Municipal Solid-State STREET LIGHTING CONSORTIUM

Sponsored by the U.S. Department of Energy

IESNA LM-80 and TM-21

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PHILIPS LUMILEDS

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What is lumen maintenance?

Well understood that LEDs are very long life light sources.
However, the light output of SSL products gradually goes down over time.

Rated lumen maintenance life of the LED (L_p) is the elapsed operating time over which the LED light source will maintain the percentage, p, of its initial light output

L_{70} (hours) = time to 70% lumen maintenance
L_{50} (hours) = time to 50% lumen maintenance

Lumen maintenance and EPA

EPA is using a simple exponential model for lumen maintenance until TM-21 is published:

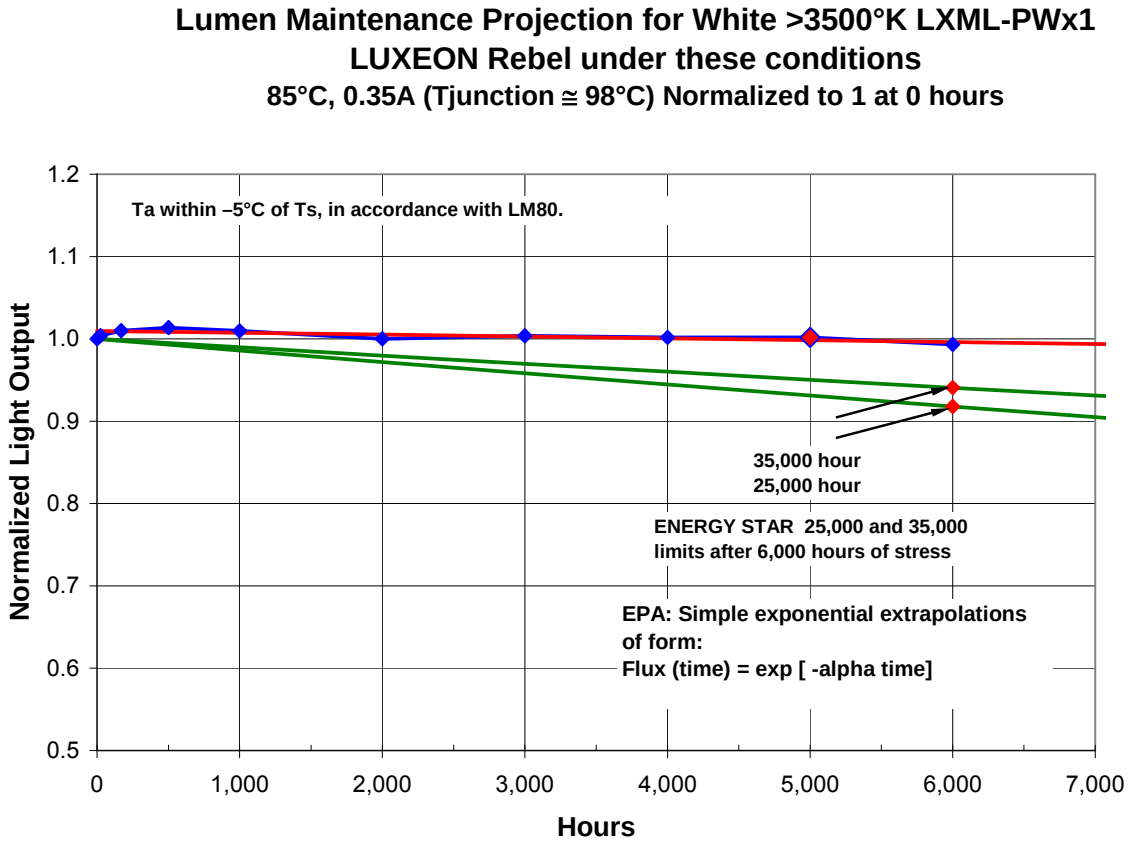
$$\phi(time) = \exp(-alpha\ time)$$

$$alpha = -\frac{\ln(0.7)}{time}$$

$$alpha(25{,}000\ hour) = -\frac{\ln(0.7)}{25{,}000} = 1.4267\,e-5$$

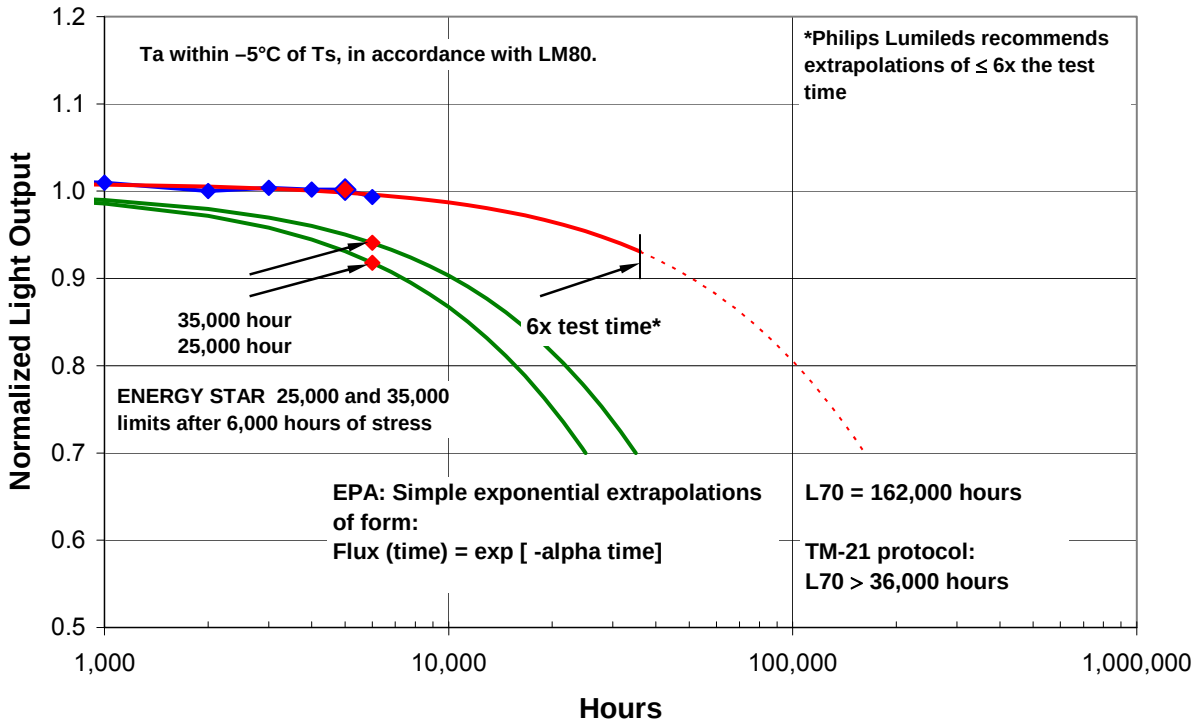
$$EPA\ limit\ LM(25{,}000) = \exp\left[-(1.467\,e-5)(6{,}000)\right] = 0.918$$

Lumen maintenance and EPA



Lumen maintenance and EPA

Lumen Maintenance Projection for White >3500°K LXML-PWx1
LUXEON Rebel under these conditions
85°C, 0.35A (Tjunction ≅ 98°C) Normalized to 1 at 0 hours



LM-80 Scope

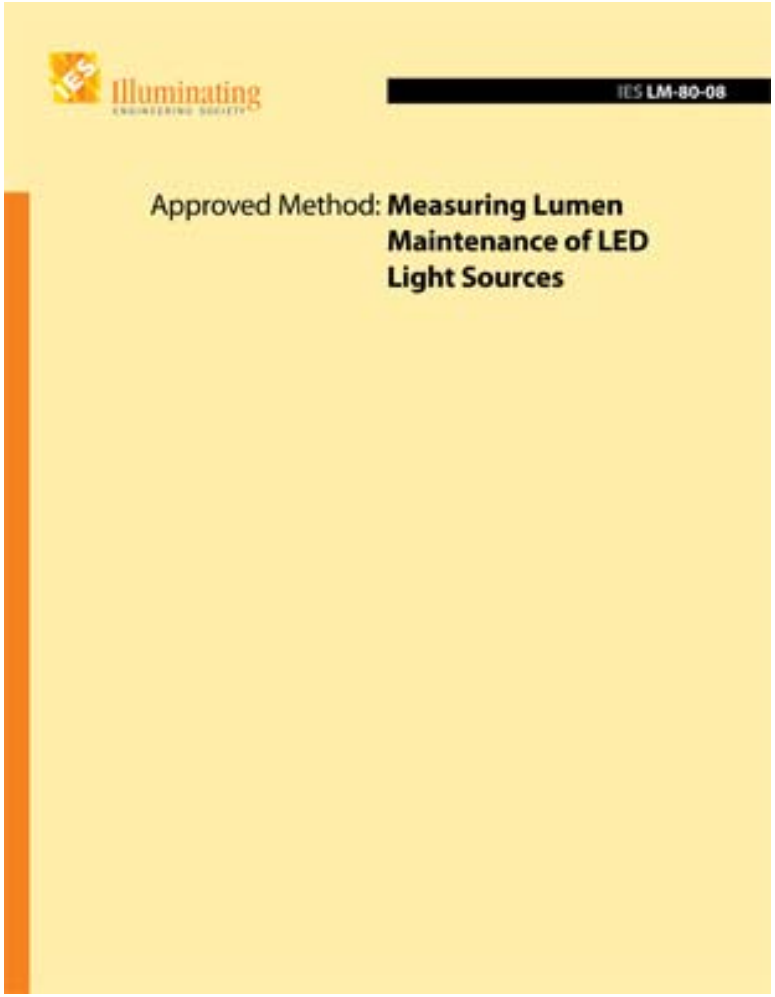
Lumen maintenance test method written by IESNA (Illuminating Engineering Society of North America)

LED package, array or module driven by auxiliary driver

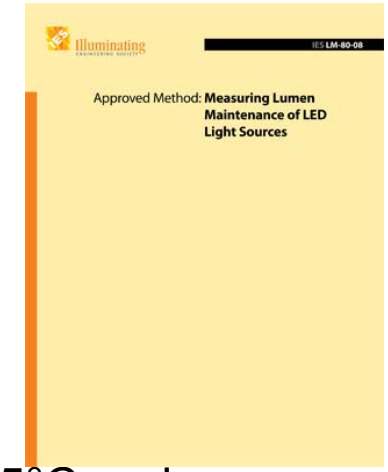
LEDs are driven with external current sources during operation and lumen maintenance testing

LED Case temperature is controlled during operation

During lumen maintenance testing, LED is allowed to cool to room temperature and tested at air temperature of 25°C



LM-80 Test Method



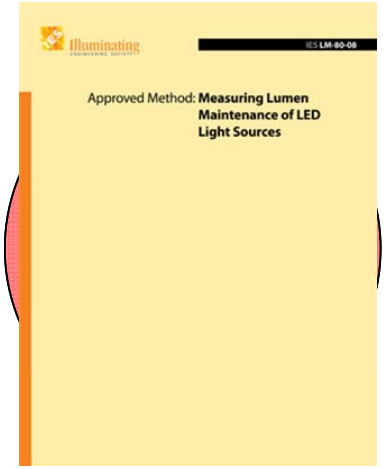
LM-80:

IES "Approved Method"

Specifies

- Operation at three case temperatures (55°C, 85°C and one selected by manufacturer)
- Air Temperature to within +/- 5°C, Case Temperature to within +/- 2°C
- RH less than 65%
- Minimum 6,000 hours, data collected every 1,000 hours
- Data collection at 25°C
- Constant current, rated voltage
- Record Lumen Maintenance, Chromaticity, Catastrophic Failures
- Reporting Format

What LM-80 Does Not Specify



LM-80 does NOT specify:

- Pass/Fail Criteria
- Graphing of results
- Curve fitting methods
- Extrapolation and L70 prediction methods
- Sample Size
- How many drive currents
- What changes to an LED package require new testing

EPA ENERGY STAR® Specific

Lumen Maintenance Requirements

- Test According to LM-80, by NVLAP accredited lab
- Min 25 samples per combination of Temperature and Current
- LM > 91.8% at 6,000 hours for residential indoor
- LM > 94.1 % at 6,000 hours for non-residential and residential outdoor
- Ts point temperature below LM-80 tested temperature
- Drive current below LM-80 tested current

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EPA ENERGY STAR®
Change in Reporting Requirements

- NO CHANGE TO IES REPORT FORMAT. However, this format is not accepted by EPA
- Until 12/31/2010 use IESNA LM-80 prescribed report format
- Starting 1/1/2011 new report format
- Starting 1/1/2011 devices tested must be of equal or lower CCT than products being used

TM-21 What it is, and why it is important

•IESNA TM-21 (Technical Memorandum) specifies how to extrapolate the LM-80-08 lumen maintenance data to times beyond the LM-80 test time. For example: EPA ENERGY STAR® Manufacturer's Guide requires L70 of 25,000 or 35,000 hours.

•TM-21 is important because it is referenced in the EPA ENERGY STAR Guides, and customers generally are concerned about getting ENERGY STAR approvals for their products.

•It is also important as it creates a common playing field for LED competitors to specify lumen maintenance behavior for their white LED products intended for illumination applications.

TM-21 status

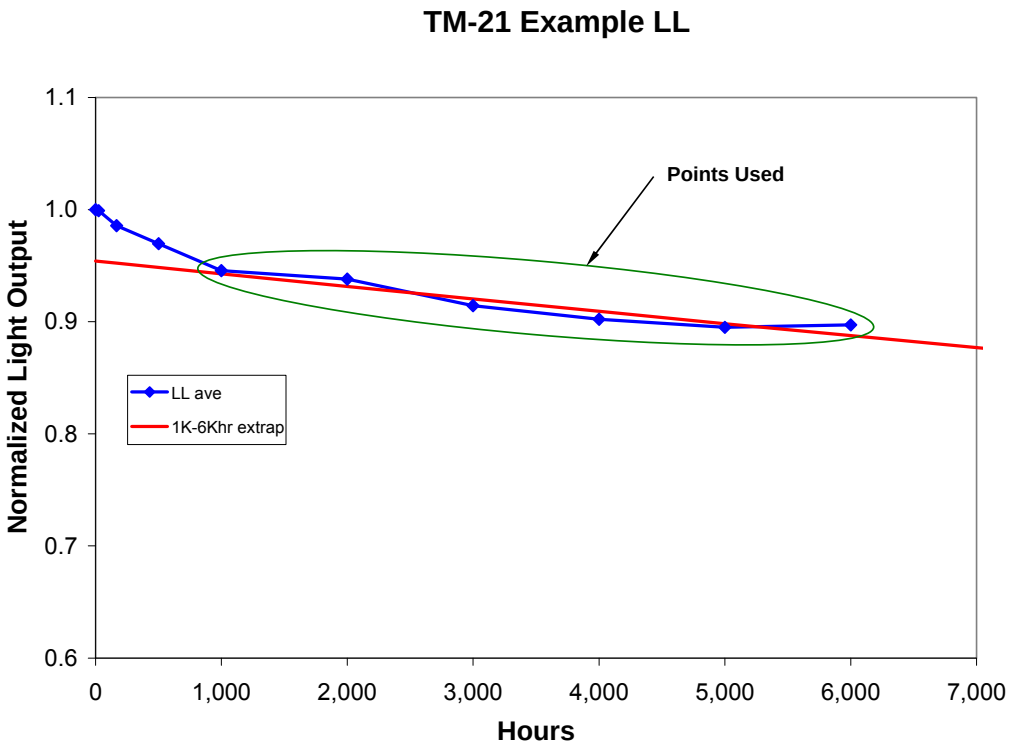
- **TM-21 is being written by a panel of industry experts:**
  - 6 LED manufacturers (Philips Lumileds, Osram, Nichia, Illumitex, GE, and Cree).
  - 2 US Government Labs (PNNL, NIST)

- **Status: Agreement has been reached by panel on basic mathematical algorithm. First draft is expected to be completed by mid February 2011. IESNA will send draft for Ballot by end of February 2011. After approval, TM-21 will become a new IESNA document.**

TM-21 Mathematical Algorithm

- Manufacturer should normalize the light output to 1 at 0 hours for each unit in the data set.
- **Data for all units are averaged together (Result represents average behavior).**
- All average lumen maintenance data points from 0 and less than 1,000 hours are removed.
- For 6,000 hour data: average lumen maintenance data points from 1,000 hours to 6,000 hours are fit to a simple exponential extrapolation model using a least-squares curve fit.
- For data $\leq$ 10,000 hours: The last 5,000 hours of data should be used for the lumen maintenance extrapolation.
- For data $>$10,000 hours. The data points from the last 50% of the total measurement time should be used. In the case where the last 50% of the total measurement time is not an integer multiple of 1,000 hours, then the interval shall be rounded-up to the next 1,000 hours should be used. [e.g.: after 11,000 hours of measurement time, the last 6,000 hours of data should be used].
- The L70 extrapolation shall be the lower of: The resulting L70 time OR 6X the LM-80 test time. [e.g. with 6,000 hours of LM-80 test data, then L70 $\leq$ 36,000 hours. With 10,000 hours of LM-80 test data then L70 $\leq$ 100,000 hours.

TM-21 Mathematical Algorithm



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

$$L70 = \frac{\ln\left(\frac{B}{0.7}\right)}{\alpha}$$

Major changes:

- B term added to simple exponential model
- Least-squares fit of data starting at 1,000 hours (6Khr data set)
- Least-squares fit of data using last 5,000 hours (7K-10K data set)
- 6X extrapolation time limit

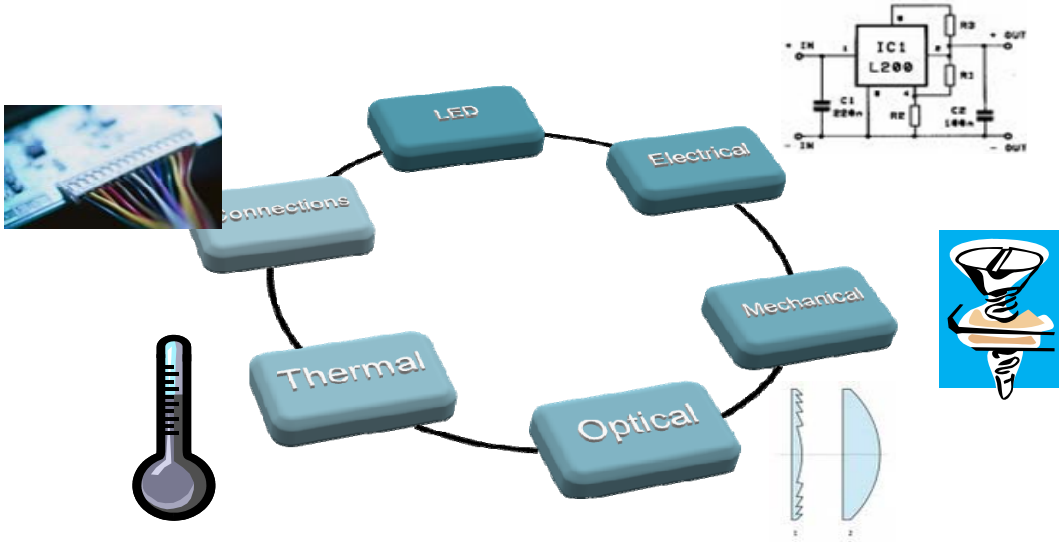
Lumen maintenance is not the whole story

•LM-80 and TM-21 provide an industry standard for lumen maintenance testing and for lumen maintenance extrapolations for LED components. LM-79 is the lumen maintenance standard for SSL systems.

•Next Generation Industry Alliance and US Department of Energy 'LED Luminaire Lifetime: Recommendations for Testing and Reporting', May 2010, discusses practical lifetime considerations for SSL luminaires.

•Lumen maintenance is not the dominant failure mode for most SSL products.

System Reliability ≠ LED Reliability



$$R_{system} = R_{electrical} * R_{connections} * R_{LEDs} * R_{optical} * R_{thermal} * R_{mechanical}$$

Philips Lumileds has developed reliability and lumen maintenance models in order to predict long-term reliability performance of LUXEON Rebel products. See WP15 'Evaluating the Lifetime Behavior of LED systems' for more information.

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sense and simplicity

Thank you for your valuable time!

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