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सॉलिड स्टेट लाइटिंग (एल ई डी) उत्पादों के विद्युतीय एवं फोटोमीटरी मापन की पद्धति

Indian Standard

METHOD OF ELECTRICAL AND PHOTOMETRIC MEASUREMENTS OF SOLID STATE LIGHTING (LED) PRODUCTS

ICS 29.140.99

BUREAU OF INDIAN STANDARDS
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Electric Lamps and Their Auxiliaries Sectional Committee, ETD 23

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Electric Lamps and Their Auxiliaries Sectional Committee had been approved by the Electrotechnical Division Council.

This standard has been developed for the electrical and photometric measurements of solid state lighting (SSL) products commonly known as LED. While many other standards for photometric measurements of light sources and luminaires are available, these standards are separated for measurement of lamps of luminaires with LED as the light source. Since the current SSL products are in the forms of luminaires or lamps, and LED light sources in the luminaires are not easily separated as replaceable lamps these existing standards cannot be applied directly to SSL products. This necessitates the use of absolute photometry. The Annex A in this standard provides the description of how absolute photometry varies from relative photometry, which have historically been the lighting industry standards. Thus, this standard provides test methods addressing the requirements for measurement of SSL products. Since SSL technologies are still at their early stages, requirements for measurement conditions and appropriate measurement techniques may be subject to change at any time as the SSL technologies advance.

This standard is based on IES-LM-79-2008 'IES approved method for the electrical and photometric measurements of solid state lighting products', issued by the Illuminating Engineering Society of North America. Reference given to other standards have been changed to corresponding Indian Standards.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

METHOD OF ELECTRICAL AND PHOTOMETRIC MEASUREMENTS OF SOLID STATE LIGHTING (LED) PRODUCTS

1 SCOPE

This standard covers the procedures to be followed and precautions to be observed in performing reproducible measurements of total luminous flux, electrical power, luminous intensity distribution, and chromaticity, of solid state lighting (SSL) products commonly known as LED products for illumination purpose, under standard test conditions.

The method covers LED based SSL products with control electronics and heat sinks incorporated, that is, those devices that require only ac mains power or a dc voltage power supply to operate. This standard does not cover SSL products that require external operating circuits or external heat sinks (for example, LED chips, LED packages, and LED modules). This standard covers SSL products in a form of luminaires (fixtures incorporating light sources) as well as integrated LED lamps (*see* **3.7**). This standard does not cover fixtures designed for SSL products sold without a light source. This standard describes test methods for individual SSL products, and does not cover the determination of the performance rating of products, in which individual variations among the products should be considered.

SSL products as defined in this standard utilize LEDs (including inorganic and organic LEDs) as the optical radiation sources to generate light for illumination purpose. An LED is a *p-n* junction semiconductor device that emits incoherent optical radiation when biased in the forward direction. White light is produced by LEDs using following two methods :

a) Visible spectra of two or more colours produced by LEDs are mixed, or
b) Emission (in the blue or ultraviolet region) from LEDs is used to excite one or more phosphors to produce broadband emission in the visible region (Stokes emission).

For stand alone LED, constant current control is typical. This standard deals with integrated SSL products incorporating the semiconductor device level current control, thus the electrical parameters of interest are the SSL product's input electrical parameters.

For special purposes, it may be useful to determine the characteristics of SSL products when they are operated at other than the standard conditions described in this standard. Where this is done, such results are meaningful only for the particular condition under which they were obtained and these conditions shall be reported in test report.

The photometric information typically required for SSL products is total luminous flux (lumens), luminous efficacy (lm/W), luminous intensity (candelas) in one or more directions, chromaticity coordinates, correlated colour temperature, and colour rendering index. For the purpose of this approved method, the determination of these data shall be considered for photometric measurements.

The electrical characteristics measured for a.c.-powered SSL products are input r.m.s a.c. voltage, input r.m.s a.c. current, input a.c. power, input voltage frequency and power factor. For d.c.-powered SSL products, measured electrical characteristics are input dc voltage, input d.c. current, and input power, For the purpose of this standard, the determination of these shall be considered for electrical measurements.

2 REFERENCE

The standard listed below contains provision which, through reference in this text, constitutes provision of this standard. At the time of publication, the edition indicated was valid. All standards are subject to revision and parties to agreements based on this standard is encouraged to investigate the possibility of applying the most recent edition of the standard listed as follows:

IS No.	*Title*
3646 (Part 1) : 1992	Code of practice for interior illumination: Part 1 General requirements and recommendations for working interiors

3 TERMINOLOGY

For the purpose of this standard, the following definitions shall apply.

3.1 Electrical Measurement — Unit of measurement in volt, ampere and watt.

3.2 Photometric Measurement — Unit of measurement in lumen and candela.

3.3 Chromaticity Coordinates — This is specified in term of the CIE recommended systems, the (*x*, *y*) or (*u′*, *v′*) chromaticity coordinates. To specify tolerance of chromaticity independent from correlated colour temperature (CCT), the (*u′*, *v′*) coordinates shall be used. The chromaticity can also be expressed by CCT and Duv (signed distance from the Planckian locus on the CIE (*u′*, 2/3 *u′*) diagram.

3.4 Regulation — Constancy of the voltage applied to the SSL product under test.

3.5 Seasoning Time — Advance operation of the test SSL product for a given number of hours from the brand new condition. Photometric data obtained immediately after this seasoning time is referred to as initial data.

3.6 Stabilization — Operation of test SSL products for a sufficient period of time such that the electrical and the photometric values become stable. This is also called warm-up time.

3.7 Integrated LED Lamp — An LED device with an integrated driver and a standardized base that is designed to connect to the branch circuit *via* a standardized lamp holder/socket (for example replacement of incandescent lamps with screw base).

LED luminaire refers to a complete LED lighting unit consisting of a light source and driver together with parts to distribute light, to position and protect the light source, and to connect the light source to a branch circuit. The light source itself may be an LED array and LED module, or an LED lamp.

3.8 Pre-burning — Operation of a light source prior to its mounting on a measuring instrument, to shorten the required stabilization time on the instrument.

3.9 Photometer Head — A unit containing a detector, a *V (Y)*-correction filter, and any additional components (aperture, diffuser, amplifier, etc) within the unit.

4 GENERAL TEST CONDITIONS

4.1 General

Photometric values and electrical characteristics of SSL products are sensitive to changes in ambient temperature or air movement due to thermal characteristics of LEDs.

4.2 Air Temperature

The ambient temperature in which measurements are being taken shall be maintained at 25°C ± 1°C, measured at a point not more than 1 m from the SSL product and at the same height as the SSL product. The temperature sensor shall be shielded from direct optical radiation from the SSL product and optical radiation from any other source. If measurements are performed at other than this recommended temperature, this is a non-standard condition and shall be noted in the test report.

4.3 Thermal Conditions for Mounting SSL Products

The method of mounting can be the primary path for heat flow away from the devices and can affect measurement results significantly. The SSL product under test shall be mounted to the measuring instrument (for example, integrating sphere) so that heat conduction through supporting objects causes negligible cooling effects. For example, when a ceiling mounted product is measured by mounting at a sphere wall, the product may be suspended in open air rather than directly mounted in close thermal contact with the sphere wall. Alternatively, the product may be held by support a material that has low heat requirement shall be evaluated for impact in measurement results. Also, care should be taken so that supporting objects do not disturb air flow around the product. 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 systems, the product shall be tested with the support structure attached. Any such support structure included in the measurement shall be reported.

4.4 Air Movement

The incidence of air movements on the surface of SSL product under test may substantially alter electrical and photometric values. Air flow around the SSL product being tested should be such that normal convective air flow induced by device under test is not affected.

5 POWER SUPPLY CHARACTERISTICS

5.1 Wave Shape of a.c. Power Supply

The a.c. power supply, while operating the SSL product, shall have a sinusoidal voltage wave shape at a frequency of 50 Hz such that the r.m.s summation of the harmonic components does not exceed 3 percent of the fundamental during operation of the test item.

5.2 Voltage Regulation

The voltage of an a.c. power supply (r.m.s voltage) of dc power supply (instantaneous voltage) applied to the device under test shall be regulated to within ± 0.2 percent under load.

6 SEASONING (AGEING) OF SSL PRODUCT

For the purpose of new SSL products, SSL products shall be tested with no seasoning or ageing.

NOTE — Some LED sources are known to increase their light output slightly during the first 1 000 h of operation; many other LED sources do not follow such behaviour. The seasoning is not done because the increase of light output of LED products between 0 h to 1 000 h, if occurs, is less than several percent, which does not result in significant changes in initial luminous flux or life of the products.

7 STABILIZATION OF SSL PRODUCT

Before measurements are taken, the SSL product under test shall be operated long enough to reach stabilization and temperature equilibrium. The time required for stabilization depends on the type of SSL products under test. The stabilization time typically ranges from 30 min for small integrated LED lamps to 2 h or more for large SSL luminaries. The SSL ambient temperature as specified in **4.2** and in the operating orientation as specified in **6**. It can be judged that stability is reached when the variation (maximum to minimum) of at least 3 readings of the light output and electrical power over a period of 30 min, taken at 5 min interval, is less than 0.5 percent. The stabilization time used for each SSL product shall be reported.

For measurement of a number of products of the same model, stabilization methods other than those described above, for example, pre-burning of the product as given in **3.8** may be used, if it has been demonstrated that the method produces the same stabilized condition to that of the standard method described above.

NOTE — Same stabilized condition is achieved when the measured total luminous flux is within 0.5 percent of the declared value.

8 OPERATING ORIENTATION

The SSL product under test shall be evaluated in the operating orientation recommended by the manufacturer for an intended use of the SSL product. Stabilization and photometric measurements of SSL products shall be done in such operating orientation.

NOTE — The light emission process of an LED is not affected by orientation. However, the orientation of an SSL product can cause changes in thermal conditions for the LEDs used in the product. And thus the light output may be affected by orientation of the SSL product. The orientation of the SSL products as mounted for measurement shall be reported with the results.

9 ELECTRICAL SETTINGS

The SSL product under test shall be operated at the rated voltage (a.c. or d.c.) according to the specification of the SSL product for its normal use. Pulsed input electrical power and measurement synchronized with reduced duty cycle input power intended to reduce *p-n* junction temperature below those reached with continuous input electrical power shall not be used for SSL product testing.

If the product has dimming capability, measurements shall be performed at the maximum input power condition. If the product has multiple modes of operation including variable CCT, measurement may be made at different modes of operation and CCTs, if necessary, and such setting conditions shall be clearly reported.

10 ELECTRICAL INSTRUMENTATION

10.1 Circuits

For d.c. input SSL product, a d.c. voltmeter and a d.c. ammeter are connected between the d.c. power supply and the SSL product under test. The voltmeter shall be connected across the electrical power inputs of the SSL product. The product of the measured voltage and the current gives the input electrical power (wattage) of the d.c. powered SSL product.

For a.c. input SSL products, an ac wattmeter shall be connected between the ac power supply and the SSL product under test, and a.c. power as well as input voltage and current shall be measured.

10.2 Uncertainties

The calibration uncertainties (*see* Note) of the instruments for a.c. voltage and current shall be ≤ 0.2 percent. The calibration uncertainty of the a.c. wattmeter meter shall be ≤ 0.5 percent and that for d.c. voltage and current shall be ≤ 0.1 percent.

NOTE — Uncertainties here refers to relative expanded uncertainly with a 95 percent confidence interval, normally with a coverage factor $k = 2$. If manufacturer's specification does not specify uncertainty as stated above, then manufacturers should be contacted for proper conversion.

11 TEST METHODS FOR TOTAL LUMINOUS FLUX MEASUREMENT

11.1 The total luminous flux (lumen) of SSL products shall be measured with an integrating sphere system of a goniophotometer. The method may be chosen depending on what other measurement quantities, namely colour, intensity distribution, etc, need to be measured, the size of SSL products, and other requirements. Some guidance on the use of each method is given below.

11.1.1 *Integrating Sphere System*

The integrating sphere system is suited for total luminous flux and color measurement of integrated LED lamps and relatively small size LED luminaires (*see* **11.2.2**) for the guidance on the size of SSL products that can be measured in an integrating sphere of a given size. The integrating sphere system has the advantage of fast measurement and does not require a dark room. Air movement is minimized and temperature within the sphere is not subject to the fluctuations potentially present in a temperature controlled room. It should be noted that heat from the SSL product mounted in or on the integrating sphere may accumulate to increase the ambient temperature of the product under test (*see* **11.2.1**).

Two types of integrating sphere systems are used one employing a $V(\lambda)$ corrected photometer head (*see* **11.3**), and another employing a spectroradiometer as the detector (*see* **11.2**). Spectral mismatch errors (*see* **11.3.6**) occur with the first method due to the deviation of the relative spectral responsivity of the integrating sphere photometer form the $V(\lambda)$, while there are theoretically no spectral mismatch errors with the second method. The spectroradiometer method is preferred for measurement of SSL products because spectral mismatch errors with the photometer head (*see* **3.9**) tend to be significant for LED emissions and correction is not trivial, requiring knowledge of the system spectral responsivity as well as the spectrum of the device under test. In addition, with the spectroradiometer method, colour quantities can be measured at the same time as total luminous flux. Further descriptions on both the methods are given in **11.2** and **11.3**.

11.1.2 *Goniophotometer*

Goniophotometers provide measurement of luminous intensity distribution as well as total luminous flux. Goniophotometer can measure total luminous flux of SSL products of relatively large size (corresponding to dimensions of traditional fluorescent lamp luminaires) while they can measure small SSL products as well. A goniophotometer is installed in a darkroom, normally temperature controlled, and is not subject to heat accumulation from a source being measured. Care shall be taken, however, for drafts from ventilation that might affect measurement of SSL products that are sensitive to temperature. The ambient temperature must be measured and maintained as specified in **4.2**. Measurements with a goniophotometer are time consuming compared to a sphere photometer. Goniophotometers using broadband photopic detectors are susceptible to the spectral mismatch errors noted above. In fact, correction for spectral mismatch can be more difficult if there is significant variation in colour with angle. The use of goniophotometers for measurement of SSL products are give in **11.4**.

11.2 Integrating Sphere with a Spectroradiometer (Sphere Spectroradiometer System)

This type of instrument measures total spectral radiant flux (W/nm), from which total luminous flux and colour quantities are calculated. By using an array spectroradiometer, the measurement speed can be of the same magnitude as for a photometer head.

11.2.1 *Integrating Sphere*

The size of the integrating sphere should be large enough to ensure that the measurement errors due to effects of baffle and self-absorption (*see* **11.2.5**) by the test SSL product are not significant. The guidance on the size of the sphere required relative to the size of the SSL products to be measured is given in **11.2.2**. In general, sphere size of 1 m or larger is typically used for compact lamps (size of typical incandescent and compact fluorescent lamps), and 1.5 m or larger of larger lamps (for example size of 4 foot linear fluorescent lamps and HID lamps). The sphere should also be large enough to avoid excessive temperature increase die to heat from the light source being measured. Two metre or larger spheres are typically used for measurement of light sources of 500 W of larger.

The integrating sphere shall be equipped with an auxiliary lamp for self-absorption measurement (*see* **11.2.5**). The auxiliary lamp for a sphere spectroradiometer system must emit broadband radiation over the entire spectral range of the spectroradiometer. Thus, a quartz halogen lamp is typically used for this purpose. The auxiliary lamp light output needs to be stable throughout all the self-absorption measurements.

An interior coating reflectance of 90 percent to 98 percent is recommended for the sphere wall, depending on the sphere size and usage of the sphere. A higher reflectance is advantageous for higher signal obtained and smaller errors associated with spatial non- uniformity of sphere response and intensity distribution variations of the SSL products measured. Higher reflectance is preferred particularly for a sphere spectroradiometer system to ensure sufficient signal-to-noise ratios in the entire visible region. It should be noted, however, that, with higher reflectance, the sphere responsivity becomes more sensitive to self-absorption effects and long-terms drift, and also, there will be more variation in spectral throughput. If there is an opening in the sphere, the average reflectance should be considered, and higher coating reflectance will be advantageous to compensate for the decrease of average reflectance.

11.2.2 *Sphere Geometry*

Figure 1 shows recommended sphere geometries of a sphere-spectroradiometer system for total luminous flux measurement of SSL products. The reference standards are for total spectral radiant flux. The 4π geometry (a) is recommended for all types of SSL product including those emitting light in all directions ($4\ \pi sr$) or only in a forward direction (regardless of orientation). The 2π geometry (b) is acceptable for SSL products emitting light only in forward direction (regardless of orientation), and may be used for SSL products having a large housing or fixture that are to large to use the 4π geometry. In either geometry, the size of the SSL product under test should be limited for a given size of the sphere to ensure sufficient spatial uniformity of light integration and accurate correction for self-absorption. For measurement of integrated LED lamps, the sphere may be equipped with a lamp holder with a screw-base socket.

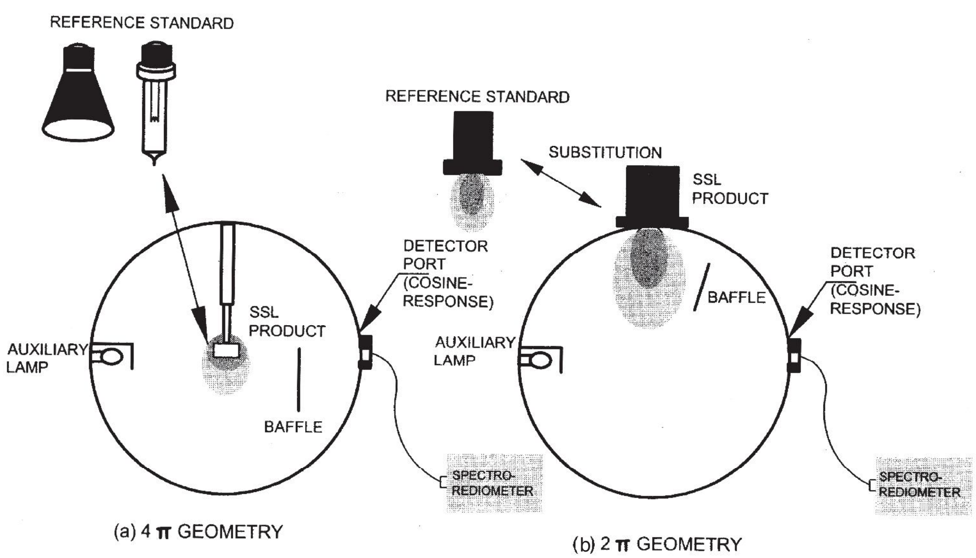
In the 4π geometry, as a guideline, the total surface area of the SSL product should be less the 2 percent of the total area of the sphere wall. This corresponds to, for example, a spherical object of less than 30 cm diameter in a 2 m integrating sphere. The longest physical dimension of a linear product should be less than 2/3 of the diameter of the sphere.

In the 2π geometry, the opening diameter to mount a SSL product should be less than 1/3 of the diameter of sphere. The SSL product shall be mounted within the circular opening and in such a way that its front edges are flush with the edges of the opening (or it can be slightly inside the sphere to ensure that all emitted light is caught in the sphere). In this case, the gaps between the edges of the opening and SSL product (or reference standard) can be covered with a surface (inner side is white) in order that the measurement can be made in a room with normal ambient lighting as the sphere is completely shielded from outside [*see* Fig. 2 (a)]. If this is not convenient and the gaps are to be kept open, a darkroom arrangement (around the opening, at least) may be necessary so that no external light or reflectance light enters the sphere [*see* Fig. 2 (b)]. In either case, the SSL product under test should be mounted to the sphere so that support material or structure does not conduct the heat from the SSL product to the sphere wall (*see also* **4.3**).

In either geometry, the size of the baffle should be as small as possible to shield the detector port from direct illumination from the largest test SSL product to be measured or the standard lamp. It is recommended that the baffle is located at 1/3 to 1/2 of the radius of the sphere from the detector port. The auxiliary lamp should have a shield so that its direct light does not hit any parts of SSL products under test or the detector port.

Standard lamps for total spectral radiant flux are normally quartz-halogen incandescent lamps that have broadband spectrum to calibrate the spectroradiometer for the entire visible region. For the 2π geometry, standard lamps having only forward distribution are required. For example, a quartz-halogen lamp with a reflector providing appropriate intensity distribution may be used as a reference standard source. For the 4π geometry, standard lamps having omni-directional intensity distribution are commonly used but standard lamps having forward intensity distribution also be needed.

It should be noted that integrating spheres do not have perfectly uniform responsivity over their internal sphere surfaces. The sphere responsivity tends to be slightly lower for the lower half of the sphere due to contamination by falling dust and also around the



All dimensions in millimetres.

FIG. 1 RECOMMENDED SPHERE GEOMETRIES FOR TOTAL LUMINOUS FLUX MEASUREMENT USING A SPECTRORADIOMETER: (A) FOR ALL TYPES OF SSL PRODUCTS, (B) FOR SSL PRODUCTS HAVING ONLY FORWARD EMISSION sphere seams where small gaps exist. Therefore, if a sphere (4π geometry) is calibrated with an omni-directional standard lamp and measures an SSL product having downward intensity distributions, the luminous flux tends to be measured slightly lower than it is. This error tends to be more prominent for light sources having narrow beam distributions. The magnitude of errors depends on how well the sphere is designed and maintained, and will be cancelled, if the angular intensity distributions of the standard lamp and the test SSL products are the same. To ensure that this error is not significant, standard lamps having different intensity distributions (omni-direction, downward/broad, downward/narrow) may be prepared and chosen for the type of SSL products to be measured. Or, if only omni-directional standard lamps are used, correction factors should be established and applied when SSL products having different intensity distributions are measured. Such correction factors may be established by measuring lamps or SSL products having different intensity distributions calibrated for total luminous flux using other accurate means (for example, calibration traceable to National Standard, or using well-designed goniphotometer).

The ambient temperature in a sphere shall be monitored according to **4.2**. A temperature probe is often mounted behind the baffle that shields the detector port from the light source if the baffle is mounted at the same height as the centre of the sphere [*see* Fig.1 (a)]. When a SSL products is mounted on the sphere wall [*see* Fig.1 (b)], the ambient temperature shall be measured behind the baffle (side of spectroradiometer) in the sphere, in addition to the ambient air outside the sphere near the product (*see* **4.2**). Both readings must meet the requirement of 25 ± 1°C requirement.

If the ambient temperature in the closed sphere exceeds 25 ± 1°C due to the heat generated by the SSL product under test, the SSL product may be stabilized with the sphere partially open to achieve the required ambient temperature within 25 ± 1°C until measurement is made with the sphere closed. When measurement is taken, the sphere shall be closed gently to avoid air movement inside the sphere.

NOTES

1 The light output of incandescent standard lamps changes if their burning position is changed.

2 If the stability of the flux output of the product is monitored with the sphere photometer when the sphere is open, the room lights shall be turned off and the position of open hemispheres should not be moved.

11.2.3 *Principle of Measurement*

The instrument (integrating sphere plus spectroradiometer) must be calibrated against a reference standard calibrated for total spectral radiant flux. Since the integrating sphere is included in this calibration, the spectral throughput of the sphere need not be known. The total spectral radiant flux $\phi_{TEST}(\lambda)$ of a SSL product under test is obtained by comparison to that of a reference standard $\phi_{REF}(\lambda)$:

$$\phi_{TEST}(\lambda) = \phi_{REF}(\lambda) \bullet \frac{y_{TEST}(\lambda)}{y_{REF}(\lambda)} \bullet \frac{1}{\alpha(\lambda)} \qquad \ldots(1)$$

Where $y_{TEST}(\lambda)$ and $y_{REF}(\lambda)$ are the spectroradiometer readings for SSL product under test and for reference standard, respectively, and $\alpha(\lambda)$ is the self absorption factor (*see* **11.2.5**).

From the measured total spectral radiant flux $\phi_{TEST}(\lambda)$ [W/nm], the total luminous flux ϕ_{Test} [lm] is

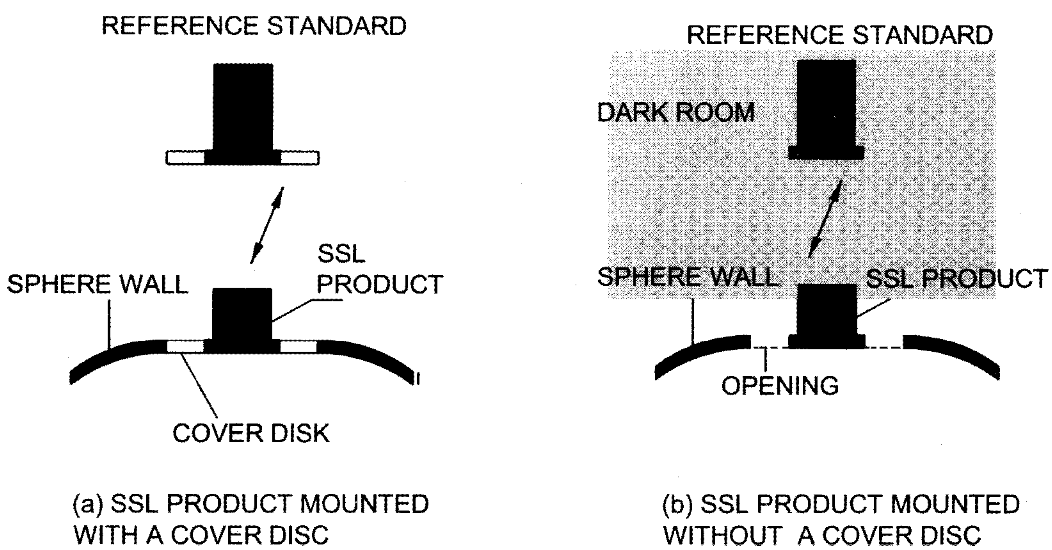


FIG. 2 MOUNTING CONDITIONS OF THE SSL PRODUCT UNDER TEST

obtained by :

$$\phi_{TEST} = K_m \int_{\lambda} \phi_{TEST}(\lambda)\, V(\lambda) d\lambda \quad ...(2)$$

where

K_m = 683 lm/W

11.2.4 *Spectroradiometer*

Either mechanical scanning type or array type spectroradiometers may be used. The array spectroradiometer has the advantage of shorter measurement time due to the multiplex nature of arrays. The spectroradiometer shall have a minimum spectral range from 380 nm to 780 nm. The defined visible spectral region is 360 nm to 830 nm[2].

The detector port of the integrating sphere shall be a flat diffuser or a satellite sphere (a very small integrating sphere-detector systems with an opening) mounted flush to the sphere coating surface, so that the input of the sepctroradiometer at the detector port has an approximate cosine response with be directional response index f_2 being less than 15 percent. It should be noted that an optical fibre input (with no additional optics), often provided with array spectroradiometer, has a narrow acceptance angle and should not be used without additional optics for cosine correction.

Calibrated spectroradiometer measure photometric quantities without spectral mismatch errors; however, there remain many other sources of error associated with spectroradiometer.

Errors can be significant when the spectral distribution of a test SSL product is dissimilar to the standard source (tungsten source). Major sources of error include bandwidth, scanning interval, wavelength accuracy, spectral stray light, detector non-linearity, and input geometry. For accurate colorimetry, a bandwidth and scanning interval of 5 nm or smaller are required for spectroradiometer methods.

NOTE — Errors in some poor quality array spectroradiometers can be larger than high quality photometer heads.

11.2.5 *Self Absorption Correction*

Self absorption is the effect, in which the responsivity of the sphere system changes due to absorption of light by the lamp itself in the sphere. Errors can occur, if the size and shape of the test light source is different from those of the standard light source. The self absorption correction is critical, since the physical size and shape of the SSL products under test are typically very different from the reference standard size and shape. The self absorption is wavelength dependent because the spectral reflectance of the sphere coating is not spectrally flat. The self absorption factor is given by :

$$\alpha(\lambda) = \frac{y_{aux,\,TEST}(\lambda)}{y_{aux,\,REF}(\lambda)} \quad ...(3)$$

Where $y_{aux,\,TEST}(\lambda)$ and $y_{aux,\,REF}(\lambda)$ are the spectroradiometer readings for the auxiliary lamp when the SSL product under test or the reference total spectral radiant standard, respectively, are mounted in or on the sphere (4π or 2π geometry). In this case, the SSL product and the reference standard are not operated. Only the auxiliary lamp is operated.

11.2.6 *Calibration*

The instrument (integrating sphere plus spectroradiometer) shall be calibrated against total spectral radiant flux standards traceable to National Physical Laboratory (NPL).

11.3 Integrating Sphere with a Photometer Head (Sphere Photometer System)

This method is a traditional approach of integrating sphere photometry, using a photometer head as the detector for an integrating sphere. This method is acceptable but less preferred due to the potential for large spectral mismatch errors in the measurement of luminous flux of SSL products (if the mismatch corrections are not applied) and also due to a need for separate measurement instruments for colour quantities.

11.3.1 *Integrating Sphere*

Descriptions given in **11.2.1**, also apply to this method, except for a difference in the requirement of auxiliary lamp. For a sphere-photometer system, the auxiliary lamp does not have to be limited to incandescent lamps. Rather, it is advantageous to use an auxiliary lamp that has a spectral distribution similar to those of the SSL products typically measured, so that self absorption is measured accurately especially when the self absorption is very large ($\alpha < 0.8$) or when the housing of SSL product under test is large and strongly coloured. The auxiliary lamp needs to be stable throughout the self absorption measurement of all SSL products under test. A stable white LED source, for example, may be used.

11.3.2 *Sphere Geometry*

The recommended integrating sphere geometries for this method are shown in Fig. 3. The difference from Fig. 1 is that a photometer head is used as the detector. The recommendations and requirements using these 4π and 2π geometries are given in **11.2.2**. All the descriptions in **11.2.2** apply for this method except differences in the requirements of reference standard lamp.

The reference standard lamps are assigned total luminous flux, and the same requirements as given in **11.2.2** on the different intensity distributions apply. For example, for a narrow beam SSL product, standard lamps having similar narrow beam intensity distribution should be used. If only omni-directional standard lamps are used, correction factors should be established for different types of intensity distribution.

While reference standards are traditionally incandescent lamps, they do not have to be limited to incandescent lamps for a sphere-photometer system. Stable and reproducible SSL product (for example, using temperature-controlled white LED sources) may be used as a reference standard of total luminous flux. It is advantageous, in reducing spectral mismatch errors, to have the spectral distribution of the reference standard to be similar to that of typical SSL product measured. Using SSL products as a reference standard may also be advantageous in achieving angular intensity distribution similar to those of the SSL products to be measured.

11.3.3 *Principle of Measurement*

The total luminous flux of the test device is obtained by comparison to that of a reference standard:

$$\Phi_{\text{TEST}} = \phi_{\text{REF}} \cdot \frac{y_{\text{TEST}}}{y_{\text{REF}}} \cdot \frac{F}{\alpha} \qquad \ldots(4)$$

Where Φ_{REF} is the total luminous flux (lumen) of the reference standard, y_{TEST} and y_{REF} are the photometer signals for SSL product under test and for reference standard, respectively. F is the spectral mismatch correction factor (*see* **11.3.6**) and α is the self absorption factor (*see* **11.3.5**). If factor F is not determined, F=1 should be used and the resulting uncertainty should be considered.

11.3.4 *Photometer Head*

The photometer head (*see* **3.9**) shall have relative spectral responsivity well matched to the $V(\lambda)$ function, while the spectral throughput of the sphere also effects the total spectral responsivity. The f_1' value of the total sphere system (photometer head plus integrating sphere) shall be less than 3 percent. To further reduce uncertainty of measurements, a spectral mismatch correction may be applied. The procedures for determining f_1' value and spectral mismatch correction factor are given in **11.3.6**.

The photometer head shall have an approximate cosine response with the f_2 (value)[10] (directional response index) of less than 15 percent and the diffuser surface shall be mounted flush to the sphere coating surface. If a satellite sphere is used for cosine response, its opening shall not be recessed; the opening edges of the satellite sphere shall be flush to the integrating sphere coating surface.

11.3.5 *Self Absorption Correction*

A self absorption correction shall be applied unless test SSL product and luminous flux reference standard are of the same model and same size (strict

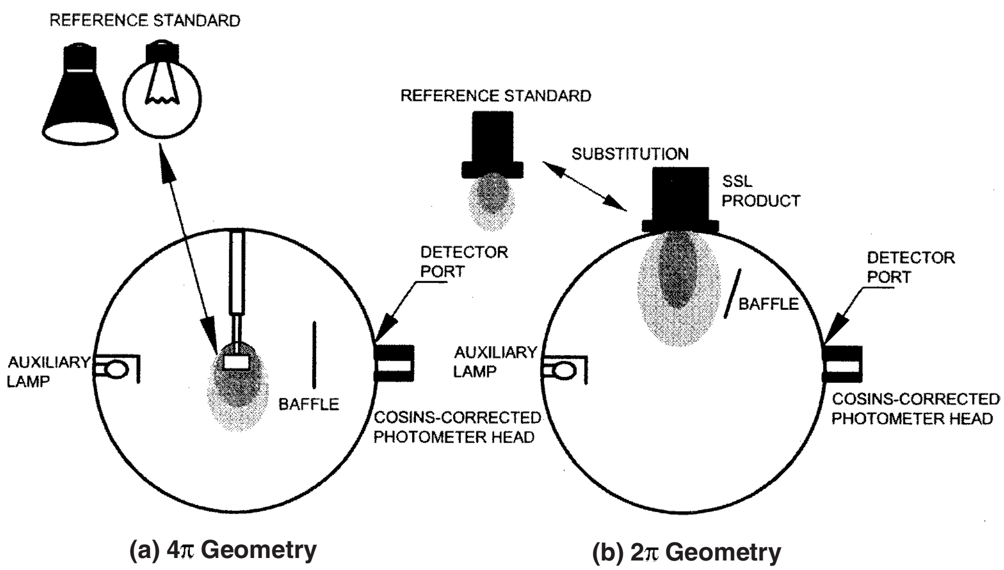


FIG. 3 RECOMMENDED SPHERE GEOMETRIES FOR TOTAL LUMINOUS FLUX MEASUREMENT USING A PHOTOMETER HEAD: (A) FOR ALL TYPES OF SSL PRODUCTS, (B) FOR SSL PRODUCTS HAVING ONLY FORWARD EMISSION

substitution). The self absorption factor can be measured by :

$$\alpha = \frac{y_{\text{aux, TEST}}}{y_{\text{aux, REF}}} \qquad \text{.... (5)}$$

Where $y_{\text{aux, TEST}}$ and $y_{\text{aux, REF}}$ are the photometer signals for the auxiliary lamp when the SSL product under test or the total luminous flux reference standard, respectively, is mounted in or on the sphere (4π or 2π geometry). They are not operated; only the auxiliary lamp is operated. The auxiliary lamp can be a halogen or incandescent lamp or a white LED source.

11.3.6 *Determination of f_1' and Spectral Mismatch Correction Factor*

The spectral responsivity of the integrating sphere photometer cannot be perfectly matched to the $V(\lambda)$ function. An error (called spectral mismatch error) occurs when a test SSL product has a different spectral power distribution from that of the standard source. The f_1' (value)[10] is an index that indicates the degree of mismatch in spectral responsivity, and the value (in percentage) gives a rough indication of the magnitude of errors that can occur for general white light sources, but errors can be larger than the f_1' value for SSL products consisting of only a few narrowband emissions.

To determine f_1' value, the relative spectral responsivity of the total sphere system $s_{\text{rel}}(\lambda)$ must be obtained. $s_{\text{rel}}(\lambda)$ is given as a product of relative spectral responsivity of the photometer head $s_{\text{ph, rel}}(\lambda)$ and the relative spectral throughput of the sphere $T_{\text{rel}}(\lambda)$:

$$s_{\text{rel}}(\lambda) = s_{\text{ph, rel}}(\lambda)\, T_{\text{rel}}(\lambda) \qquad \text{...(6)}$$

The $s_{\text{ph, rel}}(\lambda)$ shall be measured in hemispherical illumination geometry. If it is measured only in normal direction, uncertainty shall be determined. $T_{\text{rel}}(\lambda)$ is theoretically given by

$$T_{\text{rel}}(\lambda) = k \bullet \frac{\rho_a(\lambda)}{1-\rho_a(\lambda)} \qquad \text{...(7)}$$

Where $\rho_a(\lambda)$ is the average reflectance of the entire inner sphere surface (including $\rho = 0$ for an opening, if there is one) and k is a normalization factor. If $\rho_a(\lambda)$ of the integrating sphere in use is measured accurately, $T_{\text{rel}}(\lambda)$ may be obtained using this equation. However, integrating spheres in use are more or less contaminated and the data of coating samples tend to deviate from the reflectance of the real sphere surface. Therefore, it is recommended that $T_{\text{rel}}(\lambda)$ be directly measured on the integrating sphere.

Once $s_{\text{rel}}(\lambda)$ is determined, f_1' is calculated by

$$f_1' = \frac{\int_\lambda \left| s^*_{\text{rel}}(\lambda) - V(\lambda)\right| \mathrm{d}\lambda}{\int_\lambda V(\lambda)\, \mathrm{d}\lambda} \times 100\% \text{ with}$$

$$s^*_{\text{rel}}(\lambda) = \frac{\int_\lambda S_A(\lambda)\, V(\lambda) \mathrm{d}\lambda}{\int_\lambda S_A(\lambda) s_{\text{rel}}(\lambda)\, \mathrm{d}\lambda} \bullet s_{\text{rel}}(\lambda) \qquad \text{...(8)}$$

Where $S_A(\lambda)$ is spectral distribution of CIE illuminant A and $V(\lambda)$ is the spectral luminous efficiency function. With knowledge of $s_{\text{rel}}(\lambda)$ and the relative spectral power distribution $s_{\text{TEST}}(\lambda)$ of the SSL product under test, the spectral mismatch correction factor F is given by:

$$F = \frac{\int_\lambda S_{\text{REF}}(\lambda) s_{\text{rel}}(\lambda) \mathrm{d}\lambda \int_\lambda S_{\text{TEST}}(\lambda) V(\lambda) \mathrm{d}\lambda}{\int_\lambda S_{\text{REF}}(\lambda)\, V(\lambda)\, \mathrm{d}\lambda \int_\lambda S_{\text{TEST}}(\lambda)\, s_{\text{rel}}(\lambda)\, \mathrm{d}\lambda} \qquad \text{...(9)}$$

Where $S_{\text{REF}}(\lambda)$ is the spectral distribution of the reference standard source. Spectral mismatch errors can be corrected by multiplying the factor F to the measured lumen value of the SSL product. The accuracy of $S_{\text{TEST}}(\lambda)$ is generally not very critical, and thus, the nominal spectral distribution of a product may be used.

11.3.7 *Calibration*

The integrating sphere photometer shall be calibrated against total luminous flux standards traceable to national standards.

11.4 Goniophotometer

Goniophotometer are normally used for measurement of luminous intensity distribution, from which total luminous flux can be obtained.

11.4.1 *Type of Goniometer*

Goniophotometer shall be the type that maintains the burning position unchanged with respect to gravity; therefore, only Type C goniophotometer are allowable. Type C goniophotometers include moving detector goniophotometers and moving mirror goniophothometers. Care should be exercised to prevent light reflected from the mechanical structure of the goniophotometer or any other surface including secondary reflections from surfaces of the SSL product itself from reaching the photo detector. The speed of rotation of the positioning equipment should be such that it minimizes the disturbance of the thermal equilibrium of the SSL product.

11.4.2 *Principle of Total Luminous Flux Measurement*

By measuring the luminous intensity distribution $I(\theta, \Phi)$ of the source, the total luminous flux is obtained by;

$$\Phi = \int_{\phi=0}^{2\pi}\int_{\phi=0}^{\pi} I(\theta,\phi)\sin\theta \, d\theta \, d\phi \qquad \ldots(10)$$

If the photometer head is calibrated for measuring illuminance E (θ, Φ),

$$\Phi = r^2\int_{\phi=0}^{2\pi}\int_{\theta=0}^{\pi} E(\theta,\phi)\sin\theta \, d\theta \, d\phi \qquad \ldots(11)$$

Where *r* is the rotation radius of the reference plane of the photometer head. A sufficiently long photometric distance, *r*, is required for measurement of luminous intensity distribution (*see* **11.4.1**).

The distance requirement is not critical if only total luminous flux is to be measured. As indicated by equation (11), as long as the illuminance is measured accurately, the total luminous flux can be measured accurately even with a relatively short photometric distance (radius *r*), thus less space for the goniophotometer is required for a given size of light source to be measured. In this case, the detector must have cosine corrected angular responsivity within its field of view for the test SSL product. By definition given in equation (11), the location of the light source relative to the rotation center is theoretically not relevant, and therefore, the alignment of light source is not critical for measurement of total luminous flux.

11.4.3 *Scanning Resolution*

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) grids may be acceptable. 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.

11.4.4 *Angle Coverage*

The range of the angular scan must cover the entire solid angle to which the SSL product emits light. A disadvantage of a goniophotometer, when measuring total luminous flux, is that a goniophotometer in general has some angular region where emission from a light source under test is blocked by its mechanism (for example, an arm for SSL product holder) so that measurement in that direction cannot be made (such angle is called dead angle). This is not a problem for SSL products that emit light only in the forward direction similar to many existing fixtures. However, this can be a problem for SSL product that emits light in all directions (for example, integrated LED lamps similar to compact fluorescent lamps). Goniophotometers with a large dead angle are not suited for total flux measurement of such SSL products. If the dead angle is small (for example, ±10° or less), it is possible to interpolate the missing data points with an additional uncertainty.

11.4.5 *Polarization*

It should be noted that mirror type goniophotometers have a detection system that is polarization sensitive due to the slightly polarizing characteristics of mirrors themselves. Sensitivity to polarized light can cause significant errors when measuring the total luminous flux of SSL products that emit polarized light. For measurement of such SSL products, goniophotometers that do not use a mirror are recommended. Some mirror type goniophotometers have an option to mount a photometer head directly on the rotating arm for such purposes.

11.4.6 *Photometer Head*

The photometer head of the goniophotometer shall have relative spectral responsivity matched to the V (λ) function. The f_1' (value)[10] of the spectral responsivity shall be less than 3 percent. It is further desirable to apply spectral mismatch corrections for the photometer reading. For determination of f_1' and spectral mismatch correction factor, see equations (8) and (9), with s_{rel} (λ) being the relative spectral responsivity of the photometer head, measured in normal direction.

For the total luminous flux measurement described in **11.4.2**, the photometer head shall have good cosine response within the angle range where light is incident, with the f_2 (ε,Φ) value (relative deviation from the cosine function)[10] of less than 2 percent within the acceptance angle range. The field-of-view of the photometer head shall be limited (for example, using aperture screens) in order to shield stray light reflected from the angles other than from the light source being measured. To minimize stray light errors within the field-of-view of the photometer, it is recommended to use a light trap on the other side of the detector arm and/or use low reflectance material (such as black velvet) for the wall and floor surfaces.

11.4.7 *Calibration*

The goniophotometers for measuring luminous intensity distribution shall be calibrated against the illuminance or luminous intensity standard traceable to national standards. In addition, goniophotometers for measuring total luminous flux shall be validated by measurement of total luminous flux standard lamps traceable to national standards. Such validation measurements shall use standard lamps having similar angular intensity distributions (directional/omni-directional) as the type of SSL products to be tested with the goniophotometer.

12 LUMINOUS INTENSITY DISTRIBUTION

The recommendations given in **11.4** pertain to goniophotometers used to measure luminous intensity distribution as well as total luminous flux. For measurement of luminous intensity distribution, a sufficient photometric distance shall 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.

The coordinates system and geometry for mounting SSL products should follow the practice used in traditional luminaire testing in specific applications. The absolute luminous intensity distribution of measured SSL products shall be reported.

Electronic data of measured luminous intensity distributions, if necessary, shall be prepared for absolute photometry in an electronic data format by specifiers and designers to reliably predict illuminance levels in design applications. The data, however, shall be used with the understanding that the photometric result describes the performance of a single luminaire and does not necessarily represent the average performance of a group of the same SSL luminaires.

NOTE — The presentation of normalized luminous intensity data using the relative photometry method, commonly used in traditional luminaire testing, cannot be used for SSL production.

13 LUMINOUS EFFICACY

The luminous efficacy (lm/W) of the SSL product, η_v, is given as the quotient of measured total luminous flux Φ_{TEST} (lumen) and the measured electrical input power P_{TEST} (watt) of the SSL product under test as

$$\eta_v = \frac{\theta_{TEST}}{P_{TEST}} [lm/W] \qquad \ldots(12)$$

NOTE — The luminous efficacy described above is luminous efficacy of a source. It should not be confused with luminous efficacy of radiation, which is the ratio of luminous flux (lumen) to radiant flux (watt) of the source.

14 TEST METHODS FOR COLOUR CHARACTERISTICS OF SSL PRODUCTS

The colour characteristics of SSL products include chromaticity coordinates, correlated colour temperature, and colour rendering index. These characteristics of SSL products may be spatially non-uniform, and thus, in order that they can be specified accurately, the colour quantities shall be measured as values that are spatially averaged, weighted to intensity, over the angular range where light is intentionally emitted from the SSL product.

14.1 Method Using a Sphere Spectroradiometer System

The first recommended method to achieve this is to measure total spectral radiant flux using a sphere-spectroradiometer system as descried in **11.2**. The measured total spectral radiant flux is a spatially integrated quantity, thus colour characteristics calculated from this are already spatially averaged. The method given in **11.2** to perform measurements shall be followed.

14.2 Method Using a Spectroradiometer of Colorimeter Spatially Scanned

This method may be used when a sphere-spectroradiometer system is not available, or when the test sample is too large to be measured with a sphere-spectroradiometer system. This method uses a spectroradiometer and/or a colorimeter that measures the chromaticity of the SSL products under test in different directions. This can be achieved most efficiently by mounting the colour-measuring instrument on a goniometer (called gonio-spectroradiometer, or gonio-colorimeter). The luminous intensity distribution and chromaticity coordinates can be measured at the same time, taking readings at appropriate angle intervals (*see* **11.4.3**) over the entire angle range where the light is intentionally emitted from the product. Then, the spatially averaged chromaticity is obtained from all measured points using equation (13), or based on spatially integrated tristimulus values.

If a gonio-spectroradiometer or gonio-colorimeter is not available, this can also be achieved by manually positioning the instrument for given directions at a constant distance, as the angle accuracy is not very critical in this measurement. The chromaticity coordinates and luminous intensity (or illuminance) shall be measured at 10° or less intervals for vertical angle θ over the angle range where light is intentionally emitted from the source and at minimum two horizontal angles Φ = 0° and 90° (*see* Fig. 4). The chromaticity measurements need to be made only for the θ angles where the average luminous intensity is more than 10 percent of the peak intensity. The average chromaticity coordinates (x, y) or (u', v) shall be obtained as a weighted mean of all measured points, weighted by the illuminance and the solid angle factor at each point as Fig. 4.

The chromaticity coordinates and luminous intensity for Φ = 0° and Φ = 90° (or more Φ angles) are first averaged at each θ angle and expressed as $x(\theta_i)$, $y(\theta_i)$ and $I(\theta_i)$ where θ_i = 0°, 10°, 20°,….,180°. Then the average chromaticity coordinates x_a is calculated as a weighted mean:

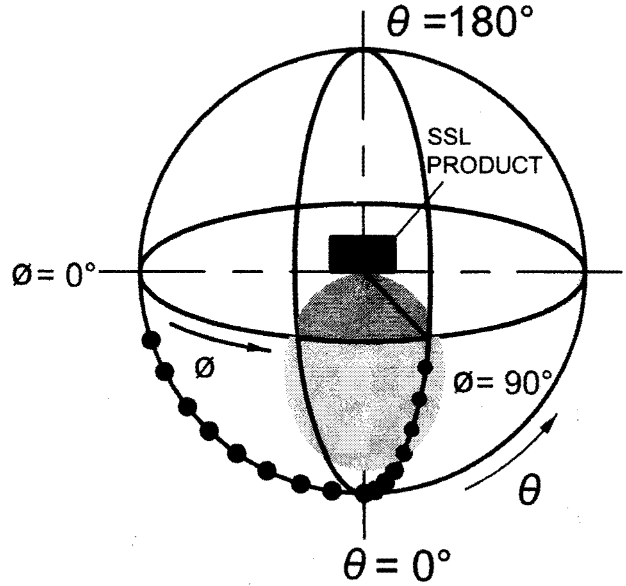


FIG. 4 GEOMETRY FOR THE CHROMATICITY MEASUREMENT USING A GONIOMETER (THE FIGURE SHOWS THE CASE FOR A SSL PRODUCT EMITTING LIGHT IN DOWNWARD DIRECTIONS ONLY)

$$x_a = \sum_{i=1}^{19} x(\theta_i)\bullet w_i(\theta_i) \text{ with } w_i(\theta_i) = \frac{I(\theta_i),\ \Omega(\theta_i)}{\sum_{i=1}^{19} I(\theta_i)\bullet\Omega(\theta_i)} \quad \ldots(13)$$

and

$$\Omega(\theta_i) = \begin{cases} 2\pi[\cos(\theta_i) - \cos(\theta_i + \frac{\Delta\theta}{2})];\ \text{for } \theta_i = 0° \\ 2\pi[\cos(\theta_i + \frac{\Delta\theta}{2}) - \cos(\theta_i + \frac{\Delta\theta}{2})];\ \text{for } \theta_i \\ \qquad = 10°, 20°, \ldots 170° \\ 2\pi[\cos(\theta_i + \frac{\Delta\theta}{2}) - \cos(\theta_i)];\ \text{for } \theta_i = 180° \end{cases}$$

$$\Delta\theta = 10°$$

Chromaticity coordinates y_a and other average colour quantities are calculated similarly. This formula is an approximation but provides sufficient accuracy for practical applications. Rigorously, the spatially integrated colour quantities are calculated from the geometrically-total flux of the tristimulus values *X*, *Y*, *Z*.

If a tristimulus colorimeter is used, it should be calibrated against the test SSL product by comparison with a spectroradiometer, or it should measure only colour differences from a reference point (for example, perpendicular direction), and the chromaticity of the reference point should be measured with a spectroradiometer so that absolute chromaticities at all the points are obtained based on the spectroradiometer reading. The photometric output (illuminance) also needs to be recorded to calculate the weighted average described above. For this colour uniformity measurement the distance shall be more than 5 times the largest dimension of the light emitting area of the product under test.

If the spatial non-uniformity of colour of a given product has been determined to be negligibly small ($\Delta u'v' \leq 0.001$, *see* **14.5**), the average chromaticity of the product of the same model can be measured in one direction near the peak of its intensity distribution.

The spectroradiometer used in this measurement (*see* **14.2**) shall be calibrated against spectral irradiance or spectral radiance standards traceable to a national metrology institute.

14.3 Spectroradiometer Parameters Impacting Measured Colour Characteristics

The spectroradiometer shall have a minimum spectral range of 380 nm to 780 nm. The spectroradiometer used in either methods (*see* **14.1** or **14.2**) shall be selected and set up so that the relative spectral distribution is measured accurately even for SSL production having narrowband spectral distributions. The bandwidth and scanning intervals are among important parameters for measurement of spectral distributions of light sources in general. The bandwidth and wavelength scanning intervals shall be 5 nm or smaller (unless appropriate correction methods are applied) and should be matched unless wavelength intervals are very small (for examaple, 1nm or less).

14.4 Colorimetric Calculations

The chromaticity (x,y) and / or (u',v',) and correlated colour temperature (CCT, unit: Kelvin) are calculated from the relative spectral distribution of the SSL product. CCT is defined as the temperature of a planckian radiator having the chromaticity nearest the chromaticity of the light source on the (u', 2/3 v') chromaticity diagram. The colour rendering index (CRI) is calculated according to the formulae defined in IS 3646 (Part 1).

14.5 Spatial Non-uniformity of Chromaticity

SSL products may have variation of colour with angle of emission. Spatial non-uniformity of chromaticity shall be evaluated using the measurement conditions described in **14.2**. The spatial distribution of chromaticity coordinates of the SSL products are measured at two vertical planes ($\Phi = 0°$, $\Phi = 90°$) and the spatially averaged chromaticity coordinate is calculated from these points according to equation (13).

The spatial non-uniformly of chromaticity, $\Delta u'v'$ is determined as the maximum deviation [distance on the CIE (u', v') diagram] among all measured points from the spatially averaged chromaticity coordinate. For this evaluation, accuracy only in chromaticity differences is critical, and thus, all measurements may be made with a tristimulus colorimeter if a spectroradiometer is not available.

15 UNCERTAINTY STATEMENT

Statement of uncertainty if required may be provided by the testing authority. For all photometric measurements, expanded uncertainty with a confidence interval of 95 percent shall be applied which in most cases use a coverage factor of $k = 2$.

16 TEST REPORT

The test report shall list all significant data for each SSL product tested together with performance data. The report shall also list all pertinent data concerning conditions of testing, type of equipment, SSL products and reference standards. Typical items reported are:

a) Date and name of the testing agency;
b) Manufacturer's name and designation of SSL product under test;
c) Measurement quantities measured (total luminous flux, luminous efficacy, etc);
d) Rated electrical values [clarify a.c. (frequency) or d.c.] and nominal CCT of the SSL product tested;
e) Number of hours operated prior to measurement (0 h for rating new products);
f) Total operating time of the product for measurement including stabilization;
g) Ambient temperature;
h) Orientation (burning position) of SSL product during test;
j) Stabilization time;
k) Photometric method or instrument used (sphere photometer, sphere spectroradio-meter, or goniophotometer);
m) Designation and type of reference standard used (wattage, lamp type, intensity distribution type omni-directional/ directional) and its traceability;
n) Correction factors applied (for example., spectral mismatch, self absorption, intensity distribution, etc);
p) Photometric measurement conditions (for sphere measurement, diameter of the sphere, coating reflectance, 4π or 2π geometry, for goniophotometer, photometric distance);
q) Measured total luminous flux (lm) and input voltage (V), current (A), and power (W) of each SSL product;
r) Luminous intensity distribution (if applicable);
s) Colour quantities (chromaticity coordinates, CCT and/or CRI for white light products);
t) Spectral power distribution (if applicable);
u) Bandwidth of spectroradiometer, if spectral distribution and/or colour quantities are reported;
v) Equipment used;
w) Statement of uncertainties (if required); and
y) Deviation from standard operating procedures, if any.

ANNEX A

(*Foreword*)

COMPARISON OF METHOD OF MEASUREMENT OF SOLID STATE LIGHTING (SSL) PRODUCTS AND MEASUREMENT OF TRADITIONAL LAMPS AND LUMINAIRES

A-1 GENERAL

This Annex explains how the measurement of solid state lighting (SSL) products differs from measurement of traditional lamps and luminaires, why this standard is needed, and why sampling is not addressed.

A-2 WHY SOLID STATE LIGHTING IS DIFFERENT

In photometric measurements of traditional lamps and luminaires, the operating conditions are different depending on the type of lamp. These operating conditions include the reference ballast, electrical measurement, stabilization time, handling of lamp, and more. Thus different standards were developed for different lamp types and even luminaires that use multiple lamp types. Standards for measurement of SSL products are needed because LED source have different requirements for operation and temperature conditions than traditional light source.

SSL products can be in the form of lamps such as integrated LED lamps, or luminaires, which range in scale from small lamps, to size of large fluorescent luminaires. Depending on the size and quantities needed, these products may be measured in an integrating sphere or a goniophotometer, thus SSL products are measured by lamp photometry engineers as well as by luminaire photometry engineers, having different practices and culture. This standard brings a common basis and uniform measurement methods for both groups of engineers.

Traditionally, photometric measurements have been made for lamps and for luminaires separately using different test methods. Lamps are typically measured with integrating spheres, and total luminous flux and chromaticity are the main quantities of interest. Luminaires are normally measured with goniophotometers, and luminous intensity distribution and luminaire efficiency are the main quantities of interest, standards have been developed separately for measurement of lamps, such as linear fluorescent lamps, incandescent lamps, and for compact fluorescent lamps and for measurement of luminaires. However, for must current SSL products, LED lamps cannot be separated form luminaires, and the nature of SSL products resembles both light sources and luminaires Thus, none of the existing standards for lamps or luminaires are directly applicable to SSL products.

A-3 RELATIVE AND ABSOLUTE PHOTOMETRY

Traditional luminaire photometry methods do not work for SSL products because traditionally, luminaries are normally tested with a goniophotometer using a procedure called relative photometry. In this method, a luminaire under test and the bare lamp(s) used in the luminaire are measured separately. Then the luminous intensity distribution data of the luminaire measured with the goniophotometer are normalized by the measured total luminous flux of lamps used in the tested luminaire. Therefore, the luminous intensity distribution is normally presented in relative scale (for example, candela per 1 000 lumens). Such test methods cannot be used for SSL products because, in most SSL products, LED lamps sources are not designed to be separated from the luminaire. Even if the LED source can be separately and measured separately, the relative photometry method will not work accurately because the light output of the LED source will change significantly if operated outside the luminaire due to differences in thermal conditions. Therefore, existing standards for measurement of luminaires cannot be used for SSL products.

SSL products should be measured using absolute photometry method. However, absolute photometry is rarely used for traditional luminaires and is not described in sufficient detail in any standards. Clause **11.4** of this standard describes detailed requirements for such absolute photometry for total luminous flux measurement of SSL products.

A-4 SAMPLING

With the relative photometry method commonly used for luminaires, the results are independent from individual variations of lamp lumen output because of the normalization using the measured total luminous flux of lamps. As a result, the individual variation of lamp light output due to lamp variation and variation in the ballast factor of the control gear is removed.

Inconsistencies in luminous flux measurements as a result of variation in luminaire geometry are normally insignificant when the inconsistencies due to variations in the luminous flux produced by the lamp(s) are removed. It should be noted that the variation in luminous flux provided by the lamp is function of both the lamp(s) and their ballast control gear. As a result, it has been historically sufficient to measure only one sample for rating a luminaire product. This is the practice often used in performance rating of luminaires. On the other hand, the results of measurement of SSL products are directly affected by the output of the sources, and are always subject to individual variations of LED sources, which tend to be significantly larger than even those of fluorescent lamps. Therefore, measurement of one sample is insufficient for rating SSL products and appropriate sampling and averaging of results is required for SSL products. The tolerance requirements for individual product variations may be different for different applications. This standard describes test methods for individual SSL product and does not cover such sampling methods for rating products, which should be covered by a regulatory requirement, customer requirement of agency requirement.

A-5 FUTURE PROJECTION

This standard would be reviewed continuously keeping in pace with the innovation of new technology and developments in the field of SSL products. In particular, measurement of luminaire characteristics using goniophotometry would be requiring further detailing. Requirements of luminaires differ for different lighting applications, and it would therefore require substantial efforts to cover this area. This standard would be upgraded in due course as well as develop additional standards and methods needed for measurement of SSL products, if considered necessary.

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