Municipal Solid-State
STREET LIGHTING
CONSORTIUM

Sponsored by the U.S. Department of Energy

SOLID-STATE STREET LIGHTING CALCULATING LIGHT LOSS FACTORS

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OUTLINE

- Why Use Light Loss Factors
- Standards
- Lamp Life
- Light Loss Factors
  - Equipment Factors
  - Maintenance Factors
    - Luminaire Dirt Depreciation (LDD)
    - Lamp Lumen Depreciation (LLD)
- L_{70}
- L_{AL}

WHY WE USE LIGHT LOSS FACTORS (LLF)

- Luminaires age over time resulting in reduced lumen output
- Recognized standards identify minimum light level requirements to be maintained on roadways and areas for life of lighting system.
  - IESNA RP-8-00
  - AASHTO
- LLF allows the forecasting of system performance over a given lifetime to meet the minimum lighting standards
- Can help minimize liability – system has been planned and designed for future operation, not just for the day it is installed.

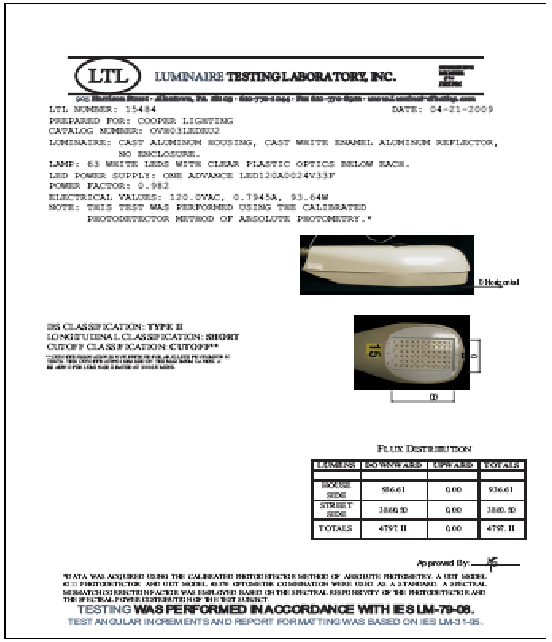
Street and Area Lighting Goal

Security, Safety, Commercial Interests, Community Pride

STANDARDS

- IESNA LM-79-08: IESNA Approved Method for the Electrical and Photometric Measurements of Solid-State Lighting
- IESNA LM-80-08: IESNA Approved Method for Measuring Lumen Maintenance of LED Lighting Sources
- IESNA TM-21-11: Projecting Long Term Lumen Maintenance of LED Light Sources

IESNA LM-79-08



LTL LUMINAIRE TESTING LABORATORY, INC.

LTL NUMBER: 15484 DATE: 04-21-2009

PREPARED FOR: COOPER LIGHTING

CATALOG NUMBER: OVH031LEDSU2

LUMINAIRE: CAST ALUMINUM HOUSING, CAST WHITE ENAMEL ALUMINUM REFLECTOR, NO ENCLOSURE.

LAMP: 63 WHITE LEDS WITH CLEAR PLASTIC OPTICS BELOW EACH.

LED POWER SUPPLY: ONE ADVANCE LED120A0024V33F

POWER FACTOR: 0.982

ELECTRICAL VALUES: 120.0VAC, 0.7945A, 93.64W

NOTE: THIS TEST WAS PERFORMED USING THE CALIBRATED PHOTODETECTOR METHOD OF ABSOLUTE PHOTOMETRY.*

IES CLASSIFICATION: TYPE II

LONGITUDINAL CLASSIFICATION: SHORT

CUTOFF CLASSIFICATION: CUTOFF**

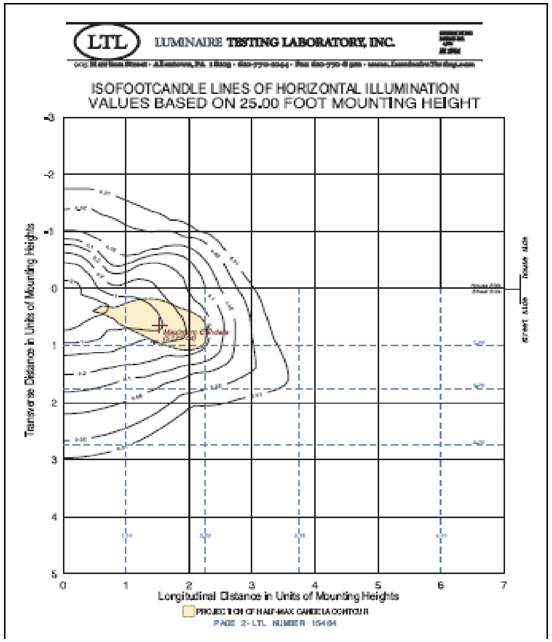
FLUX DISTRIBUTION

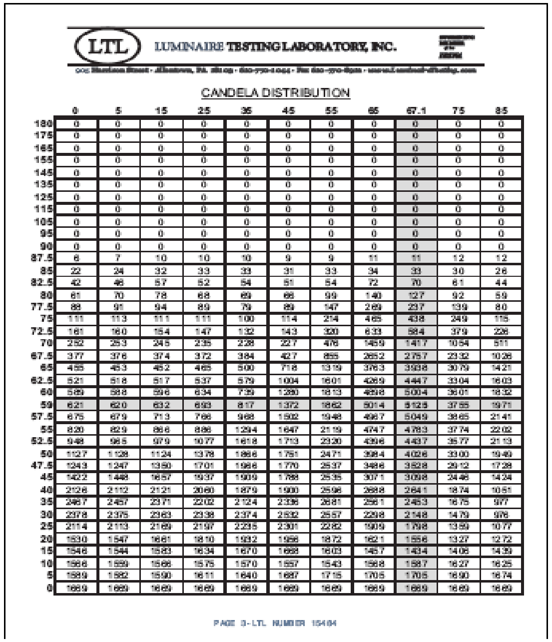
LUMENS	DOWNWARD	UPWARD	TOTALS
HOUSE SIDE	936.61	0.00	936.61
STREET SIDE	3860.50	0.00	3860.50
TOTALS	4797.11	0.00	4797.11

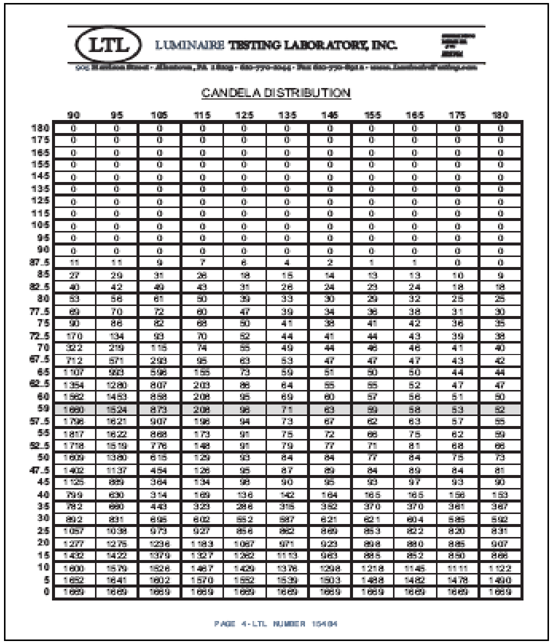
Approved By:

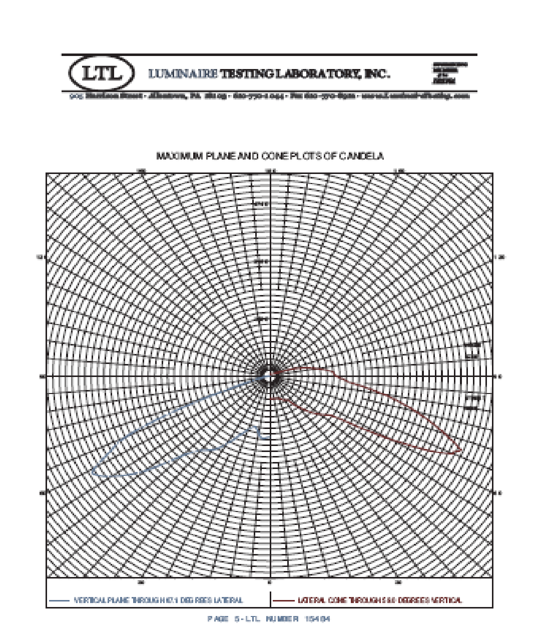
TESTING WAS PERFORMED IN ACCORDANCE WITH IES LM-79-08.

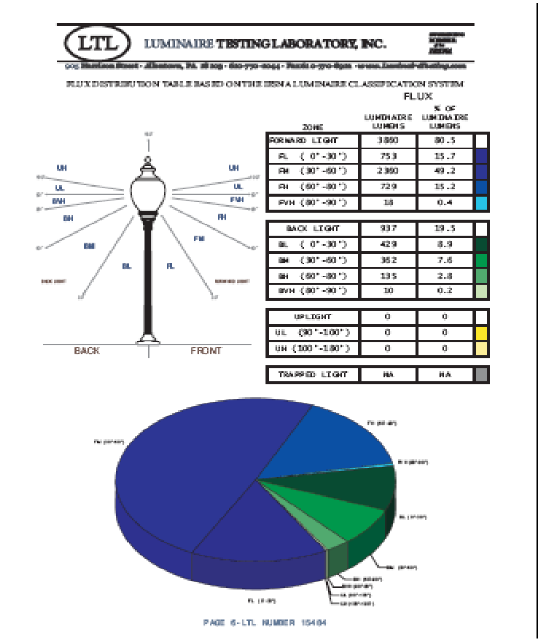
TEST ANGULAR INCREMENTS AND REPORT FORMATTING WAS BASED ON IES LM-31-95.



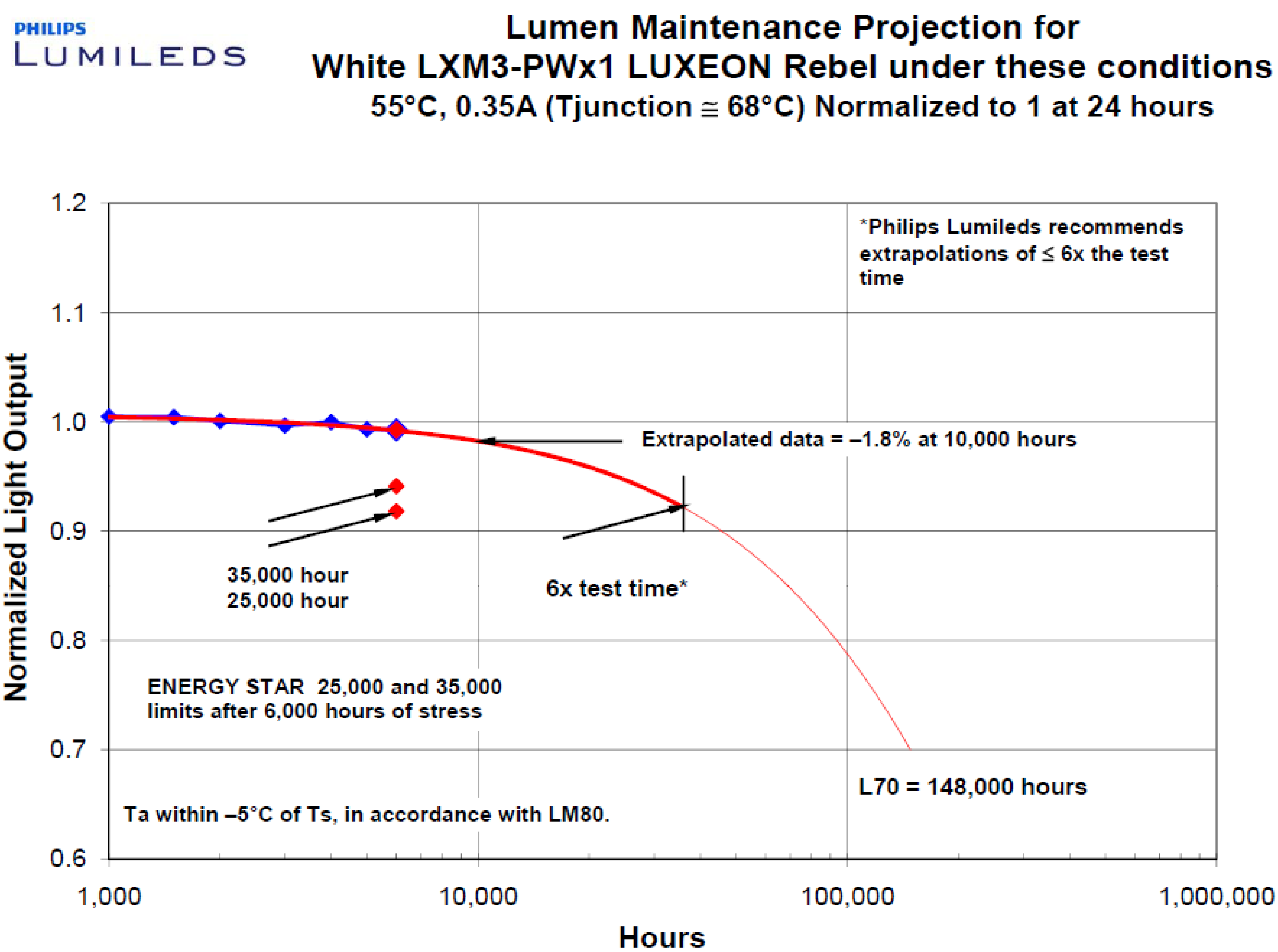








IESNA LM-80-08



RATED LAMP LIFE

HID Sources

- Time in hours at which 50% of a large sample group of initially installed lamps fail

Note:
Incandescent and fluorescent lamps are rated the same

LED Sources

- L_p = time in hours to which the lumen output has degraded to a percent "p" of initial lumens
- L_{70} commonly used
- Use LM-80 report to help determine L_p

Note:

LED lamps do not typically catastrophically fail. There lumen output degrades over time. This can be maintained through drive current control.

LIGHT LOSS FACTORS (SOLID STATE LIGHTING)

LLF = LLD x LDD x ATF x HE x VE x BF x CD

LLD:	Lamp Lumen Depreciation	Maintenance Factors
LDD:	Luminaire Dirt Depreciation	
ATF:	Ambient Temperature Effects	Equipment Factors
HE:	Heat Extraction	
VE:	Voltage Effects	
BF:	Driver and Lamp Factors	
CD:	Component Depreciation	

LIGHT LOSS EQUIPMENT FACTORS

LLF = LLD x LDD x ATF x HE x VE x BF x CD

Ambient Temperature Effects – utilizes historic ambient temperature data for area and luminaire performance data from the manufacturer

- Based on “on/off” control, max/min operation temperatures, incident sunshine on luminaire and daytime heat effects. Work with manufacturer.

Heat Extraction – luminaire has a thermal capacitance based on mass, specific heat of materials, and rate of dissipation.

- If system changes over time, it’s thermal performance should be evaluated. Work with manufacturer.

LIGHT LOSS EQUIPMENT FACTORS

LLF = LLD x LDD x ATF x HE x VE x BF x CD

Voltage Effects – Most systems operate between 120 and 277 VAC. Efficiencies can vary with changes in input voltages.

- Evaluate system for sensitive to these variations, voltage dips, or power line transients. Work with manufacturer.

Driver and Lamp Factors – Some drivers provide AC and some DC current to LED. Drivers can be dimmable (continuous or step). Efficiency of the driver is reduced when LED load decreases.

- Evaluate if power supply output varies with operating temperature, current type and driver loading effects. Work with manufacturer.

Component Depreciation – Components can be affected by heat and environmental aging. Optical systems are effected by UV and reflective surfaces by humidity and oxidation.

- Evaluate potential for aging and UV effects. Work with manufacturer.

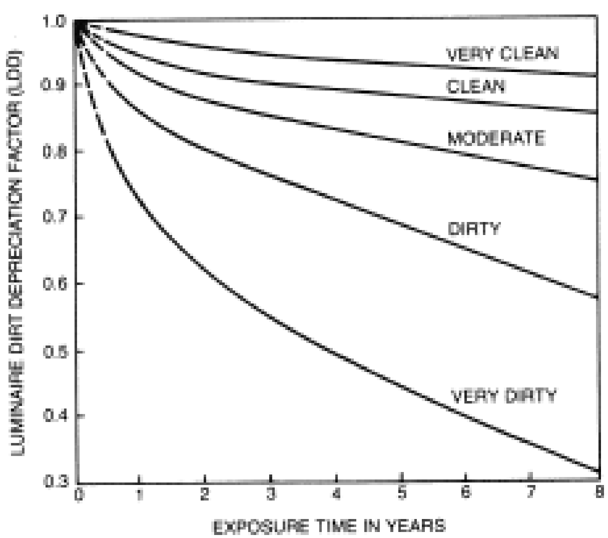
LIGHT LOSS MAINTENANCE FACTORS

LLF = LLD x **LDD** x ATF x HE x VE x BF x CD

Luminaire Dirt Depreciation – Dirt accumulates on the inside and outside of refractors, reflectors, and lamps, resulting in reduction of lumen output.

SOURCES FOR LDD DATA

- ✧ Historical site data
- ✧ Perform field measurements
- ✧ RP-8-05, Fig. 5 – LDD curves based on ambient environmental conditions and exposure time (cleaning frequency)



SELECT THE APPROPRIATE CURVE IN ACCORDANCE WITH THE TYPE OF AMBIENT AS DESCRIBED BY THE FOLLOWING EXAMPLES:

VERY CLEAN—No nearby smoke or dust generating activities and a low ambient contaminant level. Light traffic. Generally limited to residential or rural areas. The ambient particulate level is no more than 150 micrograms per cubic meter.

CLEAN—No nearby smoke or dust generating activities. Moderate to heavy traffic. The ambient particulate level is no more than 300 micrograms per cubic meter.

MODERATE—Moderate smoke or dust generating activities nearby. The ambient particulate level is no more than 600 micrograms per cubic meter.

DIRTY—Smoke or dust plumes generated by nearby activities may occasionally envelope the luminaires.

VERY DIRTY—As above but the luminaires are commonly enveloped by smoke or dust plumes.

LIGHT LOSS MAINTENANCE FACTORS

LLF = LLD x LDD x ATF x HE x VE x BF x CD

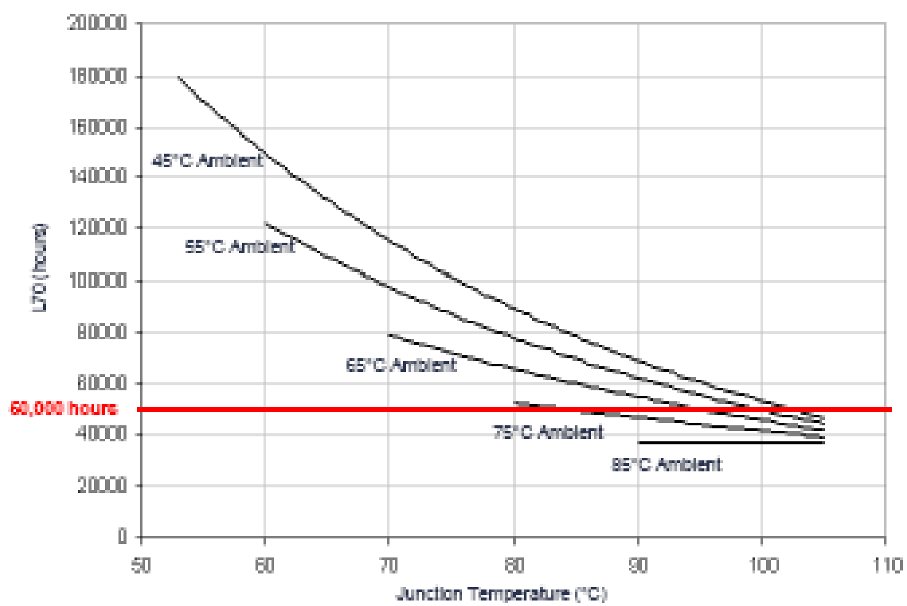
Lamp Lumen Depreciation – lumen output depreciates over time resulting in a gradual reduction in light levels.

LLD

Lumen Maintenance is a function of T_j and T_a within the LED package.

L70 vs Junction Temperature vs Ambient Temperature

- LED's do not radiate heat
- Conduction and Convection are needed to keep LED's cool.



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CREE LED Light

SOURCES FOR LLD MEASUREMENTS

- Manufacturer test data – these test should be done by independent laboratories.
- References include IESNA LM-79-08, LM-80-08, and LM-21-11.
- Reliable field test results.

METHODS FOR CALCULATING LLD

- L_{70} – life of system is based on luminaire retaining 70% of original lumen output
- Application Life (L_{AL}) – life of system is based on a chosen number of operating hours equal to or greater than the pay back period of the luminaire.

WHY L_{70}?

LM-80-08 lists a couple of examples, one indicates L_{70} (hours) = time to 70% lumen maintenance.

- OR -

The *Design Guide for Roadway Lighting Maintenance DG-4-03* indicates the "best time schedule" for relamping of HID luminaires is when the cost of **installation, energy use,** and **relamping** is minimal. This occurs at approximately 70% of rated lamp life.

- MOST LIKELY BECAUSE OF THE FOLLOWING -

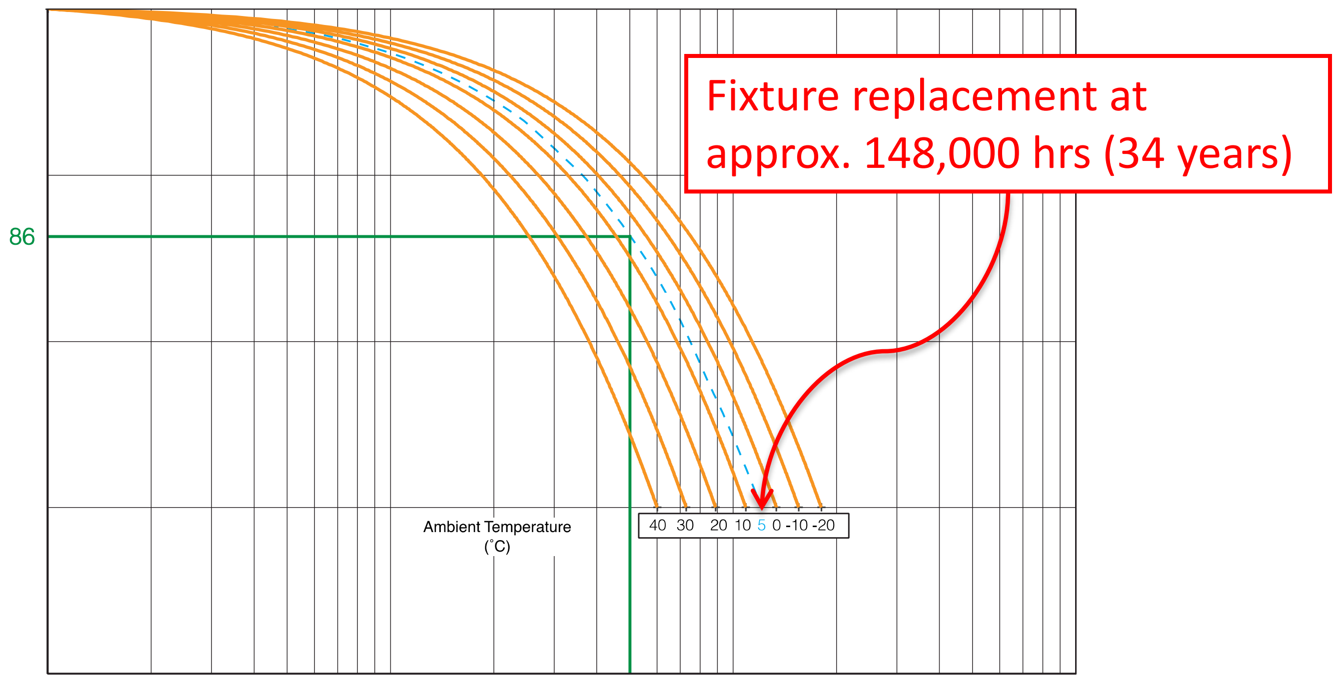
For a common application such as general lighting in an office environment, research has shown that the majority of occupants in a space will accept light level reductions of up to 30% with little notice, particularly if the reduction is gradual.[1] Therefore a level of 70% of initial light level could be considered an appropriate threshold of useful life for general lighting. Based on this research, the Alliance for Solid State Illumination Systems and Technologies (ASSIST), a group led by the Lighting Research Center (LRC), recommends defining useful life as the point at which light output has declined to 70% of initial lumens

WHAT DOES L_{70} MEAN IN TIME

LED LMF MULTIPLIER EXAMPLE: 525mA @ 5˚C

0.86	x	1.05	=	0.90
obtained from chart below See step 2 from previous page for more information		LEDs gain 0.25% lumen output for each degree C below 25% **25 - 5 = 20** **20 x .25 = 5%** **0.05 + 1.000 = 1.05**		New multiplier for this example

BetaLED® LEDway® 525mA Lumen Maintenance Predictions vs. Ambient Temperature



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WHAT DOES L_{70} MEAN IN DESIGN

- ✧Increase in system hardware for new installations

FROM

TO

Increases maintenance needs & higher capital costs

- ✧Prohibitive use of LED's on upgrade to existing installations due to light levels not able to be met
- ✧Higher initial lumen output diminishing to designed level at 34 years

- Wasted energy costs until end of life when design minimum light levels are met.
- Large change in lumen output.

LLD BASED ON APPLICATION LIFE (L_{AL})

- Life of system is based on a chosen number of operating hours equal to or greater than the pay back period of the luminaire. Payback determined by a cost/benefit analysis
- Lets make some basic assumptions to illustrate:
  - 12 year luminaire life (50,000 hours)
  - Retain L_{70} as an absolute minimum light level
  - Maintenance will occur once during lifetime of fixture
  - Failure rate of 10%

Hold it, what about our payback period, can we achieve it?

LED LUMINAIRE COST/BENEFIT

Table 8-5 Payback Calculator

Decription	Base System	Luminaire A2	Luminaire A2
Number of Luminaires	1	1	1
Number of Lamps per Luminaire	1	1	1
Cost per Luminaire	$ 133.00	$ 428.00	$ 250.00
Installation Cost	$ 63.91	$ 63.91	$ 63.91
Initial Cost	**$ 196.91**	**$ 491.91**	**$ 313.91**
Annual Operations Cost per Fixture			
Watts per Fixture (luminaire and ballast/driver)	142	109	109
kW per Fixture	0.142	0.109	0.109
Annual Hours of Operation (12 hrs per day)	4,380 hrs	4,380 hrs	4,380 hrs
kW Hours per Year	622.0 kWh	477.4 kWh	477.4 kWh
Electric Rate ($/kWH)	$ 0.0530	$ 0.0530	$ 0.0530
Annual Energy Cost	**$ 32.96**	**$ 25.30**	**$ 25.30**
Annual Maintenance Cost			
Fixture Life (yrs)	15 yrs	15 yrs	15 yrs
Lamp Life (hrs)*	30,000 hrs	50,000 hrs	50,000 hrs
Lamp Life (yrs)	6.8 yrs	11.4 yrs	11.4 yrs
Theoretical Relamps/Cleanings Over Life of Fixture	2.2	1.3	1.3
Scheduled Relamps/Cleaning Over Life of Fixture	3.0	1.0	1.0
*Cost per Relamp/Cleaning (maintenance + parts)***	$ 102.43	$ 35.00	$ 35.00
Annualized Relamp/Cleaning Cost	$ 20.49	$ 2.33	$ 2.33
Other Annulized Costs (Catastrophic Failure/Damage)***	$ 29.25	$ 11.70	$ 11.70
Annual Maintenance Cost	**$ 49.74**	**$ 14.03**	**$ 14.03**
Conservation Rebate			
kWh Saved Compared to Base System****	NA	144.54 kWh	144.54 kWh
Adjustments (Conservation Rebate $0.23/kWh)	**NA**	**$ 31.80**	**$ 31.80**
Payback (Compared to Base HPS System)			
Adjusted Initial Cost per Fixture	$ 196.91	$ 460.12	$ 282.12
Rebate Adjusted			
Annual Operations Cost	$ 32.96	$ 25.30	$ 25.30
Annual Operations Savings	NA	$ 7.66	$ 7.66
Annual Maintenance Cost	$ 49.74	$ 14.03	$ 14.03
Annual Maintenance Savings	NA	$ 35.70	$ 35.70
Total Annual O&M Savings	NA	$ 43.36	$ 43.36
Payback Period		**6.1 yrs**	**2.0 yrs**

* Current Manufacturer Claims for life of LED is 50,000 hrs to 100,000 hrs.
Low end of projected life used for comparison purposes.
** LED fixtures to be cleaned only, no relamp required.
***Assumes a 25% failure rate for HPS luminaires and theoretical 10% failure for LED fixtur
****Savings shown as a positive number.

Energy Demand and Savings

Watts per Fixture	142	109	109
Base kWh	621.96	477.42	477.42
Savings in kWh (Compared to Base System)	NA	144.54	144.54

Currently pay back is achievable within 2 to 6 years of installation when compared to existing HID installations of 100W HPS luminaires in residential areas at least in Seattle.

Payback Period		6.1 yrs	2.0 yrs

WHAT DOES L_{AL} MEAN FOR LLD

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obtained from chart below		LEDs gain 0.25% lumen output for each degree C below 25%		New multiplier for this example
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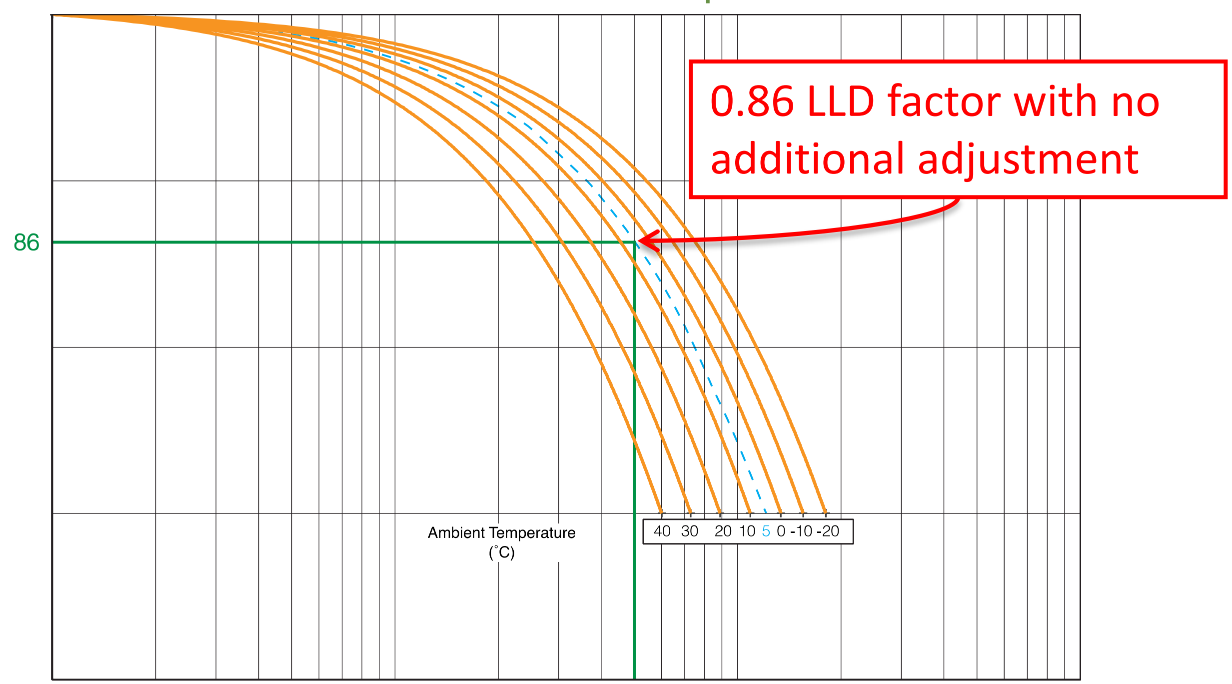
BetaLED® LEDway® 525mA Lumen Maintenance Predictions vs. Ambient Temperature



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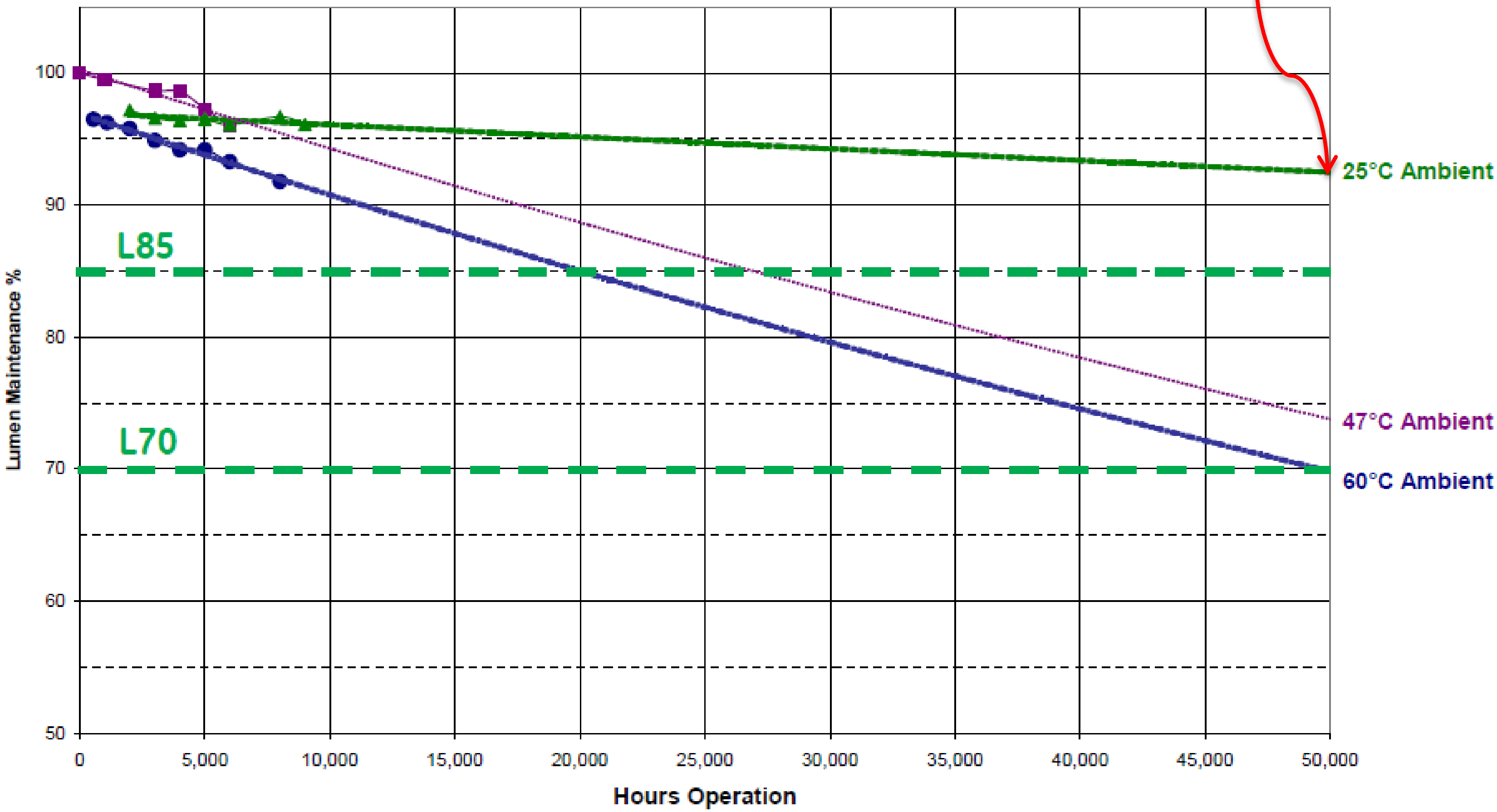
WHAT DOES L_{AL} MEAN FOR LLD

Evolve™ LED

5) System Level Lumen Maintenance Exponential Projections

0.93 LLD factor with no additional adjustment



imagination at work

GE Internal Test Data

The information in this document is subject to change without notice.

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WHAT DOES L_{AL} MEAN IN DESIGN COMPARED TO L_{70}

- Less hardware for new installations

Less hardware = less maintenance needs and less capital cost

- LED fixtures can be used for more upgrades of existing systems because light levels are more easily met
- Initial lumen output less than with L_{70}

Less wasted energy costs due to lower initial lumens

- Less variation in lumen levels over life of system compared to L_{70}

L_{AL} BENEFITS

- Better definition of system life by time. System is not defined by minimum lumen maintenance that varies between manufacturers and LED packages.
- Greater operating temperature range. System is designed to a shorter time frame than L_{70} allowing the use in a wider range of temperatures.
- Unique system design possible governed by Agency/Utility needs.
- More replacement options at selected end of life. L_{70} is still on the horizon, do I still have good light levels and can I replace system today or a year from now.
- Reduced lumen depreciation across the life of the fixture. Better lighting with less variability in lumen levels to end of life.
- Reduce wasted energy due to lower initial lumen levels needed since system is designed for near future and not distant future (i.e. 12 years not 34 years).
- Ability to deploy more LED systems due to less lumen depreciation across fixture life.