Measurement of SSL products and NVLAP accreditation

Cameron Miller
Optical Technology Division
NIST
Outline

What is laboratory accreditation? What is NVLAP?

Energy Efficient Lighting Program

LM-79 and LM-80 specifics

NVLAP SSL Proficiency Testing

Summary
Accreditation: procedure by which an authoritative body gives formal recognition that a body or person is competent to carry out specific tasks.

Accreditation is used to verify that laboratories have an appropriate quality management system and can properly perform certain test methods and calibration parameters according to their scopes of accreditation.

Certification: procedure by which a third party gives written assurance (certificate of conformity) that a product, process or service conforms to specified requirements.

Certification is used for verifying that personnel have adequate credentials to practice certain disciplines, as well as for verifying that products meet certain requirements.

ISO/IEC 17025, General requirements for the competence of testing and calibration laboratories.
National Voluntary Laboratory Accreditation Program

- A process for accreditation of testing and calibration laboratories
- Established in 1976
- Procedures set out in the U.S. Code of Federal Regulations (Part 285, Title 15)
- Linked to NIST measurement research
- Based on ISO/IEC standards
- Fee based system, available to any qualifying laboratory

ILAC Mutual Recognition Arrangement

International Laboratory Accreditation Cooperation

Signatories to the ILAC Arrangement for testing and/or calibration recognize with mutual confidence one another’s accreditations within each signatory’s scope of recognition under this Arrangement.


“The purpose of the ILAC Arrangement is to develop a global network of accredited testing and calibration laboratories that can be relied on to provide accurate results.”
Why participate in accreditation?

Recognition of Testing Competence
means for customers to identify and select reliable testing, measurement and calibration services

Benchmark for Performance
laboratories operate in isolation to their peers, and rarely receive any independent evaluation

Marketing Advantage
accreditation bodies also publish a directory of their accredited laboratories

International Recognition for your Laboratory

Do my customers require an accredited laboratory?

Regulation of products – EPAct and EnergyStar
Outline

What is laboratory accreditation? What is NVLAP?

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LM-79 and LM-80 specifics

NVLAP SSL Proficiency Testing

Summary
History

Handbook 150-1 “Energy Efficient Lighting Products”

July 1994


Test procedures for determining energy efficiency are to be prescribed by DOE, and are to be conducted by accredited laboratories using applicable IES or ANSI standards.

The Lighting Equipment Division of NEMA requested that NVLAP establish an accreditation program for laboratories that test certain types of lamps and luminaires.
## EEL Products LAP - Update

<table>
<thead>
<tr>
<th>DEPARTMENT OF COMMERCE</th>
</tr>
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<tbody>
<tr>
<td>National Institute of Standards and Technology</td>
</tr>
<tr>
<td>National Voluntary Laboratory Accreditation Program</td>
</tr>
<tr>
<td><strong>ISSUE DATE:</strong></td>
</tr>
<tr>
<td>March 5, 2009</td>
</tr>
<tr>
<td><strong>NUMBER:</strong></td>
</tr>
<tr>
<td>LB-38-2009</td>
</tr>
<tr>
<td><strong>LAP:</strong></td>
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<tr>
<td>Energy Efficient Lighting Products</td>
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**SUBJECT:** Changes to Energy Efficient Lighting Products LAP

This bulletin announces four changes in the NVLAP Energy Efficient Lighting Products (EEL) Program:

1) the EEL Test Method Selection List has been revised and expanded;
2) several changes to NIST Handbook 150-1 have been made and are published in this bulletin;
3) the Program-Specific Checklist for NIST Handbook 150-1 has been revised;
4) Solid State Lighting (SSL) test methods have been added to the EEL Program.
## EEL Products Test Method Selection List

### ENERGY EFFICIENT LIGHTING PRODUCTS TEST METHOD SELECTION LIST

**Instruction:** Check each test method for which you are requesting accreditation. Laboratories should consider selecting those test methods for which they are seeking regulatory acceptance of their test reports.

An asterisk beside the NVLAP Test Method Code indicates that proficiency testing is required. Notification will be given for the required proficiency testing by NVLAP and/or a NVLAP contractor.

<table>
<thead>
<tr>
<th>NVLAP Test Method Code</th>
<th>Test Method Designation</th>
<th>Short Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamps (NIST Handbook 150-1 Test Methods)</td>
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<tr>
<td><strong>Color Measurements</strong></td>
<td></td>
<td></td>
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<tr>
<td>______ 22/C02*</td>
<td>IES LM-58:1994</td>
<td>Spectroradiometric Measurements</td>
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<tr>
<td>______ 22/C03</td>
<td>CIE Pub. 13.3:1995</td>
<td>Method of Measuring and Specifying Color Rendering of Light Sources</td>
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<td>______ 22/C04</td>
<td>CIE Pub. 13.2:1974</td>
<td>Method of Measuring and Specifying Color Rendering of Light Sources</td>
</tr>
<tr>
<td><strong>Electrical Measurements</strong></td>
<td></td>
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<tr>
<td>______ 22/E10*</td>
<td>IES LM-9:1988</td>
<td>Fluorescent Lamps - Electrical Measurements</td>
</tr>
<tr>
<td>______ 22/E11*</td>
<td>IES LM-9:1999</td>
<td>Fluorescent Lamps - Electrical Measurements</td>
</tr>
<tr>
<td>______ 22/E12*</td>
<td>IES LM-45:1991</td>
<td>Incandescent Lamps - Electrical Measurements</td>
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<tr>
<td>______ 22/E13*</td>
<td>IES LM-45:2000</td>
<td>Incandescent Lamps - Electrical Measurements</td>
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</table>
# EEL Products Test Method Selection List

**Photometric Measurements**

<table>
<thead>
<tr>
<th>Test Code</th>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>22/P06a*</td>
<td>IES LM-9:1988</td>
<td>Fluorescent Lamps - Total Flux Measurements</td>
</tr>
<tr>
<td>22/P06b*</td>
<td>IES LM-9:1988</td>
<td>Fluorescent Lamps - Intensity Measurements</td>
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<tr>
<td>22/P07a*</td>
<td>IES LM-9:1999</td>
<td>Fluorescent Lamps - Total Flux Measurements</td>
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<tr>
<td>22/P07b*</td>
<td>IES LM-9:1999</td>
<td>Fluorescent Lamps - Intensity Measurements</td>
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<tr>
<td>22/P08a*</td>
<td>IES LM-20:1994</td>
<td>Reflector Type Lamps - Total Flux Measurements</td>
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<tr>
<td>22/P08b*</td>
<td>IES LM-20:1994</td>
<td>Reflector Type Lamps - Intensity Measurements</td>
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<tr>
<td>22/P09a*</td>
<td>IES LM-45:1991</td>
<td>Incandescent Lamps - Total Flux Measurements</td>
</tr>
<tr>
<td>22/P09b*</td>
<td>IES LM-45:1991</td>
<td>Incandescent Lamps - Intensity Measurements</td>
</tr>
<tr>
<td>22/P10a*</td>
<td>IES LM-45:2000</td>
<td>Incandescent Lamps - Total Flux Measurements</td>
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<tr>
<td>22/P10b*</td>
<td>IES LM-45:2000</td>
<td>Incandescent Lamps - Intensity Measurements</td>
</tr>
<tr>
<td>22/P11a</td>
<td>IES LM-51:2000</td>
<td>High-Intensity Discharge Lamps - Total Flux Measurements</td>
</tr>
</tbody>
</table>

Old Test Selection List – 29 tests  
New Test Selection List – 59 tests
Title 10: Energy
PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS
Subpart A—General Provisions

§ 430.3 Materials incorporated by reference.

(a) General. We incorporate by reference the following standards into Part 430. The material listed has been approved for incorporation by reference by the Director of the Federal Register in accordance with 5 U.S.C. 552(a) and 1 CFR part 51. Any subsequent amendment to a standard by the standard-setting organization will not affect the DOE regulations unless and until amended by DOE. Material is incorporated as it exists on the date of the approval and a notice of any change in the material will be published in the Federal Register. All approved material is available for inspection at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call 202–741–6030, or go to: http://www.archives.gov/federal_register/code_of_federal_regulations/ibr_locations.html. Also, this material is available for inspection at U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Program, 6th Floor, 950 L'Enfant Plaza, SW., Washington, DC 20024, (202) 586–2945, or go to: http://www1.eere.energy.gov/buildings/appliance_standards/. Standards can be obtained from the sources below.
CORM Workshop – May 2009

Code of Federal Regulations


(2) IES LM–9–88, IES Approved Method for the Electrical and Photometric Measurements of Fluorescent Lamps, approved December 7, 1988, IBR approved for Appendix R to Subpart B.


(4) IES LM–20–1994, IESNA Approved Method for Photometric Testing of Reflector-Type Lamps, approved December 3, 1994, IBR approved for Appendix R to Subpart B.

(5) IES LM–45–91, IES Approved Method for Electrical and Photometric Measurements of General Service Incandescent Filament Lamps, approved December 8, 1990, IBR approved for Appendix R to Subpart B.


(1) ENERGY STAR Program Requirements for [Compact Fluorescent Lamps] CFLs, Version 3.0, approved October 30, 2003, IBR approved for Appendix V to Subpart B.

(2) ENERGY STAR Program Requirements for [Compact Fluorescent Lamps] CFLs, approved August 9, 2001, IBR approved for Appendix W to Subpart B.

(2) ENERGY STAR Program Requirements for Residential Light Fixtures, Version 4.0, approved January 10, 2005, IBR approved for Appendix V to Subpart B.
EPAct 2005 formally recognizes the federal ENERGY STAR® program (section 131 of the Energy Policy Act, Public Law 109-58) to identify and promote energy-efficient products and buildings through labeling.

ENERGY STAR® Program Requirements for CFLs
Partner Commitments

Eligible Organizations:
Manufacturers of Compact Fluorescent Light Bulbs

ANSI C78.375 – 1997 Guide for Electrical Measurements of Fluorescent Lamps
CIE Publication No. 13.3 – 1995 Method of Measuring and Specifying Color Rendering of Light Sources
IESNA LM-9 – 1998 Electric & Photometric Measurement of Fluorescent Lamps
ENERGY STAR® program (CFL 3.0)

ENGLISH STAR® Program Requirements for CFLs
Partner Commitments

Eligible Organizations:
Manufacturers and Distributors of Compact Fluorescent Lamps (CFLs)

ANSI C78.375 – 1997 Guide for Electrical Measurements of Fluorescent Lamps
CIE Publication No. 13.3 – 1995 Method of Measuring and Specifying Color Rendering of Light Sources
IESNA LM-9 – 1999 Electric & Photometric Measurement of Fluorescent Lamps
IESNA LM-65 – 2001 Life Testing of Single-ended Compact Fluorescent Lamps
ENEFY STAR® program (CFL 4.0)

ENERGY STAR® Program Requirements for CFLs
Partner Commitments

Eligible Organizations:
Manufacturers and Distributors of Compact Fluorescent Lamps (CFLs)

CIE Publication No. 13.3 – 1995 Method of Measuring and Specifying Color Rendering of Light Sources
IESNA LM-9 – 1999 Electric & Photometric Measurement of Fluorescent Lamps
IESNA LM-16 Practical Guide to Colorimetry of Light Sources
IESNA LM-41 – 1998 Approved Method for Photometric Testing of Indoor Fluorescent Luminaires
IESNA LM-54 – 1999 IESNA Guide to Lamp Seasoning
# EEL Products Test Method Selection List

## Solid State Lighting (NIST Handbook 150-1A Test Methods)

### Color Measurements

<table>
<thead>
<tr>
<th>Method Code</th>
<th>Reference</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>22/S01*</td>
<td>IES LM-58:1994</td>
<td>Spectroradiometric Measurements</td>
</tr>
<tr>
<td>22/S02*</td>
<td>CIE Pub. 13.3:1995</td>
<td>Method of Measuring and Specifying Color Rendering of Light Sources</td>
</tr>
<tr>
<td>22/S03*</td>
<td>IES LM-79:2008 (Sec. 12)</td>
<td>Solid State Lighting Luminaires - Color Characteristic Measurements</td>
</tr>
<tr>
<td>22/S04*</td>
<td>IES LM-16:1995</td>
<td>Practical Guide to Colorimetry of Light Sources</td>
</tr>
<tr>
<td>22/S05*</td>
<td>CIE Pub. 15:2004</td>
<td>Method of Measuring and Specifying Color Rendering of Light Sources</td>
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### Electrical Measurements

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<tr>
<td>22/S06*</td>
<td>ANSI C82.2:2002</td>
<td>Ballast for Fluorescent Lamps - Methods of Measurement</td>
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<tr>
<td>22/S07*</td>
<td>ANSI C82.77:2002</td>
<td>Harmonic Emission Limits - Related Power Quality Requirements for Lighting Equipment</td>
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### Life Tests

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<tr>
<th>Method Code</th>
<th>Reference</th>
<th>Description</th>
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### Photometric Measurements

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<tr>
<th>Method Code</th>
<th>Reference</th>
<th>Description</th>
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</thead>
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<tr>
<td>22/S09*</td>
<td>IES LM-79:2008 (Sec. 9)</td>
<td>Solid State Lighting Luminaires - Total Flux Measurements (Luminous Efficacy)</td>
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<tr>
<td>22/S10*</td>
<td>IES LM-79:2008 (Sec. 10)</td>
<td>Solid State Lighting Luminaires - Luminous Intensity Measurements</td>
</tr>
</tbody>
</table>
Outline

- What is laboratory accreditation? What is NVLAP?
- Energy Efficient Lighting Program
- LM-79 and LM-80 specifics
- NVLAP SSL Proficiency Testing
- Summary
Commercial SSL Products

Niche applications

General lighting applications
Measurement of LED/SSL Products

LED chips/packages

LED modules/clusters

SSL products

Measurement quantities

- Total luminous flux (lm)
- Luminous efficacy (lm/W)
- Correlated Color Temperature (K)
- Color Rendering Index
- Color Spatial Uniformity
- Zonal Lumen Density
IES LM-79-2008

Management System Procedures

AMBIENT CONDITIONS
POWER SUPPLY CHARACTERISTICS
STABILIZATION OF SSL PRODUCT
OPERATING ORIENTATION
ELECTRICAL SETTINGS
ELECTRICAL INSTRUMENTATION

_____ 22/S09* IES LM-79:2008 (Sec. 9)
Solid State Lighting Luminaires - Total Flux Measurements (Luminous Efficacy)

_____ 22/S10* IES LM-79:2008 (Sec. 10)
Solid State Lighting Luminaires - Luminous Intensity Measurements

_____ 22/S03* IES LM-79:2008 (Sec. 12)
Solid State Lighting Luminaires - Color Characteristic Measurements
IES LM-79-2008 (Sec. 9)

Test Methods for Total Luminous Flux Measurements

Integrating sphere with a spectroradiometer

Integrating sphere shall have a broadband auxiliary lamp for self-absorption measurement

$4\pi$ geometry mounted in center of sphere
  total spectral radiant flux standard lamp

$2\pi$ geometry mounted on flush on the sphere wall
  total spectral radiant flux standard lamp with only forward distribution (required)

ambient temperature in sphere 25°C ± 1°C

input optic flat diffuser or a satellite sphere
IES LM-79-2008 (Sec. 9)

Test Methods for Total Luminous Flux Measurements

Integrating sphere with a photometer

Integrating sphere shall have an auxiliary lamp for self-absorption measurement (similar spectrum)

$4\pi$ geometry mounted in center of sphere

$2\pi$ geometry mounted on flush on the sphere wall

total luminous flux standard lamp (spatial corrections)

ambient temperature in sphere 25° C ± 1° C

detector cosine response with well matched to $V(\lambda)$ function including sphere spectral throughput
Test Methods for Total Luminous Flux Measurements

Goniophotometer

Type C only

Spatial ‘scanning resolution fine enough to accurately define the test sample shall be used.’

The range of the angular scan shall cover the entire solid angle to which the SSL product emits light.

The $f_1$ of the detector shall be less than 3 %.

Detector shall be calibrated against an illuminance or luminous intensity standard traceable to national standards.
Test Methods for Luminous Intensity Distributions

“The absolute intensity distribution of measured SSL products shall be reported.”

Zonal flux calculation guidance is available in IES LM-35-02, Approved Method for Photometric Testing of Floodlights Using High Intensity Discharge or Incandescent Filament Lamps.

Electronic data of measured luminous intensity distributions, if necessary, shall be prepared in the “IES file” format for absolute photometry specified in LM-63-02.
Test Methods for Color Characteristics of SSL Products

Sphere-spectroradiometer system
- Chromaticity coordinates
- Correlated color temperature
- Color rendering index

Gonio-spectroradiometer system
- Chromaticity coordinates
- Correlated color temperature
- Color rendering index
- Color spatial uniformity

Manual positioning system
Manual positioning system

\[ x_a = \sum_{i=1}^{19} x(\theta_i) \cdot w_i \quad \text{with} \quad w_i = \frac{I(\theta_i) \cdot \Omega(\theta_i)}{\sum_{i=1}^{19} I(\theta_i) \cdot \Omega(\theta_i)} \]

\[ \Omega(\theta_i) = \begin{cases} 
2\pi \left[ \cos(\theta_i) - \cos(\theta_i + \frac{\Delta \theta}{2}) \right] & \text{for } \theta_i = 0^\circ \\
2\pi \left[ \cos(\theta_i - \frac{\Delta \theta}{2}) - \cos(\theta_i + \frac{\Delta \theta}{2}) \right] & \text{for } \theta_i = 10^\circ, \ldots, 170^\circ \\
2\pi \left[ \cos(\theta_i - \frac{\Delta \theta}{2}) - \cos(\theta_i) \right] & \text{for } \theta_i = 180^\circ 
\end{cases} \]

\[ \Delta \theta = 10^\circ \]
Management System Procedures

AMBIENT AND PHYSICAL CONDITIONS
ELECTRICAL AND THERMAL CONDITIONS
TEST AND MEASUREMENT PROCEDURES
LUMEN MAINTENANCE TESTING METHOD FOR LED LIGHT SOURCES
TEST REPORT

On-SITE Proficiency Test

Prior to operation, sources shall be cleaned to eliminate handling marks and the manufacturer's handling instructions must be observed.

Individual LED light sources shall be tracked during life testing.

The identification method selected shall take into account the effect of exposure to light, and heat.
CIE Publications

______ 22/S02* CIE Pub. 13.3:1995  
Method of Measuring and Specifying Color Rendering of Light Sources

______ 22/S05* CIE Pub. 15:2004  Colorimetry

Management System Procedures

Proficiency Test

Several sample spectra provided to validate calculation
Outline

What is laboratory accreditation? What is NVLAP?

Energy Efficient Lighting Program

LM-79 and LM-80 specifics

NVLAP SSL Proficiency Testing

Summary
3.4.2 Laboratories applying for initial accreditation shall participate satisfactorily in a bi-lateral proficiency testing with NIST before accreditation will be granted. Solid state lighting luminaires along with instructions for specimen handling, preparation (including seasoning and pre-burning), conditioning, mounting, and testing, and data forms are provided to the participating laboratory. The completed test data forms are sent by the participating laboratory to NIST. The results are summarized in a report, which is edited and sent by NVLAP to the participant.

3.4.3 As NVLAP prescribes, NVLAP or a proficiency testing contractor conducts rounds at regular intervals. Solid state lighting luminaires along with instructions for specimen handling, preparation (including seasoning and pre-burning), conditioning, mounting, and testing, and data forms are provided to the participating laboratories. The completed test data forms are sent by the participating laboratories to NVLAP or, as directed, to the proficiency testing contractor. The results of all participants are summarized in a Tech Brief, which is edited and sent by NVLAP to the participants. The identity and performance of individual laboratories are kept confidential.
Bi-lateral Proficiency Testing with NIST

Time line
- NIST prepares 2 – 3 sets of bi-lateral artifacts
- NIST distributes a set to a lab 1 month before on-site
- On-site assessment occurs
- Lab may measure bi-lateral artifacts, again
- NIST analyzes data and prepares a report

What goes into a set of bi-lateral artifacts?
Temperature Dependence

- Substitution photometry
- Measurement of small SSL products
- Temperature range 15° C to 55° C
Zonal Flux Measurements

- Total spectral radiant flux scale
- Measurement of small SSL products
  - Angular luminous intensity distribution
  - Color uniformity
Bi-lateral Proficiency Testing with NIST

Aspects tested with colored luminaires
- Laboratory temperature
- Spectral mismatch correction – wavelength calibration
- Spatial non-uniformity
- Stray light concerns
- Sphere fluorescence

Aspects tested with white luminaires
- Spectral mismatch correction – wavelength calibration
- Spatial non-uniformity (directional – isotropic – highly directional)

Aspects tested with large luminaire
- Self-absorption correction

Calculations
NIST prepares 3 – 4 sets of round robin artifacts
Consists of 4 – 5 different artifact models (Energy Star niche applications)
Each artifact model will have 3 items (12 – 15 total items)

NIST distributes sets in a star pattern

NIST analyzes data and prepares a Tech Brief
Based on CALiPER results pick specific products

Measure, age 24 h, measure, age 24 h, measure, 120 h measure – seasoning

Measure luminaires 3 times – repeatability, stability time

<table>
<thead>
<tr>
<th></th>
<th>Current</th>
<th>Voltage</th>
<th>Power</th>
<th>Flux</th>
<th>Efficacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td>0.024 %</td>
<td>0.005 %</td>
<td>0.035 %</td>
<td>0.024 %</td>
<td>0.012 %</td>
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<tr>
<td>Model 2</td>
<td>0.139 %</td>
<td>0.005 %</td>
<td>0.101 %</td>
<td>0.015 %</td>
<td>0.086 %</td>
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<tr>
<td>Model 3</td>
<td>0.031 %</td>
<td>0.002 %</td>
<td>0.042 %</td>
<td>0.082 %</td>
<td>0.071 %</td>
</tr>
<tr>
<td>Model 4</td>
<td>0.014 %</td>
<td>0.002 %</td>
<td>0.016 %</td>
<td>0.054 %</td>
<td>0.038 %</td>
</tr>
</tbody>
</table>

Age 500 h, measure, age 1000 h, measure, age 1000 h, measure
Color Characterization

Normalized Total Spectral Flux vs. Wavelength (nm)

CORM Workshop – May 2009
Outline

What is laboratory accreditation? What is NVLAP?

Energy Efficient Lighting Program

LM-79 and LM-80 specifics

NVLAP SSL Proficiency Testing

Summary
DOE Supported Accreditation Work

- Expand the number of bi-lateral artifacts and round robin artifacts for Energy Efficient Lighting – Solid State Program.
- Expand the number of EEL-SSL assessors by offering training specific to solid state lighting testing.
- Expand the number of possible EEL-SSL testing laboratories by offering a seminar on the requirements for NVLAP accreditation.
- Expand the number of possible EEL-SSL testing laboratories by having the Department of Energy pay for the first year of fees and onsite assessment for domestic United States laboratories that qualify.
SSL Energy Efficient Lighting Program Example

**ADMINISTRATIVE / TECHNICAL SUPPORT FEE**
assessed annually on a laboratory's anniversary

**INITIAL APPLICATION FEE**
paid one time by laboratory

**ON-SITE ASSESSMENT FEE**
before initial accreditation
during the first renewal year
every two years thereafter

**BI-LATERAL PROFICIENCY TESTING FEE (Round Robin)**
 invoiced at the time the test is conducted

Initial Amount: $750
## NVLAP Fee Policy – Projected Yearly Cost

<table>
<thead>
<tr>
<th>Year</th>
<th>Type of Accreditation</th>
<th>Cost</th>
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<tbody>
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<td>2009 – Initial Accreditation</td>
<td>Initial, Administrative, On-site, Bi-lateral</td>
<td>$8,800</td>
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<td>$750</td>
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<td>2010 – First Year of Accreditation</td>
<td>Administrative, On-site</td>
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<tr>
<td>2011 – Second Year of Accreditation</td>
<td>Administrative, Proficiency</td>
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</tr>
<tr>
<td>2012 – Third Year of Accreditation</td>
<td>Administrative, On-site</td>
<td>$8,050</td>
</tr>
<tr>
<td>2013 – Fourth Year of Accreditation</td>
<td>Administrative, Proficiency</td>
<td>$5,430</td>
</tr>
</tbody>
</table>
Questions?