Safety provisions with respect to a Socketable LLE comprise—amongst others—the provisions of [IEC 62031] for a "self-ballasted LED module."

C.2 Holder requirements

Safety provisions with respect to a Holder are defined in [IEC 60061-a], [IEC 600061-b], [IEC 60061-c] and [IEC 60838].

C.3 Luminaire requirements

Safety provisions with respect to a Luminaire are defined in [IEC 60598].

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Annex D History of Changes (Informative)

Table D-1 lists the changes made in Edition 1.3.

Table D-1: Changes from Edition 1.2 to Edition 1.3

Location	Description of Change	Reference
Section 1.4.2	Reference added to NEMA SSL 7A-2013.	CR#845
	Reference added to Book 1	CR#852
Section 7.1	Optional dimming functionality added following NEMA SSL 7A-2013.	CR#845
Table A-14	Tolerance of Ga1, Ga2, Gb1, Gb2, Ha1, Ha2, Hb1, and Hb2 increased to ±0,02 mm. Nominal value of Ga2, Gb2, Ha2, and Hb2 increased by 0,02 mm.	CR#778
Annex A.2.5	Compliance test added for optional dimming.	CR#845
Annex A.2.4.3	Replaced with a reference to Book 1	CR#852
Annex A.4.5	Compliance test added for optional dimming.	CR#845
Annex B.1	Data sheet requirements added for optional dimming.	CR#845
Annex B.3	Data sheet requirements added for optional dimming.	CR#845

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