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IES LM-80-08

Approved Method: **Measuring Lumen Maintenance of LED Light Sources**

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IES Approved Method for Measuring Lumen Maintenance of LED Light Sources

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Suggestions for revision should be directed to IES

Prepared by: The Subcommittee on Solid State Light Sources
of the IESNA Testing Procedures Committee

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IESNA Approved Method for Lumen Maintenance Testing of LED Light Sources

Introduction

This approved method, LM-80, covers the measurement of lumen maintenance of inorganic LED-based packages, arrays and modules.[1] LM-80 does not attempt to induce any failure modes other than the maintenance of lumen output. In this document the use of the term 'sources' refers to packages, arrays and modules only.

This approved method describes the procedures by which LED light sources can be operated under controlled conditions to obtain optimally comparable data on changes in light output during the life of the lamp. These sources must be operated on external auxiliary devices.

LEDs typically exhibit very long operational life characteristics and, depending on drive current and use conditions, can be in use for 50,000 hours or longer. Like all light sources, the light output from LEDs slowly decreases in output over time. Unlike traditional light sources, LEDs do not tend to fail catastrophically. Therefore, over time, lumen maintenance can result in lower light output than intended in the specification or required by codes, standard practices or regulations.

LEDs may also undergo gradual shifts in the emitted spectra over time that may result in unacceptable appearance or color rendering. These changes may affect the lumen maintenance due to changes in the lumen output resulting from a varying spectral power distribution.

It is important to know the light output, efficacy, and lumen maintenance as well as the life of these light sources. For information on the photometry of the LED light source, see Reference 2.1.2, LM-79. The term 'lifetime' is often used to describe end-of-life criteria such as when lumen maintenance falls below a defined threshold. This standard establishes procedures for the measurement of lumen maintenance.

Performance of LED light sources is typically affected by variables such as operating cycle, conditions imposed by auxiliary equipment and fixtures, ambient temperature, airflow and orientation. Test conditions and programs should be designed to give comparable results when adopted by various laboratories. The recommendations of this approved method have been made with this objective.

[1]See IES Publication RP-16-05 Nomenclature and Definitions for Illumination Engineering. Addendum A.

1.0 SCOPE

This approved method is one of a continuing series of IESNA Approved Methods, which are written to permit reliable comparison of test results among laboratories by establishing uniform test methods. It addresses the measurement of lumen maintenance testing for LED light sources designed and certified to meet lighting industry standards.

This document provides the methods of the measurement of lumen maintenance of sources including LED packages, arrays and modules only. Lumen maintenance is a characteristic measured under controlled conditions. Performance in a particular application may be different. This approved method does not provide guidance or make any recommendation regarding predictive estimations or extrapolation for lumen maintenance beyond the limits of the lumen maintenance determined from actual measurements.

2.0 REFERENCES

2.1 Normative References

2.1.1 Measurement of LEDs (2nd ed.), CIE 127:2007, ISBN 978 3 901 906 58 9

2.1.2 IESNA Testing Procedures Committee. IESNA LM-79-2008 *Approved Method for the Electrical and Photometric Measurements of LED Light Sources*, New York: Illuminating Engineering Society of North America, 2008.

2.2 Non-Normative References

2.2.1 ASSIST Recommends: *LED Life Testing.* Vol. 1-6, 2005. Lighting Research Center, Rensselaer Polytechnic Institute, Troy, NY, 2005.

2.2.2 ANSI/IESNA Testing Procedures Committee, IESNA RP-16-07, *Nomenclature and Definitions for Illuminating Engineering*. See also Addendum A on solid-state lighting (Document is now continuously updated)

2.2.3 IESNA Testing Procedures Committee, IESNA LM-40-01, *Approved Method for Life Performance Testing of Fluorescent Lamps*, New York: Illuminating Engineering Society of North America, 2001.

2.2.4 IESNA Testing Procedures Committee, IESNA LM-65-01 Life Testing of Single-Ended Compact Fluorescent Lamps, New York: Illuminating Engineering Society of North America, 2001.

2.2.5 *Experimental Statistics Handbook 91*, Chapter 1. National Institute of Standards, U.S. Government Printing Office, Washington, D.C.

2.2.6 *IESNA Lighting Handbook*, 9th Edition, New York: Illuminating Engineering Society of North America, 2000.

2.2.7 ASTM Standard E230-03, "Standard Specification and Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples," ASTM International, West Conshohocken, PA, www.astm.org.

3.0 DEFINITIONS

3.1 Measurement units

Electrical measurement units are the volt, the ampere, and the watt. Temperature is in degree Celsius and unit of photometry is the lumen.

3.2 LED Light Source

LED package, array, or module that is operated via an auxiliary driver.

3.3 Lumen Maintenance

Lumen maintenance is the luminous flux output remaining output (typically expressed as a percentage of the maximum output) at any selected elapsed operating time. Lumen maintenance is the converse of lumen depreciation.

3.4 Lumen Maintenance Life

The elapsed operating time at which the specified percentage of lumen depreciation or lumen maintenance is reached expressed in hours. Operating time does not include elapsed time when the light source is cycled off or periodically shut down.

3.5 LED Light Source Failure

Failure to produce light. The failures, such as early failure to function due to manufacturing defects are reported but not included in the calculation of LED light source lumen maintenance.

3.6 Rated Lumen Maintenance Life, (L_p)

The elapsed operating time over which the LED light source will maintain the percentage, p, of its initial light output e.g.

- L_{70} (hours): Time to 70% lumen maintenance
- L_{50} (hours): Time to 50% lumen maintenance

3.7 Case Temperature, (T_s)

Ts is the temperature of the thermocouple attachment point on the LED light source package as defined by the manufacturer of the package.

4.0 AMBIENT AND PHYSICAL CONDITIONS

4.1 General

It is recommended laboratory practice that the storage and testing of LED sources should be undertaken in a relatively clean environment. Prior to operation, sources shall be cleaned to eliminate handling marks and the manufacturer's handling instructions must be observed, e.g., electro-static discharge, ESD.

4.2 LED Unit Marking

Individual LED light sources shall be tracked during life testing. Units can be identified by markings applied directly to the units or by labels that can be attached units during transport and evaluation or to the life test rack position occupied by the unit during life test.

The identification method selected shall take into account the effect of exposure to light, and heat. Suitable marking methods or materials include durable bar coding, ceramic ink marking, high temperature markers or any other method, which can be periodically renewed for the duration of the life testing.

4.3 Sample Selection

Sample selection of the LED light sources is important since the value of the test will depend upon the method of sampling, size of the sample, conditions of testing and other factors. Sample sources shall be selected to be sufficiently representative of the overall population being tested. In most cases, this sampling shall be specified by an appropriate standards committee document. The sampling method and sample size used shall be reported.

4.4 Environmental Conditions

4.4.1 Vibration Lamps should not be subjected to excessive vibration or shock during life testing. This is less an issue for LEDs than other light sources.

4.4.2 Temperature and Humidity Operation of the LED light sources between photometric measurements shall be at a minimum of three case temperatures, T_s, using the same drive current. The three case temperatures, T_s, shall be 55°C and 85°C with a third temperature selected by the manufacturer. The case temperature and drive current selected by the manufacturer should represent their expectation for customers applications and should be within the recommended operating temperature range. Case temperatures shall be controlled to - 2°C during life testing. The temperature of the surrounding air should be maintained to within -5°C of the case temperature during testing. The surrounding air temperature should be monitored within the test chamber. Humidity shall be maintained to less the 65 RH throughout the life test.

4.4.3 Airflow Airflow shall be minimized for proper light source starting and operation because of heat flow characteristics that differ due to variation in airflow. Because some air movement is necessary to avoid thermal stratification, care should be taken to minimize any drafts in the immediate vicinity of the devices under test.

4.4.4 Operating Orientation and LED Unit Spacing The operating orientation of the LED light sources under test should be as specified by the manufacturer. In general, orientation will not affect LED light sources as they are solid-state but there may be effects from convection airflow due to heat-sinks and thermal management. The units shall be spaced to allow airflow around each test sample. This is facilitated by designing open life testing racks with minimal structural components to block airflow.

5.0 ELECTRICAL AND THERMAL CONDITIONS

5.1 Input Voltage and Current

Input voltage shall conform to the rated input voltage (rms) and frequency of the driver. When using direct current, dc, ripple voltage shall not exceed 2% of the dc output voltage.

5.2 Line Voltage Waveshape

The power supply shall have a voltage waveshape such that the total harmonic distortion does not exceed 3% of the fundamental.

5.3 Input Current Regulation

The input current shall be monitored and regulated to within +/-3% of the rated rms value during life testing and to +/- 0.5% of the rated rms value during photometric measurements. The drive currents shall be maintained over the entire period of the operation of the LED light source. The current can be de-rated as a function of temperature in accordance with the manufacturer's recommendation. The intent is to test the LEDs at the same current as during realistic operation.

5.4 Auxiliary Equipment including Drivers

For LED light source external drivers compliant with manufacturer's guidance shall be used.

5.5 Case Temperature

A thermocouple measurement system complying with ASTM E230 Table 1 "Special Limits" ($\leq$1.1°C or 0.4%, whichever is greater) shall be used to monitor the case temperature. The case temperature T_s, shall be monitored during life testing. T_s is measured directly on the component at the manufacturer-designated case temperature measurement point (i.e. thermocouple attachment point) on the LED unit. A heat sink meeting the recommendations of the manufacturer should be used.

6.0 TEST AND MEASUREMENT PROCEDURES

6.1 Instrumentation

In life testing, accurate recording of elapsed operating time is critical. If used, an elapsed time meter shall be connected to the particular test positions and shall accumulate time only when the installed LED light sources are energized. In the event of a power failure to a position, monitoring devices shall not accumulate time. Video monitoring, current monitoring, or other means shall be used to determine elapsed operating time if designed to provide sufficient temporal accuracy. All equipment calibration shall be in accordance with manufacturer specifications. Total elapsed time uncertainty should be within ± 0.5%.

6.2 Photometry Measurement

Photometric measurements shall be in conformance with the appropriate laboratory method for the LED light source under test. Luminous flux shall be measured at the drive current used during life testing. Ideally, the drive current should be initially set at the drive current used in determining the manufacturer's literature rating of luminous flux.

Because the color stability over life is an important parameter for many lighting applications, the chromaticity values shall be determined. It is strongly recommended that photometric and colorimetric values be determined from total spectral radiant flux measurements using a spectroradiometer.

6.3 Photometry Measurement Temperature

The ambient temperature during lumen and chromaticity measurements shall be set to 25C +/- 2C. The ambient temperature throughout the test duration shall be provided in the test report for each photometric measurement. The LED light source shall be required to cool to room temperature prior to measurement.

7.0 LUMEN MAINTENANCE TESTING METHOD FOR LED LIGHT SOURCES

7.1 Lumen Maintenance Testing Duration and Interval

At the specified ambient temperature noted in section 4.4 the unit shall be driven for at least 6,000 hours with data collection at a minimum of every 1000 hours. 10,000 hours are preferred for the purposes of improved predictive modeling

7.2 Operating Cycle

Unlike other sources where power cycling adversely affects lifetime and performance, LEDs can be 100% modulated at high rates with little effect on lifetime. However, the devices and modules shall be driven at constant current to remove any issues of modulation affecting results. Drive methods shall be reported.

7.3 Recording Failures

Checking for LED light source failures either by visual observation or automatic monitoring shall be done at a minimum of every measurement interval. Each failure shall be investigated to make certain that it is actually an LED light source failure and is not caused by improper functioning of the auxiliary equipment or electrical connections. Catastrophic LED light source failure shall be reported and included in the test report.

7.4 Chromaticity

The chromaticity shift shall be measured and reported over the course of the lumen maintenance test time by measuring chromaticity at each photometric test interval.

8.0 TEST REPORT

The report shall list all pertinent data concerning conditions of testing, type of equipment, and types of LED light sources being tested. The following items shall be included in the test report:

1. Number of LED Light Sources tested
2. Description of LED light sources
3. Description of auxiliary equipment
4. Operating cycle
5. Ambient conditions including airflow, temperature and relative humidity
6. Case temperature (test point temperature)
7. Drive current of the LED light source during lifetime test.
8. Initial luminous flux and forward voltage at photometric measurement current
9. Lumen maintenance data for each individual LED light source along with median value, standard deviation, minimum and maximum lumen maintenance value for all of the LED light sources.
10. Observation of LED light source failures including the failure conditions and time of failure.
11. LED light source monitoring interval
12. Photometric measurement uncertainty
13. Chromaticity shift reported over the measurement time.

All reported items are reported for each test. A table format shall be used to present test results.

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