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IES LM-84-14

Approved Method: **Measuring Luminous Flux and Color Maintenance of LED Lamps, Light Engines, and Luminaires**

IES Approved Method for Measuring Luminous Flux and Color Maintenance of LED Lamps, Light Engines, and Luminaires

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INTRODUCTION

The method for measuring luminous flux and color maintenance of LED light sources has been documented in IES LM-80-08. At the solid-state lighting (SSL) system level such as LED lamps, light engines, and luminaires, other system components, in addition to the LED light sources, also contribute to luminous flux decay and color change over time. The system performance changes over time can be directly tested at the SSL product level. This document addresses the evaluation of the changes in performance of SSL systems over time and can be a useful tool for engineering evaluations and luminous flux maintenance for entire assemblies when environmental considerations and variability for the base LED deprecation is incorporated into the analysis.

Furthermore, performances of SSL systems, LED integrated lamps, non-integrated lamps, LED light engines, and LED luminaires, are typically but not without exception affected by operational and environmental variables such as operating cycle, conditions imposed by auxiliary equipment and fixtures, ambient temperature, airflow and orientation. This test method has been developed to establish consistent and environmental conditions across laboratories to achieve reproducible results and to permit reliable comparison of results.

1.0 Scope

This document provides the method for measurement of luminous flux and color maintenance of LED lamps, integrated; LED lamps, non-integrated; LED light engines, and LED luminaires. The method describes the procedures to be followed and the precautions to be observed in obtaining and reproducing luminous flux and color maintenance measurements under standard operating conditions.

This approved method does not provide guidance or recommendations regarding sampling, predictive estimations or extrapolation of luminous flux maintenance beyond the final measurement.

2.0 NORMATIVE REFERENCES

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

3.0 DEFINITIONS

3.1 Device Under Test (DUT)

An LED lamp, integrated; LED lamp, non-integrated; LED light engine or LED luminaire that is being tested.

3.2 Luminous Flux Maintenance

Luminous flux maintenance (often referred to as "lumen maintenance") is the remaining luminous flux over the initial flux (typically expressed as a percentage) at any selected elapsed operating time. Luminous flux maintenance is the complement of luminous flux depreciation (or "lumen depreciation").

3.3 Maintenance Test

The continuing steady operation test for the DUT when it is energized.

3.4 Non-Operational DUT

A DUT which, when energized, does not emit light.

4.0 PHYSICAL AND ENVIRONMENTAL CONDITIONS DURING OPERATION AND HANDLING

4.1 General

Variation may occur in luminous flux maintenance values of the DUT due to changes in ambient temperature or air movement due to the DUT's thermal management design. DUTs should be checked and as necessary cleaned prior to measurement and maintenance test. Manufacturers handling instructions (e.g., electro-static discharge or ESD, etc.) shall be observed. Unusual environmental conditions, such as thermal interference from HVAC systems or solar loading, are to be reduced to levels reasonably expected to minimize influence relative to operation when the conditions are removed.

4.2 Mounting DUTs

The DUT shall be mounted in accordance with the manufacturer recommendations

4.3 Vibration

DUTs should not be subjected to excessive vibration or shock during operation or handling.

4.4 Ambient Temperature During Maintenance Test

If a maintenance test at other ambient temperature is not specified, the ambient temperature during maintenance test of the DUT between photometric measurements shall be maintained at 25°C ± 5°C. The ambient temperature variation of the operating environment shall be monitored with a sufficient number of and appropriately located temperature measurement points. Ambient temperature sensors shall be shielded from direct optical radiation from the DUTs and from thermal interference from any other sources (e. g., heat sink). When the ambient temperature falls outside of the allowed temperature range, testing shall be terminated and the event noted, including the out of tolerance ambient temperature.

If an ambient temperature other than 25°C is specified, the ambient temperature tolerance shall be ± 5°C and the test conditions shall be included in the test report.

4.5 Humidity

Humidity of the DUT operating environment shall be maintained to less than 65% RH during the maintenance test.

4.6 Air Movement

The DUT's self-induced airflow should not be restricted, and should reflect the DUT's installation or application condition. All other airflow to the DUT should be minimized.

4.7 Operating Orientation

During maintenance test, the DUT shall be in the same the orientation as it will be during its photometric measurement (**Section 6.1**). Operating orientation shall correspond to the manufacturer's recommended orientation, and shall be reported.

5.0 ELECTRICAL CONDITIONS

5.1 Input Voltage

Continuous rated input voltage per the manufacturer's specifications shall be applied for operation of the DUT for the duration of the maintenance test.

5.2 AC Line Voltage Wave Shape

When a wave form altering DUT control device is not used, an AC power supply shall have a sinusoidal voltage wave shape at the prescribed frequency (typically 60 Hz or 50 Hz) such that the total harmonic distortion does not exceed 3% of the fundamental during the maintenance test of the DUT.

5.3 Line Impedance

Optionally, the impedance of the electrical system powering the DUT should be identified. Use of AC power supplies with low output impedance may be preferable to maintain consistent test conditions.

5.4 Line Voltage Regulation

Branch circuit input voltage shall be regulated to within ≤ 2% of the rated rms value. The input voltage to each DUT or driver shall be verified periodically. Time between verifications shall not exceed 3000 hours of DUT operation.

5.5 Wiring

Wiring of test racks should be in accordance with national, state or provincial, and local electrical codes, and in accordance with the manufacturer's recommendations of the DUT or system. For non-integrated lamps, the driver shall be grounded per the manufacturer's specifications.

An inspection of electric contacts including the DUT holder contacts and verification of the driver operation should be performed each time DUTs are installed.

6.0 PHOTOMETRIC AND THERMAL MEASUREMENT PROCEDURE

6.1 Photometry Measurement

At each measurement interval (**Section 7**), the DUT shall be taken off the test racks and measured per IES LM-79-08 for electrical, photometric, and colorimetric characteristics. After measurement, the DUT shall be placed back on the test rack for the next cycle if required.

For dimmable or otherwise controllable DUTs, the photometric measurements shall be performed at the maximum input power condition.

6.2 LED Source In-Situ Case Temperature Measurement

If in-situ LED source case temperature, T_s, is measured, the recommended procedures are listed in **Annex A**.

7.0 MAINTENANCE TEST PROCEDURES

7.1 Seasoning or Aging

Seasoning or aging shall not be performed for DUTs.

7.2 Handling

When handling, transporting, or storing the DUTs, care should be taken to prevent any damage or contamination that may affect the test results. Handling, transporting and storing shall be performed per the manufacturer's guidance if such exists.

7.3 Marking

Individual DUT shall be tracked during the maintenance test. DUTs can be identified by markings applied directly to the DUTs or by labels that can be attached to the DUTs during transport, operation and evaluation or to the test rack position occupied by the DUT. The identification method selected should take into account the effect of exposure to light and heat.

Possible suitable marking methods/materials include durable bar coding, ceramic ink marking, high temperature markers, or any other method which endures or can be periodically renewed for the duration of the test.

7.4 Operating Cycle

It is recommended to operate the DUT continuously. Luminous flux and color maintenance data from different operating cycles cannot be compared without first evaluating if the lumen and color maintenance of the DUT is affected by the operating cycle.

7.5 Timekeeping

Accurate recording of elapsed operating time is critical. Elapsed time recording devices shall be connected to the particular test positions and accumulate time only when the DUTs are operating. Video monitoring,current monitoring or other means can be used to determine elapsed operating time if designed to provide sufficient temporal accuracy. All equipment used for measuring elapsed operating time shall be calibrated in accordance with the manufacturer specifications. Total minimum temporal resolution should be ± 0.5%.

7.6 Operating Duration and Measurement Intervals

Initial photometric and colorimetric measurement shall be performed prior to the starting of the maintenance test and recorded as the 0 hours data.

Photometric measurements of the DUT shall be made at each measurement interval of the maintenance test duration.

The maintenance test duration and measurement intervals shall be based on and consistent with the design operating life, the intent of the test including evidence of compliance to the regulations requested and planned analysis of the data (e.g., data for predictive luminous flux maintenance modeling, or data for actual luminous flux maintenance validation).

7.7 Operation of Dimmable or Controllable DUTs

If the DUT is dimmable or otherwise controllable, the operation shall be performed at the maximum input power condition for the mode of operation.

A DUT may have multiple modes of operation including variable correlated color temperature or CCT. The mode(s) of operation specified for this measurement shall remain the same throughout the test, and such setting conditions shall be clearly reported.

7.8 Reporting Non-Operational DUTs

Checking for DUT operation either by visual observation or automatic monitoring shall be done at a minimum of the start of the maintenance test and at every photometric measurement interval, or as specified. Each non-operational DUT shall be investigated to make certain that it is actually a DUT failure, and that is not caused by improper functioning of the test equipment or electrical connections. The recorded time the DUT stops operating shall be determined as the midpoint of the last monitoring interval.

8.0 TEST REPORT

The report shall list all pertinent data concerning conditions of the maintenance test, type of equipment, and types of DUTs. Typical items reported are:

8.1 Administrative Information

8.1.1 Testing agency identification

8.1.2 Report issue date

8.1.3 Testing start date

8.1.4 Testing completion date

8.1.5 Description of Test Equipment

8.1.6 Individual(s) performing testing

8.1.7 Individual(s) reviewing and approving test results

8.2 DUT Identification

Information specific enough to duplicate the test shall be provided including:

8.2.1 Manufacturer's name

8.2.2 Design (or model) identifier

8.2.3 DUT identification, e.g. serial number

8.2.4 Description of DUT under test

8.2.5 Non-integrated LED driver or power supply (if applicable)

8.2.6 Date of manufacture of the DUT

8.3 Physical and Ambient Conditions

8.3.1 Operating orientation

8.3.2 Ambient temperature

8.3.3 Humidity

8.4 Deviations

8.4.1 Deviations from test method listed in this document

8.4.2 List of non-standard conditions

8.4.3 Deviation from nominal or specified operating conditions or testing

8.5 Maintenance Test Duration (in Hours)

8.6 Measurement Intervals (in Hours)

8.7 Non-operational DUTs

Hours at which non-operational DUT was observed (if applicable)

8.8 Results

Data for electrical, photometric, and colorimetric measurements for each DUT at each interval including:

8.8.1 Luminous Flux

8.8.2 Luminous Flux maintenance

8.8.3 Chromaticity coordinates

8.8.3 Electrical parameters: input voltage, input current, and input power

8.9 Other Typical Items

8.9.1 Special test conditions (Example: Minimum light output of individual DUTs before it is considered a failure; any unusual conditions observed.)

8.9.2 Measured L_{50} (hours) and L_{70} (hours) of individual DUTs, when applicable

8.9.3 Statement of uncertainties (if required)

ANNEX A RECOMMENDATIONS FOR MEASUREMENT OF IN-SITU CONDITIONS LED CASE TEMPERATURE, T_s

This Annex provides guidance on approaches to establish representative T_s conditions within an SSL product. The general goal is to determine the T_s maximum value in the product, as this serves as a worst case bounding condition, up to which all LEDs will operate in the lamp or luminaire. In most instances, thermocouple measurements are taken during thermal measurement activity associated with safety evaluations.

A1 Basic Assessment

The use of IR thermography or other types of non-contact IR thermometers can be used to conduct a basic assessment of the hottest regions of an LED printed circuit board assembly (PCBA). To utilize these methods, it may be necessary to remove one or more layers of optics so that the IR camera or IR thermometer can receive a direct IR image of the PCBA. **Figure A1** depicts two photographs: one of PCBAs in a multi-PCBA assembly (exposed with optics removed) and one of the associated IR thermograph, correspondingly.

Based on the content of the IR thermograph or "point-and-shoot" style non-contact IR thermometers, the overall relative temperature profiles of the assembly can be documented and the hottest groups of LEDs as well as the hottest LEDs within a group can be identified. These hottest LEDs are then candidates for thermocouple attachment, for accurate measurements using thermocouple methods.

A2 Symmetry Conditions

In many cases conditions of symmetry can be used to reduce the total number of LEDs that must have thermocouples attached, in order to obtain a useful representation of the T_s conditions in the SSL fixture. **Figure A2** is a typical example of a PCBA with mid-line symmetry in 2 dimensions from the perspective of the LEDs on the PCBA. In the case of symmetric conditions, it is not necessary to instrument LEDs' in all quadrants of the PCBA and it would be sufficient to instrument a logical subset of the LEDs that reflect the symmetry.

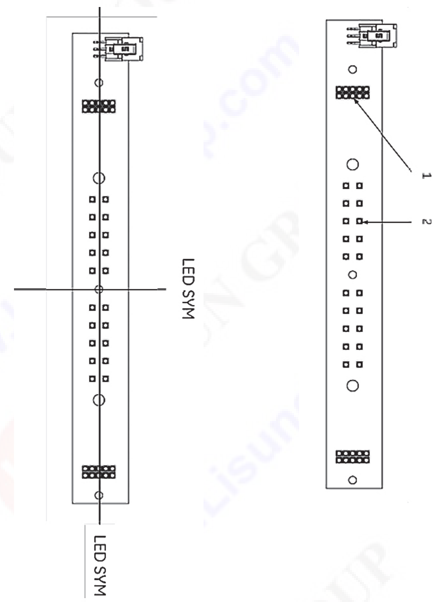

Figure A2. (Left) Example of PCBA with mid-line symmetry. (Right) Example of selected LED's for TC on a PCBA with 4 quadrant LED symmetry based on IR thermographic assessment of hottest groups.

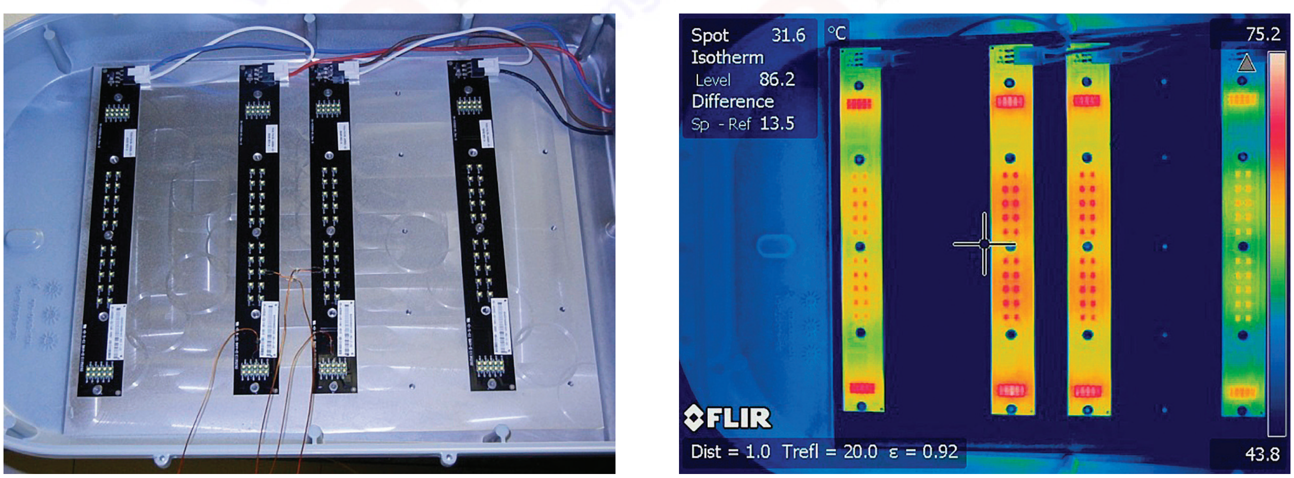

Figure A1. (Left) Typical luminaire assembly with PCBAs exposed for IR thermography or non-contact IR thermometer measurement. (Right) Typical IR thermograph from hot PCBAs in a luminaire assembly.

A3 Thermocouples

In all cases using the combined method, LED packages should be instrumented with thermocouples (TC) in accordance with the manufacturer's recommendations for TC location. Thermocouples should be placed in intimate contact with the surfaces indicated in the LED manufacturer's literature and bonded using an appropriate method (e.g. adhesive or soldering) endorsed by the manufacturer. It is recommended that multiple LEDs in the assembly be fitted with TCs, to ensure that the testing is capturing representative values.

A4 Maximum T_s Values

Typically, multiple T_s will be applied to the PCBAs and multiple PCBAs may be instrumented in a SSL lamp or luminaire. These values should all be recorded and reviewed, to establish the maximum T_s for the assembly.

ANNEX B RATIONALE FOR NOT DESCRIBING MAINTENANCE TEST DURATION AND MEASUREMENT INTERVALS

Describing or prescribing maintenance test duration and measurement interval, defining the requirements for a single type of DUT to be representative of a family of DUTs, and prescribing sampling methods are not appropriate topics for a method of measurement.

ANNEX C CHECKING AND RECORDING NON-OPERATIONAL DUTS DURING MAINTENANCE TEST

If it is desired to more precisely determine when the DUTs stop operating for the purpose of calculating Weibull failure distributions then more frequent operation checks may be performed. Typical checking intervals range from 0.5% to 1% of rated life for predicting Weibull distributions for other lighting technologies.

INFORMATIVE REFERENCES

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