Regulations and Quality Assurance of SSL products in USA and international efforts

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OUTLINE

- Overview
- Standards
- ENERGY STAR
- DLC
- DOE regulations and programs
- International efforts
Regulations supported by Standards, Testing, and Accreditation in USA

Lighting Market

Regulations and voluntary programs

Standards, Specifications

- Test Methods
  - Photometric
  - Lifetime
- Chromaticity
- Safety

Products Test data

Test methods
- LM-79
- LM-80
...

Manufacturers, testing labs

Accredited

Laboratory Accreditation Programs

Proficiency Testing (NIST)
Products Certification Programs

ENERGY STAR (Lighting)
- covers consumer products
- Product Specification for Lamps (Light Bulbs) Ver.2.1 June 2017
- Product Specification for Luminaires (Light Fixtures) Ver.2.1 March 2018

Design Lights Consortium
- covers commercial products
- Technical Requirements Ver 4.4
  - Testing and Reporting Requirements for LED-based Horticultural Lighting Ver 1.0
  - Networked Lighting Control System Technical Requirements V3.0
Regulations supported by Standards, Testing, and Accreditation (Example in USA)

Lighting Market

Regulations and voluntary programs

Standards, Specifications

- Test Methods
  - Photometric
  - Lifetime
- Chromaticity
- Safety

Products Test data

Manufacturers, testing labs

- DOE regulations on GSL

Laboratory Accreditation Programs

Proficiency Testing (NIST)

Accredited

Test methods
LM-79
LM-80

EPA

DOE

FTC

DOEFTC

Test Methods
- Photometric
- Lifetime
- Chromaticity
- Safety

EPA DOE

DOE regulations on GSL

Regulations and voluntary programs

Standards, Specifications
NVLAP (National Voluntary Laboratory Accreditation Program) is the laboratory accreditation body established within NIST.

EELP existed since ~1990s for CFLs.

SSL testing program added in 2009 for IES LM-79 to support ENERGY STAR and other programs. LM-80 added later.

ENERGY STAR requires that SSL testing accreditation includes proficiency test.

NIST’s Proficiency Test Program for SSL
Measurement Assurance Program (MAP)

• Serves NVLAP and other accreditation programs.

• Bilateral comparisons between NIST and applicant labs measuring several SSL products.

• Luminous flux, luminous efficacy, Active power, power factor, chromaticity, CCT, color rendering index.

• MAP 2 started in 2015.

MAP 1 (2009 - 2014)
118 laboratories
49 United States
45 China
9 Taiwan
4 Korea
3 Canada
1 Germany
1 Hungary
1 Italy
1 Malaysia
1 Singapore
1 India
1 Brazil
1 Netherlands

MAP 2 (2015 - )
Over 100 labs
International harmonization

- **DOE new LED lamp regulations**
- **International Test Method CIE S 025**
- **IES LMs**
- **Accreditation Programs for SSL Testing (NVLAP, ..)**
- **EN Test Method**
- **Accreditation Programs for SSL Testing**
- **Chinese regulations**
- **Chinese CQC and GB stds**
- **Accreditation Program for SSL Testing (CNAS)**
- **JIS Test Methods**
- **Accreditation Program for SSL Testing (IA-Japan)**

**Eco-design**

**Energy Label**

**JAPAN Eco mark Top Runner**
OUTLINE

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  - DOE programs and regulations
  - International efforts
The U.S. and International Standards on LED lighting

### <Components>

| LED packages | IES LM-85 photometric testing  
CIE 225 (TR)  
CIE 226 (TR) |
| LED modules | IES LM-80  
Lumen maintenance  
IES TM-21 lifetime prediction |
| LED light engines | IES LM-82 |

#### Definitions (terminology)

IES/ANSI RP-16

### <Complete products>

| LED lamps | IEC 62612 |
| LED luminaires | IES LM-79 Photometric test  
CIE S 025  
IES LM-84 / TM-28 life time  
ANSI C78.377 Chromaticity |
| Safety | UL 8750, IEC  
CIE S009 (photobiological) |
| Electrical | ANSI, NEMA, IEC |

#### IES/ANSI RP-16

CIE DIS 017:2016 ILV (incl. LED terms)

#### IEC 62504

IEC 62722-2-1
IES LM-79-08 Approved Method for Electrical and Photometric Measurement of SSL Products

- Used by ENERGY STAR, Lighting Facts, DLC, etc.
- Used in accreditation (NVLAP SSL Testing)
- Covers LED luminaires and LED lamps.
- Covers measurements of
  - Total luminous flux (lumen)
  - Luminous efficacy (lm/W)
  - Chromaticity, CCT, CRI
  - Luminous intensity distribution

Prepared by the IES Testing Procedures Committee
Solid-State Lighting Subcommittee
Kevin Dowling, Chair
Yoshi Ohno, Technical Coordinator

Published 2008 (still current)
Revision in progress
CIE S 025

International Test Method
for LED lamps, LED modules, and LED luminaires

• Intended for use in SSL regulations and for testing laboratory accreditation worldwide.

• Joint work with CEN TC169 WG7, that produced a harmonized std:

EN 13032-4 Lighting Applications — Measurement and presentation of photometric data of lamps and luminaires — Part 4: LED lamps, modules and luminaires

• Covers LED lamps, LED luminaires and LED modules.

• Covers electrical, photometric, and colorimetric measurements

• Not including lifetime, flicker, etc.
Standard Test Conditions
(For operation of LED lamp/luminaire)

- Ambient temperature: 25 °C ± 1.2 °C
- Air movement: 0 to 0.25 m/s
- Test voltage: rated supply voltage ± 0.4 %
- Stabilization

\[ \Phi \quad < 0.5 \% \]

\[ P \quad 15 \text{ min} \quad 30 \text{ min} \leq \]
4.3 Electrical Test Conditions and Electrical Equipment

- **Calibration uncertainty of AC Voltmeters and ammeters** ≤ 0.2 % for AC, ≤ 0.1 % for DC
- **Calibration uncertainty of AC power meter** ≤ 0.5 %
- **Bandwidth of AC power meter** ≥ 100 kHz.
- **Internal impedance of the voltage measurement**: ≥ 1 MΩ
- **AC power supply THD** ≤ 1.5 % (≤ 3 % for PF > 0.9) at DUT terminal
- **AC power supply frequency uncertainty** ≤ 0.2 %
- **DC power supply voltage AC ripple** ≤ 0.5 %

**THD**: Total harmonic distortion
4.5 Photometric and Colorimetric Measurement Instruments

- $f_1$ of the photometer system (gonio, sphere) $\leq 3\%$
- $f_2$ of the detector head of sphere system $\leq 15\%$
- Repeatability of sphere (open/close) $\leq 0.5\%$
- Stability of the sphere between recalibrations $\leq 0.5\%$
- Spectroradiometer bandwidth and interval $\leq 5\text{ nm}$
- Spectroardiometer wavelength uncertainty $\leq 0.5\text{ nm}$
- Angle uncertainty of goniophotometers $\leq 0.5^\circ$

- Photometric distance of goniophotometers
  - Near cosine (beam angle $\geq 90^\circ$): $\geq 5 \times D$
  - Broad distribution (b.a.$\geq 60^\circ$): $\geq 10 \times D$
  - Narrower distribution: $\geq 15 \times D$

*where $D$ is the maximal luminous dimension of the DUT*
Test Methods for lifetime (IES)
Projection of lifetime $L_{70}$

Components approach
IES LM-80 /TM-21
6000 h aging test data of components (LEDs, modules)

Direct approach
IES LM-84 /TM-28
Aging test directly on LED lamps, LED luminaires for changes of luminous flux, color (6000 h, 3000 h).

Lifetime $L_{70}$ (h) of LED lamps, LED luminaires
- Lower cost (for luminaires)
- Electronics not tested.

Higher cost
Test includes electronics
Test Methods for lifetime (IEC)

IEC 62612 (Self-ballasted LED lamps)

7.1 General test conditions

Testing duration is 25 % of rated life time up to a maximum of 6 000 h.

Table 5 – Lumen maintenance code at an operational time as stated in 7.1

<table>
<thead>
<tr>
<th>Lumen maintenance (%)</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 90</td>
<td>9</td>
</tr>
<tr>
<td>≥ 80</td>
<td>8</td>
</tr>
<tr>
<td>≥ 70</td>
<td>7</td>
</tr>
</tbody>
</table>

IEC 62722-2-1 (LED luminaires): similar test required, or allows submission of LED module test data in the similar method.
ANSI C78.377 (for Solid State Lighting Products)

First version 2008.

2015 version

“Extended Specification” added in 2017 version

Widely used in ENERGY STAR, DLC, etc.

Included in ENERGY STAR - Luminaires
OUTLINE

- Overview
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- DOE programs and regulations
- International efforts
ENERGY STAR (Lighting)

- covers consumer products
- For high performance products
- Product Specification for Lamps
  (Light Bulbs) Ver.2.1 June 2017
- Product Specification for Luminaires
  (Light Fixtures) Ver.2.1 March 2018

Voluntary Products Certification Program by EPA
Lamp technologies
• Solid state
• Compact fluorescent

Product categories
• Omnidirectional
• Directional
• Decorative
Performance Requirements

9. Photometric Performance requirements
9.1. Luminous Efficacy (lm/W)
9.2. Light Output
9.3. Elevated Temperature Light Output Ratio (Directional Lamps)
9.4. Center Beam Intensity (PAR, MR and MRX Lamps)
9.5. Luminous Intensity Distribution (Omnidirectional and Decorative)
9.6. Correlated Color Temperature
9.7. Color Rendering
9.8. Color Maintenance (All Solid-State Lamps)
9.9. Color Angular Uniformity (Solid-State Directional Lamps)

10. LUMEN MAINTENANCE AND RATED LIFE
10.1. Lumen Maintenance: All Lamps
10.2. Rated Life: All Lamps
10.3. Rapid Cycle Stress Test: Compact Fluorescent Lamps
### 9.1. Luminous Efficacy: All Lamps

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>ENERGY STAR Requirements</th>
<th>Methods of Measurement and/or Reference Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reported values for each lamp model shall meet the applicable requirement in the table below.</td>
<td>Measurement (fluorescent): 10 CFR Part 429 and 430 Appendix W to Subpart B</td>
</tr>
<tr>
<td></td>
<td>Additionally eight or more units individually shall meet the requirement.</td>
<td>Measurement (solid-state): IES LM-79-08 or 10 CFR Part 429 and 430 Appendix BB to Subpart B</td>
</tr>
<tr>
<td></td>
<td>Minimum Lamp Efficacy (initial lm/W)</td>
<td>Reference Documents for all lamps not covered by DOE: IES LM-54-12</td>
</tr>
<tr>
<td>CRI ≥ 90</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>CRI &lt; 90</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Omnidirectional</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Directional</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td>Decorative</td>
<td>65</td>
<td></td>
</tr>
</tbody>
</table>
9.2. Light Output
(vs. equivalent incandescent lamp wattage)

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>ENERGY STAR Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Omnidirectional</td>
<td>Reported initial light output (in lumens) value for each lamp model shall fall within the range of the referenced incandescent lamp per the table below. Additionally 8 or more units individually shall meet the requirement.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rated Wattage of the Referenced Incandescent Lamp (watts)</th>
<th>Light Output (lumens)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>250–449</td>
</tr>
<tr>
<td>40</td>
<td>450–799</td>
</tr>
<tr>
<td>60</td>
<td>800–1,099</td>
</tr>
<tr>
<td>75</td>
<td>1,100–1,599</td>
</tr>
<tr>
<td>100</td>
<td>1,600–1,999</td>
</tr>
<tr>
<td>125</td>
<td>2,000–2,549</td>
</tr>
<tr>
<td>150</td>
<td>2,550–3,000</td>
</tr>
<tr>
<td>200</td>
<td>3,001–3,999</td>
</tr>
<tr>
<td>300</td>
<td>4,000–6,000</td>
</tr>
<tr>
<td>30-60-100</td>
<td>1,200–1,999</td>
</tr>
<tr>
<td>30-70-100</td>
<td></td>
</tr>
<tr>
<td>40-60-100</td>
<td></td>
</tr>
<tr>
<td>50-100-150</td>
<td>2,150–3,000</td>
</tr>
</tbody>
</table>

**Methods of Measurement and/or Reference Documents**

- Measurement (fluorescent): 10 CFR Part 429 and 430 Appendix W to Subpart B
- Measurement (solid-state): IES LM-79-08 or 10 CFR Part 429 and 430 Appendix BB to Subpart B
- Measurement (incandescent): IES LM-45-15

Reference Documents:

- IES LM-54-12
10.1. Lumen Maintenance: All Lamps

Early Interim Certification After 3,000 Hours:

<table>
<thead>
<tr>
<th>Maximum Life Claim (hours to L70)</th>
<th>Minimum Lumen Maintenance After Test Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>15,000</td>
<td>86.7%</td>
</tr>
<tr>
<td>20,000</td>
<td>89.9%</td>
</tr>
<tr>
<td>25,000</td>
<td>91.8%</td>
</tr>
<tr>
<td>30,000</td>
<td>93.1%</td>
</tr>
<tr>
<td>35,000</td>
<td>94.1%</td>
</tr>
<tr>
<td>40,000</td>
<td>94.8%</td>
</tr>
<tr>
<td>45,000</td>
<td>95.4%</td>
</tr>
<tr>
<td>50,000</td>
<td>95.8%</td>
</tr>
</tbody>
</table>

+ LM-80 test
TM-21 lifetime projection
ENERGY STAR – Luminaires 2.1 (March 15, 2018)

Source Type
• Fluorescent lamp
• Solid State

Product categories (Solid State)
• LED Light engine
• Surface-mounted retrofit
• Concave or Under Cabinet Mount
• Downlight retrofit
• Accent Light
• Outdoor, Wall-, porch-, post-mounted and security
• Portable Desk Task
Luminaire 2.1

Performance requirements

9.1 Luminous Efficacy and Output
9.2 Luminous Efficacy, Output and Zonal Lumen Density: DIRECTIONAL Luminaires
9.3 Correlated Color Temperature (CCT): All Indoor Luminaires
9.4 Color Rendering Index: All Indoor Luminaires (Exempt: Outdoor Luminaires
9.5 Color Angular Uniformity: Directional Solid State Indoor Luminaires Only

10 LUMEN MAINTENANCE AND RATED LIFE REQUIREMENTS
10.1 Lumen Maintenance: All Luminaires
### Luminaire 2.1 Performance requirements (example)

<table>
<thead>
<tr>
<th>Luminaire Type</th>
<th>ENERGY STAR Requirements</th>
<th>Methods of Measurement and/or Reference Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cove or Under Cabinet Mount</strong></td>
<td>Luminaire shall deliver a minimum of 125 lumens per lineal foot.</td>
<td>Referring to the plane perpendicular to the length of the luminaire, the luminaire shall deliver a minimum of 60% of total lumens within the 0-60° zone (symmetric about the nadir).</td>
</tr>
<tr>
<td></td>
<td>The minimum required light output (in lumens) is calculated by dividing the measured luminaire length in inches by 12, then multiplying the result by 125.</td>
<td>Methods of Measurement: IES LM-41-14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reference Document: ANSI/UL 1598C</td>
</tr>
<tr>
<td><strong>Downlights:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Recessed</td>
<td>≤ 4.5” aperture: 345 lumens</td>
<td></td>
</tr>
<tr>
<td>• Surface</td>
<td>&gt; 4.5” aperture: 575 lumens</td>
<td></td>
</tr>
<tr>
<td>• Pendant</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Downlight retrofits:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 lm/W</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**IES LM-79-08**
Luminaire 2.1
10.1 Lumen Maintenance (Option 1)

| Solid State Option 1: Luminaire, Retrofit kit, LED Light Engine, LED Package, Module or Array | The LED package(s) /module(s)/array(s), including those incorporated into luminaires, retrofit kits and LED light engines, shall meet the following $L_{70}$ rated lumen maintenance life values, in situ:
| Option 1: Lumen Maintenance: IES LM-80-08 and its Addendum A or ANSI/IES LM-80-15
| Lumen Maintenance Projection Method: IES TM-21-11 and its Addendum B
| CCT Calculation: CIE 15.2004
| ANSI/UL 153:2002 |

- $L_{70}(6k) \geq 25,000$ hours for indoor
- $L_{70}(6k) \geq 35,000$ hours for outdoor
- $L_{70} \geq 50,000$ hours for inseparable luminaires

Based on aging test data of LED components
<table>
<thead>
<tr>
<th>Source Type</th>
<th>ENERGY STAR Requirements</th>
<th>Methods of Measurement and/or Reference Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid State</td>
<td>The LED luminaires, retrofit kits, and LED light engines, shall meet the following L&lt;sub&gt;70&lt;/sub&gt; rated lumen maintenance life values, in situ:</td>
<td>Option 2:</td>
</tr>
<tr>
<td>Option 2: Luminaire, Retrofit kit or LED Light Engine</td>
<td>• L&lt;sub&gt;70&lt;/sub&gt; ≥ 25,000 hours for indoor &lt;br&gt;• L&lt;sub&gt;70&lt;/sub&gt; ≥ 35,000 hours for outdoor &lt;br&gt;• L&lt;sub&gt;70&lt;/sub&gt; ≥ 50,000 hours for inseparable luminaires</td>
<td>Methods of Measurement:  &lt;br&gt;Lumen Maintenance: IES LM-84-14 &lt;br&gt;Lumen Maintenance Projection Method: IES TM-28-14 – Projection Method 1, Direct Extrapolation &lt;br&gt;CCT Calculation: CIE 15.2004</td>
</tr>
</tbody>
</table>

Based on aging test of luminaires
OUTLINE

- Overview
- Standards
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- DLC
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- International efforts
DesignLights Consortium

• DLC is a non-profit organization dedicated to accelerating the widespread adoption of high-performing commercial lighting solutions.

• DLC promotes high-quality, energy-efficient lighting products in collaboration with utilities and energy efficiency program members, manufacturers, lighting designers, and federal, state, and local entities.

• Voluntary product certification program

https://www.designlights.org

Product Categories (commercial lighting products)

- Outdoor luminaire
- Indoor luminaire
- Outdoor Retrofit Kit
- Indoor Retrofit Kit
- Linear Replacement Lamps
- Mogule Screw base (E39) Replacements
- Four-pin Base Replacements
### Luminaire requirements (example)

<table>
<thead>
<tr>
<th>#</th>
<th>Category</th>
<th>General Application</th>
<th>Minimum Light Output (lm)</th>
<th>DLC Standard</th>
<th>DLC Premium**</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td></td>
<td><strong>Interior Directional</strong></td>
<td>250-4,500</td>
<td>65</td>
<td>90</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td><strong>Case Lighting</strong></td>
<td>≥50 lm/ft</td>
<td>80</td>
<td>125</td>
</tr>
<tr>
<td>7</td>
<td>Indoor</td>
<td><strong>Troffer</strong></td>
<td>≥1,500</td>
<td>65</td>
<td>125</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Linear Ambient</strong></td>
<td>≥375 lm/ft</td>
<td>105</td>
<td>130</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td><strong>High Bay</strong></td>
<td>≥5,000</td>
<td>105</td>
<td>130</td>
</tr>
</tbody>
</table>

**Notes:**
- **DLC Standard**
  - Minimum Efficacy (lm/W)
  - Minimum Warranty (years)
  - CCT / CRI / L₇₀
- **DLC Premium**
  - Minimum Efficacy (lm/W)
  - Minimum Warranty (years)
  - CCT / CRI / L₉₀ / L₇₀
DLC applications require test results that are issued from an accredited laboratory or EPA-Recognized Laboratories (LM-80).

- In-situ Temperature Measurement Tests (ISTMT)
- **IES-LM-79-08** Approved Method: Electrical and Photometric Measurements of Solid-State Lighting Products
- **IES-LM-80-08** Approved Method: Measuring Lumen Maintenance of LED Light Sources
- Compatibility testing for four pin-base replacement lamps for CFLs
OUTLINE

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- Phasing out of incandescent lamps between 40 and 100 watts of electricity
- Specialty bulbs, three-way bulbs, chandelier bulbs, refrigerator bulbs, plant grow lights and others, are exempt.
- In January 2017, DOE announced new regulations to expand this scope.
Department of Energy (DOE)  
Energy Policy and Conservation Act

Issued on January 18, 2017

- Energy Policy and Conservation Act requires that beginning January 1, 2020, DOE shall prohibit sale of any GSL that does not meet a minimum efficacy standard of 45 lm/W.
- DOE may propose additional regulations for LED lamps and that notice is expected in August of next year (2019).

- Recently in 2019, DOE proposed to withdraw the Jan 2017 definition and that 45 lm/W backstop is not a requirement.
Lighting Facts label (DOE)

Widely used for LED luminaires
Lighting Facts label (FTC)

- Required for all General Service Lamps.
DOE CALiPER Test (Market Monitoring)

- **Snapshot: Troffers** (8 pages, February 2018)
- **Snapshot: Outdoor Area Lighting** (8 pages, September 2017)
- **Snapshot: Downlights** (7 pages, July 2017)
- **Snapshot: Industrial Luminaires** (6 pages, March 2017)
- **Snapshot: Troffers** (6 pages, December 2016)
- **Snapshot: Outdoor Area Lighting** (8 pages, September 2016)

![Graph showing luminous efficacy (lm/W) for all products over years 2010 to 2017. Maximum, 75th Percentile, Mean (value), Median, 25th Percentile, and Minimum values are indicated.]

KILT International Seminar 2019 Seoul
OUTLINE

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4E Solid State Lighting Annex

4E (Efficient Electrical End-Use Equipment)

SSL Annex

Member countries (governments)
- France
- Australia
- Sweden
- USA
- Denmark
- Canada
- UK
- South Korea
(China, Japan, Netherlands … Phase I)

Work related to Testing (Y. Ohno leads)
- Phase I (2010-2015) - Task 2 SSL Testing, Task 3 Accreditation
- Phase II (2015-2019)- Task 4 Intercomparison of goniophotometers

https://ssl.iea-4e.org
Needs for international harmonization of test methods and accreditation

- **DOE new LED lamp regulations**
- **Chinese regulations**
- **Eco-design**
- **Top Runner**

**Support on Performance Specifications**

- **International Test Method CIE S 025**
- **EN Test Method**
- **Chinese CQC and GB stds**
- **JIS Test Methods**

**Performance Tiers**

- **IES LMs**
- **Accreditation Programs for SSL Testing (NVLAP, ..)**
- **Accreditation Programs for SSL Testing**
- **Accreditation Program for SSL Testing (CNAS)**
- **Accreditation Program for SSL Testing (IA-Japan)**

**Interlaboratory Comparison**

- **IC 2013**
- **IC 2017**

**Support on Performance Specifications**

- **Accreditation Programs for SSL Testing**

**Chinese regulations**

- **Eco-mark**

**Support on Performance Specifications**

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- **Accreditation Program for SSL Testing (IA-Japan)**

**Interlaboratory Comparison**

- **IC 2013**
- **IC 2017**
Interlaboratory Comparison (IC 2013)

- **Total 110 laboratories’** measurements of solid state lighting products were compared, including data linked from:
  - 35 labs in NVLAP - NIST MAP
  - 19 labs from APLAC SSL PT program

Comparison quantities:
- Luminous flux (lm)
- Luminous efficacy (lm/W)
- Electrical power, current
- Power factor
- Chromaticity, CCT, CRI

Why Interlaboratory Comparison is important
(IEA 4E SSL Annex, IC 2013)

An example data

Ref. IC 2013 Final Report at http://ssl.iea-4e.org
Interlaboratory Comparison IC 2017

• Compare goniophotometer measurements of LED luminaires (not covered in IC 2013)

• 38 labs participating. Now being completed.

• CIE S 025 used for the test method.

• Serve as a proficiency test for SSL testing accreditation programmes (as done in IC 2013)
# Measurement Quantities for IC 2017

## #1 to 8: Quantities used in IC 2013 / #9 to 14: Gonio quantities

<table>
<thead>
<tr>
<th>#</th>
<th>Quantity</th>
<th>Art-1 Lamp</th>
<th>Art-2 Planar</th>
<th>Art-3 Batten</th>
<th>Art-4 Street</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total luminous flux (lm)</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>2</td>
<td>Luminous efficacy (lm/W)</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>3</td>
<td>Chromaticity coordinate (u’, v’)*</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>4</td>
<td>Correlated colour temperature (K)</td>
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<tr>
<td>5</td>
<td>Colour rendering index (CRI) Ra</td>
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<tr>
<td>6</td>
<td>Active power (W)</td>
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<td>7</td>
<td>RMS current (A)</td>
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<tr>
<td>8</td>
<td>Power factor</td>
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<td>9</td>
<td>Luminous intensity distribution</td>
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<td>10</td>
<td>Partial luminous flux (lm)</td>
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<td>11</td>
<td>Street light partial flux (lm)</td>
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<td>12</td>
<td>Beam angle</td>
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<td>13</td>
<td>Central beam intensity</td>
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<td>14</td>
<td>Angular spatial colour uniformity</td>
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</tbody>
</table>

* Chromaticity in IC 2013 used (x, y); IC 2017 will use (u’,v’).
Thank you for your attention

Contact: ohno@nist.gov