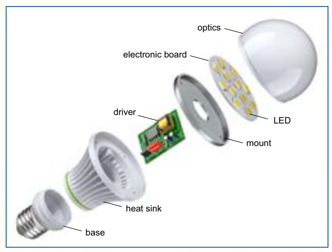
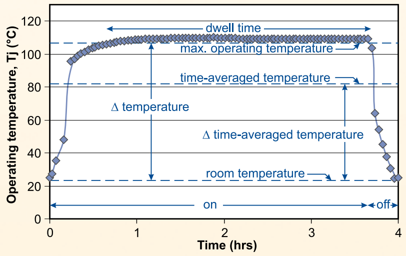
Predicting LED System Life under Real-World Conditions

Users may find their LED products failing much faster than the life values claimed on the data sheet. LED system failure can be catastrophic (no light emitted by the product) or parametric (there is light but much less compared to its designed value). An LED system has many components, as shown in the figure, and the failure of any component can lead to system failure. Present industry practice tests the LED device and considers lumen depreciation time (i.e., parametric failure) to 70% as the life of an LED system. Because the industry standard calls for testing only one component in the system and considers only one type of failure for rating LED system life, the reported product life may be much longer than what a consumer might get when using the product in an application.



Exploded view of an LED lamp

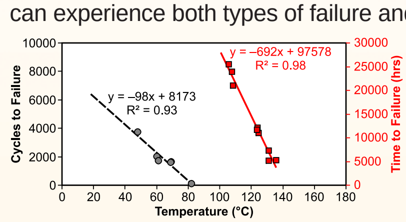
Since 2010, the LRC has been investigating LED system life to develop a short duration, predictive life-test procedure that can provide more realistic values for the product lifetime when used in an application if the operating temperature and the use pattern for switching the lighting system on and off are known. Early studies funded by ASSIST found that time to failure was affected by delta temperature (the temperature change during the on-off cycle) and dwell time (the duration the system is operating at maximum steady-state temperature). In 2014, the Bonneville Power Administration and the New York State Energy Research and Development Authority provided co-funding to expand the earlier studies.



Example of a temperature cycle profile experienced by the LED junction as a function of time, illustrating the parameters used in this study for the experiment and analysis.

For the LED A-lamps tested, both catastrophic failure and parametric failure exist. On-off switching encourages catastrophic failure, which results from thermal stresses introduced into the system by the temperature change caused by power cycling and the thermal expansion coefficient mismatch between adjacent components. This leads to fatigue failure of interface materials such as the solder attaching the LED to the electronic board and/or the components within the driver. Maximum operating temperature influences lumen depreciation rate and parametric failure time because of the optical transmission reduction of the binding materials that hold phosphor particles in an LED package; such failures become rapid at higher temperatures. In addition high operating temperature can degrade components in the driver that affect the driver output current that flows though the LEDs causing lumen depreciation and thus parametric failure. For the lamps tested, catastrophic failure times were shorter than parametric failure times. When reporting system life, the shorter of the two should be considered as the product lifetime because in applications, LED systems can experience both types of failure and depending on conditions, one type could dominate. To obtain more accurate LED system life estimates, new testing practices must include whole system testing and on-off switching.

Contrary to common belief, on-off switching can reduce LED system life.



For the LED A-lamps tested, a) Black line: Cycles to failure as a function of delta time-averaged temperature; b) Red line: L70, time to failure as a function of maximum operating temperature

The study results provide encouragement that a test procedure can be developed to accurately predict LED system life in any application if the operating temperature and typical on-off pattern are known. By testing the whole LED system and including power cycling with sufficient dwell time, and by considering both catastrophic and parametric failures, an accurate prediction of LED system life can be made within a 3000-hour testing period.

Using the data gathered, the LED A-lamp tested was estimated to last nearly 9 years in a table lamp when used for 3 hours daily, and 2 years in a non-IC recessed downlight when used 2 hours daily. These are much shorter than the rated life of the LED product, which is over 22 years when used for 3 hours daily. The incorrect expectation set by the specifications reported is caused by the present industry test standard. Therefore, there is an urgent need for the industry testing standard to be revised to better guide product manufacturers and consumers.

Sponsors

Bonneville Power Administration (BPA) TIP 322: Predictive Life Test Method for LED Luminaires

New York State Energy Research and Development Authority (NYSERDA) Agreement no. 46905

Alliance for Solid-State Illumination Systems and Technologies (ASSIST)

Support does not constitute an endorsement by these sponsors of the views expressed therein.

Citation

Narendran, N., Y. Liu, X. Mou, D.R. Thotagamuwa, and O.V. Madihe Eshwarage. 2016. Projecting LED product life based on application. *Proceedings of SPIE 9954, Fifteenth International Conference on SSL and LED-based Illumination Systems, 99540G* (September 14, 2016); doi: 10.1117/12.2240464.

www.lrc.rpi.edu/programs/solidstate/LEDSystemLife.asp.

Rensselaer

Lighting Research Center