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Projecting Long Term Lumen Maintenance of LED Light Sources

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Projecting Long Term Lumen Maintenance of LED Light Sources

Publication of this Committee
report has been approved by IES.
Suggestions for revision should
be directed to IES.

Prepared by:
The Subcommittee on Solid State Lighting of
the IES Testing Procedures Committee

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Projecting Long Term Lumen Maintenance of LED Packages

INTRODUCTION

One of the benefits that LED light sources can provide is very long usable life. Unlike other lighting technologies, LEDs typically do not fail catastrophically during use. However, over time the light output will gradually depreciate. At some point in time, the light emitted from an LED depreciates to a level where it is no longer considered adequate for a specific application. It is important in lighting design to understand when this “useful lifetime” of an LED source is reached.

IES LM-80-08 is the Approved Method for Measuring Lumen Maintenance of LED Light Sources. It defines the setup, conditions, and procedures for performing lumen maintenance testing of LED packages, arrays, and modules. LM-80-08 is the IES recommendation that is used widely to characterize the lumen depreciation behavior of LEDs. LED device manufacturers routinely provide LM-80-08 reports for their products with data collected during testing for 6000 hours or more. However, how the data collected from LM-80-08 testing are actually used to best determine the useful lifetime of the tested product is not well defined.

The rated Lumen Maintenance life of an LED is the elapsed operating time over which an LED light source maintains a given percentage of its initial light output. It is defined as L_p , where p is the percentage value. For example, L_{70} is the time (in hours) when the light output from the LED has dropped to 70% of its initial output. The time when the rated lumen maintenance life of an LED light source is reached is dependent upon many variables, including the operating temperature, drive current, and the technology and materials used to construct the products. As such, the lumen maintenance of LEDs can vary not only from manufacturer to manufacturer, but also between different LED package types produced by a single manufacturer.

This Technical Memorandum recommends a method of projecting the Lumen Maintenance of LED Light Sources from the data obtained by LM-80-08 testing.

This document was developed by a dedicated TM-21 Working Group of LED industry professionals. The analyses of the LM-80-08 test data provided by major LED manufacturers are used to rationalize and support this document. Much of this LM-80-08 data were from testing that extended to 10000 hours and beyond.

1.0 SCOPE

This document provides recommendations for projecting long term lumen maintenance of LED light sources using data obtained when testing them per IES LM-80-08, “IES Approved Method for Measuring Lumen Maintenance of LED Light Sources.”

2.0 NORMATIVE REFERENCES

IES LM-80-08, *Approved Method for Measuring Lumen Maintenance of LED Light Sources*.

3.0 DEFINITIONS

3.1 LED Light Source (IES LM-80-08)

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

3.2 DUT

Device under testing (DUT) is the LED light source defined in **Section 3.1**.

3.3 Rated Lumen Maintenance Life, L_p (IES LM-80-08)

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

4.0 TEST DATA AND SAMPLE SIZE

4.1 Data to be Used

The data to be used in this projection method shall be collected according to the methods described in IES LM-80-08.

4.2 Sample Size Recommendation

All data from the sample set at a given case temperature and drive current from the LM-80-08 test report for a specific product model should be used for lumen maintenance life projection. The recommended number of the sample set is a minimum of 20 units to be able to use a multiplication factor of 1.5.

times the test duration, as specified in **Section 5.2.5**, for lumen maintenance life projection.

A sample size less than 20 units may be used when specified by the requestor of the application of this estimation method. When a sample size less than 20 units is specified and used, the sample size shall be noted in any reporting of the use of this method. Any change in sample size will lead to a change in uncertainty and the time interval for the projection of the lumen maintenance life. For a sample size of 10 units to 19 units, a multiplication factor of 5.5 times the test duration, as specified in **Section 5.2.5**, shall be used for lumen maintenance life projection. For a sample size less than 10 units this method for lumen maintenance life projection shall not be used.

4.3 Luminous Flux Data Collection

Additional measurements after the initial 1000 hours at intervals smaller than 1000 hours (including every 1000 hour points) are encouraged. Additional measurements beyond 6000 hours are encouraged and will provide the basis for more accurate lumen maintenance predictions.

5.0 LUMEN MAINTENANCE LIFE PROJECTION

5.1 Method

The recommended method of lumen maintenance projection is to use a curve-fit to the collected data, to extrapolate the lumen maintenance value to the time point where the luminous flux output decreases to the minimum acceptable level (for example, 70% of initial luminous flux). That time point is the lumen maintenance life. The same curve-fit of the collected data can also be used to determine the luminous flux output level at given future time points (i.e., 25000 hours, 35000 hours).

This method is applied separately for each set of DUT test data collected at each operational (e.g., drive current) and environmental (e.g., case temperature) condition as specified in LM-80-08.

5.2 Procedures

5.2.1 Normalization

Normalize all collected data to a value of 1 (100%) at 0 hours for each DUT tested.

5.2.2 Average

Average the normalized measured data of all samples within the same data set defined in 5.1 for each test condition at each measurement point.

5.2.3 Data Used for Curve-fit

For data sets of test duration, D , from 6000 hours up to 10000 hours, the data used for the curve-fits shall be the last 5000 hours of data. Data before the 1000 hour reading shall not be used for the curve fit.

For data sets of test duration greater than 10000 hours, the data for the last 50% of the total test duration shall be used for curve-fit. In other words, all data points between $D/2$ and D shall be used. For example, if the test duration is 13000 hours, use all data points between 6500 hours and 13000 hours. If there is no data point at $D/2$, then the next lower time point shall be included in the data fitting. For example, for D of 13000 hours of data taken every 1000 hours, use the data points between 6000 and 13000 hours.

5.2.4 Curve-fit

Perform an exponential least squares curve-fit through the averaged values as specified in **Section 5.2.3** for the following equation (see **Annex E** for calculation examples):

$$\Phi(t) = B \exp(-\alpha t)$$

where:

t = operating time in hours;

$\Phi(t)$ = averaged normalized luminous flux output at time t ;

B = projected initial constant derived by the least squares curve-fit;

α = decay rate constant derived by the least squares curve-fit.

Use the following equations to project the lumen maintenance life.

$$L_{70} = \frac{\ln\left(\frac{B}{0.7}\right)}{\alpha}$$

or

$$L_{50} = \frac{\ln\left(\frac{B}{0.5}\right)}{\alpha}$$

For any levels of lumen maintenance, use the following generic form of the equation:

$$L_p = \frac{\ln\left(100 \times \frac{B}{p}\right)}{\alpha}$$

where:

L_p = lumen maintenance life expressed in hours where p is the percentage of initial lumen output that is maintained.

When $\alpha > 0$, then the exponential curve-fit decays to zero, and L_p is positive. When $\alpha < 0$, then the exponential curve-fit increase over time, and L_p is negative.

Whenever an L_p value is reached experimentally in the course of LM-80-08 testing, the reported value shall be obtained by linear interpolation between the two nearest test points and takes precedence over any value projected by the formulas above.

5.2.5 Adjustment of Results

For a sample size of 20 units or more, luminous flux values must not be projected beyond 6 times the total test duration (in hours) of measured data. For a sample size of 10 units to 19 units, luminous flux values must not be projected beyond 5.5 times the total test duration of measured data.

When the calculated lumen maintenance life (e.g., L_{70}) is positive and less than or equal to 6 (5.5 for a sample size of 10 units to 19 units) times the total test duration, the calculated lumen maintenance life is the reported lumen maintenance life.

When the calculated lumen maintenance life (e.g., L_{70}) is positive and greater than 6 (5.5 for a sample size of 10 units to 19 units) times the total test duration, the reported lumen maintenance life value is limited to 6 (5.5 for a sample size of 10 units to 19 units) times the total test duration.

When the calculated lumen maintenance life (e.g., L_{70}) is negative, the reported lumen maintenance life will be 6 (5.5 for a sample size of 10 units to 19 units) times the total test duration, and any projections of normalized lumen output at specific operating times beyond the duration of the tests shall be reported to

be equal to the normalized lumen output at the last measurement point.

5.2.6 Notation for Projected Lumen Maintenance Life

The lumen maintenance life projected in this method shall be expressed using the following notation:

$$L_p (Dk)$$

where p is the percentage of initial lumen output that is maintained, and D is the total duration of the test in hours divided by 1000 and rounded to the nearest integer. For example,

$L_{70}(6k)$ for 6000 hours test data;
 $L_{70}(10k)$ for 10000 hours test data.

If the calculated L_p value is reduced by the 6 (5.5 for a sample size of 10 units to 19 units) times rule (see **Section 5.2.5**), the lumen maintenance life value shall be expressed with a symbol ">". For example,

$L_{70}(6k) > 36000$ hours (at $T_s = 55^\circ\text{C}$, $I_F = 350$ mA).

If the L_p value is reached experimentally in the course of LM-80-08 testing then the lumen maintenance life shall be expressed with the D value to be equal to the L_p value in hours divided by 1000 and rounded to a nearest integer. For example,

$L_{70}(4k) = 4400$ hours (at $T_s = 55^\circ\text{C}$, $I_F = 350$ mA).

6.0 TEMPERATURE DATA INTERPOLATION

When in-situ DUT case temperature, $T_{s,i}$, is different from the temperatures used for LM-80-08 tests (e.g., 55°C , 85°C , and a third temperature provided by the DUT manufacturer), the following procedures should be used to predict lumen maintenance life of the DUTs corresponding to the in-situ case temperature with the same or lower operational condition (e.g., drive current).

6.1 Select Tested Case Temperatures

The tested case temperatures used for in-situ case temperature lumen maintenance life interpolation must contain the closest lower temperature, $T_{s,1}$, and the closest higher temperature, $T_{s,2}$, to the in-situ case temperature to be interpolated.

6.2 Convert All Temperatures to Kelvins

The following formula shall be used to convert the temperatures to the unit of Kelvins: