Municipal Solid-State STREET LIGHTING CONSORTIUM

U.S. Department of Energy

Model Specification for LED Roadway Luminaires

DOE Solid-State Lighting Webcast

November 15, 2011

Presented by: Jason Tuenge

Pacific Northwest National Laboratory

Moderated by: Edward Smalley

Seattle City Light Manager and Consortium Director

Municipal Solid-State STREET LIGHTING CONSORTIUM

U.S. Department of Energy

About The Consortium - Background

- Created by the U.S. Department of Energy (DOE) in March 2010 using American Recovery and Reinvestment Act (ARRA) funding
- Supported by the DOE GATEWAY program
- Intended to be an **educational resource** on Solid-State street lighting and associated technology for those involved in lighting streets and other outdoor public areas.
  - As an independent resource, the Consortium is available to help those unfamiliar with LED technology identify important issues and how to how to begin the evaluation process
- **…and** to help **accelerate adoption** of SSL technology in the nations street lighting systems

Municipal Solid-State
STREET LIGHTING
CONSORTIUM

U.S. Department of Energy

Our Vision

- Accelerate the adoption of high performance solid-state street and area lighting by leading end-user collaboration in the areas of performance, evaluation, application, and standardization.

Municipal Solid-State
STREET LIGHTING
CONSORTIUM

U.S. Department of Energy

Mission

- Increase **KNOWLEDGE** around the performance, quality, and application of SS Street Lighting.
- Develop a national **STRUCTURE** to provide oversight and guidance on the evaluation of SSL for public areas.
- Influence national **STANDARDIZATION** of benchmarks, classification, design, and performance criteria. Set standard benchmarks.

Mission

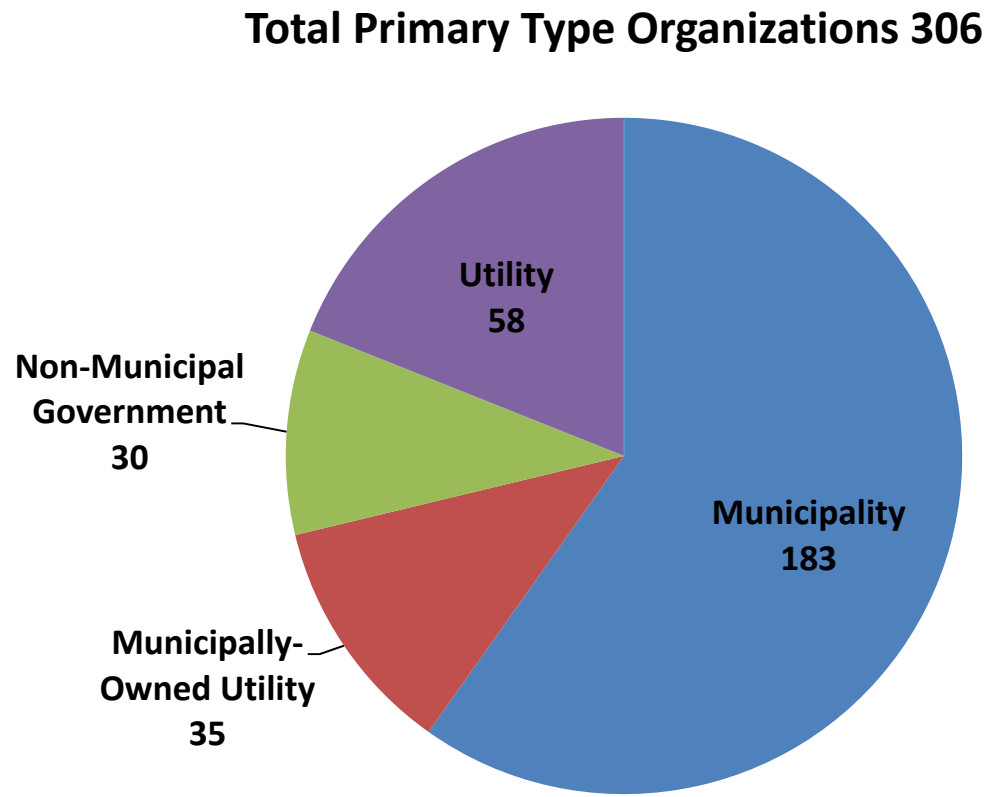
- **Primary Membership** is open to municipalities and other governmental agencies, utilities, and others responsible for public lighting systems
- **Guests** are found among consultants, members of academia, and numerous public service energy efficiency organizations
- **Advisory Members** are selected by Primary Members from among guests and serve on committees and other specific activities

Note: Manufacturers and sales representatives are excluded from membership, however, the may be invited to contribute to workshops and development of Consortium documents and programs

Municipal Solid-State
STREET LIGHTING
CONSORTIUM

U.S. Department of Energy

Membership



Municipal Solid-State
STREET LIGHTING
CONSORTIUM

U.S. Department of Energy



Support Materials in Development

- ☑ **Model Specification for LED Roadway Luminaires**
- ☐ Model Specification for Adaptive Control and Remote Monitoring of LED Roadway Luminaires
- ☐ Cost-Benefit Analysis Tool
- ☐ Guidance Document for LED Roadway Luminaire Specification



Model Luminaire Spec – Timeline

- September 2010 – Concept introduced at inaugural meeting
- November 2010 – “Beta release” used by Kansas City, MO
- April 2011 – Public review of first draft
- June 2011 – Manufacturer workshop #1
- August 2011 – Manufacturer workshop #2
- September 2011 – Manufacturer meetings at IES SALC (www.ies.org/salc)
- October 2011 – Version 1.0 released



Purpose

- Developed in response to demand from Consortium members and others
  - To compile experience gained by members
  - To establish a common language and framework
  - To serve as a checklist to minimize errors and omissions
  - To serve as a living document, undergoing continual revision
  - To allow for customization by each adopting entity



Scope

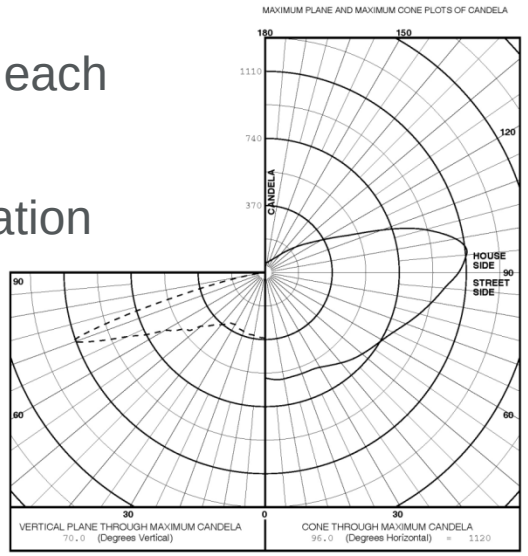
- Addresses
  - Streets, roadways, and nearby pedestrian ways
  - Pole-mounted luminaires
  - Initial and maintained quality and quantity of illumination
  - Warranty details
  - Input power, electrical immunity, housing finish, vibration, etc.
  - Drivers, including lighting controls interface
  - Photocontrol receptacles
- Doesn't address
  - Lamp/ballast retrofit products
  - Lighting control systems
  - Detailed guidance for proper usage of the model specification
    - ➢ Limited guidance is provided in hidden text

Concept

- Derived from the DOE Commercial Building Energy Alliances (CBEA) specification for LED parking lot lighting

  http://www1.eere.energy.gov/buildings/alliances/rea_subcommittees.html

  - Application-dependent photometric evaluation
    - ➢ Footcandles rather than lumens
  - Cannot result in a single qualified products list
- Intended to be used as a template, customized by each adopter to meet unique requirements
- Adopter to choose between two means of specification
  - Application-*dependent* (preferred)
  - Application-*independent*



Structure

- Brief instructions
  - To be deleted by adopter before issuance (but after reading)
- Body of Text
  - References, Related Documents, Definitions
  - Quality Assurance, Lighting System Performance, Required Submittals
  - Warranty
  - Product Requirements
- Appendix A – Criteria by Luminaire Type
  - Contained in separate files (application-dependent or independent)
- Appendix B – Lumen Maintenance
- Appendix C – Product Family Testing
- Appendix D – Electrical Immunity
- Appendix E – Product Submittal Form

Body of Text

- Seven pages total
  - (Excluding cover sheet, instructions, Appendices and hidden text)

(insert owner/utility/esco name here)
Specification for LED Roadway Luminaires

PART 1 – GENERAL

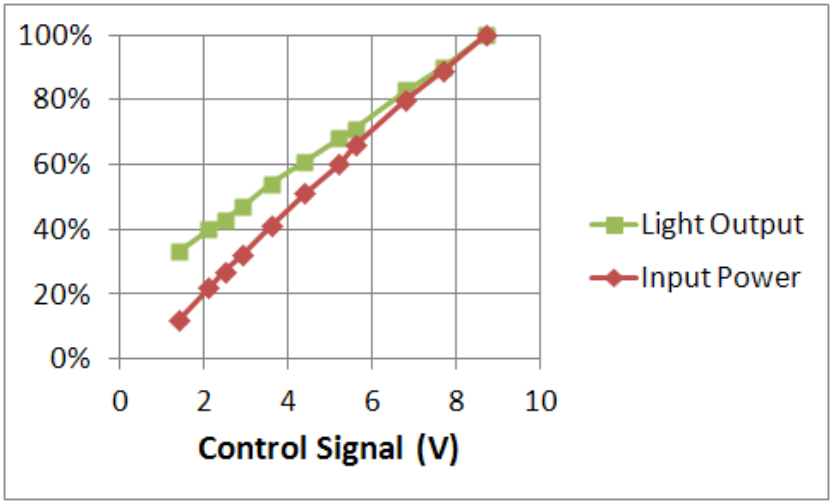
1.1. REFERENCES *(may separate into Normative and Informative)*

The publications listed below form a part of this specification to the extent referenced. Publications are referenced within the text by their basic designation only. Versions listed shall be superseded by updated versions as they become available.

A. American National Standards Institute (ANSI) *The Consortium will monitor progress of the draft ANSI C82.SSL1 (SSL Drivers).*
   1. C136.2-2004 (or latest), American National Standard for Roadway and Area Lighting Equipment—Luminaire Voltage Classification
   2. C136.10-2010 (or latest), American National Standard for Roadway and Area Lighting Equipment - Locking-Type Photocontrol Devices and Mating Receptacle Physical and Electrical Interchangeability and Testing
   3. C136.15-2011 (or latest), American National Standard for Roadway and Area Lighting

Body of Text

- Addresses both LED-specific and technology-neutral parameters
  - Nearly every parameter is a “can of worms,” meriting evaluation on a case-by-case basis
  - A default value is typically given as an acceptable balance of cost and quality for most applications, often using HID as the benchmark
- LED drivers
  - Physical interface with separately specified control system
  - Submittals to include curves for light output and input power as a function of control signal



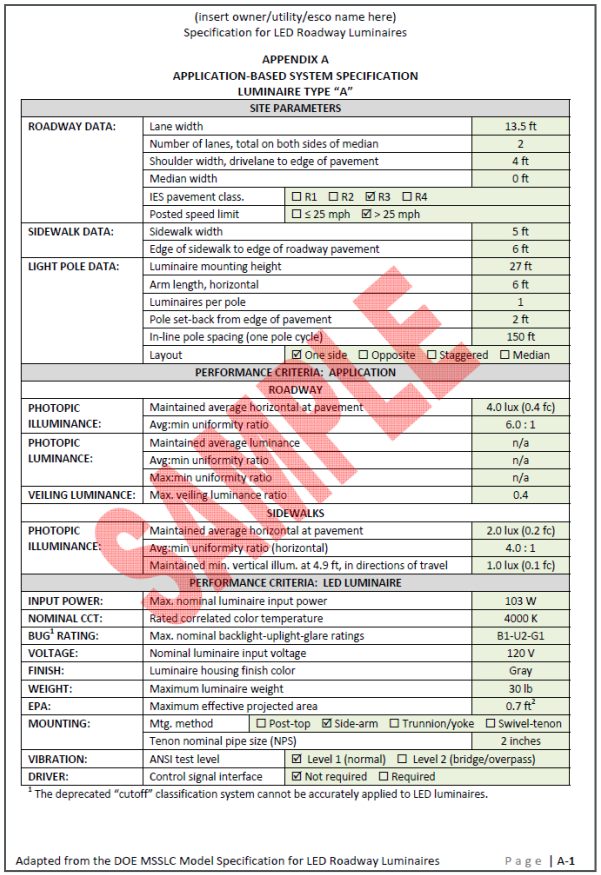
Body of Text

- Non-trivial technology-neutral parameters include
  - Serviceability
  - Resistance to the elements
    - E.g., salt spray and UV testing
    - Insects and birds
  - Vibration resistance
    - Component connections are often the weak link
    - No known standard for HID lamp testing



Appendix A – Criteria by Luminaire Type

- Adopting entity must choose dependent/independent and edit values!



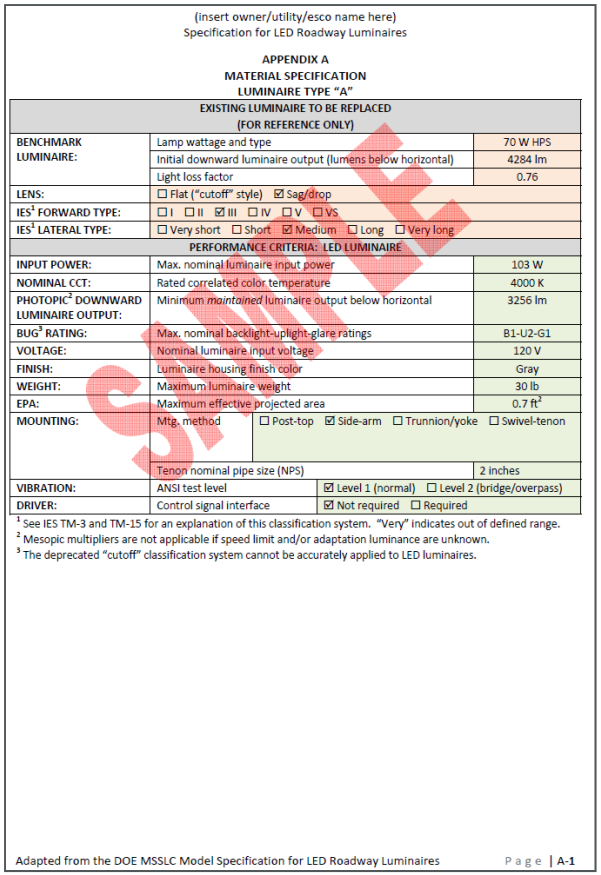
(insert owner/utility/esco name here)
Specification for LED Roadway Luminaires

APPENDIX A
APPLICATION-BASED SYSTEM SPECIFICATION
LUMINAIRE TYPE "A"

SITE PARAMETERS		
ROADWAY DATA:	Lane width	13.5 ft
	Number of lanes, total on both sides of median	2
	Shoulder width, drivelane to edge of pavement	4 ft
	Median width	0 ft
	IES pavement class.	☐ R1 ☐ R2 ☑ R3 ☐ R4
	Posted speed limit	☐ ≤ 25 mph ☑ > 25 mph
SIDEWALK DATA:	Sidewalk width	5 ft
	Edge of sidewalk to edge of roadway pavement	6 ft
LIGHT POLE DATA:	Luminaire mounting height	27 ft
	Arm length, horizontal	6 ft
	Luminaires per pole	1
	Pole set-back from edge of pavement	2 ft
	In-line pole spacing (one pole cycle)	150 ft
	Layout	☑ One side ☐ Opposite ☐ Staggered ☐ Median
PERFORMANCE CRITERIA: APPLICATION		
ROADWAY		
PHOTOPIC ILLUMINANCE:	Maintained average horizontal at pavement	4.0 lux (0.4 fc)
	Avg:min uniformity ratio	6.0 : 1
PHOTOPIC LUMINANCE:	Maintained average luminance	n/a
	Avg:min uniformity ratio	n/a
	Max:min uniformity ratio	n/a
VEILING LUMINANCE:	Max. veiling luminance ratio	0.4
SIDEWALKS		
PHOTOPIC ILLUMINANCE:	Maintained average horizontal at pavement	2.0 lux (0.2 fc)
	Avg:min uniformity ratio (horizontal)	4.0 : 1
	Maintained min. vertical illum. at 4.9 ft, in directions of travel	1.0 lux (0.1 fc)
PERFORMANCE CRITERIA: LED LUMINAIRE		
INPUT POWER:	Max. nominal luminaire input power	103 W
NOMINAL CCT:	Rated correlated color temperature	4000 K
BUG[1] RATING:	Max. nominal backlight-uplight-glare ratings	B1-U2-G1
VOLTAGE:	Nominal luminaire input voltage	120 V
FINISH:	Luminaire housing finish color	Gray
WEIGHT:	Maximum luminaire weight	30 lb
EPA:	Maximum effective projected area	0.7 ft²
MOUNTING:	Mtg. method	☐ Post-top ☑ Side-arm ☐ Trunnion/yoke ☐ Swivel-tenon
	Tenon nominal pipe size (NPS)	2 inches
VIBRATION:	ANSI test level	☑ Level 1 (normal) ☐ Level 2 (bridge/overpass)
DRIVER:	Control signal interface	☑ Not required ☐ Required

[1] The deprecated "cutoff" classification system cannot be accurately applied to LED luminaires.

Adapted from the DOE MSSLC Model Specification for LED Roadway Luminaires Page | A-1



(insert owner/utility/esco name here)
Specification for LED Roadway Luminaires

APPENDIX A
MATERIAL SPECIFICATION
LUMINAIRE TYPE "A"

EXISTING LUMINAIRE TO BE REPLACED (FOR REFERENCE ONLY)		
BENCHMARK LUMINAIRE:	Lamp wattage and type	70 W HPS
	Initial downward luminaire output (lumens below horizontal)	4284 lm
	Light loss factor	0.76
LENS:	☐ Flat ("cutoff" style) ☑ Sag/drop	
IES[1] FORWARD TYPE:	☐ I ☐ II ☑ III ☐ IV ☐ V ☐ VS	
IES[1] LATERAL TYPE:	☐ Very short ☐ Short ☑ Medium ☐ Long ☐ Very long	
PERFORMANCE CRITERIA: LED LUMINAIRE		
INPUT POWER:	Max. nominal luminaire input power	103 W
NOMINAL CCT:	Rated correlated color temperature	4000 K
PHOTOPIC[2] DOWNWARD LUMINAIRE OUTPUT:	Minimum *maintained* luminaire output below horizontal	3256 lm
BUG[3] RATING:	Max. nominal backlight-uplight-glare ratings	B1-U2-G1
VOLTAGE:	Nominal luminaire input voltage	120 V
FINISH:	Luminaire housing finish color	Gray
WEIGHT:	Maximum luminaire weight	30 lb
EPA:	Maximum effective projected area	0.7 ft²
MOUNTING:	Mtg. method	☐ Post-top ☑ Side-arm ☐ Trunnion/yoke ☐ Swivel-tenon
	Tenon nominal pipe size (NPS)	2 inches
VIBRATION:	ANSI test level	☑ Level 1 (normal) ☐ Level 2 (bridge/overpass)
DRIVER:	Control signal interface	☑ Not required ☐ Required

[1] See IES TM-3 and TM-15 for an explanation of this classification system. "Very" indicates out of defined range.
[2] Mesopic multipliers are not applicable if speed limit and/or adaptation luminance are unknown.
[3] The deprecated "cutoff" classification system cannot be accurately applied to LED luminaires.

Adapted from the DOE MSSLC Model Specification for LED Roadway Luminaires Page | A-1

Appendix A – Criteria by Luminaire Type

- Application-*dependent*

APPENDIX A
APPLICATION-BASED SYSTEM SPECIFICATION
LUMINAIRE TYPE "A"

SITE PARAMETERS			
ROADWAY DATA:	Lane width		13.5 ft
	Number of lanes, total on both sides of median		2
	Shoulder width, drivelane to edge of pavement		4 ft
	Median width		0 ft
	IES pavement class.	☐ R1 ☐ R2 ☑ R3 ☐ R4	
	Posted speed limit	☐ ≤ 25 mph ☑ > 25 mph	
SIDEWALK DATA:	Sidewalk width		5 ft
	Edge of sidewalk to edge of roadway pavement		6 ft
LIGHT POLE DATA:	Luminaire mounting height		27 ft
	Arm length, horizontal		6 ft
	Luminaires per pole		1
	Pole set-back from edge of pavement		2 ft
	In-line pole spacing (one pole cycle)		150 ft
	Layout	☑ One side ☐ Opposite ☐ Staggered ☐ Median	
PERFORMANCE CRITERIA: APPLICATION			
ROADWAY			

Appendix A – Criteria by Luminaire Type

- Application-*dependent*

	Layout	☑ One side ☐ Opposite ☐ Staggered ☐ Median
PERFORMANCE CRITERIA: APPLICATION		
	ROADWAY	
PHOTOPIC ILLUMINANCE:	Maintained average horizontal at pavement	4.0 lux (0.4 fc)
	Avg:min uniformity ratio	6.0 : 1
PHOTOPIC LUMINANCE:	Maintained average luminance	n/a
	Avg:min uniformity ratio	n/a
	Max:min uniformity ratio	n/a
VEILING LUMINANCE:	Max. veiling luminance ratio	0.4
	SIDEWALKS	
PHOTOPIC ILLUMINANCE:	Maintained average horizontal at pavement	2.0 lux (0.2 fc)
	Avg:min uniformity ratio (horizontal)	4.0 : 1
	Maintained min. vertical illum. at 4.9 ft, in directions of travel	1.0 lux (0.1 fc)
PERFORMANCE CRITERIA: LED LUMINAIRE		
INPUT POWER:	Max. nominal luminaire input power	103 W

SAMPLE

Appendix A – Criteria by Luminaire Type

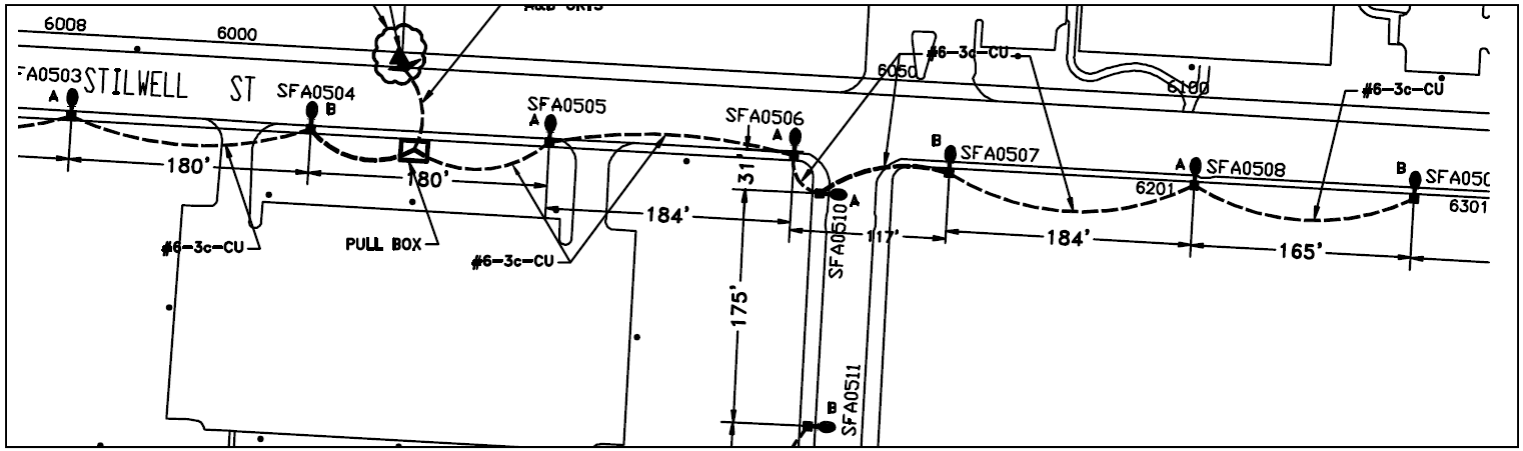
- Application-*dependent*

	Maintained min. vertical illum. at 4.5 ft, in directions of travel		1.0 lux (0.1 fc)
PERFORMANCE CRITERIA: LED LUMINAIRE			
INPUT POWER:	Max. nominal luminaire input power		103 W
NOMINAL CCT:	Rated correlated color temperature		4000 K
BUG[1] RATING:	Max. nominal backlight-uplight-glare ratings		B1-U2-G1
VOLTAGE:	Nominal luminaire input voltage		120 V
FINISH:	Luminaire housing finish color		Gray
WEIGHT:	Maximum luminaire weight		30 lb
EPA:	Maximum effective projected area		0.7 ft^2
MOUNTING:	Mtg. method	☐ Post-top ☑ Side-arm ☐ Trunnion/yoke ☐ Swivel-tenon	
	Tenon nominal pipe size (NPS)		2 inches
VIBRATION:	ANSI test level	☑ Level 1 (normal) ☐ Level 2 (bridge/overpass)	
DRIVER:	Control signal interface	☑ Not required ☐ Required	

[1] The deprecated "cutoff" classification system cannot be accurately applied to LED luminaires.

Appendix A – Criteria by Luminaire Type

- Application-*dependent*
  - Defining representative “typical” scenario(s) for each type is critical
  - In practice, pole spacing varies along any given street



Appendix A – Criteria by Luminaire Type

- Application-*independent*

APPENDIX A
MATERIAL SPECIFICATION
LUMINAIRE TYPE "A"

EXISTING LUMINAIRE TO BE REPLACED (FOR REFERENCE ONLY)		
BENCHMARK LUMINAIRE:	Lamp wattage and type	70 W HPS
	Initial downward luminaire output (lumens below horizontal)	4284 lm
	Light loss factor	0.76
LENS:	☐ Flat ("cutoff" style) ☑ Sag/drop	
IES[1] FORWARD TYPE:	☐ I ☐ II ☑ III ☐ IV ☐ V ☐ VS	
IES[1] LATERAL TYPE:	☐ Very short ☐ Short ☑ Medium ☐ Long ☐ Very long	
PERFORMANCE CRITERIA: LED LUMINAIRE		
INPUT POWER:	Max. nominal luminaire input power	103 W
NOMINAL CCT:	Rated correlated color temperature	4000 K
PHOTOPIC[2] DOWNWARD LUMINAIRE OUTPUT:	Minimum *maintained* luminaire output below horizontal	3256 lm
BUG[3] RATING:	Max. nominal backlight-uplight-glare ratings	B1-U2-G1
VOLTAGE:	Nominal luminaire input voltage	120 V

SAMPLE

Appendix A – Criteria by Luminaire Type

- Application-*independent*

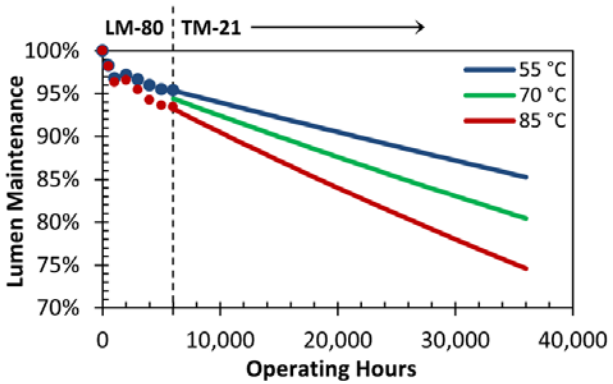
BUG[1] RATING:	Max. nominal backlight-uplight-glare ratings		B1-U2-G1
VOLTAGE:	Nominal luminaire input voltage		120 V
FINISH:	Luminaire housing finish color		Gray
WEIGHT:	Maximum luminaire weight		30 lb
EPA:	Maximum effective projected area		0.7 ft^2
MOUNTING:	Mtg. method	☐ Post-top ☑ Side-arm ☐ Trunnion/yoke ☐ Swivel-tenon	
	Tenon nominal pipe size (NPS)		2 inches
VIBRATION:	ANSI test level	☑ Level 1 (normal) ☐ Level 2 (bridge/overpass)	
DRIVER:	Control signal interface	☑ Not required ☐ Required	

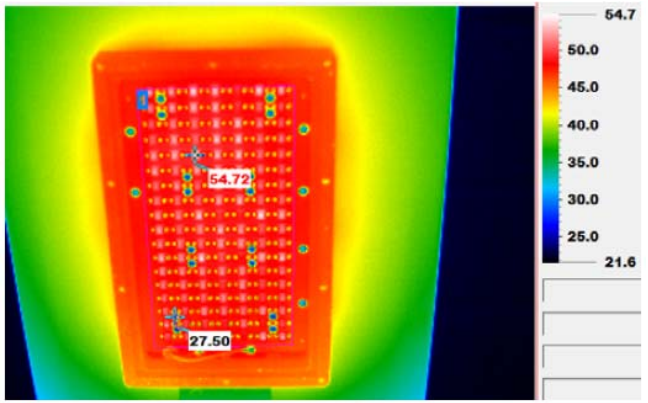
[1] See IES TM-3 and TM-15 for an explanation of this classification system. "Very" indicates out of defined range.
[2] Mesopic multipliers are not applicable if speed limit and/or adaptation luminance are unknown.
[3] The deprecated "cutoff" classification system cannot be accurately applied to LED luminaires.

Appendix B – Lumen Maintenance

- The IES TM-21 methodology allows for extrapolation beyond duration of lumen maintenance testing
- The model spec offers two compliance paths for long-term testing
  - Use of ISTMT and IES LM-80 data (component level)

    OR
  - Testing of complete luminaires (luminaire level)
    - ➢ May prove cost-prohibitive, but preferred in terms of system reliability





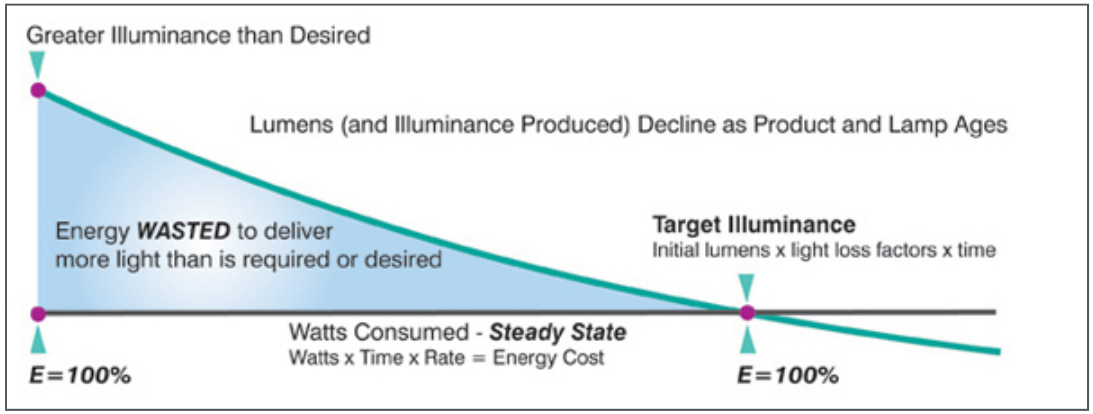
Appendix B – Lumen Maintenance

- No longer setting a minimum percentage lumen maintenance at 6000 hr
  - Pre-TM-21 thresholds were based on assumed “universal” curve form
- Two options, extrapolating to a specified minimum useful lifetime
  - Product-specific lamp lumen depreciation (LLD)

    OR
  - Same LLD simply assumed for all products (L70 by default)
    - Consistent with IES HB-10-11 pg 13.8 (recommends L70)
    - Conservative – products might not be replaced until visibly dim
    - No credit for higher LLD calculated per TM-21
    - TM-21 may not allow extrapolation to L70 for some products
    - Implications for pricing and lifetime

Appendix B – Lumen Maintenance

- Some products designed for constant output and increasing input over time



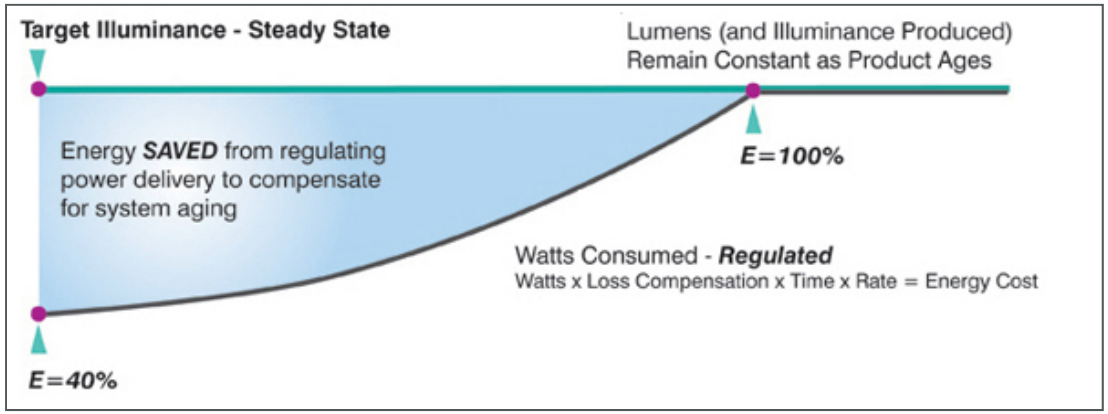
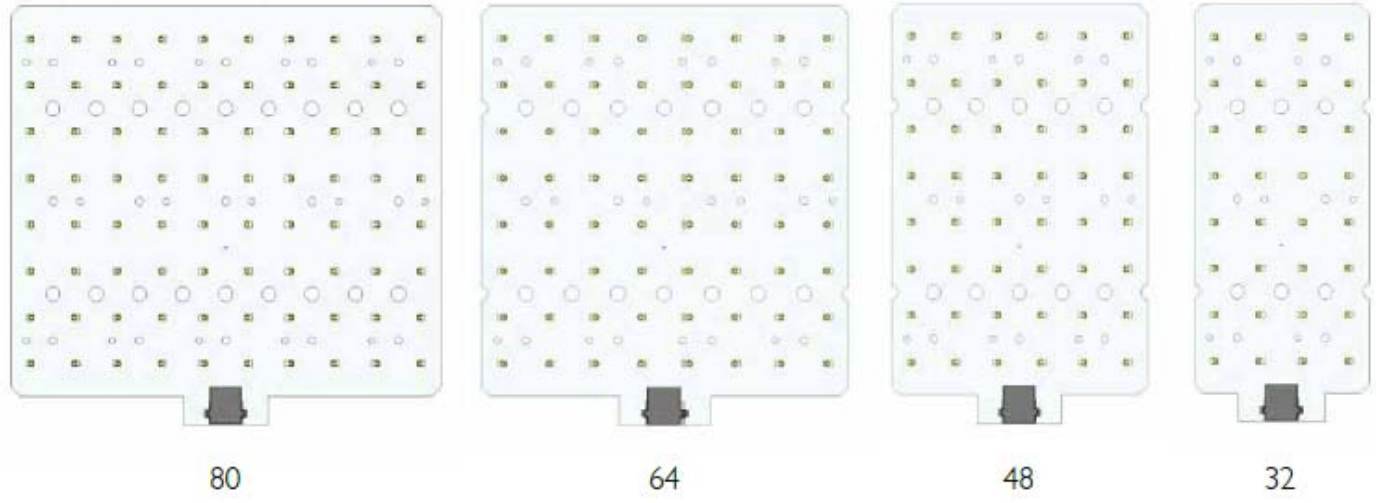


Image credits: LUMENPRIORITY

Appendix C – Product Family Testing

- Recognizes that testing of every possible configuration would be cost-prohibitive and unnecessary
- Allows some interpolation between tested products
- Applicable to LM-79 and ISTMT
  - LM-80 data is applicable to products listed in LM-80 report
  - “Successor” LED package(s)/array(s)/module(s) difficult to define



Appendix C – Product Family Testing

- Example assuming constant driver loading (and driver efficiency)

Table C.1. Representative testing of a single luminaire housing size

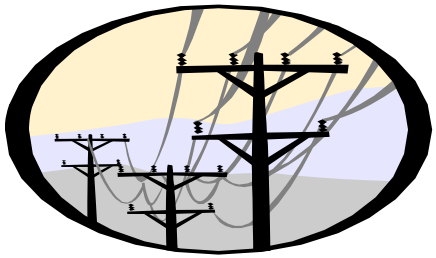
Tests	Intensity distribution (IES Type)	CCT (K)	Drive current (mA)	# of LEDs
1, 2, 3	II, III, IV	4000	700	80
4, 5	IV	5000, 6000	700	80
6, 7	IV	4000	325, 525	80
8, 9, 10	IV	4000	700	20, 40, 60

Table C.2. Multipliers for Test #2 to yield: Type III , 5000K, 525mA, 40 LEDs

Test #	Intensity distribution (IES Type)	CCT (K)	Drive current (mA)	# of LEDs	Multiplier (lumens ratio)
2	III	4000	700	80	n/a
3	IV	4000	700	80	n/a
4	IV	5000	700	80	#4 / #3
7	IV	4000	525	80	#7 / #3
9	IV	4000	700	40	#9 / #3

Appendix D – Electrical Immunity

- Basis for test procedures and criteria
  - IEEE C62.41.2-2002, *IEEE Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and less) AC Power Circuits*
  - ANSI/IEEE C62.45-2002, *IEEE Recommended Practice on Surge Testing for Equipment Connected to Low-Voltage (1000 V and Less) AC Power Circuits*
- Test procedures utilized
  - Ring Wave
  - Combination Wave
    - ➢ "Basic" or "Elevated" (only item requiring specification by user)
  - Electrical Fast Transient



- Manufacturer to indicate on submittal form whether failure of the electrical immunity system can possibly result in disconnect of power to luminaire

Appendix E – Submittal Form by Luminaire Type

Luminaire Type[1]		
Manufacturer		
Model number		
Housing finish color		
Tenon nominal pipe size (inches)		
Nominal luminaire weight (lb)		
Nominal luminaire EPA (ft^2)		
Nominal input voltage (V)		
ANSI vibration test level	☑ Level 1 (Normal)	☐ Level 2 (bridge/overpass)
Nominal BUG Ratings		
Make/model of LED light source(s)		
Make/model of LED driver(s)		
Dimmability	☐ Dimmable	☑ Not dimmable
Control signal interface		
Upon electrical immunity system failure	☐ Possible disconnect	☐ No possible disconnect
Thermal management	☐ Moving parts	☑ No moving parts
Lumen maintenance testing duration (hr)		
Reported lumen maintenance life (hr) [2]		
Warranty period (yr)		
Parameter	Nominal value	Tolerance (%)
Initial photopic output (lm)		
Maintained photopic output (lm)		
Lamp lumen depreciation		
Initial input power (W)		
Maintained input power (W)		
Initial LED drive current (mA)		
Maintained LED drive current (mA)		
Drive current used		
In-situ LED T_c (°C)		
CCT (K)		
S/P ratio		
Additional product description		

DRAFT

Model Luminaire Spec… Where?

- Shown below is one of the nine sites in Kansas City where HPS luminaires (left) were replaced with LED luminaires (right)
- Existing HPS lamps ranged from 100W to 400W
- Initial measurements have been performed
- Report is in progress





Model Luminaire Spec… Where?

- A number of municipalities are reportedly using the April draft
- A number of others indicated interest in Version 1.0 before its release
  - Iowa Association of Municipal Utilities
  - Bay Area Climate Collaborative
  - City of Philadelphia, PA



LED Street Lighting in Philadelphia, PA

- Project scope
  - Field measurements *and* visual evaluations/surveys
    - ➢ Three HPS cobrahead wattages, each on a different street
  - Visual evaluations/surveys
    - ➢ To be performed on a variety of additional streets
  - Vibration
    - ➢ For luminaires mounted beneath an elevated rapid-transit line
  - Products already selected and ordered
  - Field measurements, surveys, and report forthcoming
- Project team
  - City of Philadelphia
  - Pacific Northwest National Laboratory (PNNL)
    - ➢ Representing the Consortium

LED Street Lighting in Philadelphia, PA

- Baseline: 100W HPS ($)
  - Field measurements and visual evaluation
  - Numerous photopically-equivalent or comparable LED luminaires



Photo credit: Google

LED Street Lighting in Philadelphia, PA

- Baseline: 150W HPS ($$)
  - Field measurements and visual evaluation
  - Numerous photopically-equivalent or comparable LED luminaires
    - ➢ One viable lamp-ballast retrofit kit identified
  - Vibration testing and security concerns



Photo credit: Google

LED Street Lighting in Philadelphia, PA

- Baseline: 250W HPS ($$$)
  - Field measurements and visual evaluation
  - Two photopically-equivalent manufacturers identified



Photo credit: Google

Next Steps

- Possible future Task Force topics
  - End-of-life indication
  - Lumen depreciation compensation
  - Warranty coverage of lumen maintenance
  - Determination of equivalence without knowledge of site parameters
  - Durability of luminaire housing finish
  - Characterizing dimming performance
  - LED package (chip) reliability
  - Coordination with ANSI C136.37-2011, *American National Standard for Roadway and Area Lighting Equipment – Solid State Light Sources Used in Roadway and Area Lighting*

Next Steps

- Ongoing updates as needed, based on member feedback and experience from demonstrations
- Report for demonstration in Kansas City, MO
- Additional demonstration projects TBD
- Lighting controls specification
- Supplemental guidance document
- Possible additional LED luminaire specifications
  - Parking lot lighting (derived from CBEA)
    - Retailers and hospitals often require levels higher than recommended by IES
  - Parking structure lighting (derived from CBEA)
    - LED-only

End of Presentation

Questions