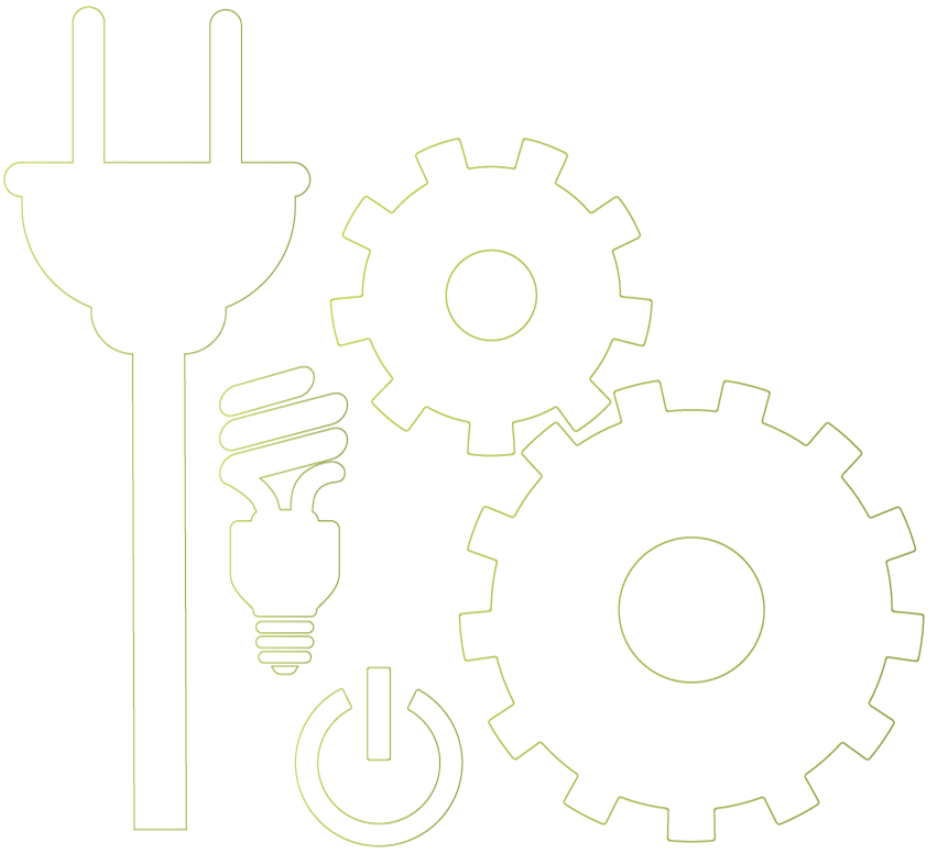
Efficient Electrical End-Use Equipment
International Energy Agency



Solid State Lighting Annex: Interlaboratory Comparison Test Method

VERSION 1.0

Efficient Electrical End-Use Equipment (4E)
International Energy Agency

SSL Annex Task 2

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iea Energy Technology Network

The IEA Implementing Agreement on Efficient Electrical End-Use Equipment (4E)

4E is an International Energy Agency (IEA) Implementing Agreement established in 2008 to support governments to formulate effective policies that increase production and trade in efficient electrical end-use equipment.

Globally, electrical equipment is one of the largest and most rapidly expanding areas of energy consumption which poses considerable challenges in terms of economic development, environmental protection and energy security. As the international trade in appliances grows, many of the reputable multilateral organisations (for example the G8, APEC, IEA and IPEEC2) have highlighted the role of international cooperation and the exchange of information on energy efficiency as crucial in providing cost-effective solutions to climate change.

Thirteen countries have joined together to form 4E as a forum to cooperate on a mixture of technical and policy issues focused on increasing the efficiency of electrical equipment. But 4E is more than a forum for sharing information – it initiates projects designed to meet the policy needs of participants.

Participants find that pooling of resources is not only an efficient use of available funds, but results in outcomes which are far more comprehensive and authoritative. The main collaborative research and development activities under 4E are undertaken within a series of Annexes, each of which has a particular project focus and agreed work plan. These currently comprise:

- **Mapping and Benchmarking**
- **Electric Motor Systems (EMSA)**
- **Standby Power**
- **Solid State Lighting (SSL)**

Current members of 4E are: Australia, Austria, Canada, Denmark, France, Japan, Republic of Korea, The Netherlands, Switzerland, Sweden, UK and USA. Information on the 4E Implementing Agreement is available from: www.iea-4e.org

Current members of the 4E SSL Annex are: Australia, China, Denmark, France, Japan, The Netherlands, Republic of Korea, Sweden, UK and USA. China works as an expert member of the 4E SSL Annex.

This test method has been prepared by the Team working on Task 2 of SSL Annex, with primary contribution by Yoshi Ohno of the National Institute of Standards and Technology (NIST) in Gaithersburg, Maryland, USA.

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Disclaimer

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1 Introduction

This document is prepared as the test method for LED lamps and LED luminaires (referred to as "Solid State Lighting (SSL) products" or simply "products" in this document) to be used in the 2013 Interlaboratory Comparison performed by International Energy Agency (IEA) 4E SSL Annex. This document covers test methods for many of the performance characteristics specified in the IEA 4E "Performance Tiers" [1]. This test method is written so in such a way that the measurement requirements encompass those in IES LM-79-08 [2], EN 13032-4 (Draft) prepared by CEN TC169 WG7 and CIE TC2-71 [3] (excluding the method based on corrections to the standard conditions with no tolerances and the parts on LED modules), the test methods drafts included in the Annexes of IEC performance standards (drafts) on LED lamps and LED luminaires [4], the test methods covering LED lamps and LED luminaires in the Japanese standards: JIS C 7801:2009, JIS C 8105-5:2011, and JIS C 7801 Amendment 1: 2012 [5], and the test methods covered in the Chinese standards: GB standards Drafts for self-ballasted LED reflector lamps, and CQC3127-2010, CQC3128-2010, CQC3129-2010, CQC3130-2011 [6]. By complying with this IEA Interlaboratory Comparison Test Method, all the measurement requirements for LED lamps and LED luminaires in the above listed test methods are considered to be satisfied. This document is to be revised when the referred test method standards drafts have been published.

2 Scope

This document covers test methods for measurements of electrical, photometric, and colorimetric quantities of LED lamps and LED luminaires that are covered in IEA 4E SSL Annex Interlaboratory Comparisons, which deal only with complete SSL products (LED lamps and LED luminaires) that require AC mains power or a DC voltage power in branch circuit to operate. Non-integrated LED lamps (including tubular LED lamp) and luminaires with a separate LED driver (physically separate from the lamp or the luminaire) are also covered in this document if its driver is sold together or clearly specified by the product specification. LED light engines, LED modules and LED packages are not covered in this document. Testing of the lifetime of the products is not covered.

The performance characteristics of SSL products include: voltage (unit: volt), current (unit: ampere), power (unit: Watt), power factor, total harmonic distortion of current, total luminous flux (unit: lumen), luminous efficacy (unit: lumen/Watt), luminous intensity distribution, chromaticity coordinates, correlated colour temperature (CCT), colour rendering index (CRI), and spatial uniformity of chromaticity.

3 Terminology

The terms used in this document follow definitions in CIE S017 (ILV) [7], IEC 62504 [8], IEC 60050 (International Electrotechnical Vocabulary) [9], and LM-79 [2]. Some important terms in these standards are repeated below, and other important terms used as defined in the document are included below.

3.1 Aging (seasoning) [8].
preconditioning period of the LED light source before initial values are taken

3.2 Stabilization [2]
operation of SSL products under test for a sufficient period of time such that the electrical and the photometric, and temperature values become stable

3.3 Ambient temperature [8]
average temperature of air or another medium in the vicinity of the product under test

3.4 LED luminaire [8]
luminaire designed to incorporate one or more LED light source(s)

3.5 Photometer head [2]
unit containing a detector, a V(λ)-correction filter, and any additional components (aperture, diffuser, amplifier, etc.) within the unit as a whole

3.6 Colorimeter head
unit containing filtered detectors to measure the CIE tristimulus values (X, Y, Z), and any additional components (aperture, diffuser, amplifier, etc.) within the unit as a whole

Note: The Y-channel of a colorimeter head works as a photometer head.

3.7 Sphere-photometer
integrating sphere employing a photometer head as the detector

3.8 Sphere-spectroradiometer
Integrating sphere employing a spectroradiometer as the detector.

3.9 Goniophotometer [7]
Photometer for measuring the directional light distribution characteristics of sources, luminaires, media or surfaces

Note: In this document, "goniophotometer" includes gonio-colorimeter and gonio-spectroradiometer.

3.10 Gonio-colorimeter
goniophotometer equipped with a tristimulus colorimeter head as the detector.

Note: A tristimulus colorimeter is an instrument incorporating three or four filtered detectors matching their relative spectral responsivity to the CIE colour matching functions $\overline{x}(\lambda), \overline{y}(\lambda), \overline{z}(\lambda)$. For the details, see Ref. 10.

3.11 Gonio-spectroradiometer
goniophotometer equipped with a spectroradiometer as the detector.

3.12 Absolute photometry (with a goniophotometer)
configuration of a goniophotometer to measure absolute luminous intensity distribution (cd), from which total luminous flux (lm) can be obtained

3.13 Relative photometry (with a goniophotometer)
configuration of a goniophotometer to measure relative luminous intensity distribution, normally in cd per 1000 lm of the light source used in the luminaire

3.14 Traceability [11]
property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty

Note: The ILAC considers the elements for confirming metrological traceability to be an unbroken metrological traceability chain to an international measurement standard or a national measurement standard, a documented measurement uncertainty, a documented measurement procedure, accredited technical competence, metrological traceability to the SI, and calibration intervals (See note 7 of *metrological traceability* [11]).

3.15 National Metrology Institute (NMI)
national laboratory that maintains the SI units for the country and authorized to disseminate the units and calibration standards for measurements

4 Environmental Conditions

4.1 Ambient temperature

4.1.1 The ambient temperature during the measurement of the product shall be maintained at (25 ± 1) °C.

If a laboratory does not meet this requirement, outside the range (25 ± 1) °C and within 21°C to 27°C is allowed only if the results are corrected to the values for 25°C, using the ambient-temperature dependence data for the particular device under test for particular measurement quantities. In this case, the actual measured ambient temperature, method (formula) of correction, and temperature dependence data of the device shall be reported.

4.1.2 The temperature sensor shall be placed at the same height and within 1 m from LED lamp or luminaire under test.

4.1.3 The temperature sensor shall be shielded from direct optical radiation from the SSL product and from any other light source. Environment of the temperature sensor and the lamp or luminaire should not be isolated.

4.1.4 The thermometer shall have resolution of 0.1 °C or less.

Note: It is recommended that the thermometer has a calibration uncertainty[1] of 0.2°C or less.

4.2 Air movement

4.2.1 Air flow around the SSL product being tested should be such that normal convective air flow induced by device under test is not affected. The air flow shall be less than 0.2 m/s.

Note 1: Air flow in an integrating sphere (without forced air cooling system) when closed is considered to be satisfying this requirement.

Note 2: Portable anemometers are commercially available with measurement uncertainty of 0.05 m/s.

Note 3: In case the light source is moved on the goniophotometer during measurements, the moving speed should be chosen adequately to meet the requirement in 4.2.1.

4.3 Laboratory humidity

4.3.1 Relative humidity of the laboratory should be 65 % or less.[2]

5 Mounting Conditions

5.1 Operating position

5.1.1 The operating position of the artefacts used for the Interlaboratory Comparison are specified in the Test Protocol. Measurement shall be made with the artefact operated accordingly.

5.2 Supporting objects

5.2.1 SSL products with a screw base or bayonet shall be supported only by the socket.

5.2.2 LED luminaires shall be mounted to the measuring instrument (integrating sphere or goniophotometer) so that heat conduction through supporting objects causes negligible temperature effects. (The product may be suspended in air by wire or held by support materials that have low heat conductivity, e.g., Teflon).

5.2.3 If the SSL product under test is provided with a support structure that is designated to be used as a component of the luminaire thermal management system, the product shall be tested with the support structure attached.

[1] All uncertainty values stated in this document are expanded uncertainty with a 95 % confidence interval, normally with a coverage factor k=2, as prescribed in [12].
[2] The humidity requirement follows the requirement of the IEC [4] and Chinese [6] test methods.

6 Electrical conditions and measurement

6.1 Operation of SSL product

6.1.1 The SSL product under test shall be operated at the rated voltage (AC or DC) and frequency (for AC operation, normally 50 Hz or 60 Hz) according to the specification of the product under test for its normal use.

Note: Operating voltage and frequency of each SSL product will be provided in the Interlaboratory Comparison Test Protocol prepared by IEA 4E SSL Annex.

6.1.2 The tolerance of the test voltage for AC-input products is ±0.2 % of the rated value and the tolerance of frequency is ±0.2 %. The tolerance of test voltage for DC-input products is ±0.1 % of the rated value.

6.1.3 The voltage shall be measured at the socket (for screw-base or bayonet-base lamps), or at the power input line as close to the product as possible. The measurement position (length from the socket or the power input line) shall be reported.

Note: This is critical especially for low-voltage lamps. For screw base lamps, 4-pole socket is commercially available, which allows measurement of voltage directly across the cap with no effect of contact resistance.

6.1.4 If the product has dimming capability, measurements shall be performed at the maximum input power condition, which should be identified in the Interlaboratory Comparison Test Protocol for each region, if applicable.

6.1.5 Care should be taken when applying the power to the product under test.

Note 1: When applying a constant DC voltage, the voltage should be ramped up slowly to protect the device. Large frame power supplies can apply a surge before recovering to an appropriate DC power.

Note 2: When applying AC voltage, the power supply should be set to come on at a zero degree phase. A few LED drivers that involve capacitors may have a large in-rush current if the AC voltage is applied at a non-zero degree phase.

6.1.6 The voltage (V), current (A), power (W) (RMS for AC operation), and power factor for AC operation, shall be measured at the time photometric measurements are taken.

6.1.7 For AC-input products, if required, the total harmonic distortion of the current waveforms during the operation of the product under test should also be measured. This can be measured with some digital AC power meter or a power analyser.

Note: Measuring total harmonic distortion of voltage waveform may also be useful to reveal the mains impedance effects.

6.2 Electrical instrumentation

6.2.1 The voltage of an AC power supply or DC power supply applied to the product under test shall be regulated to within ±0.2 % (AC) or ±0.1 % (DC) under load.

6.2.2 AC voltage ripple of the DC power supply shall be 0.5 % or less.

6.2.3 The AC power supply shall have a sinusoidal voltage waveshape at the prescribed frequency with the total harmonic distortion not exceeding 3 % under a resistive load.

6.2.4 For AC-input SSL products, an AC power meter shall be connected between the AC power supply and the SSL product under test, and AC power as well as input voltage and current shall be measured.

6.2.5 The AC power meter shall have the capability of measuring power factor. If required by the Interlaboratory Comparison Test Protocol, the AC power meter should also have capability of measuring total harmonic distortion of current (and voltage).

6.2.6 The AC power meter shall have a sampling rate that is capable of resolving the current wave for the SSL product. Many LED drivers based on capacitors and diode bridges have very sharp current waves requiring a high sampling rate. Analogue AC power meters will not measure properly.

Note: IEC 61000-3-2 [13] states that the electrical characteristics of lighting products should be analysed in a frequency range covering the fundamental (50 Hz or 60 Hz) and up the 40^{th} order (2 kHz or 2.4 kHz). IEC 61000-4-7 [14] indicates that power measurement equipment should be able to analyse components up to 9 kHz

6.2.7 The calibration uncertainties (see the Note below) of the instruments for AC voltage and AC current shall be ≤ 0.2 %. The calibration uncertainty of the AC power meter shall be ≤ 0.5 % and that for DC voltage and current shall be ≤ 0.1 %.

Note: Uncertainty here, and throughout this document, refers to relative expanded uncertainty with a 95 % confidence interval, normally with a coverage factor k=2, as prescribed in ISO Guide for expression of uncertainties in measurement [12].

6.2.8 For DC-input SSL products, a DC voltmeter and a DC ammeter shall be connected between the DC power supply and the SSL product under test. The voltmeter is connected across the electrical power inputs of the SSL product (separate from the power supply contacts).

Note: The product of the measured DC voltage and the DC current gives the input electrical power (wattage) of the DC powered SSL products.

7 Seasoning

The Interlaboratory Comparison artefacts shall not be seasoned or pre-burned by the participants. If any pre-burning is required, it will be specified in Interlaboratory Comparison Test Protocol.

8 Stabilization

Prior to taking measurements, the product under test shall be operated at the rated condition to stabilize so that the changes of electrical power and total luminous flux (for integrating sphere) or luminous intensity (for a goniophotometer setup) in a fixed direction are less than 0.5 % over a 30 minute window by monitoring the signal every minute. The actual stabilization time shall be reported for each SSL product tested.

9 Photometric and colorimetric measurement

The following instruments are used for the measurement quantities needed:

- Sphere-spectroradiometer (for total luminous flux, colour quantities, CRI)
- Sphere-photometer (for total luminous flux)
- Goniophotometer with a photometer head (luminous intensity distribution, total luminous flux (if configured for absolute photometry)).
- Gonio-spectroradiometer (luminous intensity distribution, total luminous flux, colour quantities, CRI, chromaticity spatial uniformity)
- Gonio-colorimeter (luminous intensity distribution, total luminous flux, chromaticity spatial uniformity)

9.1 Total luminous flux

9.1.1 Total luminous flux of an SSL product shall be measured using an integrating sphere system (a sphere-spectroradiometer and/or a sphere-photometer) or a goniophotometer (configured for absolute photometry).

Integrating sphere systems

9.1.2 A sphere-spectroradiometer shall be calibrated with a total spectral radiant flux standard traceable to an NMI.

Note 1: If total spectral radiant flux standard lamps are not available from the local NMI, the standard may be derived by the user from spectral irradiance standard lamp(s) and total luminous flux standard lamp(s), both shall be traceable to an NMI. In this case, the derivation methods and related data (e.g., angular uniformity of spectrum or CCT of the standard lamp) shall be reported.

Note 2: It would not be acceptable if the spectroradiometer used with the integrating sphere is calibrated for spectral irradiance only without considering the relative spectral throughput of the integrating sphere. The integrating sphere and

the spectroradiometer together shall be calibrated as one system for total spectral radiant flux.

9.1.3 The spectroradiometer used for the sphere-spectroradiometer system shall cover the wavelength range of at least 380 nm to 780 nm, and the bandwidth (full width half maximum) and scanning interval to be no greater than 5 nm. Wavelength scale uncertainty shall be within 0.3 nm.

9.1.4 A sphere-photometer system or sphere-spectroradiometer system shall be equipped with an auxiliary lamp and self-absorption measurement shall be carried out and correction made for each product under test.

9.1.5 A sphere-photometer shall be calibrated with a total luminous flux standard traceable to an NMI.

9.1.6 A sphere-photometer shall have a total relative spectral responsivity (sphere plus photometer head) that meets the f_1' value [15] of 2% [3] or less. If f_1' of the sphere-photometer exceeds 2%, then f_1' no greater than 6 % is acceptable if spectral mismatch correction is applied to each product tested. For this correction, the relative spectral distribution of the product and the relative spectral responsivity of the sphere-photometer is necessary. In this case, the correction factor and data for spectral mismatch correction shall be reported.

Note 1: If f_1' value of the total sphere system is not available from the manufacturer, guidance on how to measure the relative spectral responsivity of a sphere-photometer system is available in [16].

Note 2: The formula for f_1' and spectral mismatch correction are available in [2], [16].

9.1.7 A combination of a photometer head and a spectroradiometer may also be used, with the photometer head used for luminous flux measurement and the spectroradiometer used for spectral mismatch correction determinations and for measurement of colour quantities.

Note: In this case, the spectroradiometer measures only the relative total spectral radiant flux and needs to be calibrated only for relative total spectral radiant flux scale.

9.1.8 The photometer head of a sphere-photometer and the spectroradiometer input optics at integrating sphere detector port (normally equipped with a diffuser) shall have approximate cosine correction, with the f_2 value [15] of 15 % or less.

9.1.9 Further guidance on construction and use of a sphere-spectroradiometer and a sphere-photometer for measurement of SSL products are available in [2].

Goniophotometer

[3] This is the requirement of the EN 13032-4 (draft). $f_1' \leq 3$ % qualifies for LM-79 and other test methods. See Annex A for the details.

9.1.10 The goniophotometer to be used shall be the type, in which the operating position of the SSL product under test with respect to gravity is not changed (known as Type C in USA [17])[4].

Note: Type C goniophotometers include the moving detector type for relatively short photometric distances (for smaller SSL products) and the moving mirror type for larger photometric distances (larger SSL products or having a narrow beam angle).

9.1.11 For goniophotometers employing a photometer head, the relative spectral responsivity of the photometer head (plus mirror if used) shall have an f_1' value [15] of 1.5 %[5] or less. If the f_1' of the photometer head (or the Y channel of a colorimeter head) of a goniophotometer exceeds 1.5 % (but < 6 %), the spectral mismatch correction shall be applied to each product under test. For this correction, the relative spectral distribution of the product is necessary.

Note: Guidance for spectral mismatch correction is available in [2], [16].

9.1.12 Scanning resolution fine enough to accurately define the test sample shall be used. For typical wide-angle, smooth intensity distributions, a 22.5° lateral (horizontal) and 5° longitudinal (vertical) grid may be acceptable. For reflector lamps, the longitudinal angle increments shall be 1/10 or less of the beam angle (diameter of the angular cone emitting more than 1/2 of the peak intensity) but not larger than 5°. Finer angle resolution (smaller test increments) shall be used where the luminous intensity from the SSL product is changing rapidly or is erratic, such as in beam forming sources.

Note: For SSL products having rapidly changing intensity distribution, measurements may be repeated with another randomly selected vertical reference plane to ensure that results are within laboratory's uncertainty budget for the test.

9.1.13 The goniophotometer used for total luminous flux measurement shall be calibrated for luminous intensity standard or illuminance standard traceable to an NMI, and measured total luminous flux value (lm) shall be verified by measuring a total luminous flux standard traceable to an NMI. Alternately, the goniophotometer system may be calibrated against a total luminous flux standard traceable to an NMI, if the dead angle of the Goniophotometer does not affect the measurement of the total luminous flux standard lamp.

Note 1: For mirror type goniophotometers, a luminous intensity standard lamp is normally used to calibrate the photometer head, in which case, the photometric distance and the reflectance of mirror are automatically included in the calibration.

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[4] Type C is required in IES LM-79. Other types of goniophotometer, if corrections are applied appropriately for the effect of changes of operating position of the SSL product, may qualify for other test methods.

[5] $f_1' \leq 1.5$ % is required in the EN 13032-4 (draft). $f_1' \leq 3$ % qualifies for LM-79 and other test methods. See Annex A for the details

Note 2: Illuminance (lx) integration method may be used only for a goniophotometer with the photometer head rotating (no mirror). In this case, the photometric distance needs to be determined accurately.

9.1.14 Goniophotometers shall have an angular scan range covering the entire solid angle to which the SSL product emits light.

Note: Goniophotometers in general have some angular region (called dead angle) where emission from a light source is blocked by its mechanism, e.g., an arm to hold the light source. Goniophotometers having a large dead angle (exceeding ±10°) should not be used to measure total luminous flux of omnidirectional lamps or luminaires unless appropriate correction procedures are implemented.

9.1.15 Care should be taken to minimize stray light errors.

Note 1: The goniophotometers should be installed in a dark room with low reflectance wall surfaces, and should preferably be equipped with a light trap or light absorbing surface on the opposite side of the mirror or detector on the rotating arm, so that the errors due to reflections and stray light from surrounding surfaces are minimized.

Note 2: The photometer head or spectroradiometer input should be equipped with a hood or aperture screens to receive the light only from the effective angle range of the SSL product under test.

9.2 Luminous intensity distribution

9.2.1 Luminous intensity distribution of an SSL product shall be measured with a goniophotometer that fulfils requirements in 9.1, except the need for verification with total luminous flux standard in 9.1.13. The results are normally expressed in absolute luminous intensity in candela. For relative luminous intensity distribution, there is no need to calibrate the goniophotometer against absolute luminous intensity or illuminance standard.

9.2.2 The coordinate system and geometry for mounting SSL products should follow the general practice used in traditional luminaire testing [17], [18].

9.2.3 A sufficient photometric distance should be used – generally, more than five times of the largest dimension of the test SSL product having broad angular distributions. A longer distance may be needed for narrow beam sources.

9.3 Centre-beam luminous intensity

9.3.1 The centre-beam luminous intensity is the luminous intensity along the centre axis of the SSL product. The centre axis is the axis defined by the SSL product mounting base and the intended direction of the light determined by the optical components built into the SSL product. For further details of measurement conditions, see [23].

9.4 Luminous efficacy

9.4.1 The electrical input power P_{TEST} (W) of the SSL product under test shall be measured according to section 6.

9.4.2 The luminous flux Φ_{TEST} (lm) shall be measured according to section 9.1.

9.4.3 The luminous efficacy η_{v} (lm/W) of the product under test shall be determined by

$$\eta_{\mathrm{v}} = \frac{\Phi_{\mathrm{TEST}}}{P_{\mathrm{TEST}}} \qquad (1)$$

9.5 Colour quantities

9.5.1 Colour quantities to be measured for SSL products include chromaticity coordinates (x, y) and/or (u', v'), correlated colour temperature (CCT), and general Colour Rendering Index (CRI R_a) [21]. Duv [20] and the special CRI (R_i) [21] are optional and to be reported if required in the Interlaboratory Comparison Test Protocol. Colour quantities are calculated from the measured relative spectral power distribution of the SSL product according to the definitions given in [19]-[21].

9.5.2 The colour quantities of SSL products shall be measured as spatially averaged values, with its value at each point weighted by the intensity and the solid angle, over the angular range where light is intentionally emitted from the SSL product.

Note 1: A sphere-spectroradiometer automatically measures the spatially averaged spectral power distribution, from which spatially averaged colour quantities can be calculated. The sphere-spectroradiometer to be used shall meet the requirements in section 9.1.

Note 2: Spatially averaged colour quantities can also be measured with a gonio-spectroradiometer or a gonio-colorimeter. In this case, the angular scan shall be made for at least two vertical planes at 90° apart (ϕ angle), and at 10° increments for a vertical angle scan (θ angle) in each vertical plane. For reflector lamps, the θ angle increments shall be 1/10 or less of the beam angle (diameter of the angular cone emitting more than 1/2 of the peak intensity) but no larger than 10°. The colour quantities and (relative) luminous intensity at each goniometer angle shall be recorded over the angle range where the luminous intensity is more than 10 % of the peak intensity, which are used for the calculation of spatially averaged colour quantities. The colour quantity values are weighted by the solid angle (represented by the θ angle) and the luminous intensity of the point. An example of calculation formulae is available in section 12 of [2].

9.5.3 If a gonio-colorimeter is used, the chromaticity at one of the angular points shall be measured with a spectroradiometer to calibrate the colorimeter head, and all

measured results by the colorimeter shall be corrected based on the spectroradiometer reading.

9.5.4 If necessary, chromaticity spatial uniformity can be measured using a gonio-spectroradiometer or gonio-colorimeter. First, the spatially averaged chromaticity (u'_a, v'_a) is calculated according to 9.5.1 to 9.5.3. The spatial uniformity of chromaticity, $\Delta u'v'$, is determined as the maximum differences in chromaticity (u', v') between the average chromaticity (u'_a, v'_a) and the measured chromaticity coordinates at all angle points measured.

9.6 Lag start time

The lag time is the time needed after switching on for the SSL product to start fully and remain lighted. If measurement is required, the following procedures should be taken.

9.6.1 Lag start time is measured using a fast photometer head (having time constant of less than 10 ms) measuring the relative luminous intensity in one direction near the centre of the beam or relative total luminous flux in an integrating sphere.

9.6.2 The SSL product is thermally stabilized at (25 ± 1) °C without electrical power supplied.

9.6.3 For AC powered products, the AC power supply should start at zero degree phase.

9.6.4 The electrical power is applied with a trigger that simultaneously triggers an oscilloscope that receives the output signal from the photometer head and the voltage signal from the power supply.

9.6.5 The lag time is determined from subtracting the time where the power is initially applied from the time where the photometer signal indicates that the SSL product has started fully.

10 Measurement Uncertainty

The uncertainties should be reported for all measurement results.[6] In reporting uncertainties, the international recommendation [12] should be followed to evaluate and express uncertainties of measurement. For all measurements covered in this document, a coverage factor of k=2 (generally corresponding to a confidence interval of 95 %) shall be used. Guidance on evaluation of uncertainty in photometry is available in [22].

[6] Statement of uncertainty is required in the EN 13032-4 (draft) [3] but not required in other test methods (LM-79, etc.) listed in section 1. See Annex A for the details.

11 References

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11. JCGM 200:2012: International vocabulary of metrology – Basic and general concepts and associated terms (VIM) 3rd edition.
12. ISO, Guide to the Expression of Uncertainty in Measurement, 1st Edition, 1993.
13. IEC 61000-3-2:2005 Limits for harmonic current emissions (equipment input current ≤ 16 A per phase).
14. IEC 61000-4-7:2002/A1:2008 Testing and measurement techniques: general guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto.
15. CIE 69: 1987: Methods of Characterizing Illuminance Meters and Luminance Meters.
16. IESNA LM-78-07, IESNA Approved Method for Total Luminous Flux Measurement of Lamps Using an Integrating Sphere Photometer.
17. IESNA LM-75-01, Goniophotometer Types and Photometric Coordinates.
18. CIE 121:1996, The Photometry and Goniophotometry of Luminaires.
19. CIE 15:2004 Colorimetry, 3rd edition.

20. ANSI NEMA ANSLG C78.377-2008 Specifications for the Chromaticity of Solid State Lighting Products.
21. CIE 13.3-1995: Method of Measuring and Specifying Colour Rendering Properties of Light Sources.
22. CIE 198:2011: Determination of Measurement Uncertainties in Photometry.
23. IEC TR61341:2010 Method of measurement of centre beam intensity and beam angle(s) of reflector lamps.

Annex A: SSL Test Methods Comparison Table

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Thermal Conditions									
Ambient Temperature	25 ±1 °C (4.1.1)	All except JIS	25 ±1 °C (2.2)	25 ±1 °C	25 ±1 °C	25 ±1 °C (A1)	room temperature is within 2 deg. In the range of 21 to 27 °C (5.2) ambient temperature of a lamp is based on a standard or the conditions which were specified. (4.2)	20 to 30 °C (Incandescent lamp, HID lamp, Low-pressure sodium lamp) 23 to 27 °C (Other lamps (include LED))	25 ±1 °C
Outside the specified temperature range	outside the range (21 to 27 °C) is allowed only if all measured results are corrected to the value at 25 °C using the ambient-temperature dependence data of the device for all quantities (total luminous flux, chromaticity, CRI, etc.), which must be tested for the particular device under test. In this case, the measured temperature, method (formula) of correction, and temperature dependence data of the device shall be reported. (4.1.1)	LM79 but considers CEN and JIS	Not specified (not allowed)	Not allowed (in Option 1)			Not specified	Not specified	Not specified
Products with feedback control	Not specified.	LM79	Not specified	Not specified.			Not specified	Not specified	Not specified
Measurement point	Not more than 1 m from device.	LM-79	not more than 1 m from device and at the same height	Shall be measured at horizontal distance maximum 1.5 m			Not specified	at a distance of 0.5 m to 2 m from the end of a luminaire and the temperature sensor of a thermometer shall not be directly subjected to light irradiation of the luminaire.	Not specified
For products specified for ambient temperature other than 25 °C	Not included in RR.	IEC, CEN	Not specified.	When manufacturer specifies ambient temp other than 25 °C, "service factor" shall be measured and reported.	a correction factor will need to be established to correct the measured luminous flux value at 25 °C to the luminous flux value at the declared ambient. This shall be done using relative photometry in a temperature controlled cabinet. (A.1)		Not specified	Not specified	GB: For the lamps with declared applicable ambient temperature range more wide, tests under Tmax±2℃ and Tmin±2℃ should also be performed.

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Temperature measurement resolution	Resolution within 0.1 °C (4.1.4)	CEN	Not specified	Resolution within 0.1 °C			Not specified	Not specified	0.1℃
Temperature measurement uncertainty	Uncertainty ≤ 0.2 °C (guidance) (4.1.4)	CEN	Not specified	Uncertainty ≤ 0.2 °C (guidance)			Not specified	Not specified	Not specified
Relative humidity	Less than 65 % (4.3.1)	IEC, China	Not specified	Not specified	less than 65 % (A.1 of IEC 62717)	less than 65 % (A.1)			less than 65%
Mounting method	Supporting objects shall not cause cooling effect (5.2.1)	LM-79	Supporting objects shall not cause cooling effect (2.3)	Operated in free air			Not specified	Not specified	heat insulation material shall be used
Air flow / Air movement	Air movement shall not exceed 0.2 m/s. (4.2.1)	CEN	Only guidance with no number requirement (2.4)	Air movement shall not exceed 0.2 m/s.	shall be made in a draught free room - see CIE 121, section 4.3.2 (A.1 of IEC 62717)	shall be made in a draught free room - see CIE 121, section 4.3.2 (A.1)	Only guidance with no number requirement (5.2)	Only guidance with no number requirement (7.2)	only guidance without number requirement for normal test. For test under Tmax/Tmin±2℃, shall be ≤0.2m/s
Air velocity measurement uncertainty	≤ 0.05 m/s (recommendation) (4.2.1)	CEN	not required	≤ 0.05 m/s (recommendation)			Not specified	Not specified	Not specified
Electrical Conditions									
Test voltage (AC and DC)	tolerance of within 0.2 % for AC, 0.1% for DC products. (6.1.2)	CEN, IEC	Rated voltage (AC or DC) of the product (7.0) -- no tolerance	tolerance of within 0.2 % for AC, 0.1 % for DC products.	Rated voltage, current, or power with tolerance 0.2 % (A.2.1 of IEC 62717)	Rated voltage, current, or power with tolerance 0.2 % (A.3.1)	Rated electric condition (Volt, Current, power) of the product (4.2) -- no tolerance	Rated electric condition (Volt, Current, power) of the product, or user specified condition (8.2.1) -- no tolerance	AC220V50Hz. For the lamps declaring large voltage range, also Vmax and Vmin
AC power supply THD	≤ 3% (6.2.3)	All	≤ 3% (3.1)	≤ 3%	≤ 3% (A.1 of IEC 62717)	≤ 3% (A.1)	≤ 3% (table.1 informative)	≤ 3% (table.3)	≤ 3%
AC power supply voltage regulation	≤0.2 % (6.2.1)		≤ 0.2 % (3.2)	≤ 0.2 %	≤ 0.2 % (A.1 of IEC 62717)	≤ 0.2 % (A.1)	≤ 0.2% (table.1 informative)	≤ 0.2% (table.3)	≤ 0.2%
DC power supply voltage regulation	≤0.1 % (6.2.1)	CEN	≤ 0.2 % (3.2)	≤ 0.1 %	≤ 0.2 % (A.1 of IEC 62717)	≤ 0.2 % (A.1)	≤ 0.1% (table.1 informative)	≤ 0.1% (table.3)	NA
AC power supply frequency uncertainty	≤ 0.2 % (6.1.2)	CEN, JIS	Not specified	≤ 0.2 %			≤ 0.2% (table.1 informative)	≤ 0.5% (table.4)	Not specified
DC power supply voltage AC ripple	≤ 0.5 % (6.2.2)	CEN	Not specified	≤ 0.5 %			Not specified	≤ 5% (table.3)	NA
AC voltmeter and ammeter uncertainty	≤ 0.2% (6.2.7)		≤ 0.2% (8.2)	≤ 0.2%			≤ 0.2% (table.1 informative)		Not specified

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AC power measurement uncertainty	≤ 0.5% (6.2.7)	LM79 CEN	≤ 0.5% (8.2)	≤ 0.5%			≤ 0.2% (table.1 informative)		Not specified
DC voltage and current measurement Uncertainty	≤ 0.1 % (6.2.7)	LM79	≤ 0.1 % (8.2)				≤ 0.2% (table.1 informative)		NA
Four-wire contacts socket	recommended (6.1.3)	CEN	Not specified.	recommended			Not specified.		Not specified
Test Procedures									
Ageing / Seasoning	No aging. If any pre-burning is required, it will be specified in Round Robin Protocol. (7.)		No aging (4.0)	according to appropriate LED device standard	Not required (but manufacturer can define aging period) (A.2.2 of IEC 62717)	Not required (but manufacturer can define aging period up to 500 h) (A.2.2)	Not specified	Not specified	1000hrs
Stabilization of test device	within 0.5 % in 30 min (8.)	LM-79 (Chinese requirement for change of direction is not considered)	within 0.5 % in 30 min (5.0)	within 0.5 % in 15 min	light output within 0.5 % in 15 min and V, A, W within 1 %. (A.1 of IEC 62717)	light output within 0.5 % in 15 min and power within 1 %. (A.1)	secure the time until optical power is sufficiently stabilized(7.3)	Warm up the luminaire and goniophotometer sufficiently, and after confirming that they become stabilized, perform the measurement. (8.2.1)	within 0.5% in 30min, and should not be change in the same direction
Monitoring stabilization	monitor light output and electrical power every 1 min. (8.)	IEC, CEN, LM79	monitor light output and electrical power at every 15 min or less apart.(5.0)	monitor light output every 1 minute (Power will be added.)	monitor light output every 1 min.	monitor light output every 1 min.	Not specified	for example, measures such as the measurement of luminous intensity performed at intervals of five minutes should be taken.(8.2.1)	monitor the light output and power every 5min
If it takes very long time	not specified	LM79	not specified	Max 45 min for module, lamp Max 150 min for luminaire but declare observed fluctuations	Max 45 min for module, lamp Max 150 min for luminaire (A.1 of IEC 62717)	Max 45 min (A.1)	Not specified	Not specified	not specified
Operating orientation/operating position	Specified by the RR protocol (5.1.1). (cap up for LED lamps)		Use the operating position recommended by the manufacturer (6.0)	LED lamp: cap up unless otherwise specified by the manufacturer		vertical position, cap-up, unless otherwise specified by the manufacturer or responsible vendor.	Not specified	Not specified	base up, if others, should make correction
Different position than specified by the manufacturer (or protocol)	Not specified. (Not allowed)		Not allowed.	Not allowed (in Option 1)			Not specified	Not specified	not specified

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If a number of same type of products are measured	Not applicable for RR.		pre-aging is allowed.		shorter time allowed with 1.05 method (A.1of IEC 62717)	shorter time allowed with 1.05 method. (A.1)	Not specified	Not specified	not specified
LED device with dimming control	Specified by the RR protocol, if such a device is included in RR.		Maximum setting (7.0)	Maximum setting			Not specified	Not specified	maximum power setting
LED device with multiple/variable colour/CCT	Specified by the RR protocol, if such a device is included in RR.		measurement may be made at different modes of operation (and CCTs) if necessary, and such setting conditions shall be clearly reported (7.0)	each defined settings or indicated by the manufacturer			Not specified	Not specified	test under each condition
Integrating Sphere									
Calibration of int. sphere for luminous flux	Calibration by total luminous flux or total spectral radiant flux standards traceable to NMI is required (9.1.2, 9.1.5) If the standard is derived from spectral irradiance standard lamp(s) and total luminous flux standard lamp(s), both shall be traceable to an NMI and the derivation methods and related data (e.g., angular uniformity of spectrum or correlated colour temperature) shall be reported.	LM-79 but consider the fact that total spectral radiant flux standards are not available in many NMIs other than NIST.	Calibration by total luminous flux or total spectral radiant flux standards traceable to NMI is required (9.1.6)	Required, NMI traceable.			Calibration by total luminous flux or total luminous flux standards traceable to NMI is required (5.1)	Out of scope	not specified
Self-absorption measurement for sphere system	Required (9.1.4)	LM-79 CEN	Required (9.1)	Required			if need(7.3,7.4)	Out of scope	required
f1' of sphere photometer	≤ 2 % (9.1.6)	CEN	≤ 3 %	≤ 2 % or 3% still under discussion			≤ 6 %	Out of scope	＜3.5%
f2 of photometer head of sphere system	≤ 15% (9.1.7)	LM79, CEN	≤ 15%	≤ 15%			Not specified.	Out of scope	not specified

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Goniophotometer									
Operating position of LED device for goniophotometer	Type C. Burning position shall not change on goniophotometer (9.1.9)	China (but the requirement "spatial position of the lamp should not change" is not considered, as it is covered by the limit of the drafts.)	Type C. Burning position shall not change on goniophotometer (9.3.1)	Shall not change (in Option 1)			Out of scope	Not specified.	type c. burning position and spatial position of the lamps should not change
Other than Type C	Not allowed.	LM79	Not allowed.	Not allowed (in Option 1)					near-field goniophotometer may also applicable
Scanning angle resolution	Scanning resolution fine enough to accurately define the test sample shall be used. (9.1.11)	Maybe Chinese, but specification is not clear. LM-79 language is used.	22.5° hor. 5 ° ver. (only guidance) (9.3.3)	as specified in application standard			Out of scope	specified(7.6).	For reflector lamps:1°ver ; 5°hor (for lamp with irregular distribution)
Angle coverage (for luminous flux)	Cover entire range of emission from device. For omnidirectional lamp, dead angle <=±10° (interpolation correction is only guidance)	LM79	Cover entire range of emission. dead angle ≤ ±10° allowed but correction needed (only guidance) (9.3.4)	Cover entire range of emission.		In case of directional lamps the luminous flux shall be measured in a solid angle of 90° (0.6 π sr). In case of directional lamps having the beam angle greater than 90°, the luminous flux shall be measured in a solid angle of 120° (π sr) (A.3.2)	Out of scope	Not specified.	not specified
f1' of photometer head of the goniophotometer (including mirror)	≤ 1.5 %. (9.1.10)	LM79	≤ 3 %. (9.3.6)	≤ 1.5 %			Out of scope	≤ 6 %	≤ 3.5%
Calibration of goniophotometer for luminous flux measurement	luminous. Intensity or illuminance standards traceable to NMI, plus verification with total luminous flux standard is required. (9.1.12)	LM79, JIS	luminous. Intensity or illuminance standards traceable to NMI, plus check with total luminous flux standard is required. (9.3.7)	Required, NMI traceable.			Out of scope	Calibration by specified standards traceable to NMI is required (6,annex A)	not specified
Luminous flux by goniophotometer	Absolute photometry required. (9.1.1)	LM79	Absolute photometry required.	Absolute photometry required.			Out of scope	Calibration by luminous flux standards traceable to NMI is required (annex A)	not specified

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Photometric center of luminaire (for goniophotometry)	Specified in RR protocol if necessary.		Not specified.	Center of luminous surface			Out of scope	specified(7.4).	
Coordinate system for goniophotometer (data format)	Follow the general practice used in traditional luminaire testing, referring to CIE 121 and LM-63 (9.2.2)		LM-63 format required. (10.0)	CIE C, γ (CIE 121)		shall be provided for the LED lamp in accordance with an established international or regional format	Out of scope	specified(Annex.D)--compatible to LM-63	
Photometric distance of Goniophotometer for intensity distribution	more than five times of the largest dimension of the test product is recommended (9.2.3)		longer than five times of the longest dimension of the source (only guidance) (10.0)				Out of scope	longer than five times of the longest dimension of the source (only guidance) (7.5)	5m for reflector lamp
Intensity distribution of LED luminaire with interchangeable LED lamps	Not covered in the current RR.		Not specified (not allowed)	Relative goniophotometry may also apply for LED luminaire with interchangeable LED lamps			Out of scope	Not specified.	not specified
Peak intensity	Not covered in the current RR.					measured in accordance with IEC/TR 61341 (A.3.4)	Out of scope	specified(8.2.2)	IEC/TR 61341
Beam angle	Not covered in the current RR.					measured in accordance with IEC/TR 61341. (A.3.5)	Out of scope	specified(8.2.3)	IEC/TR 61341
Colour measurement	Colour quantities shall be spatially averaged (with some exceptions). (9.5.2)	LM79 JIS	Colour quantities shall be spatially averaged (with some exceptions). (12.0)	spatially average by default except if request is made for directional			Colour quantities shall be spatially averaged (when related with total luminous flux measurement). (9.2)	Out of scope	
with a gonio-spectroradiometer or gonio-colorimeter	Every 10 deg. vertical and 2 horizontal planes 90 deg. apart at minimum. (9.5.2)	LM79	Every 10 deg. vertical and 2 horizontal planes 90 deg. apart at minimum. (12.2)				Not specified.	Out of scope	
Gonio-colorimeter (calibration)	shall be calibrated against spectroradiometer (at one point for that device under test) (9.5.3)	LM79	shall be calibrated against spectroradiometer (at one point for that device under test) (12.2)	Not specified			Not specified.	Out of scope	

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Spatial colour uniformity	Every 10 deg. Vertical and 2 horizontal planes 90 deg. Apart at minimum. Maximum deviation from spatial average. (recommendation only) (9.5.4)	LM79	Every 10 deg. Vertical and 2 horizontal planes 90 deg. Apart at minimum. Maximum deviation from spatial average. (12.5)	Similar to LM-79.			Not specified.	Out of scope	
Spectroradiometer requirement	380 to 780 nm, 5 nm or less bandwidth and interval. Wavelength scale uncertainty ≤ 0.3 nm. (9.1.3)	JIS	380 to 780 nm, 5 nm or less bandwidth and interval	380 to 780 nm, 5 nm or less bandwidth and interval			360(380) to 830(780) nm, 5 nm or less bandwidth and interval, wavelength scale is within 0.3nm(9.2)	Out of scope	
Measurement uncertainty	Uncertainty is required. (but not required for accreditation using test methods other than EN13032-4)	CEN	Not required but some guidance given with references. (13.0)	Uncertainty statement is required. Use of default uncertainties is allowed in Option.			specified, but not required.	Not specified.	