The Latest in LED Lighting Test Methods and Standards

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#### Outline

- Introduction
- Updates for LED lighting standards referred to or referenced in ENERGY STAR<sup>®</sup> Specifications
  - ANSI
  - IESNA
  - UL
  - NEMA
- Implementations of LED lighting standards in ENERGY STAR<sup>®</sup> Programs
  - Testing for qualifications
  - Development of new standards



#### LED Lighting Standardization Bodies in USA for General Lighting

- Professional associations
  - IESNA (Illumination Engineering Society North America)
  - IEEE-SA (Institute of Electrical and Electronics Engineers Standards Association)
- Standard organizations
  - UL (Underwriter Laboratories)
  - ANSI (American National Standard Institute)
- Trade associations
  - NEMA (National Electrical Manufacturers Association)
  - JEDEC (Joint Electron Device Engineering Council)



#### Government Regulations or Specifications for LED Lighting

- Federal government EPA
  - ENERGY STAR<sup>®</sup> luminaires
  - ENERGY STAR<sup>®</sup> lamps
- Federal government DOE
  - DOE sponsored Commercial Building Energy Alliance (CBEA) for SSL parking structure lighting and SSL troffers
  - DOE sponsored Municipal Solid-State Street Lighting Consortium (MSSLC) for SSL street lighting
  - DOE rulemaking for regulating testing LED lamps (proposal)
- Local government (states, authority having jurisdiction, or AHJ)
  - State building codes, products requirements, etc.



#### Purposes of LED & SSL Standards and Specifications

- Product safety
  - Ensure LED product safety: tests, requirements, and certifications
- Testing methods
  - Describe consistent methods to test LED and SSL products
- Performance requirements
  - Define performance related characteristics
- US governmental programs specifications
  - ENERGY STAR<sup>®</sup>: Qualify products for energy saving and consumers (users) protection
  - Consortiums: DLC, CBEA, MSSLC, etc.: Specify energy saving and products performance requirements
  - State (CA, MA, etc.): Regulate energy saving products
  - AHJ: Ensure public safety or environment protection



### ENERGY STAR<sup>®</sup>

 Program Requirements Product Specification for Luminaires (Light Fixtures) V1.1

Organization	identifier	Description		
ANSI	C78.376-2001	Specifications for the Chromaticity of Eugrescent Lamps		
ANSI/NEMA/	C78.377-2008	Specifications for the Chromaticity of Solid State Lighting Products		
ANSI	C78.389-2004 (B2009)	High-Intensity Discharge (HID)—Methods of Measuring Characteristics		
ANSI/ANSLG	C78.42-2009	High-Pressure Sodium (HPS) Lamos		
ANSI/ANSLG	C78.43-2007	Single-Ended Metal Hailde Lamps		
ANSI	C78.5-2003	Specifications for Performance of Self-ballasted Compact Fluorescent Lamps		
ANSI/ANSLG	C78.81-2010	Double-Capped Fluorescent Lamps—Dimensional and Electrical Characteristics		
ANSI/IEC	C78.901-2005	Single-Based Fluorescent Lamps—Dimensional and Electrical Characteristics		
ANSI/ANSLG	C81.61-2009	Specifications for Bases (Caps) for Electric Lamps		
ANSI/ANSLG	C81.62-2009	Lampholders for Electric Lamps		
ANSI	C82.11 Consolidated- 2002	High-Frequency Fluorescent Lamp Ballasts—Supplements		
ANSI/ANSLG	C82.14-2006	Low-Frequency Square Wave Electronic Ballasts—for Metal Halide Lamps		
ANSI	C82.2-2002	Method of Measurement of Fluorescent Lamp Ballasts		
ANSI	C82.4-2002	Ballasts for High-Intensity-Discharge and Low-Pressure Sodium Lamps (Multiple Supply Types)		
ANSI	C82.6-2005	Ballasts for High Intensity Discharge (HID) Lamps - Methods of Measurement		
ANSI	<u>C82.77-2002</u>	Harmonic Emission Limits—Related Power Quality Requirements for Lighting Equipment		
ANSI/IEEE	C62.41.1-2002	IEEE Guide on the Surge Environment in Low-Voltage (1000 V and Less) AC Power Circuits		
ANSI/IEEE	C62.41.2-2002	IEEE Recommended Practice on Characterization of Surges in Low-Voltage (1000V and Less) AC Power Cli		
ANSI/UL	153-2002	Standard for Safety of Portable Electric Luminaires		
ANSI/UL	935-2009	Standard for Safety of Fluorescent-Lamp Ballasts		
ANSI/UL	1029-2010	Standard for Safety of High-Intensity-Discharge Lamo Ballasts		
ANSI/UL	1310-2010	Standard for Safety of Class 2 Power Units		
ANSI/UL	1574-2004	Standard for Safety of Track Lighting Systems		
ANSI/UL	1598-2008	Standard for Safety of Luminaires		
ANSI/UL	1598B-2010	Standard for Supplemental Requirements for Luminaire Reflector Kits for Installation on Previously Installed Europeaned Luminaires		
ANSI/UI	1993-2009	Standard for Safety of Self-Ballasted Lamps and Lamp Adapters		
ANSI/UI	2108-2004	Standard for Low-Vidiane Linhing Systems		
ANSULL	8750-2009	Standard for Light Englished (LED) Equipment for Lise in Lighting Products		
ASTM	E283-04	Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and D Under Specified Pressure Differences Across the Specimen		
CAN/CSA	C22.2 NO 74-95 (B2010)	Equipment for Lise With Electric Discharge Lamps		
CIE	Pub No 13.3-1995	Method of Measuring and Specifying Color Rendering of Light Sources		
	Pub No 15:2004	Colorimetry		
EU	Directive 2002/95/EC	Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the Restriction of Lise of Certain Hazarrious Substances in Electrical and Electronic Environment		
FCC	CER Title 47 Part 15	Radio Frequencia Devices		
FCC	CFR Title 47 Part 18	Industrial Scientific and Medical Equipment		
IEC	<u>60061-1</u>	Lamp Caps and Holders Together with Gauges for the Control of Interchangeability and Safety – Part 1: Lamp Caps		
IEC	60081 Amend 4 Ed 5.0	Double-capped Fluorescent Lamps - Performance Specifications		
IEC	60901	Single-capped Fluorescent Lamps - Performance Specifications		
IEC	61347-2-3-am2 ed1.0 b.2006	Amendment 2 - Lamp Control Gear - Part 2-3: Particular Requirements for A.C. Supplied Electronic Ballasts Fluorescent Lamps		
IEC	62321 Ed. 1.0	Electrotechnical Products - Determination Of Levels Of Six Regulated Substances (lead, mercury, cadmium, hexavalent chromium, polybrominated biphenvis, polybrominated diphenvi ethers)		
IES	LM-9-09	Electric and Photometric Measurements of Fluorescent Lamps		
ES	LM-10-11	Photometric Testing of Outdoor Fluorescent Luminaires (renewal anticipated in 2011)		
ES	LM-15-03	Guide for Reporting General Lighting Equipment Engineering Data for Indoor Luminaires		
ES	LM-31-11	Photometric Testing of Roadway Luminaires Using incandescent Filament and High Intensity Discharge (HIC Lamps (renewal anticipated in 2011)		
ES	LM-35-02	Photometric Testing of Floodlights Using High Intensity Discharge or Incandescent Filament Lamps		
ES	LM-40-01	Life Testing of Fluorescent Lamps		
ES	LM-41-11	Approved Method for Photometric Testing of Indoor Fluorescent Luminaries (renewal anticipated in 2011)		
ES	LM-46-04	Photometric Testing of Indoor Luminaires Using High Intensity Discharge or Incandescent Filament Lamps		
ES	LM 47-11	Life Testing of High Intensity Discharge (HID) Lamps (renewal anticipated in 2011)		
ES	LM-49-11	Life Testing of Incandescent Filament Lamps (renewal anticipated in 2011)		
ES	LM-51-11	Electrical and Photometric Measurements of High Intensity Discharge Lamps (renewal anticipated in 2011)		
ES	LM-58-11	Guide to Spectroradiometric Measurements (renewal anticipated in 2011)		
ES	LM-65-11	Life Testing of Compact Fluorescent Lamps (renewal anticipated in 2011)		
ES	LM-66-11	Electrical and Photometric Measurements of Single-Ended Compact Fluorescent Lamps (renewal anticipated 2011)		
ES	LM-79-08	Electrical and Photometric Measurements of Solid-State Lighting Products		
IES	LM-80-08	Measuring Lumen Maintenance of LED Light Sources		
ES	LM-82-11	IES Approved Method for the Characterization of LED Light Engines and integrated LED Lamps for Electrica Photometric Properties as a Function of Temperature /oublication anticipated in 2011)		
ES	BP-16-10	Nomenclature and Definitions for Illuminating Engineering		
	TM-21-11	Projecting Long Term Lumen Maintenance of LED Sources (nublication anticipated in 2011)		
IES				
IES I RC	ACTV Test 2007	Testing Guideline for the Accelerated Cycling, Thermal, and Voltage (ACTV) Stress Test		
IES LRC NEMA	ACTV Test 2007	Testing Guideline for the Accelerated Cycling, Thermal, and Voltage (ACTV) Stress Test Dimming of T8 Elugrescent Lighting Systems		

### ENERGY STAR®

#### Program Requirements Product Specification for Lamps (Light Bulbs) Eligibility Criteria Version 1.0, DRAFT 2

Organization	Identifier	Description		
ANSI/IEEE	<u>C62.41.2-2002</u>	IEEE Recommended Practice on Characterization of Surges in Low Voltage (1000V and Less) AC Power Circuits		
ANSI	<u>C78.20-2003</u>	Electric Lamps—A, G, PS and Similar Shapes with E26 Medium Screw Bases		
ANSI	C78.21-2011	Electric Lamps—PAR and R Shapes		
ANSI	C78.23-1995 (R2003)	Incandescent Lamps—Miscellaneous Types		
ANSI/ANSLG	C78.357-2010	For Incandescent Lamps: Tungsten Halogen Lamps (non-vehicle)		
ANSI	C78.376-2001	Specifications for the Chromaticity of Fluorescent Lamps		
ANSI/ANSLG	C78.377-2011	Specifications for the Chromaticity of Solid State Lighting Products		
ANSI	C78.389-2004 (R2009)	Electric Lamps - High-Intensity Discharge (HID) - Methods of Measuring Characteristics		
ANSI	<u>C78.5-2003</u>	Specifications for Performance of Self-ballasted Compact Fluorescent Lamps		
ANSI	C79.1-2002	Nomenclature for Glass Bulbs Intended for Use with Electric Lamps		
ANSI/ANSLG	C81.61-2009	Specifications for Bases (Caps) for Electric Lamps		
ANSI/NEMA	<u>C82.2-2002</u>	Fluorescent Lamp Ballasts, Methods of Measurement of (includes supplements)		
ANSI	C82.77-2002	Harmonic Emission Limits-Related Power Quality Requirements for Lighting Equipment		
ANSI/IEEE	C62.41.2-2002	IEEE Recommended Practice on Characterization of Surges in Low Voltage (1000V and		
		Less) AC Power Circuits		
ANSI/IES	RP-16-10	Nomenclature and Definitions for Illuminating Engineering		
ANSI/UL	1993-2009	Standard for Safety of Self-Ballasted Lamps and Lamp Adapters		
ANSI/UL	8750-2009	Standard for Light Emitting Diode (LED) Equipment for Use in Lighting Products		
CIE	Pub. No. 13.3-1995	Method of Measuring and Specifying Color Rendering of Light Sources		
CIE	Pub. No. 15:2004	Colorimetry		
Commission of	(EC) No 244/2009	Commission Regulation (EC) No 244/2009 of 18 March 2009 Implementing Directive		
the European		2005/32/EC of the European Parliament and of the Council		
Communities				
FCC	CFR Title 47 Part 2	Frequency Allocations and Radio Treaty Matters; General Rules and Regulations		
FCC	CFR Title 47 Part 15	Radio Frequency Devices		
FCC	CFR Title 47 Part 18	Industrial, Scientific, and Medical Equipment		
IEC	62321:2008 (Ed. 1)	Electrotechnical Products - Determination Of Levels Of Six Regulated Substances (lead,		
		mercury, cadmium, hexavalent chromium, polybrominated biphenyls, polybrominated		
		diphenyl ethers)		
IES	LM-9-09	Electrical and Photometric Measurements of Fluorescent Lamps		
IES	LM-20-12	Photometric Testing of Reflector-Type Lamps (renewal anticipated in 2012)		
IES	LM-40-10	Life Testing of Fluorescent Lamps		
IES	LM-47-12	Life Testing of High Intensity Discharge (HID) Lamps		
IES	LM-51-00	Electrical and Photometric Measurements of High Intensity Discharge Lamps		
IES	LM-54-12	Guide to Lamp Seasoning (renewal anticipated in 2012)		
IES	LM-58-12	Guide to Spectroradiometric Measurements of Light Sources (renewal anticipated in 2012)		
IES	LM-65-10	Life Testing of Compact Fluorescent Lamps		
IES	LM-66-11	Electrical and Photometric Measurements of Single-Ended Compact Fluorescent Lamps		
IES	LM-79-08	Electrical and Photometric Measurements of Solid-State Lighting Products		
IES	LM-80-08	Measuring Lumen Maintenance of LED Light Sources		
IES	TM-21-11	Projecting Long Term Lumen Maintenance of LED Light Sources		

Methods of Measurement and Reference Documents

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### ANSI Standard: ANSI/IES RP-16-10

- Purpose
  - To establish definitions for solid-state lighting devices and their components to ensure a common understanding of the terminology
- Status
  - Published
  - Continuous revisions
- Commonly used terminologies
  - LED package
  - LED array or module
  - LED driver & LED driver class II
  - LED lamp integrated & non-integrated
  - LED light engine
  - LED luminaire





#### ANSI Standard: ANSI C78.377-2011

- Purpose
  - To communicate the indoor lighting SSL products color characteristics to SSL producers and users
- Status
  - New revision published
  - Ad hoc to be formed for next revision
- Clarification
  - Lighting products outside of "color zone" ≠ poor color quality
  - Lighting products meeting this standard ≠ color consistency
  - The standard does not reflect users visual preference, acceptability, and adoptability for white color
  - ANSI standard is not the same as for the Energy Star requirements





#### **Nominal CCT Categories**

- Nominal CCT: white light chromaticity information of a product
- Requirements
  - 8 fixed or selected CCTs, or
  - Flexible CCTs with 100 K step





#### **Chromaticity Tolerances**

- Quadrangle for a nominal CCT
  - In both  $\triangle$ CCT and Duv directions
  - Approximately equal to 7-step MacAdam ellipses

Nominal CCT	Target CCT and tolerance (K)	Target Duv	Duv tolerance range
2700 K	2725 ± 145	-0.0001	
3000 K	3045 ± 175	0.0001	$D_{m}(T_{r}) \pm 0.006$
3500 K	3465 ± 245	0.0004	where
4000 K	3985 ± 275	0.0009	$D_{\rm mv}(T_{\rm x}) = 57700 \times (1/T_{\rm x})^2$
4500 K	4503 ± 243	0.0014	$-44.6 \times (1/T_{\rm x})$
5000 K	5029 ± 283	0.0019	+ 0.0085
5700 K	5667 ± 355	0.0024	$T_{x}$ : CCT of the source
6500 K	6532 ± 510	0.0030	
Flexible CCT (2800 - 6400 K)	$T_{\rm F}^{1)} \pm \Delta T^{2)}$	$D_{\rm uv}(T_{\rm F})^{3)}$	

1) T<sub>F</sub> is chosen to be at 100 K steps (2800, 2900, ...., 6400 K), excluding those eight nominal CCTs listed in Table 1.

2)  $\Delta T$  is calculated by  $\Delta T = 1.1900 \times 10^{-8} \times T^3 - 1.5434 \times 10^{-4} \times T^2 + 0.7168 \times T - 902.55$ 

3) the same equation given in the column of Duv tolerance range.





### New in ANSI C78.377-2011

- Added Annex for conversions between CCT,  $D_{UV}$  and (x, y) or (u', v').
  - Calculation  $D_{uv}$  from x, y or u', v' values

$$\begin{split} \mathsf{L}_{\mathsf{FP}} &= \sqrt{(\mathsf{u} - 0.292)^2 + (\mathsf{v} - 0.24)^2} \\ \mathsf{a} &= \arccos\!\left(\frac{\mathsf{u} - 0.292}{\mathsf{L}_{\mathsf{FP}}}\right) \\ \mathsf{L}_{\mathsf{BB}} &= \mathsf{k}_6 \mathsf{a}^6 + \mathsf{k}_5 \mathsf{a}^5 + \mathsf{k}_4 \mathsf{a}^4 + \mathsf{k}_3 \mathsf{a}^3 + \mathsf{k}_2 \mathsf{a}^2 + \mathsf{k}_1 \mathsf{a}^4 + \mathsf{k}_0 \\ \mathsf{D}_{\mathsf{uv}} &= \mathsf{L}_{\mathsf{FP}} - \mathsf{L}_{\mathsf{BB}} \end{split}$$

- Added Annex to describe 4-step MacAdam ellipse equivalent quadrangles
  - It is for reference for comparison of the requirements used for linear fluorescent lamp (LFL), not to make any recommendations

k <sub>6</sub>	0.00616793	
k <sub>5</sub>	0.0893944	
k4	-0.5179722	
k <sub>3</sub>	1.5317403	
k <sub>2</sub>	-2.4243787	
k <sub>1</sub>	1.925865	
k <sub>0</sub>	-0.471106	



#### IES Document: IES LM-79-08

- Purpose
  - Provide procedures for reproducible measurements of photometry, color and electrical characteristics of SSL products
- Status
  - Published
  - Revision in process
- What can be tested with this standard?
  - Total luminous flux
  - Luminous intensity
  - Zonal lumen summation
  - CCT (Correlated Color Temperature)
  - CRI (Color Rendering Index)
  - Chromaticity Coordinates (x,y and u',v')
  - Spatial uniformity of color





#### **Test Requirements**

- Absolute photometry
  - Luminaire (or other SSL product) is referenced to a calibrated standard lamp
  - No luminous efficiency calculations or comparisons
- Testing procedures
  - No seasoning
  - Thermal stabilization

$$\Delta_{15}(t) = \frac{\Phi(t) - \Phi(t - 15)}{\Phi(t)} < 0.005$$

- Ambient temperature 25°C ± 1°C
- Use of integrating sphere ( $2\pi$  or  $4\pi$  setup) with spectroradiometer, or with a photometer head (sphere-photometer system)
- Use of goniophotometer with photometer head or spectroradiometer





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#### IES Document: IES LM-80-08

- Purpose
  - Provide methods of the measurement of lumen maintenance of LED packages, arrays and modules
- Status
  - Published
  - Revision in process
- Clarification
  - It does not provide performance requirements
  - It 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





#### **Test Requirements: Proposed Revisions**

- Extend scope to include photon flux and radiant flux maintenance
  - For blue or UV LEDs so test data may be used with remote phosphor testing
  - For LEDs used in horticultural applications
- Extend to wide range of LEDs
  - Current of voltage controlled LEDs
  - AC LEDs
- Test procedure
  - Shall be tested for at least 6,000 hours with data collection at a minimum of every 1,000 hours
  - Test two case temperatures T<sub>s</sub>, recommend nominal 55°C and 85°C.
  - The case temperature and drive current selected by the manufacturer should represent their expectation and be within recommended operating temperature range.



#### LM-80 Test Report (to be updated)

- Contents to be included
  - Number of LED sources tested
  - Description of LED sources
  - Description of auxiliary equipment
  - Test duration
  - Ambient conditions including airflow, temperature and relative humidity
  - Case temperature (test point temperature)
  - Drive level
  - Initial flux and forward voltage at photometric measurement current
  - Flux maintenance data for each individual LED light source
  - Observation of LED light source failures including the failure conditions and time of failure
  - LED light source monitoring interval
  - Flux measurement uncertainty
  - Chromaticity or wavelength shift reported over the measurement time.



#### IES Document: IES TM-21-11

- Purpose
  - Provide a calculation tool to interpret the data collected from LM-80 testing; to provide users with lumen maintenance life (e.g., L<sub>70</sub>) projection, or to predict estimated lumen output values at a given time duration; to interpolate lumen maintenance behaviors for the in-situ temperature (different from testing temperature)
- Status
  - Published
- Clarification
  - It does not provide performance requirements
  - It does not give the criteria if a product is good or bad
  - It only addresses lumen maintenance, not rated life or reliability of the products





#### Sample Size & Test Data

- Sample size recommendation
  - 20 samples to project 6 times of test duration
  - 10 to19 samples to project 5.5 times test duration
- Luminous flux data collection
  - Additional measurements after the initial 1,000 hours at intervals smaller than 1,000 hours are encouraged. Additional measurements beyond 6,000 hours are encouraged and will provide the basis for more accurate lumen maintenance projections
- Normalization & average
  - Normalize all collected data to a value of 1 (100%) at 0 hours
  - Average the normalized measured data of all samples
- Data used for curve-fit
  - Data before 1,000 hour reading shall not be used
  - For curve fit, use last 5,000 hours of data for test duration  $\leq$  6,000 hours, or
  - Last 50% of total test duration for test duration > 10,000 hours



#### **Data Interpolation**

- Applicability of the Arrhenius equation
  - Both  $\alpha_1$  and  $\alpha_2$  are positive
- Limit for extrapolation
  - In-situ temperature is within 2 LM-80 tested temperatures



#### IES Document: IES LM-82-11

- Purpose
  - To describe the procedures in performing reproducible measurements of LED light engines and integrated LED lamps, at any given temperature for the performance characteristics (total luminous flux, electrical power, etc.)
- Status
  - Published
- Clarification
  - It does not provide performance requirements
  - It does not give the criteria if a product is good or bad
  - It only addresses the lumen output vs. temperature.





#### **Test Procedures**

- Initial measurement
  - Measure per LM-79-08 in room temperature condition
- Calibration
  - Repeat the measurement for the same unit with the temperature-controlled device in the room temperature condition
  - Establish correction factors between the room temperature LM-79 measurements and measurements with the temperature-controlled device
  - Select spatial point for relative photometry measurements
- Measuring at the elevated temperatures
  - Measure the unit (integrating sphere or spatial point) at room temperature + 25°C
  - Measure the unit at room temperature +  $\Delta T \circ C$



Source: Permlight



### UL Standard: UL8750

- Purpose
  - To provide safety requirements for LED equipment that is an integral part of a luminaire or other equipment and which operates in the visible light spectrum between 400 – 700 nm. The requirements also covers the component parts of the light emitting diode (LED) equipment, including LED drivers, controllers, arrays, modules, and packages as defined within this standard
- Status
  - Published
  - Continuous revisions
- Notice
  - LED light source safety standard that are also referred by other UL lighting standards







#### **UL Recognition for LED Packages**

- Program framework and objective
  - Create component level recognition
  - Standardize reporting on LED package characteristics (for safety)
  - UL recognized LED packages can be searched from UL certification database
- UL recognized LED packages characteristics based on UL8750
  - Input type
  - Maximum junction temperature
  - Environmental location suitability
  - Enclosure consideration
  - Maximum operating voltage
- Marking
  - Components recognized under UL's Component Recognition
    Program bear the Recognized Component Mark





#### NEMA White Paper: LSD-45

- Purpose
  - To make recommendations for Solid State Lighting Sub-Assembly Interfaces for Luminaires
  - Setup guidelines are intended for SSL interconnects which enable the repeated insertion and the withdrawal of components and are intended for use in general lighting
  - Focus on Mechanical, Electrical and Thermal interfaces. Interfaces to both branch circuitry and low voltage sources will be included.
- Status
  - Published
- Notice
  - Guidelines do not apply to LED retrofit lamps



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#### **Testing for Qualifications**

- System level tests
  - Documents: ANSI C78.377, LM-79, LM-82, (LM-84, TM-28)
  - Performance characteristics: photometry and colorimetry
  - Electrical characteristics: calculation of efficacy
  - Thermal characteristics: lumen output temperature dependency
- Sub-component level tests
  - Documents: LM-80, TM-21, UL8750, (LM-85)
  - Durability of the performance: light output changes over time
  - Safety: UL recognized LED packages with conditions of usage



#### New Standards: IES LM-84

- Title
  - IES Approved Method for Measuring Lumen and Color Maintenance LED Lamps, Lighting engines, and Luminaires
- Purpose
  - To provide the method for measurement of lumen and color maintenance of LED lamps, light engines, and LED luminaires. To describe the procedures to obtain uniform and reproducible lumen and color maintenance measurements under standard operating conditions
  - It does not cover LED luminaires without a light source. It does not cover the determination of the performance rating of products, in which individual variations among the products should be considered
- Status
  - Committee balloting



#### New Standards: LM-84 (cont.)

- Clarification
  - It does not provide performance requirements
  - It 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
- Contents
  - Burning temperature: at ambient temperature: 25 ± 5 °C
  - Burning cycle: 11 hours on, 1 hour off
- Test duration and photometry test interval
  - Does not include testing duration and measurement intervals
  - Determining testing duration and measurement intervals based on the intended purpose of this test, which may be for a number of reasons such as detecting severe degradation, projecting lumen maintenance, measuring actual lumen maintenance life.
  - When a product can represent a family of products



#### New Standards: IES TM-28

- Title
  - Projecting long-term lumen maintenance for LED lamps and luminaires
- Background
  - LED lighting industry desires to have shorter than 6000 hours test for lamps and luminaires
  - Current Energy Star and other specifications allow 3000 hours test results to be used for prequalification
- Purpose
  - To develop a LED lamp and luminaire level counterpart to TM-21 using the new LM-80 and LM-84 testing data for projecting long-term lumen maintenance.
- Status
  - Drafting in working group



#### New Standards: IES TM-28 (cont.)

- Sample size for projection
  - Same as in TM-21 (when using LM-80 data)
- LM-84 direct test results
  - If the mean lumen maintenance value of interest (e.g. L70) is crossed experimentally during operation per LM-84, use linear interpolation between the nearest two LM-84 measurement points bracketing the value of interest from above and below to report it.
- LM-84 test duration ≥ 6000 hours
  - If at least 6000 hours of LM-84 data are available, use a TM-21 like projection based on the data.
  - LM-84 data may be interpolated between ambient temperatures in a TM-21 like manner (i.e. using the Arrhenius equation), as long as the LM-84 data represent the same product under the same driving conditions at each ambient temperature
- LM-84 test duration < 6000 hours, but  $\geq$  3000 hours
  - LM-84 data may be used in conjunction with LM-80 data for the same type of LEDs

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#### New Standards: IES LM-85

- Title
  - IES Approved Method for the Electrical and Photometric Measurements of High-Power LEDs
- Purpose
  - Address the measurements for high-power LEDs that require heat sink for their normal operation, and include white LEDs as well as single color LEDs
  - Does not cover measurement of ultraviolet LEDs, IR emitters, and AC-driven LEDs
- Status
  - Committee balloting



#### New Standards: IES LM-85 (cont.)

- Test procedure
  - Measure total luminous flux, total radiant flux (optical power), electrical power, luminous efficacy, and color characteristics of high-power LEDs
  - Measure under pulse operation as well as steady DC operation of LEDs, and in all cases, the thermal condition of LEDs refers to their junction temperature.
  - Applies to laboratory measurements and does not apply to measurements in LED manufacturer's production control nor relative measurements of LED's thermal characteristics





#### New Standards: IES TM-26

- Title
  - Projecting rated life for LED pakcages
- Background
  - LED rated life has not been defined
  - Lumen maintenance life (e.g., L70) does not include LED catastrophic failures, and it is based on small sample size (e.g., 20) LM-80 test
  - LED users (luminaire makers, specifiers, etc.) need to know LED component level reliability
- Purpose for developing TM-26
  - LED lighting industry and US need to specify LED lamp or luminare level reliability
  - TM-21 projection for LED source level lumen maintenance
  - It is desired to have standard to project LED source level rated life
  - It is also desired to have standard to project LED driver rated life
  - With LED source and driver rated life information, LED lamp or luminaire level reliability may be projected

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#### New Standards: IES TM-26 (cont.)

- Define LED rated life
  - Time in hours when Lp is reached (based upon TM-21). In addition, the accumulated catastrophic failures (in % or ppm) at the same Lp (hours)
- Failure rate
  - Early failure
  - Random failure
  - Wear out failure
- Proposed projection model
  - To define:
  - Acceleration factor (AF)
  - Sample size (n)
  - Test duration (t)
  - Confidence level

$$FIT = \frac{\chi_{\alpha}^2 (2r+2)}{2T} \times 10^9$$

$$T = \sum \left( n \times t \times AF \right)$$





#### New Standards: IES LM-xx

- Title
  - LED package reliability tests
- Background
  - LED package level reliability tests have been practiced by all reputable LED makers
  - SSL outdoor lighting specifications refer to JEDEC tests for LED reliability
  - LED users (luminaire makers, specifiers, etc.) what consistent reliability tests to be done on the LED component level
- Purpose to develop LM-xx
  - More LED specific tests (based on JEDEC, etc.) are needed to be referenced in SSL specifications



#### New Standards: IES LM-xx (cont.)

- Qualification test definition for LED package
  - The document should consider categorizing minimum requirements by application, etc.
  - List optional tests for various applications.
- Proposed tests
  - High Temperature Operating Life (HTOL) Test (AEC 6)
  - Temperature Cycling (TMCL) Test
  - Resistance to Soldering Heat (RSH-reflow) Test
  - Wet High Temperature Operating Life (WHTOL) Test
  - Electrostatic Discharge, Human Body Model (ESD-HBM) Test
  - Electrostatic Discharge, Machine Model (ESD-MM) Test
  - Vibrations Variable Frequency (VVF) Test



#### New Standards: ANSI LED Datasheet Standard

- Title
  - Light Emitting Diode Datasheet for General Illumination Applications
- Background
  - Datasheets published by LED manufacturers are not consistent, and LED characteristics measured or disclosed are not standardized
  - LED users need to have consistent information from LED makers to make fare comparison
- Purpose
  - To specify the standardized white light emitting diode (LED) package datasheet, or data reporting format, as the means of communication between LED package producers and users. The defined contents and format of the datasheet shall be followed.



#### New Standards: ANSI LED Datasheet Standard (cont.)

- Obtaining and reporting data
  - Method of measurements must be disclosed
  - Photometric: Applicable standard methods shall be used (LM-85, CIE-127)
  - Thermal: Applicable standard methods shall be used (JEDS15-51)
  - Lumen and color maintenance: Applicable standard methods shall be used (LM-80)
  - Lumen maintenance projection: Applicable standard methods shall be used (TM-21)
  - Electrical: Applicable standard methods shall be used (JEDEC for junction temperature)



#### New Standards: ANSI LED Datasheet Standard (cont.)

- Performance and operational characteristics
  - Photometric characteristics
  - Lumen and color maintenance (optional)
  - Electric characteristics
  - Thermal characteristics
- Physical and electrical connection characteristics
  - Mechanical characteristics (drawings)
  - Electrical diagram (optional)
- Usage recommendation
  - Assembly
  - Packaging information
  - Handling (optional)
  - Storage (optional)
  - Order of the content in the datasheet



#### Considerations of New Standard: Flicker

- LRC ASSIST Recommends
  - Only applicable when the flicker source is the only light source
  - In general, 1000 Hz / 100% flicker was more preferred than 100 Hz / 25% flicker



#### Detection of Stroboscopic Effects

Acceptability of Stroboscopic Effects

100%

(%) 54%

Percent Flicker

25%

-5%

-1-0

0-0.5

0.5-1

1-1.5

1.5-2

HPS 0

MH 0

INC 0

0 WWF

Opto Semiconductors

#### Summary

- ENERGY STAR®
  - A performance based product specifications
  - Energy saving is essential
  - Product quality and durability is important for users acceptance
- US industry standards for LED lighting
  - Standards are based on industry's best practice, should be consistent, objective, and scientifically sound
  - Standards are to ensure measurements reliability, and repeatability
  - Standards should assist technology implementations



# **Thank You!**

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