LED Lighting Standards in ENERGY STAR® Programs

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OSRAM Opto Semiconductors Inc.

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Outline

- Introduction
- LED lighting standards referred to or referenced in ENERGY STAR® Specs
  - ANSI
  - IESNA
  - UL
  - NEMA
- Implementations of LED lighting standards in ENERGY STAR® Programs
  - Testing for qualifications
  - Considerations of new standards

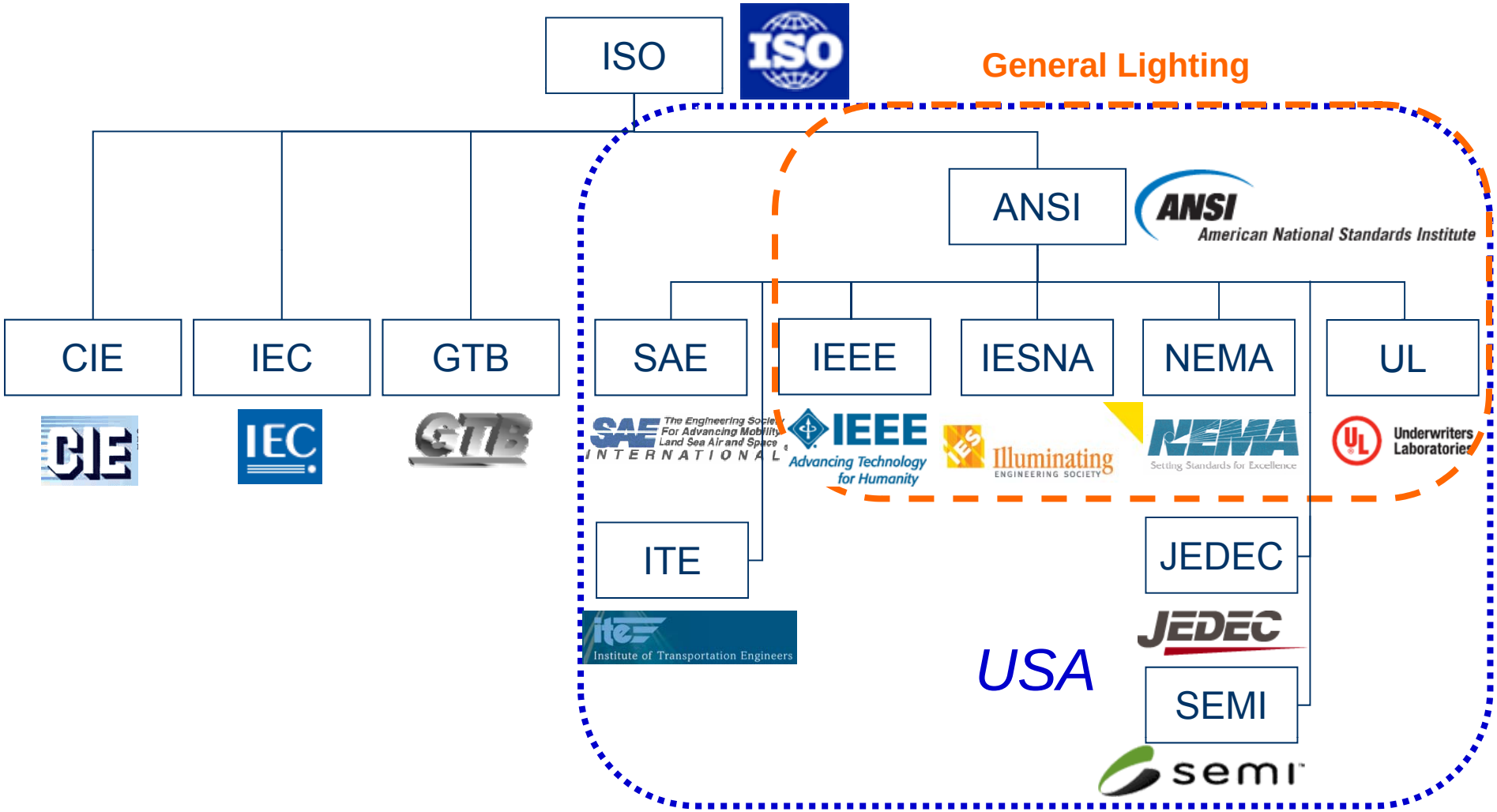
Introduction

LED Lighting Standardization Bodies in USA

- Professional associations
  - SAE (Society of Automotive Engineers)
  - 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)
  - SEMI (Semiconductor Equipment and Materials International)

Introduction

U.S. Standard Organizations



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Introduction

Government Regulations or Specifications for LED Lighting

- Federal government: DOT, EPA, DOE, …
  - Rule making (establish rules by federal agencies)
  - Enforcement
  - “Endorsement”, approval, labeling
- Federal government: DOC
  - National Institute of Standards and Technology (NIST): US National Metrology Institute
  - Promote US innovation and industrial competitiveness by advancing measurement science, standards, and technology
- Local government (states, authority having jurisdiction, or AHJ)
  - State vehicle codes, building codes , etc.
- Government rules and specs often refer to or reference industry’s standards

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Introduction

Purposes of LED & SSL Standards

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

Introduction

ENERGY STAR®

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

Methods of Measurement and Reference Documents

Organization	Identifier	Description
ANSI	C78.376-2001	Specifications for the Chromaticity of Fluorescent Lamps
ANSI/NEMA/ ANSLG	C78.377-2008	Specifications for the Chromaticity of Solid State Lighting Products
ANSI	C78.389-2004 (R2009)	High-Intensity Discharge (HID)—Methods of Measuring Characteristics
ANSI/ANSLG	C78.42-2009	High-Pressure Sodium (HPS) Lamps
ANSI/ANSLG	C78.43-2007	Single-Ended Metal Halide 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	C82.77-2002	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 Circuits
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 Lamp 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 Fluorescent Luminaires
ANSI/UL	1993-2009	Standard for Safety of Self-Ballasted Lamps and Lamp Adapters
ANSI/UL	2108-2004	Standard for Low-Voltage Lighting Systems
ANSI/UL	8750-2009	Standard for Light Emitting Diode (LED) Equipment for Use in Lighting Products
ASTM	E283-04	Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen
CAN/CSA	C22.2 NO. 74-95 (R2010)	Equipment for Use With Electric Discharge Lamps
CIE	Pub. No. 13.3-1995	Method of Measuring and Specifying Color Rendering of Light Sources
CIE	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 the Use of Certain Hazardous Substances in Electrical and Electronic Equipment
FCC	CFR Title 47 Part 15	Radio Frequency Devices
FCC	CFR Title 47 Part 18	Industrial, Scientific, and Medical Equipment
IEC	60061-1	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 for Fluorescent Lamps
IEC	62321 Ed. 1.0	Electrotechnical Products - Determination Of Levels Of Six Regulated Substances (lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls, polybrominated diphenyl ethers)
IES	LM-9-09	Electric and Photometric Measurements of Fluorescent Lamps
IES	LM-10-11	Photometric Testing of Outdoor Fluorescent Luminaires (renewal anticipated in 2011)
IES	LM-15-03	Guide for Reporting General Lighting Equipment Engineering Data for Indoor Luminaires
IES	LM-31-11	Photometric Testing of Roadway Luminaires Using Incandescent Filament and High Intensity Discharge (HID) Lamps (renewal anticipated in 2011)
IES	LM-35-02	Photometric Testing of Floodlights Using High Intensity Discharge or Incandescent Filament Lamps
IES	LM-40-01	Life Testing of Fluorescent Lamps
IES	LM-41-11	Approved Method for Photometric Testing of Indoor Fluorescent Luminaries (renewal anticipated in 2011)
IES	LM-46-04	Photometric Testing of Indoor Luminaires Using High Intensity Discharge or Incandescent Filament Lamps
IES	LM 47-11	Life Testing of High Intensity Discharge (HID) Lamps (renewal anticipated in 2011)
IES	LM-49-11	Life Testing of Incandescent Filament Lamps (renewal anticipated in 2011)
IES	LM-51-11	Electrical and Photometric Measurements of High Intensity Discharge Lamps (renewal anticipated in 2011)
IES	LM-58-11	Guide to Spectroradiometric Measurements (renewal anticipated in 2011)
IES	LM-65-11	Life Testing of Compact Fluorescent Lamps (renewal anticipated in 2011)
IES	LM-66-11	Electrical and Photometric Measurements of Single-Ended Compact Fluorescent Lamps (renewal anticipated in 2011)
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	LM-82-11	IES Approved Method for the Characterization of LED Light Engines and Integrated LED Lamps for Electrical and Photometric Properties as a Function of Temperature (publication anticipated in 2011)
IES	RP-16-10	Nomenclature and Definitions for Illuminating Engineering
IES	TM-21-11	Projecting Long Term Lumen Maintenance of LED Sources (publication anticipated in 2011)
LRC	ACTV Test 2007	Testing Guideline for the Accelerated Cycling, Thermal, and Voltage (ACTV) Stress Test
NEMA	LL 9-2009	Dimming of T8 Fluorescent Lighting Systems
NEMA	LSD 45-2009	Recommendations for Solid State Lighting Sub-Assembly Interfaces for Luminaires

Introduction

ENERGY STAR®

- Requirements for Integral LED Lamps Eligibility Criteria V1.4
- Program Requirements Product Specification for Lamps (Light Bulbs) Eligibility Criteria V1.0, DRAFT 1

Methods of Measurement and Reference Documents

Organization	Identifier	Description
ANSI/IEEE	C62.41.2-2002	IEEE Recommended Practice on Characterization of Surges in Low Voltage (1000V and Less) AC Power Circuits
ANSI	C78.20-2003	Electric Lamps—A, G, PS and Similar Shapes with E26 Medium Screw Bases
ANSI	C78.21-2003	Electric Lamps—PAR and R Shapes
ANSI	C78.23-1995 (R2003)	Incandescent Lamps—Miscellaneous Types
ANSI	C78.375-1997	Fluorescent Lamps—Guide for Electrical Measurements
ANSI	C78.376-2001	Specifications for the Chromaticity of Fluorescent Lamps
ANSI/NEMA/ ANSLG	C78.377-2008	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	C78.5-2003	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	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
CIE	Pub. No. 13.3-1995	Method of Measuring and Specifying Color Rendering of Light Sources
CIE	Pub. No. 15:2004	Colorimetry
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 Ed. 1.0	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 47-11	Life Testing of High Intensity Discharge (HID) Lamps (renewal anticipated in 2011)
IES	LM-51-00	Electrical and Photometric Measurements of High Intensity Discharge Lamps
IES	LM-58-11	Guide to Spectroradiometric Measurements (renewal anticipated in 2011)
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

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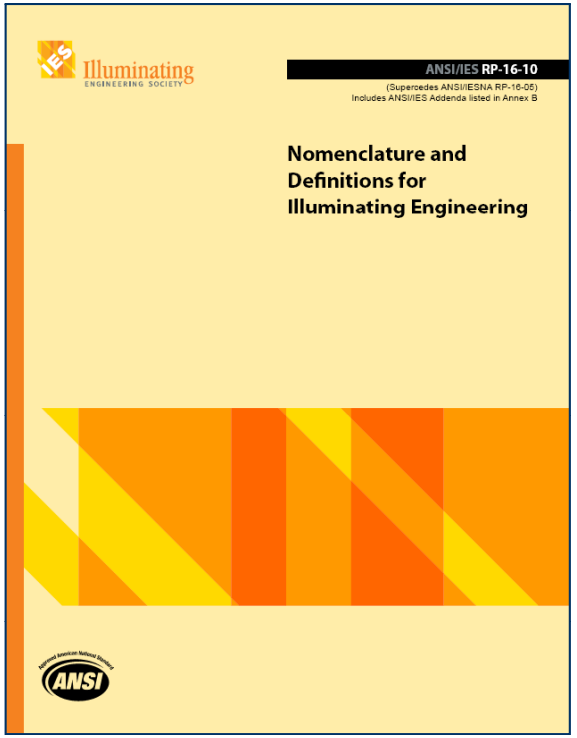
Industry's Standards for LED Lighting

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, and LED driver class II
  - LED lamp integrated, and non-integrated
  - LED light engine
  - LED luminaire



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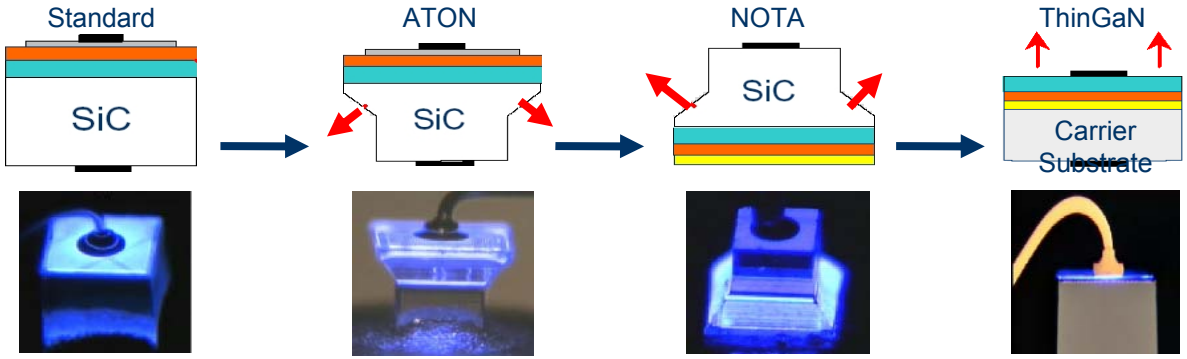
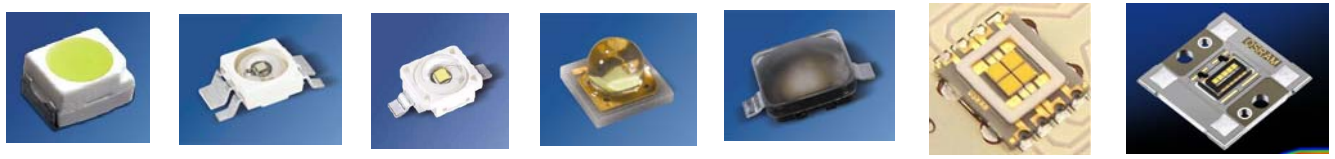
Example of Definition

- LED Die
  - A small block of light-emitting semi-conducting material on which a functional LED circuit is fabricated



- LED Package
  - An assembly of one or more LED dies that includes wire bond or other type of electrical connections, possibly with an optical element and thermal, mechanical, and electrical interfaces. Power source and ANSI standardized base are not incorporated into the device. The device cannot be connected directly to the branch circuit.



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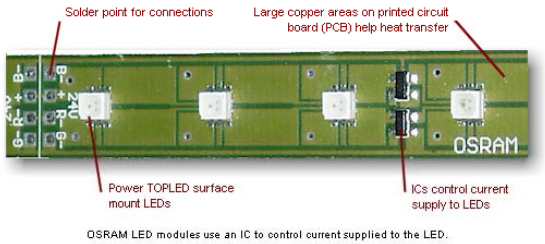
Industry's Standards for LED Lighting

Example of Definition (cont.)

- LED Array or Module
  - An assembly of LED packages (components), or dies on a printed circuit board or substrate, possibly with optical elements and additional thermal, mechanical, and electrical interfaces that are intended to connect to the load side of a LED driver. Power source and ANSI standard base are not incorporated into the device. The device cannot be connected directly to the branch circuit.



OSRAM LED modules use an IC to control current supplied to the LED.

- LED Driver
  - A device comprised of a power source and LED control circuitry designed to operate a LED package (component), or an LED array (module) or an LED lamp.

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Example of Definition (cont.)

- LED Lamp – Integrated
  - An integrated assembly comprised of LED packages (components) or LED arrays (modules), LED driver, ANSI standard base and other optical, thermal, mechanical and electrical components. The device is intended to connect directly to the branch circuit through a corresponding ANSI standard lamp-holder

- LED Light Engine
  - An integrated assembly comprised of LED packages (components) or LED arrays (modules), LED driver, and other optical, thermal, mechanical and electrical components. The device is intended to connect directly to the branch circuit through a custom connector compatible with the LED luminaire for which it was designed and does not use an ANSI standard base.

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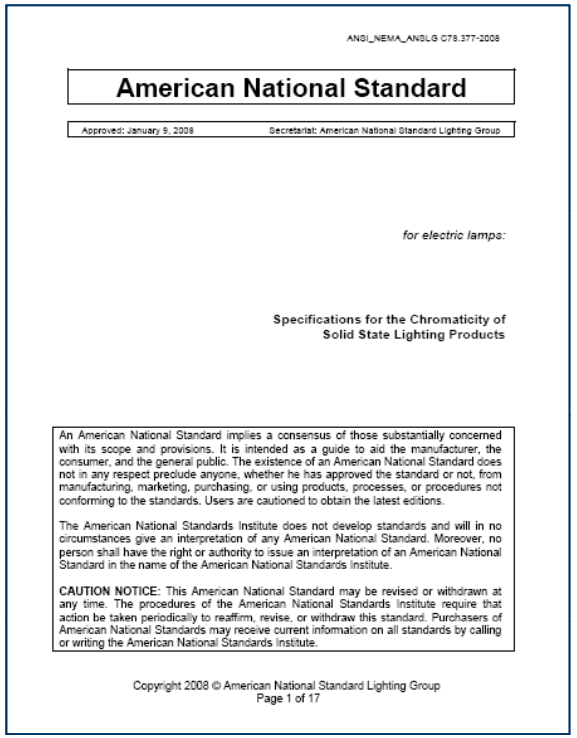
Industry's Standards for LED Lighting

ANSI Standard: ANSI C78.377

- Purpose
  - To communicate the indoor lighting SSL products color characteristics to SSL producers and users
- Status
  - Published
  - Revision in process
- 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



ANSI_NEMA_ANSLG C78.377-2008

American National Standard

Approved: January 9, 2008 Secretariat: American National Standard Lighting Group

for electric lamps:

Specifications for the Chromaticity of Solid State Lighting Products

An American National Standard implies a consensus of those substantially concerned with its scope and provisions. It is intended as a guide to aid the manufacturer, the consumer, and the general public. The existence of an American National Standard does not in any respect preclude anyone, whether he has approved the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standards. Users are cautioned to obtain the latest editions.

The American National Standards Institute does not develop standards and will in no circumstances give an interpretation of any American National Standard. Moreover, no person shall have the right or authority to issue an interpretation of an American National Standard in the name of the American National Standards Institute.

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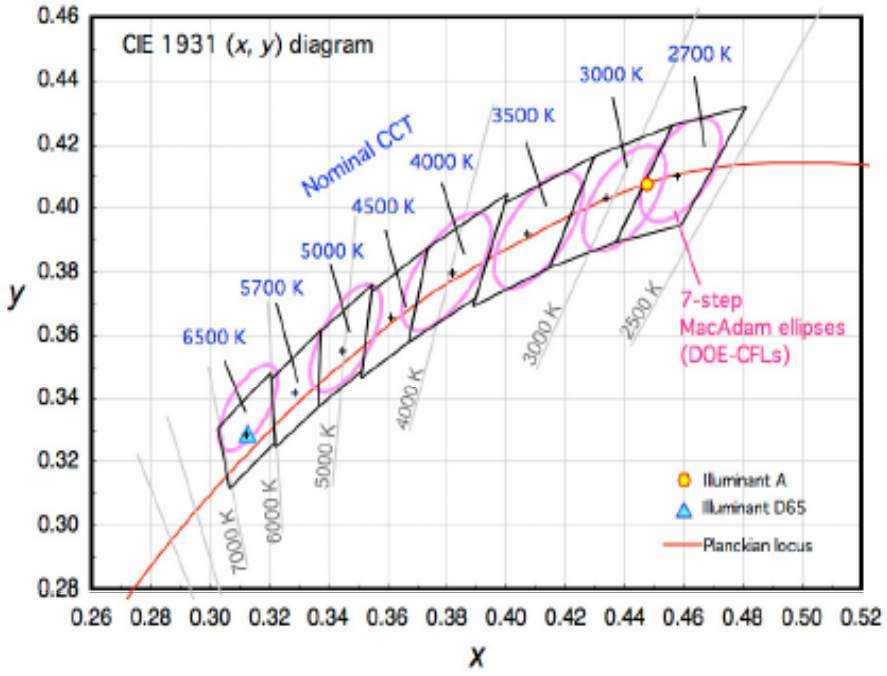
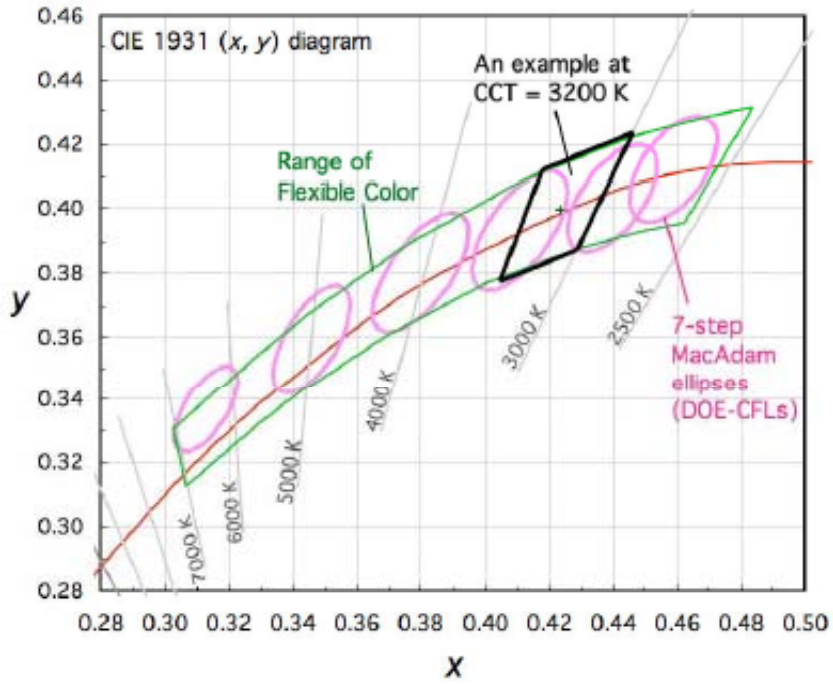
Industry's Standards for LED Lighting

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





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Chromaticity Tolerances

- Quadrangles
  - In both ΔCCT and Duv directions
  - Approximately equal to 7-step MacAdam ellipses

Nominal CCT[1)]	Target CCT and tolerance (K)	Target Duv and tolerance
2700 K	2725 ± 145	0.000 ± 0.006
3000 K	3045 ± 175	0.000 ± 0.006
3500 K	3465 ± 245	0.000 ± 0.006
4000 K	3985 ± 275	0.001 ± 0.006
4500 K	4503 ± 243	0.001 ± 0.006
5000 K	5028 ± 283	0.002 ± 0.006
5700 K	5665 ± 355	0.002 ± 0.006
6500 K	6530 ± 510	0.003 ± 0.006
Flexible CCT (2700 - 6500 K)	T [2)] ± ΔT [3)]	D_{uv} [4)] ± 0.006

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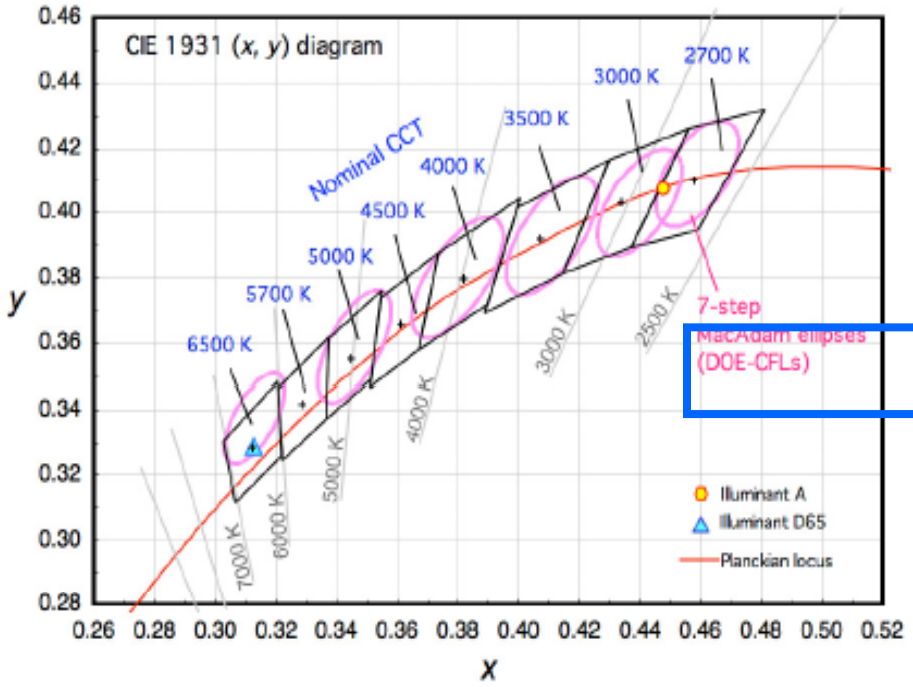
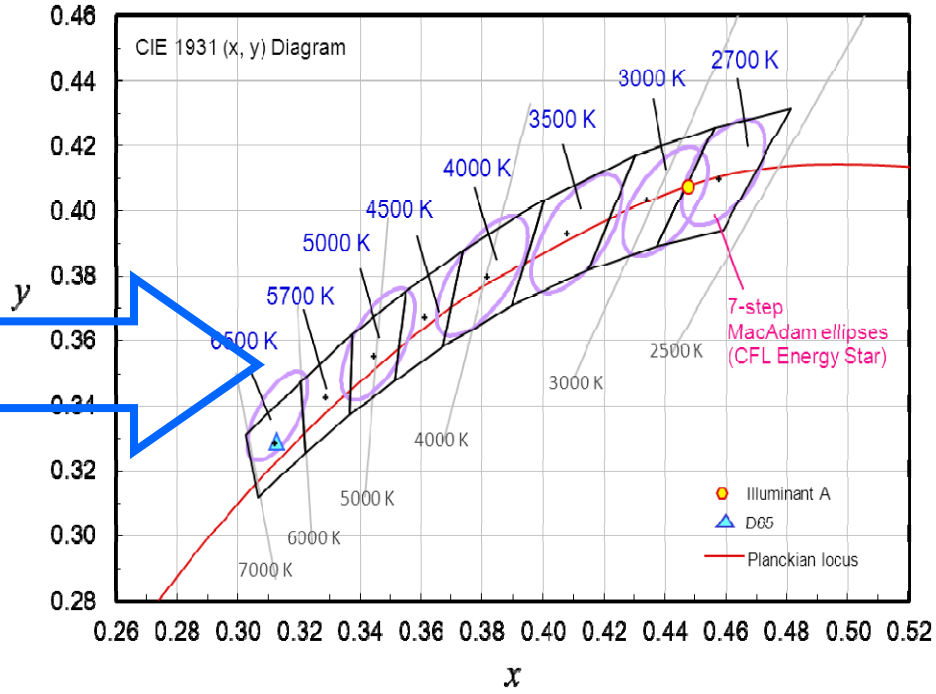
ANSI Ad hoc: Revision for ANSI C78.377

- Scope of the revision
  - Make tolerance continuous for all nominal (fixed and flexible) CCTs





$$D_{uv}(T_x) \pm 0.006$$

where

$$D_{uv}(T_x) = 57700 \times (1/T_x)^2 - 44.6 \times (1/T_x) + 0.0085$$

T_x : CCT of the source

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ANSI Ad hoc: Revision for ANSI C78.377 (cont.)

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

$$L_{FP} = \sqrt{(u-0.292)^2 + (v-0.24)^2}$$

$$a = \arccos\left(\frac{u-0.292}{L_{FP}}\right)$$

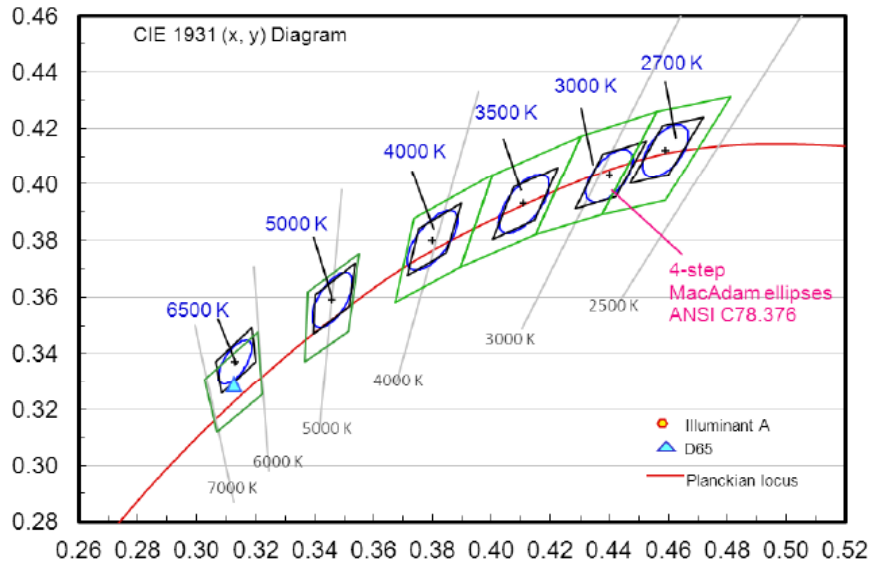
$$L_{BB} = k_6 a^6 + k_5 a^5 + k_4 a^4 + k_3 a^3 + k_2 a^2 + k_1 a + k_0$$

$$D_{uv} = L_{FP} - L_{BB}$$

Table A5 Coefficients for D_{UV} calculation

k_6	0.00616793
k_5	0.0893944
k_4	-0.5179722
k_3	1.5317403
k_2	-2.4243787
k_1	1.925865
k_0	-0.471106

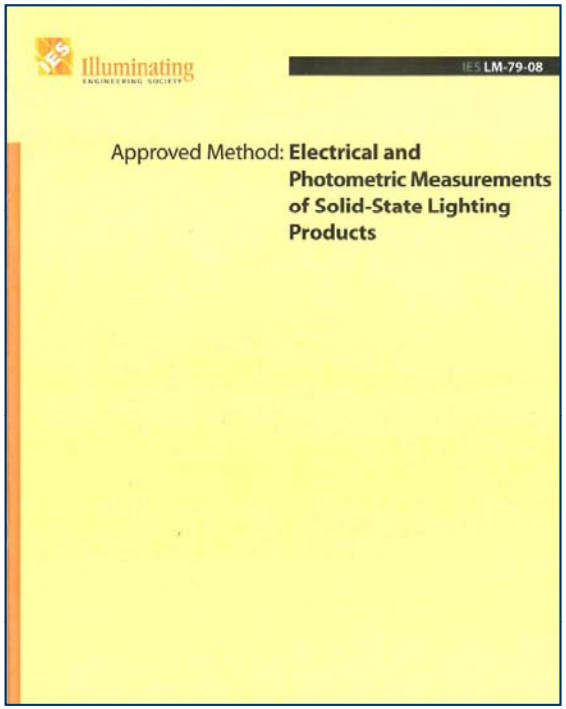
- Added Annex to describe 4-step MacAdam ellipse equivalent quadrangles
  - It is for reference for comparison of the requirements used for linear fluorescent lamp (LFL)



Industry's Standards for LED Lighting

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 values (x,y and u',v')
  - Color spatial uniformity



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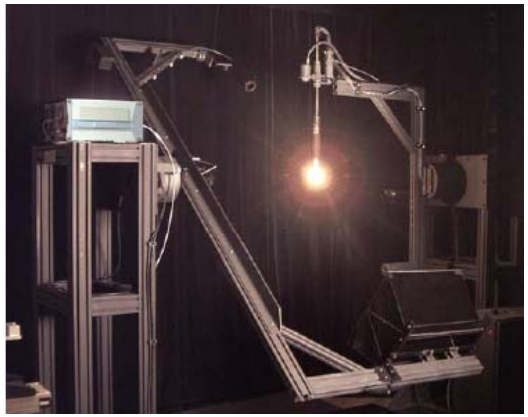
Industry's Standards for LED Lighting

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

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



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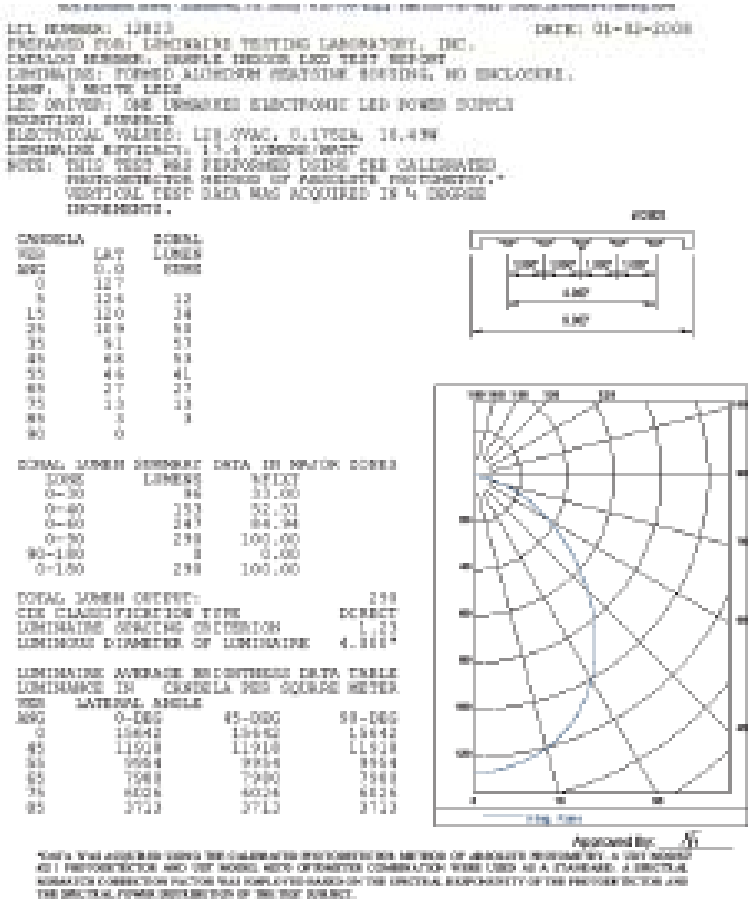
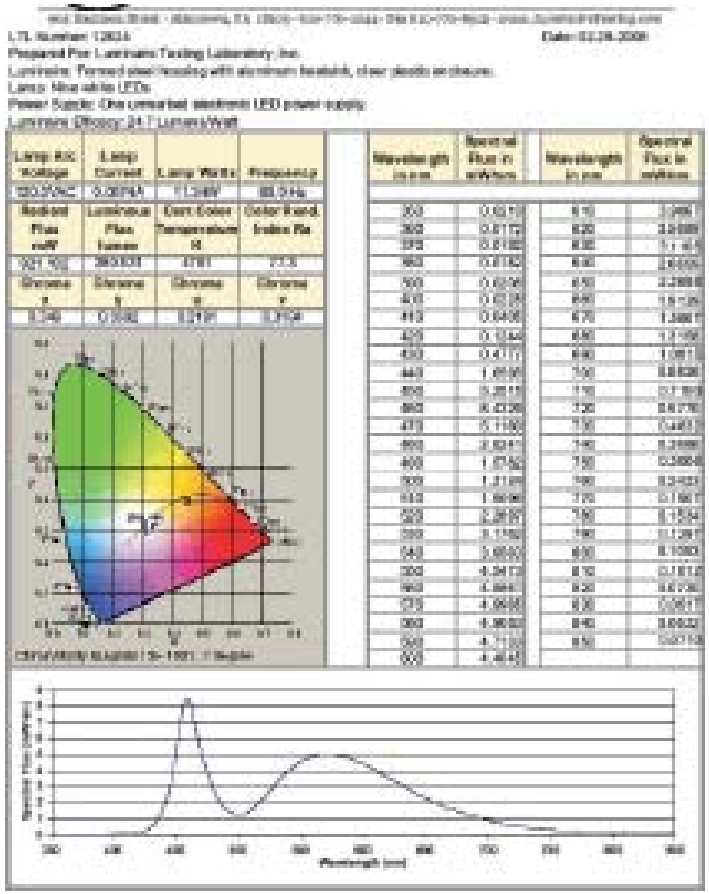
Industry's Standards for LED Lighting

LM-79 Test Report

- Report contents
- IES format files





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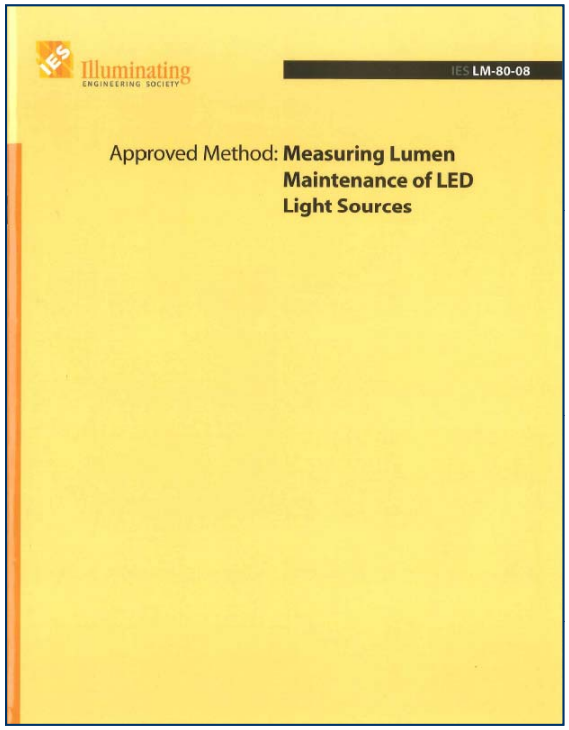
Industry's Standards for LED Lighting

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



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Industry's Standards for LED Lighting

Test Requirements

- General
  - Sample marking: individual LED light sources shall be marked and tracked during life testing
  - Sample selection: shall be selected to be sufficiently representative of the overall population being tested
- Photometry test
  - Luminous flux shall be measured at the drive current used during life testing, at ambient temperature 25 ^{o}C ± 2 ^{o}C
  - The chromaticity shift shall be measured and reported over the course of the life testing
- Test procedure
  - Shall be tested for at least 6,000 hours with data collection at a minimum of every 1,000 hours
  - The case temperatures T_s shall be 55°C, 85°C, with the third temperature selected by the manufacture. The case temperature and drive current selected by the manufacturer should represent their expectation and be within recommended operating temperature range.

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Industry's Standards for LED Lighting

LM-80 Test Report

- Contents to be included
  - Number of LED sources tested
  - Description of LED sources
  - Description of auxiliary equipment
  - Operating cycle
  - Ambient conditions including airflow, temperature and relative humidity
  - Case temperature (test point temperature)
  - Drive current of the LED light source during lifetime test
  - Initial luminous flux and forward voltage at photometric measurement current
  - Lumen 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
  - Photometric measurement uncertainty
  - Chromaticity shift reported over the measurement time.

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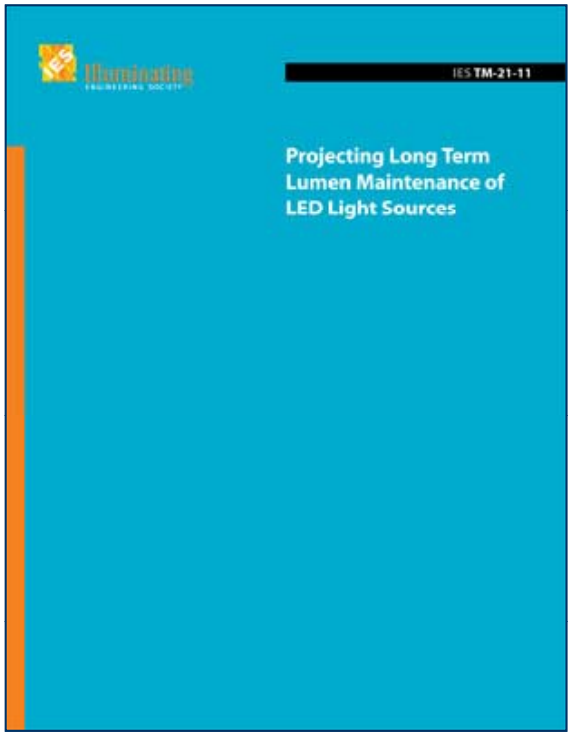
IES Document: IES TM-21-11

- Purpose
  - Provide a calculation tool to interpret the data collected from LM-80 testing; to provide users with lumen maintenance life (e.g., L_{70}) 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



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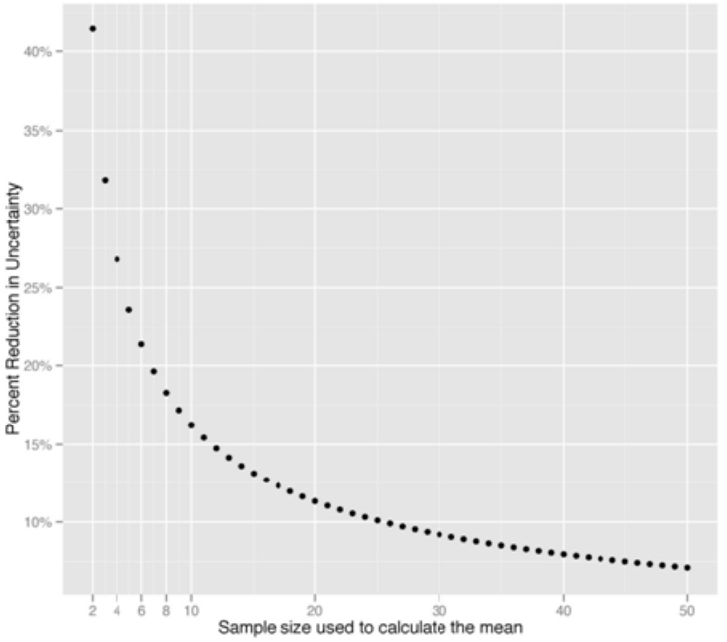
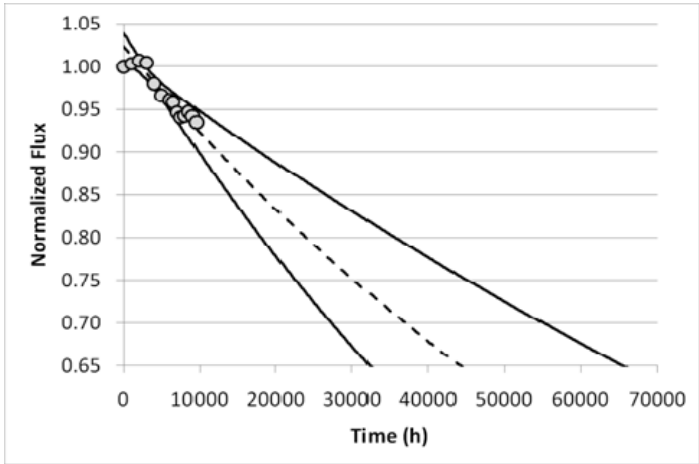
Industry's Standards for LED Lighting

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 prejections
- Normalization & average
  - Normalize all collected data to a value of 1 (100%) at 0 hours
  - Average the normalized measured data of all samples





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Projection Procedure

- 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 ≤ 6,000 hours, or
  - Last 50% of total test duration for test duration > 10,000 hours
- Curve-fit
  - Perform an exponential least squares fit $\Phi_i(t) = B_0 \exp(-\alpha_i t)$
  - Use the following equations to project the lumen maintenance life

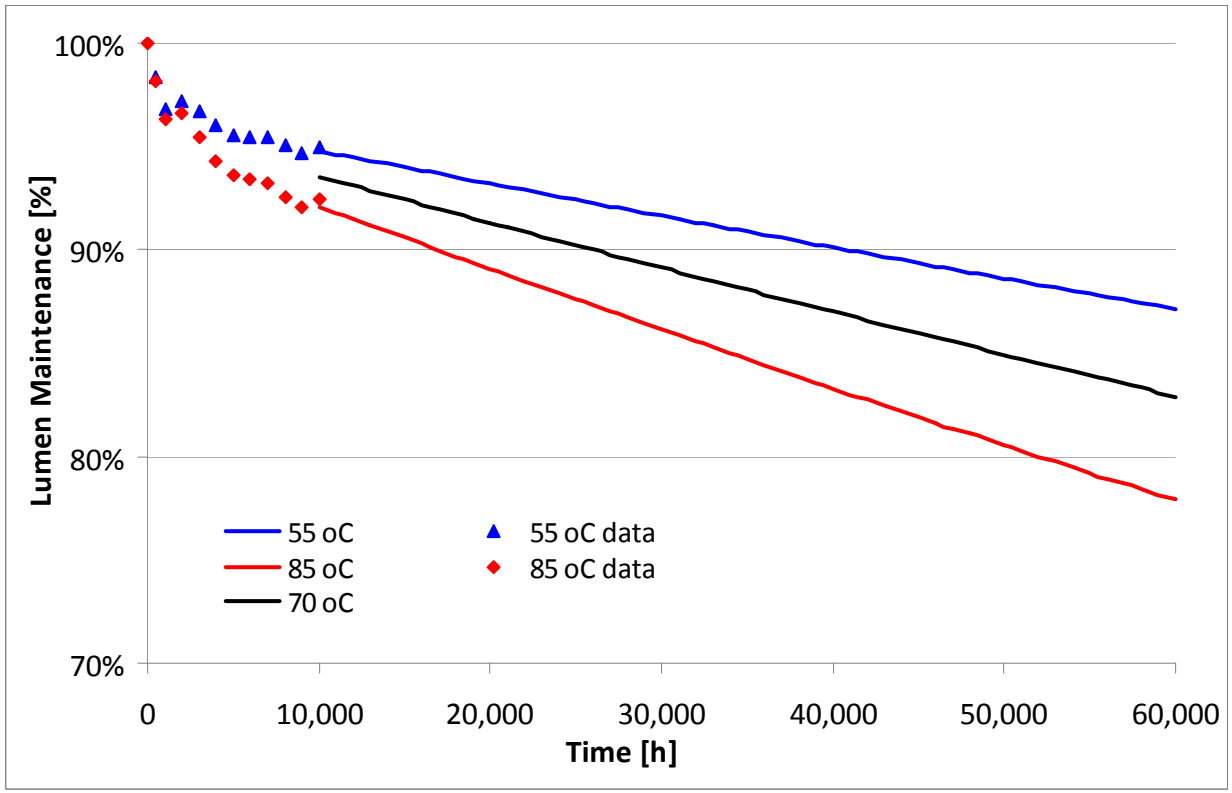
$$L_p = \frac{\ln\left(100 \times \frac{B}{p}\right)}{\alpha}$$

- Adjustment of results
  - Luminous flux values must not be projected beyond 6 times of the test duration
  - When calculated L_{70} > 0 and ≤ 6 times of the test duration, reported L_{70} is the calculated L_{70}
  - When calculated L_{70} > 0 and ≥ 6 times of the test duration, reported L_{70}, is limited to 6X total test duration
  - When calculated L_{70} < 0, the reported L_{70}, will be 6 times of the test duration, and equal to the normalized lumen output at the last measurement point

Industry's Standards for LED Lighting

Data Interpolation

- Applicability of the Arrhenius equation
  - Both α_1 and α_2 are positive
- Limit for extrapolation
  - In-situ temperature is within 2 LM-80 tested temperatures



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Industry's Standards for LED Lighting

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
  - To be 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.


IES LM-82-2011

DRAFT

IES Approved Method for the Characterization of LED Light Engines and LED Lamps for Electrical and Photometric Properties as a Function of Temperature

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 Light Sources of the IESNA Testing Procedures Committee

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Industry's Standards for LED Lighting

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^{o}C
  - Measure the unit at room temperature + ΔT ^{o}C

Source: Permlight

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Industry's Standards for LED Lighting

LM-82 Test Report

- Content to be included
  - Input power
  - Input voltage
  - Input current
  - Luminous flux
  - Luminous efficacy
  - Chromaticity as optional
  - Correlated color temperature as optional
  - T_d, monitoring pointer temperature
  - Test date
  - Test facility
  - Test instrumentation
  - UUT description
  - Internal procedure reference

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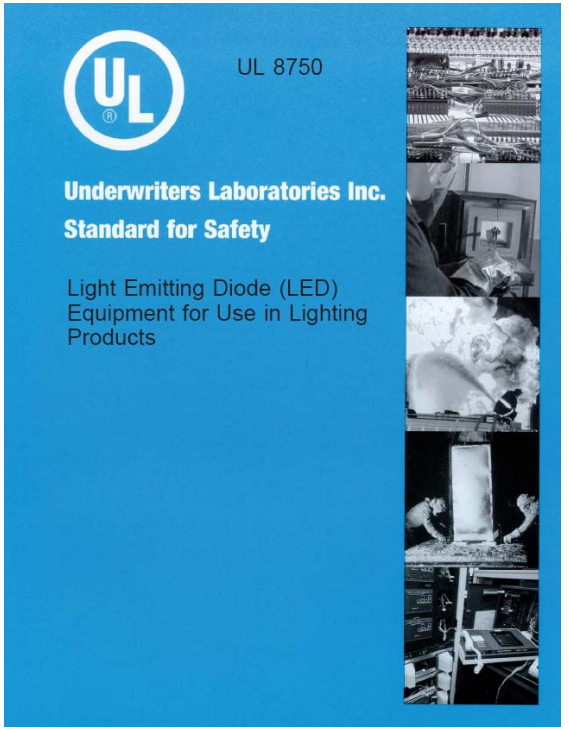
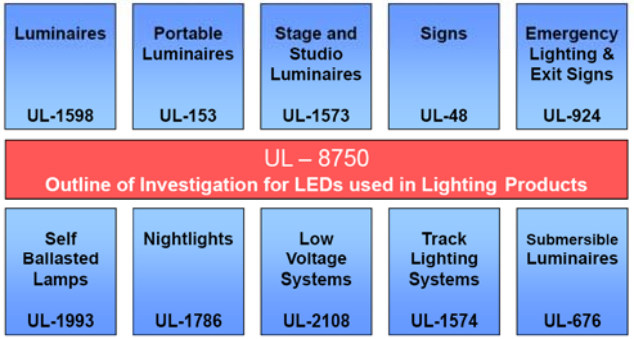
Industry's Standards for LED Lighting

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





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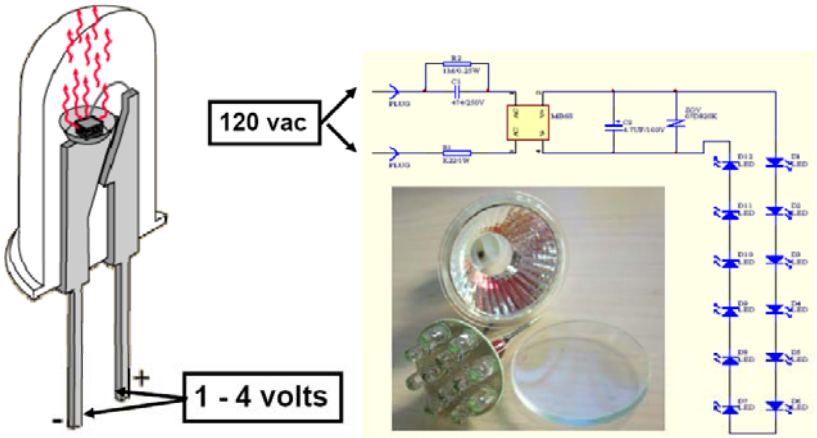
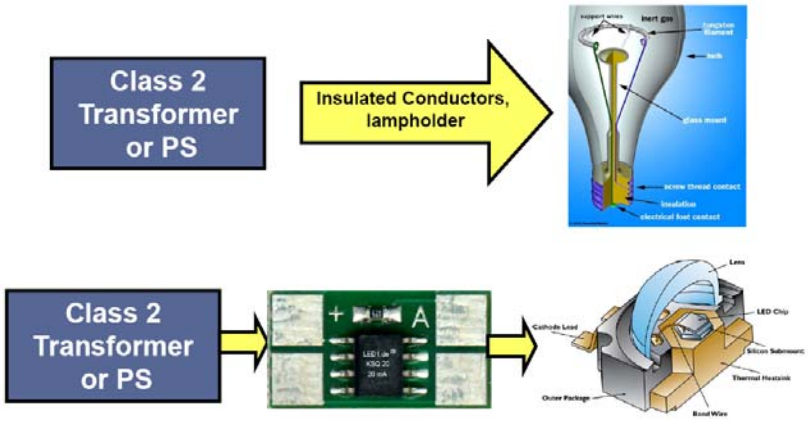
Industry's Standards for LED Lighting

LED Sources Safety

- UL safety concerns
  - Risk of electrical shock injury
  - Risk of fire
- Requirements for risk of electrical shock injury
  - >5 mA and
  - >30 VAC rms or >60 VDC (dry)
  - >15 VAC rms or >30 VDC (wet)
- Requirement for risk of fire
  - Electric energy: power above Class 2
  - Thermal energy: end product temperature test, end product abnormal test





Source: Strategies in Light 2009

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Industry's Standards for LED Lighting

Requirements in UL8750

- Construction
  - Environmental considerations
  - Mechanical constructions
  - Electrical constructions
- Performance
  - Performance tests
  - Markings
- LED lens must subject to additional tests for non class II applications
  - Dielectric voltage withstand test: 500-V potential the LED and the lens surface.
  - Flammability test: V1 test in UL94
  - Impact test: drop test: 09m
  - Probing force: 4.45N

Industry's Standards for LED Lighting

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

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Industry's Standards for LED Lighting

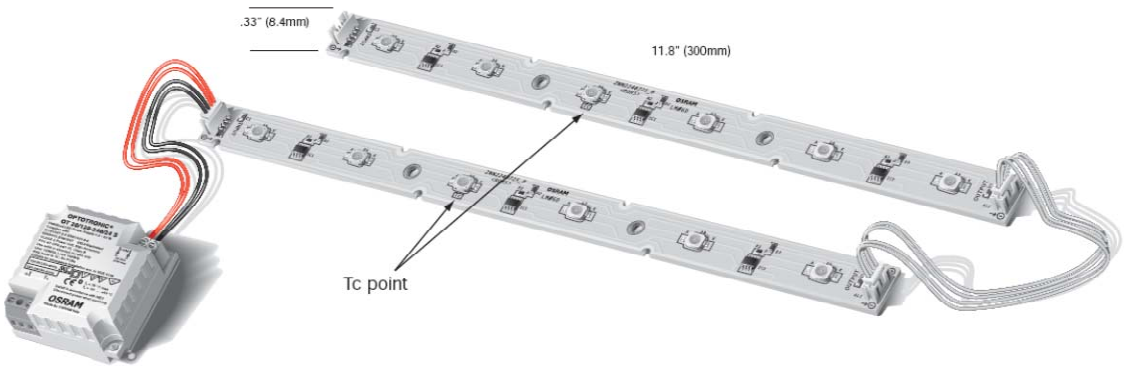
NEMA White Paper: LSD-45

- 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

Industry's Standards for LED Lighting

NEMA White Paper: LSD-45 (cont.)

- Mechanical interface
  - Dimensions & tolerances
  - Weight
  - Coupling
  - Materials
  - Glass
- Electrical interface
  - Safety
  - Number of electrical connections
  - Type of connections
- Thermal interface
  - Recommended interconnect provisions for the safe operation of LED modules/light engines
  - Recommended interconnect provisions for the proper performance of LED modules/light engines
  - Provisions for luminaires and interconnects for LED modules/light engines



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Outline

- Introduction
- LED lighting standards referred to or referenced in ENERGY STAR® Specs
  - ANSI
  - IESNA
  - UL
  - NEMA
- Implementations of LED lighting standards in ENERGY STAR® Programs
  - Testing for qualifications
  - Considerations of new standards

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Standards Implementations in ENERGY STAR®

Testing for Qualifications

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

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Standards Implementations in ENERGY STAR®

Considerations of New Standards

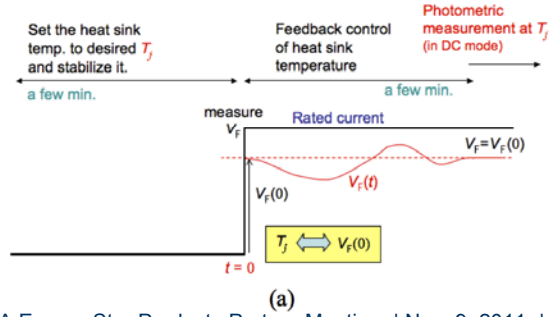
- System level test: new IES LM, IES Approved Method for Measuring Lumen and Color Maintenance LED Lamps, Lighting engines, and Luminaires
  - Addresses the methods of measurement of lumen maintenance of LED lamps, light engines and luminaires. Different from LM-80 for testing LED light sources or subcomponents, the standard will provide recommendations for:
  - Temperature setup
  - Operation duty cycle
  - It may not specify testing duration and measurement intervals

Standards Implementations in ENERGY STAR®

Considerations of New Standards (cont.)

- Component level test: new IES LM, IES Approved Method for the Electrical and Photometric Measurements of High-Power LEDs
  - 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.
  - 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

    Does not cover measurement of ultraviolet LEDs, IR emitters, and AC-driven LEDs.



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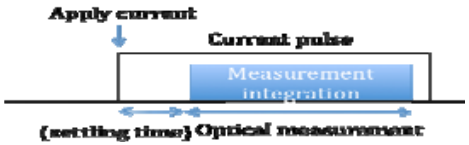
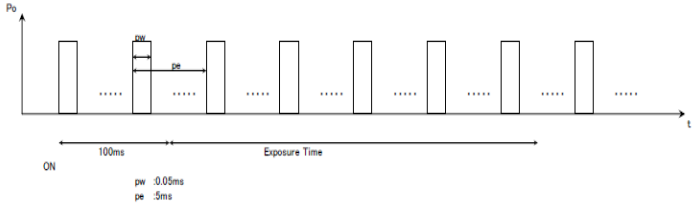




Standards Implementations in ENERGY STAR®

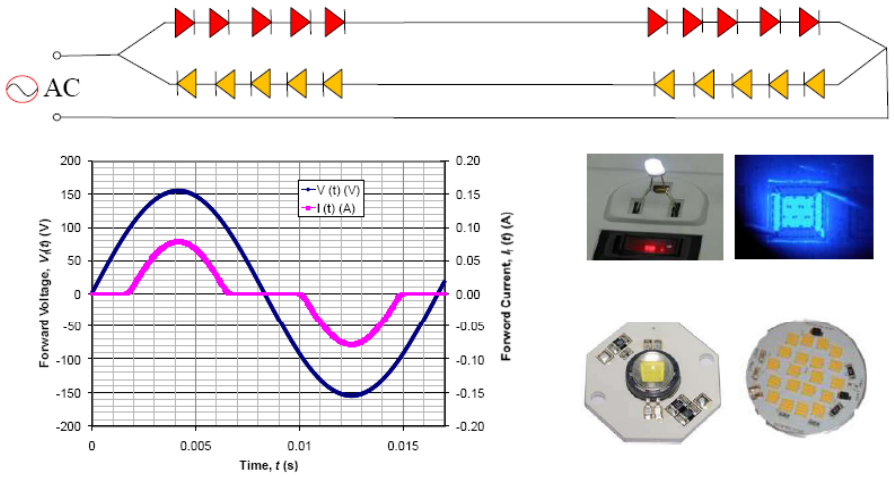
Considerations of New Standards (cont.)

- Component level test: new IES LM, Measuring Remote Phosphor Systems Characteristics Change Over Time
  - Address the measurements for remote phosphor components in the SSL products for their photometry and colorimetry characteristics change over time
  - Link the phosphor lumen and color maintenance behaviors to the pumping LED die behavior
  - Reduce burden for testing entire SSL products where remote phosphor is used

Standards Implementations in ENERGY STAR®

Considerations of New Standards (cont.)

- Component level test: new IES LM, AC LED Measurements
  - Measure AC LED packages photometric, colorimetric, and electrical characteristics
  - It may cover high voltage LEDs
  - Does not cover AC LED modules



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Standards Implementations in ENERGY STAR®

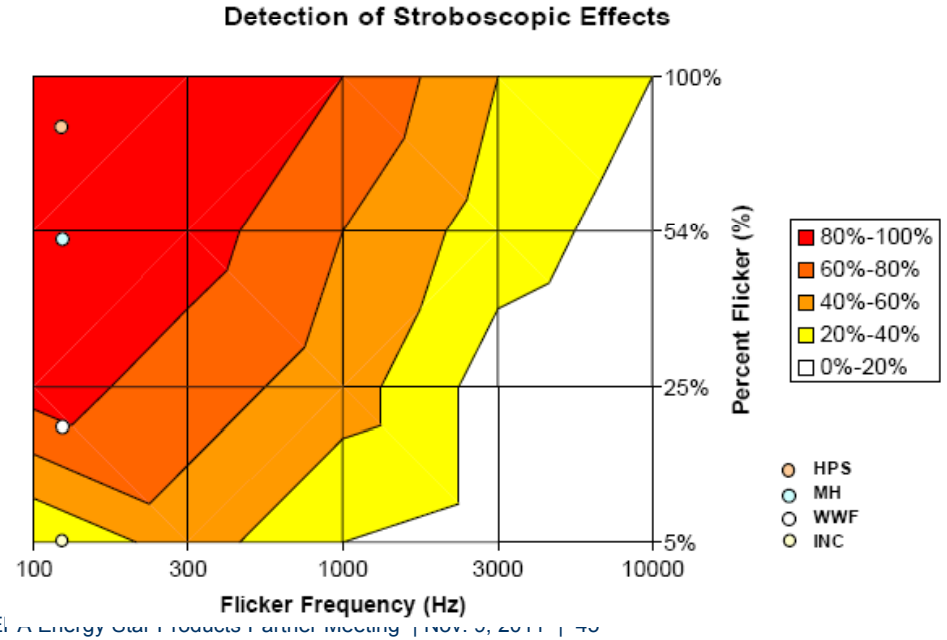
Considerations of New Standards (cont.)

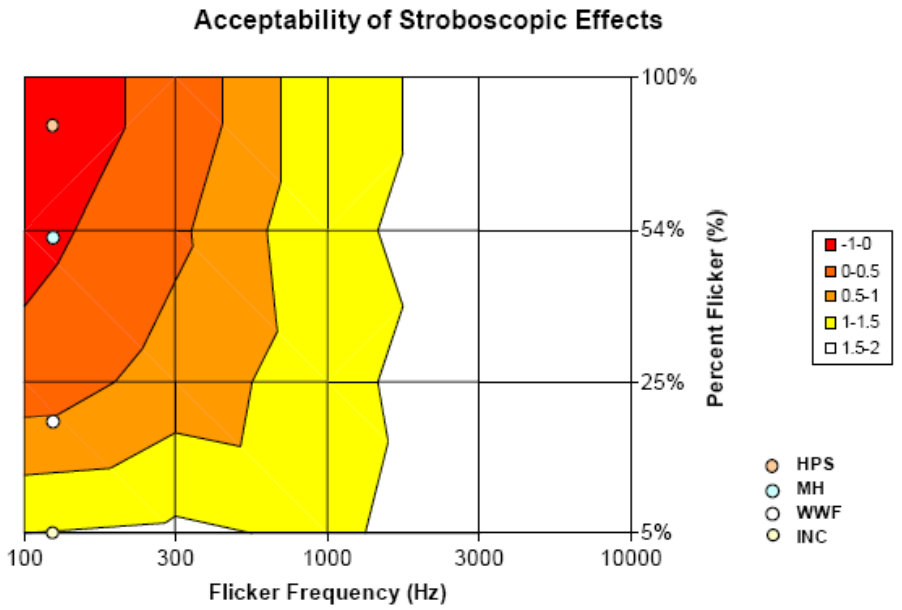
- Component level test: new IES TM, Rated Life for LED Sources
  - Clarify the difference between "B_p" life and "L_p" life
  - Develop definition of rated life for LED sources that includes both catastrophic failure and lumen maintenance life
  - Establish methods to project rated life for LED sources

Standards Implementations in ENERGY STAR®

Considerations of New Standards (cont.)

- Flicker issue: IEEE PAR 1789
  - Defining Measures of Flicker
  - Risk Matrix Analysis
  - Flicker Education to Stakeholders and Handling Comments on Flicker Report
- LRC ASSIST work
  - Flicker detections and acceptability
  - Identify flicker parameters: frequency, modulation depth, duty cycle





Summary

- ENERGY STAR®
  - A performance based product specifications
  - Energy saving is essential
  - Product quality and durability is important for users to accept SSL products
- US industry standards for LED lighting
  - Based on industry's best practice, should be consistent, meaningful, and scientifically sound
  - To ensure measurements are reliable and repeatable
  - To assist new technology implementations

Thank You!

For more information, contact:
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