APLAC T088

Appendix Measurement method for the proficiency testing program

Introductions

This measurement method is prepared for use by the APLAC Proficiency Testing Program – Photometric measurement of Solid State Lighting Program. As this APLAC PT Program cooperates with *IEA SSL Annex Interlaboratory Comparison 2013* [1], this measurement method follows the *IEA SSL Annex Interlaboratory Comparison Test Method* [2] and made basically compatible with the IEA's test method.

1. Environmental Conditions

A. Ambient temperature

- 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.
- The temperature sensor shall be placed at the same height and within 1 m for LED lamps or luminaire under test.
- 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.
- The thermometer shall have resolution of 0.1 °C or less.

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

B. Air movement

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 above.

C. Laboratory humidity

Relative humidity of the laboratory should be 65 % or less.

2. Mounting Conditions

A. Operating position

The operating position of the artefacts used for the proficiency testing are specified in the program description. Measurement shall be made with the artefact operated accordingly.

B. Supporting objects

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

3. Electrical conditions and measurement

A. Operation of SSL product

- 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.
- The tolerance of the test voltage is ±0.2 % of the rated value and the tolerance of frequency is ±0.2 %.
- 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.

- 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.

- 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.

B. Electrical instrumentation

- 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.
- AC voltage ripple of the DC power supply shall be 0.5 % or less.
- 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.
- 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.
- The AC power meter shall have the capability of measuring power factor.
- 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 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 40th 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

- 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.

4. 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.

5. Photometric and colormetric 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)

A. Total luminous flux

- 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

- 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.

- 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.

- 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.

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

- A sphere-photometer shall have a total relative spectral responsivity (sphere plus photometer head) that meets the f1’ value of 2% or less. If f1’ of the sphere-photometer exceeds 2%, then f1’ 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.

- 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.

- 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 f2 value of 15 % or less.

Goniophotometer

- 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.

  Note 1: 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).

- For goniophotometers employing a photometer head, the relative spectral responsivity of the photometer head (plus mirror if used) shall have an f1' value of 1.5 % or less. If the f1' 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.

- 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.*

- 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.

  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.

- 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.

- 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.

B. Luminous intensity distribution

- Luminous intensity distribution of an SSL product shall be measured with a goniophotometer that fulfils requirements in 5.A. There is no need to calibrate the goniophotometer against absolute luminous intensity or illuminance standard, as luminous intensity distribution measurements can be done on a relative photometric scale.

- The coordinate system and geometry for mounting SSL products should follow the general practice used in traditional luminaire testing.
- 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.

C. Centre-beam luminous intensity

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 IEC/TR 61341.

D. Luminous efficacy

- The electrical input power P_{TEST} (W) of the SSL product under test shall be measured according to section 3.
- The luminous flux Φ_{TEST} (lm) shall be measured according to section 5.A.
- The luminous efficacy η_{v} (lm/W) of the product under test shall be determined by

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

E. Colour quantities

- Colour quantities to be measured for SSL products include chromaticity coordinates (x, y) and/or (u’, v’), correlated colour temperature (CCT), Duv, and general Colour Rendering Index (CRI Ra). Colour quantities are calculated from the measured relative spectral power distribution of the SSL product according to the definitions given in CIE 13.3 and CIE 15.

- 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 5.A.

  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 (□angle), and at 10° increments for a vertical angle scan (□□angle) in each vertical plane. For reflector lamps, the□□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 angle) and the luminous intensity of the point.
- 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.

6. Measurement Uncertainty

The uncertainties should be reported for all measurement results. In reporting uncertainties, the international recommendation, ISO GUM (Guide to the Expression of Uncertainty in Measurement), 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 CIE 198.

References

[1] IEA SSL Annex: Interlaboratory Comparison 2013,

http://ssl.iea-4e.org/task-2-ssl-testing/2013-ic

[2] IEA SSL Annex: Interlaboratory Comparison Test Method, Version 1.0, http://ssl.iea-4e.org/files/otherfiles/0000/0051/SSL_Annex_2013_IC_Test_Method_v.1.0.pdf