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# Recommendations for Testing LED Lighting Systems and Projecting System Lifetime in Different Applications

Volume 14, Issue 1
May 2020

A publication of the Alliance for Solid-State Illumination Systems and Technologies

Lighting Research Center

Rensselaer

Published by the Lighting Research Center, Rensselaer Polytechnic Institute, 21 Union St., Troy, NY 12180, USA. Online at http://www.lrc.rpi.edu.

This publication can be cited in the following manner:

Alliance for Solid-State Illumination Systems and Technologies (ASSIST). 2020. *ASSIST recommends… Recommendations for Testing LED Lighting Systems and Projecting System Lifetime in Different Applications.* Vol. 14. Troy, N.Y.: Lighting Research Center. Internet: http://www.lrc.rpi.edu/programs/solidstate/assist/recommends/systemlife.asp

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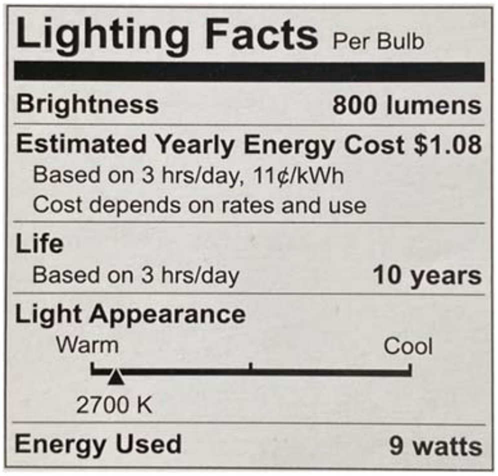
## Introduction

This document outlines a recommendation for testing LED lighting systems (i.e., lamps and luminaires) and estimating system lifetime in different real-world lighting applications.

One key piece of information users consider when buying LED lighting products (i.e., systems) for applications is the expected lifetime, expressed in hours or years. Commercial LED lighting products carry a label that shows the expected lifetime of the product in applications. A sample data label for an LED A-lamp is shown in Fig. 1.



**Lighting Facts** Per Bulb

**Brightness** **800 lumens**

**Estimated Yearly Energy Cost $1.08**
Based on 3 hrs/day, 11¢/kWh
Cost depends on rates and use

**Life**
Based on 3 hrs/day **10 years**

**Light Appearance**
Warm Cool
2700 K

**Energy Used** **9 watts**

***Fig. 1: LED product label***

Present industry practice allows reporting of LED system lifetime as the time for the light output of the LED (as used in the system) to reach 70% of its initial value (L70), estimated according to IES LM-80 and TM-21 standards. In these procedures, only the LED is tested under a continuous-on condition and only lumen maintenance failure is considered. According to the product label in Fig. 1, the lamp life is about 10 years, based on 3 hour use per day. After 10 years, the LEDs in the lamp would emit 70% of their initial flux. However, a user generally considers a lamp to have failed when there is no light output from the lamp, not when the light dims to 70% of its initial light output.

LED systems have multiple components, as shown in Fig. 2. Failure of any component can cause the system to fail. The present industry-recommended test methods consider only lumen maintenance of the LEDs used in the lamp and do not consider the possibility of catastrophic failure of the system. As a result, the current industry test methods often do not produce accurate lifetime estimates. In 2014, IES LM-84 was released for testing LED systems. Even though it was an improvement over the LM-80 method that tested the LED device only, here too it considered only lumen maintenance and continuous operation without on-off switching.

***Fig. 2: LED lighting system***

The method presented in this ASSIST recommendation is a short duration, predictive test method for LED system life that can estimate product lifetime in any lighting application if the temperature of the LED junction and the use pattern, or switching cycle time, are known. The method tests the whole system, includes on-off power cycling with sufficient dwell time and thermal stabilization, and considers both catastrophic and lumen maintenance (L70) failures.

The intent of this document is to encourage common, consistent methods of testing, lifetime estimation, and data presentation. The target audience for this document is manufacturers of LED lighting systems (lamps and luminaires). Results produced using this test method will provide users of LED lighting with a more accurate lifetime value.

This recommendation was developed by the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute on behalf of the Alliance for Solid-State Illumination Systems and Technologies (ASSIST).

## Proposed Test Method

This method tests the whole system, includes on-off power cycling with sufficient dwell time, and considers both catastrophic and parametric failure (lumen maintenance, $L_{70}$), similar to what the system experiences during real-life applications.

**Determining test conditions:** The first step is to determine the appropriate delta temperature and cycle times (on-dwell-off times) to be used in the long-term life test. Delta temperature (ΔT) is defined as the temperature difference between the stabilized operating temperature during on-time and the stabilized temperature during off-time. Dwell time is defined as the time of operation at stabilized operating temperature while the lamp is switched on.

If the test product is a replacement lamp, such as an LED A-lamp, sample lamps are to be placed inside a luminaire. Alternatively, if the test product is an integral LED downlight, the product is to be placed inside an insulated recessed cavity, similar to how a downlight is mounted in an application. These testing setups create a worst-case scenario for temperature.

A thermal sensor is attached to the lamp housing (see Fig. 3) and to the LED pin to obtain a relationship between the LED housing temperature and the LED junction temperature (Tj). The light fixture is turned on and the corresponding junction temperature is recorded until the lamp reaches full thermal stabilization (on time) and remains at the maximum operating temperature for a prescribed amount of time (dwell time). The lamp is then switched off and Tj continues to be recorded for an additional hour until the temperature has stabilized at room temperature (off time). Next, a similar procedure is followed with the lamp operating in open air at room temperature, 25°C (i.e., the low temperature experienced by the LED junction temperature, Tj).

***Fig. 3: Example of a thermocouple attached to the body of the LED A-lamp***

These tests provide estimates for the lower and upper Tj values that can be found in most applications using this LED product, as well as the time required for the system to reach maximum operating temperature (full stabilization) after switching on and the time required for the system to cool down to room temperature (full stabilization) after switching off. For example, in a life test study conducted by the Lighting Research Center on LED A-lamps, three delta temperatures and three dwell times were selected as independent variables: delta temperatures of 80°C, 90°C, and 100°C; dwell times of 2-hrs ON with 1-hr OFF, 4-hrs ON with 1-hr OFF, and continuous-on. For each ΔT, lamps were switched on and off to achieve the 2-hour and 4-hour dwell times. For the third dwell time, the lamp was powered on continuously. Figure 4 shows the temperature profile experienced by the LED junction during power on and off for the tested LED A-lamp. (These test conditions are specific to the lamp tested at the LRC; other lamps will require different ΔTs and dwell times.)

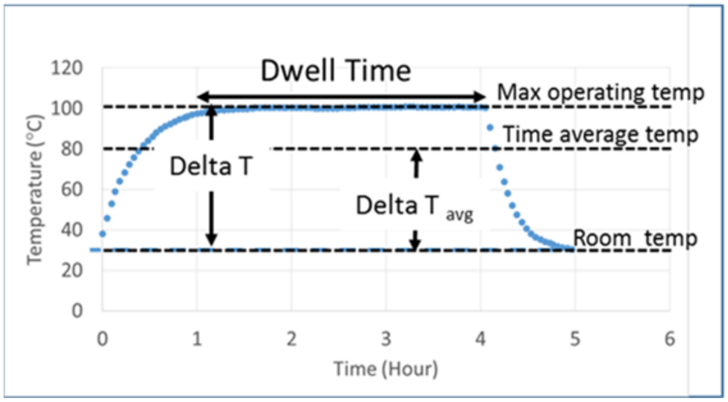


*Fig. 4: Temperature cycle profile (temperature measured on the housing of the LED A-lamp)*

**Test setup:** The test setup used for a replacement lamp (A-lamp) uses a downlight can and a heater pad wrapped around the can to control the Tj of the test lamps. A lamp sample placed inside the test fixture is shown in Fig. 5. A light sensor is attached to the opening of the test fixture at the bottom to monitor the light output and detect catastrophic failure and lumen depreciation of the lamp. At regular intervals, the light sensor box detector is replaced by a spectrometer to gather spectral power distribution data. A thermocouple is attached to the system housing to estimate the LED Tj. Control circuits switch the lamp and the heater pad on and off at the designated dwell time and ΔT. Wooden boxes containing groups of five test fixtures are placed on a rack, and each lamp test assembly is connected to a data acquisition system for continuous monitoring and recording of the dependent variables: light output, spectral power distribution, input power, input current, and lamp housing temperature.

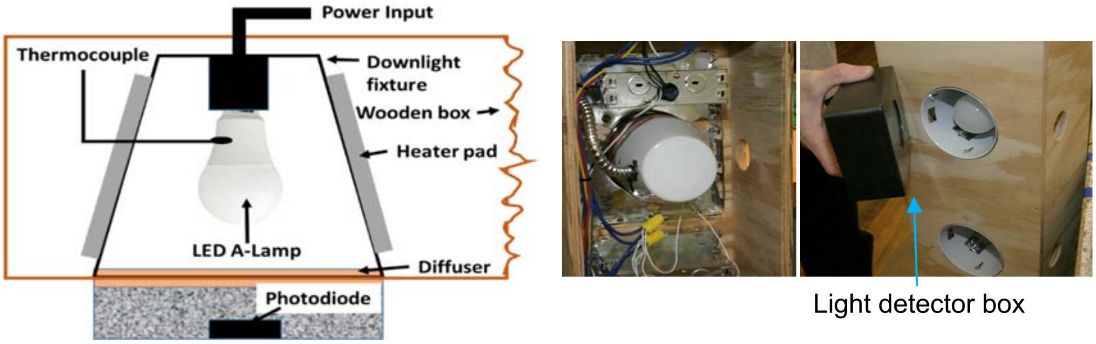


***Fig. 5: Lamp test box setup (an A-lamp is shown in this testing scenario)***

**Results:** *Catastrophic failure* – The average time between the 5th and the 6th lamp failures (in a group of 10 lamps) is the median life. Generally, higher ΔT conditions will result in a shorter time to failure. Additionally, the cycles to failure (median life) and delta time-averaged temperature will have an inverse linear relationship, as shown in Fig. 6.

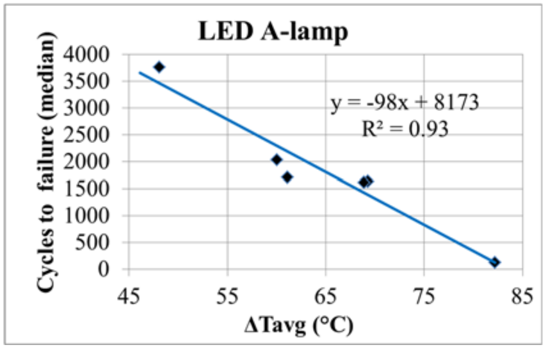


***Fig. 6: Catastrophic failure data for a tested group of 10 LED A-lamps***

*Parametric failure* – The L70 values for each test condition are determined by extrapolating the lumen depreciation data that is available before the lamps failed catastrophically. The median lamp life, based on lumen depreciation, L70 in hours, as a function of maximum operating temperature, will have an inverse linear relationship, as shown in Fig. 7. The estimated L70 values will decrease when the maximum operating temperature increases.

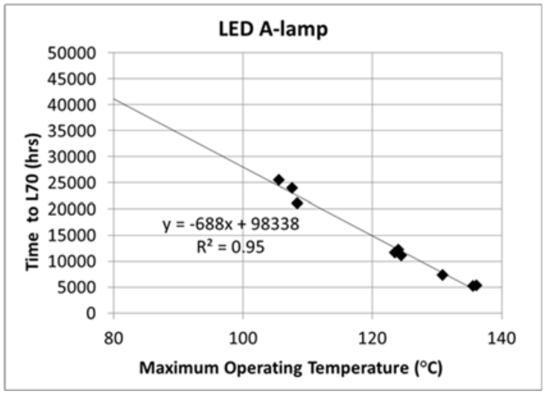


*Fig. 7: Lumen maintenance data*

**Alternative test setups:** Life test setups for other types of LED lighting systems, such as a linear fluorescent replacement or an integrated downlight, can be made similarly by creating a housing with the right dimensions to hold the fixture, lining it with a heating element (heater rope or heating pad) to control the thermal environment surrounding the system (indicated by the Tj of the LEDs), and mounting light sensors to the test enclosure to monitor the system light output over time. Data collection will be similar to the procedure described above. The median system life, based on catastrophic and parametric (lumen depreciation) failures, is then measured. The data plots for catastrophic failure median life (in hours) as a function of time-averaged ΔT and lumen depreciation median life (L70) (in hours) as a function of maximum operating temperature can be used for estimating the life of the system in applications.

## LED System Life Prediction Method

To show the usefulness of the test method and further illustrate how lifetime is dependent upon application environment and use pattern, two sample applications where the same lamp (the tested LED A-lamp, in this case) can be used were selected to estimate lamp life.

The first application considered was a table lamp that is switched on for 3 hours per day and off during the rest of the day. The maximum operating junction temperature experienced by the LED within the A-lamp, Tj, is 95°C, and the room temperature, Troom, is 30°C. The estimated time-averaged temperature, Tavg, is 80°C, and therefore ΔTavg = (Tavg – Troom ) is 50°C. The cycles to failure at 50°C is estimated as 3250 cycles, corresponding to 3250 days or 8.9 years (Fig. 8, left). At 95°C maximum operating temperature, the time to L70 can be estimated as 32,000 hrs by extrapolating the linear fit to 95°C (Fig. 8, right). This corresponds to 29 years. Therefore, in the table lamp application the estimated lifetime of the lamp is 8.9 years, which is the shorter of the two lifetimes.

The second application considered was a non-IC recessed downlight switched on for 2 hours per day. The maximum Tj is 129°C at room temperature, Troom, which is 30°C, and the corresponding ΔTavg is 77°C. The estimated lamp life values for catastrophic failure and lumen depreciation failure are 1.9 years (700 cycles to failure) and 12.3 years (9000 hours to L70), respectively. Therefore, in this application the same LED A-lamp life is only 1.9 years.

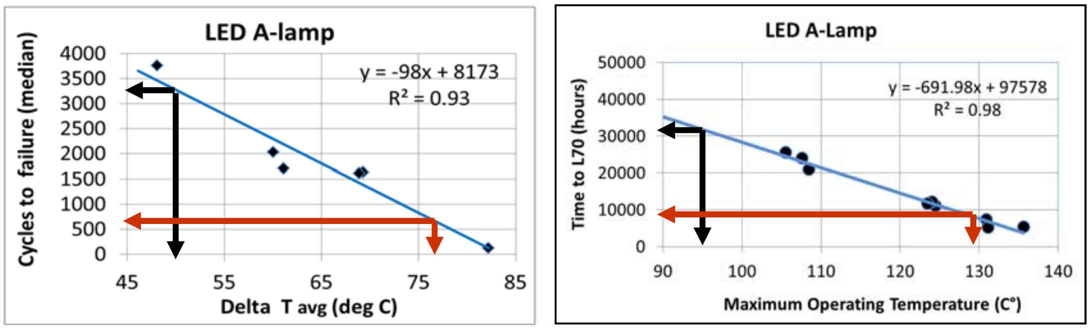


***Fig. 8: Cycles to failure (left) and time to L70 (right) for the same LED A-lamp in two different applications.***

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## About ASSIST

ASSIST was established in 2002 by the Lighting Research Center at Rensselaer Polytechnic Institute to advance the effective use of energy-efficient solid-state lighting and speed its market acceptance. ASSIST’s goal is to identify and reduce major technical hurdles and help LED technology gain widespread use in lighting applications that can benefit from this rapidly advancing light source.