History of Electric Lamps

- 1879 1st Commercial Carbon Filament Incandescent Lamp (T.A. Edison)
- 1930 1st High Pressure Mercury Discharge Lamp (G.E.)
- 1938 1st Commercial Fluorescent Lamp (G.E.)

Beta LED

What Is a Light Emitting Diode (LED)?

- Light Emitting Diodes (LEDs) are *solid-state semiconductors* that convert electrical energy directly into visible light.

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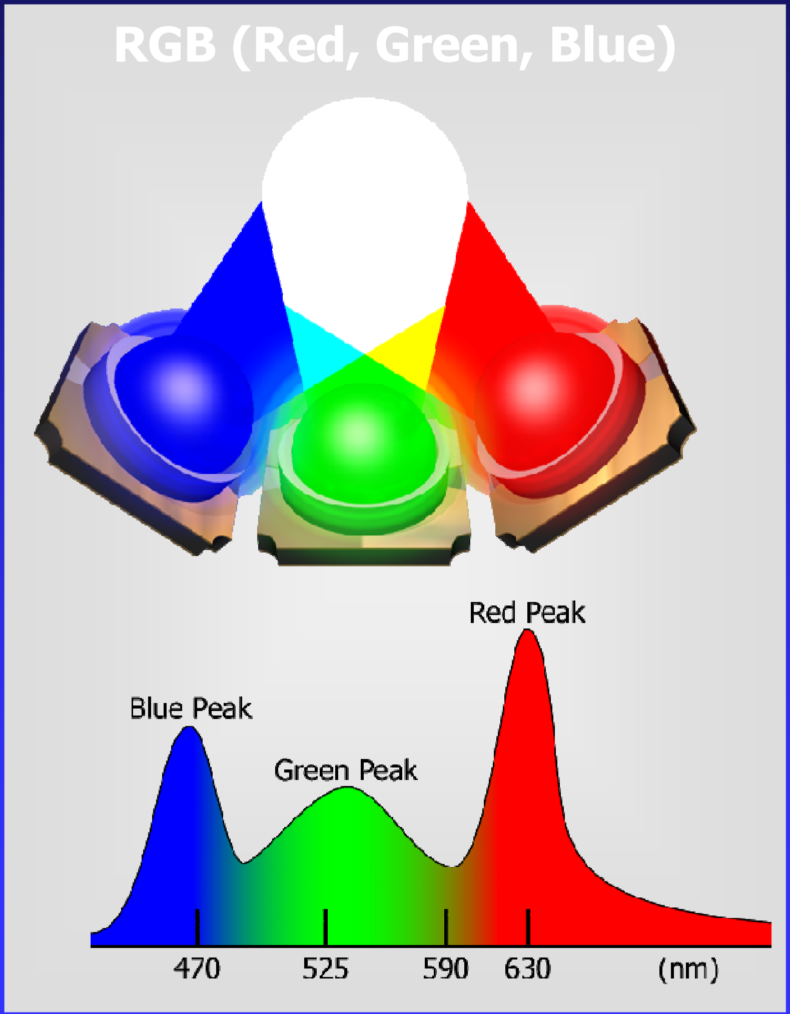
LED History

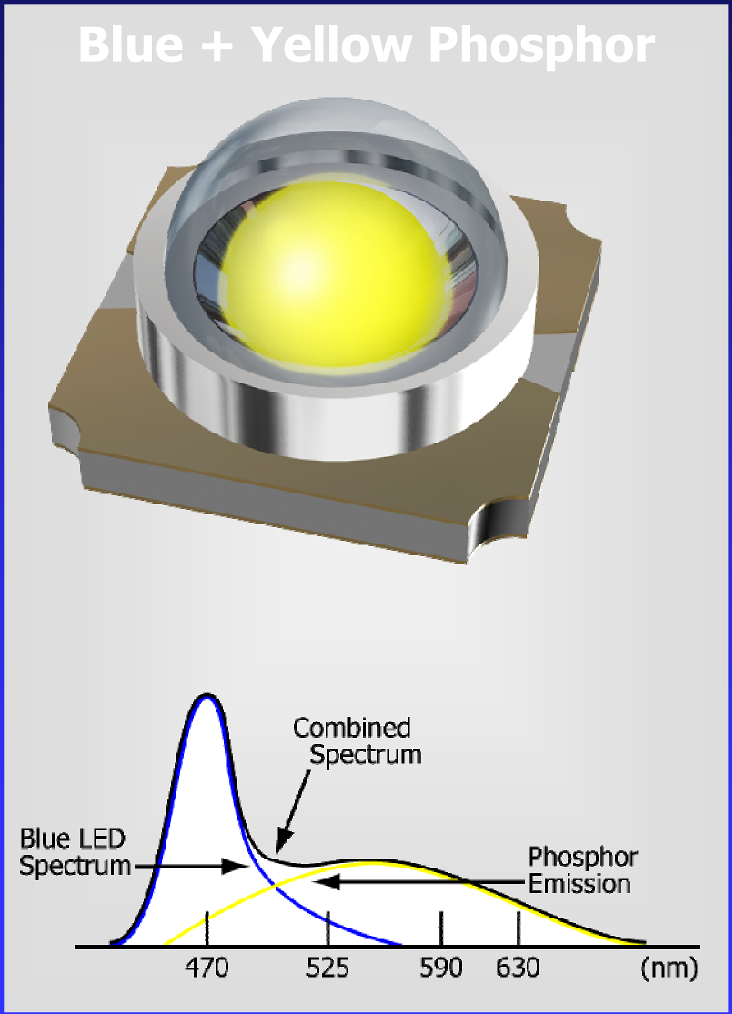
- 1968 – First Red LED (GaAs)
- 1990 – first **AlInGaP** (Aluminium Indium Gallium Phosphide) low power high brightness absorbing substrate
  - Red, Orange, Amber LEDs by HP (now Philips Lumileds Lighting)
- 1994 – **InGaN** (Indium Gallium Nitride)
  - Blue, Green low power LEDs by Nichia
- 1996 – "Blue + Phosphors" low power White LED by Nichia
  - YAG Phosphor (Cerium-doped Yttrium Aluminum Garnet)

LED History

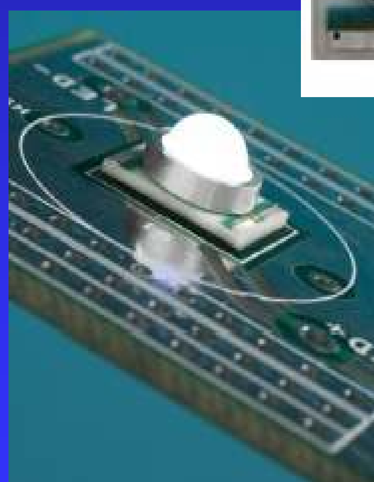
- 2001 – "Blue + Phosphors" high power 1-watt White LED by Phillips Lumileds Lighting
  - High Power (HP) LEDs are ≥ 1 Watt
- 2003 & On – "Blue + Phosphors" >3 watt White LED by Phillips Lumileds Lighting and others

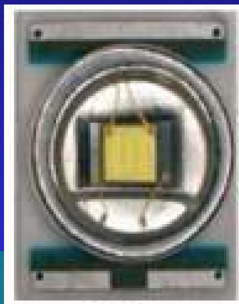
Two Popular Ways To Produce White Light with LEDs



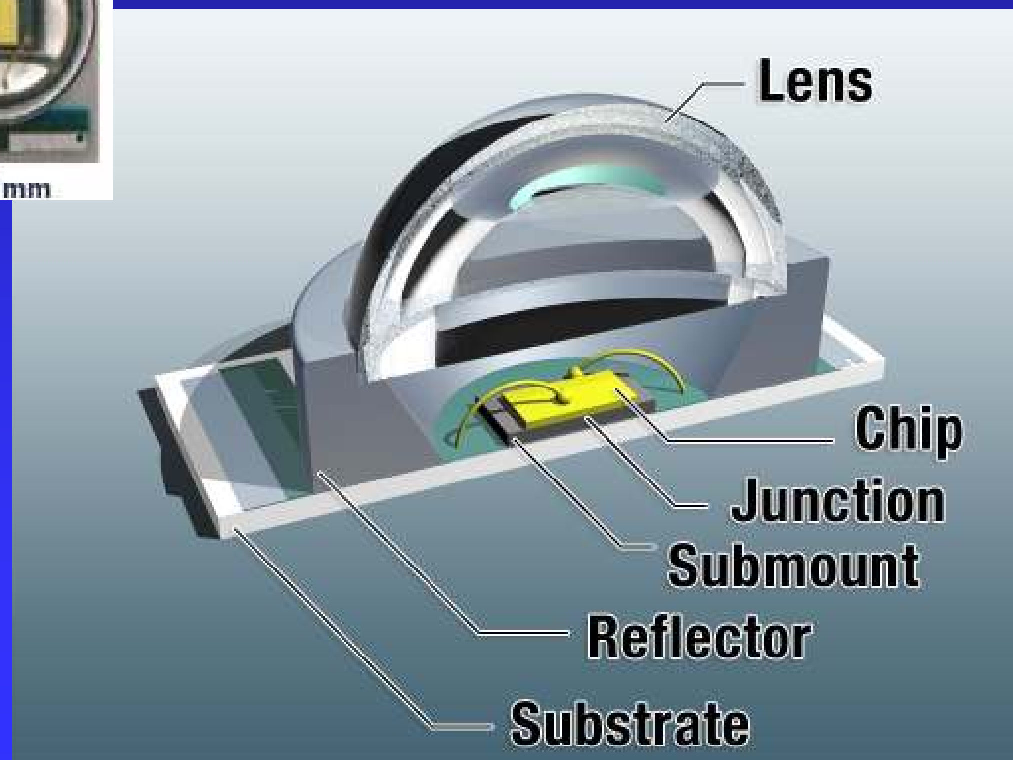


Basic High Power (HP) LED Package

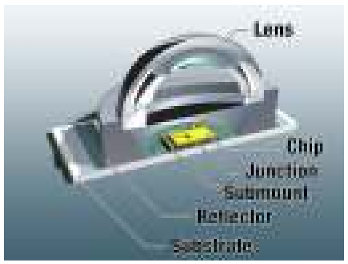


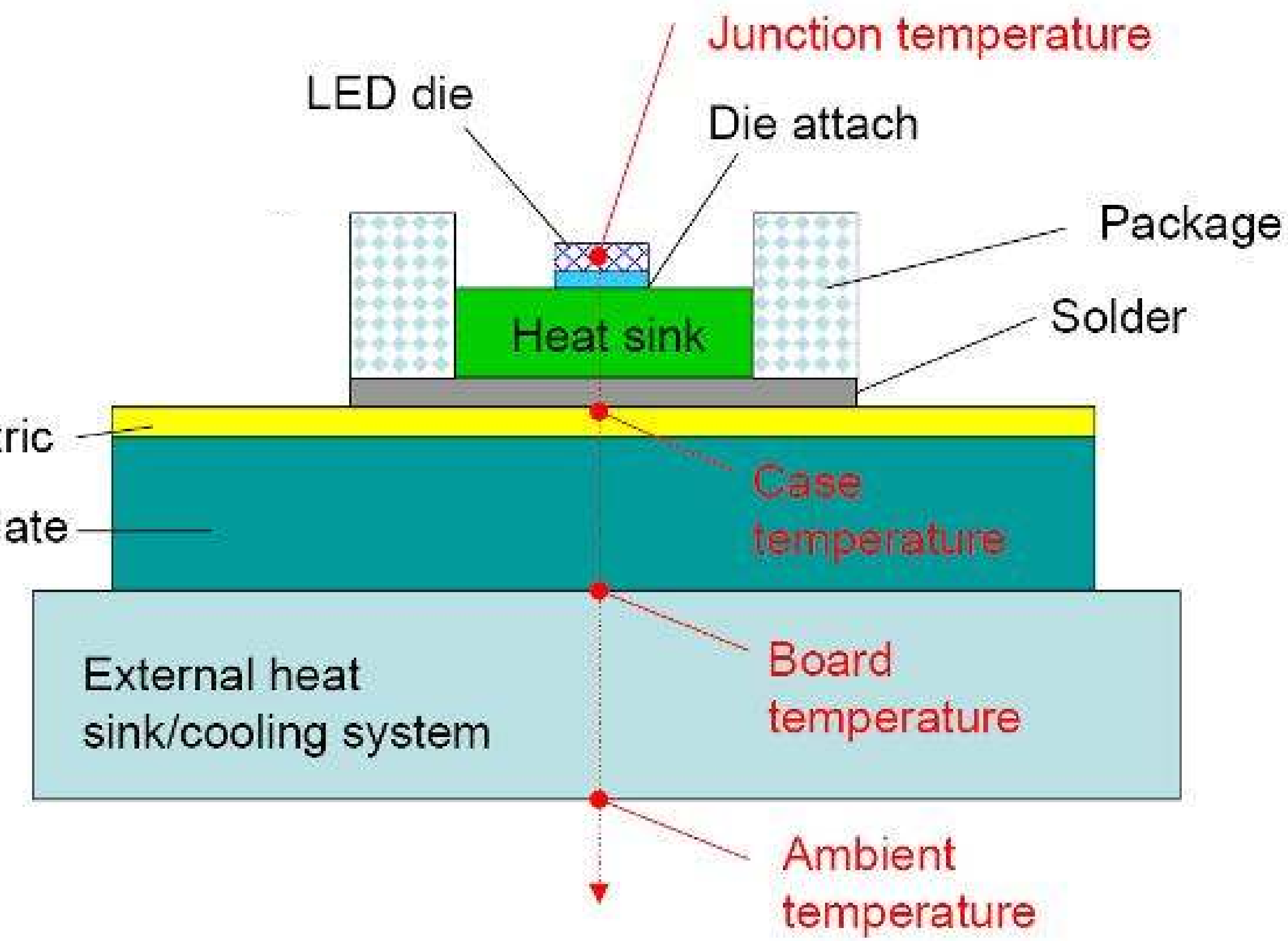


7x9 mm



Generic Thermal Management System Example





www.LEDsMagazine.com

HP White LED
Source Efficacy Ratings

Example

- **"Today's Best"** Commercially Available High Power White LED's
  ~100 Lumens/Watt
    - Measured at 25°C
        - ~25 Millisecond Time Duration
        - 350 mA Drive Current
    - ~6000 K Correlated Color Temperature (CCT)
        - Limited Indoor Applications
        - Appropriate for Many Outdoor Applications

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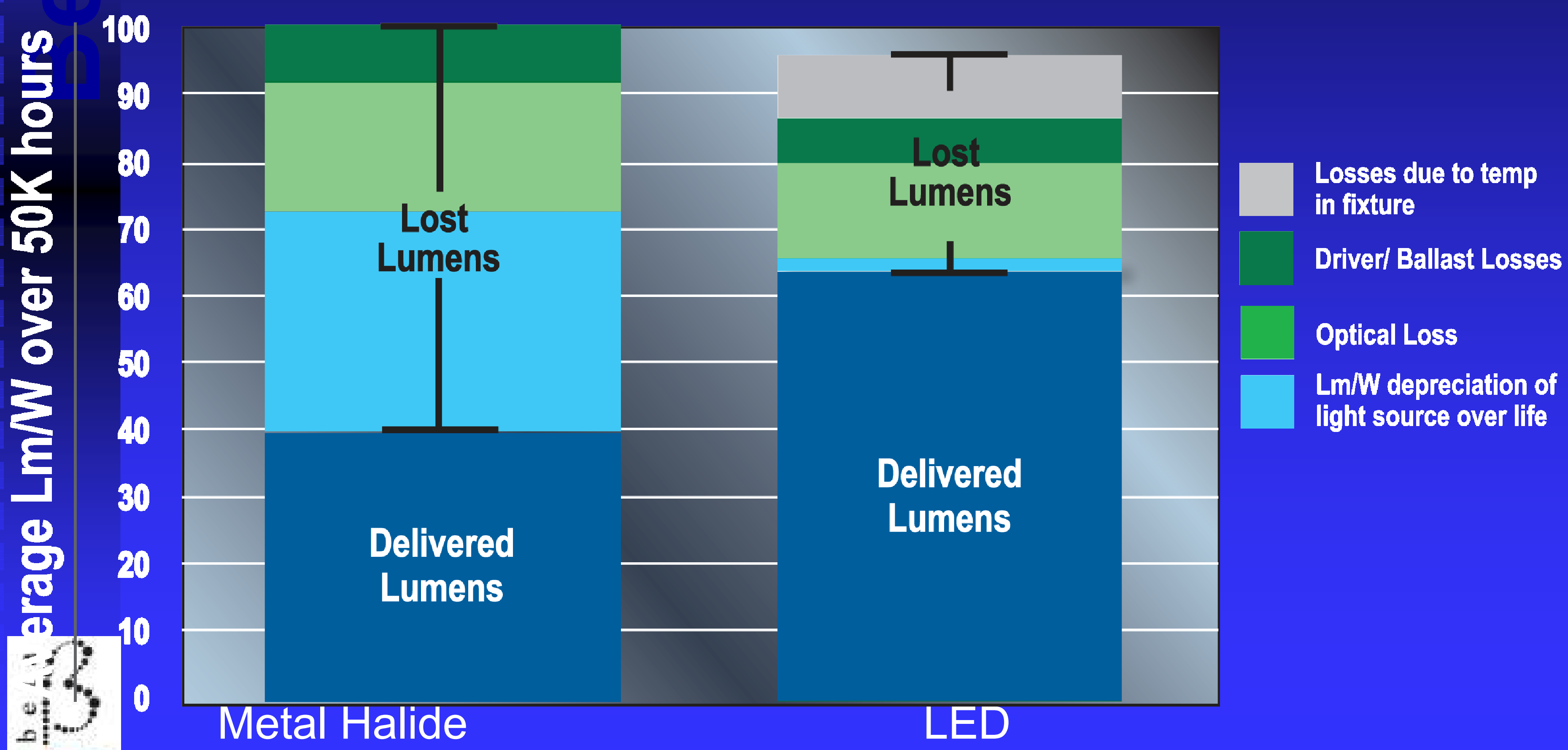
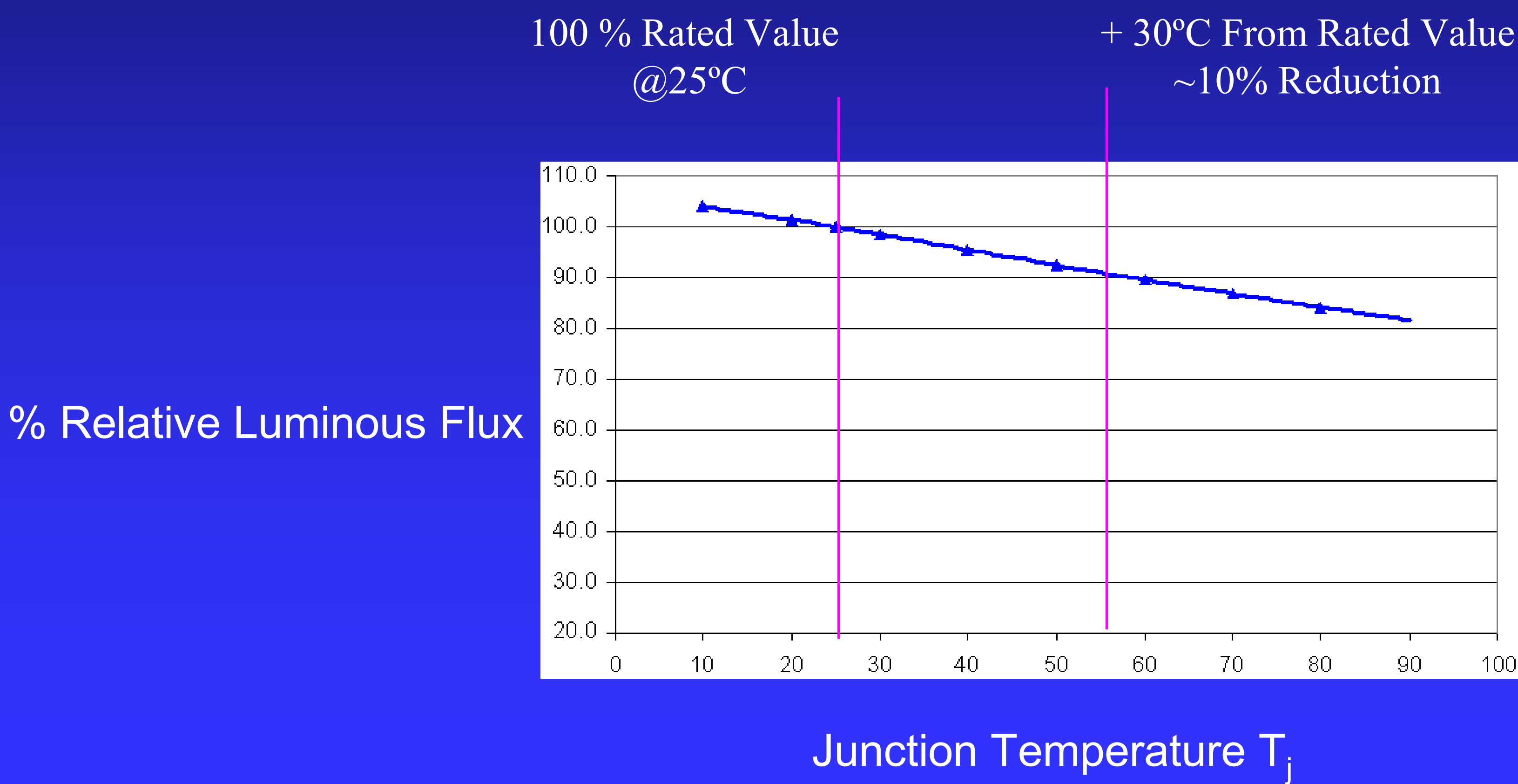
Basic System Comparison

- 100 Lumen/Watt Metal Halide
- 97 Lumen/Watt LED



HB White LED
Relative Initial Source Efficacy

- At Constant Time and Drive Current
  - Junction Temperature (T_j) Varies



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Total Systems Approach

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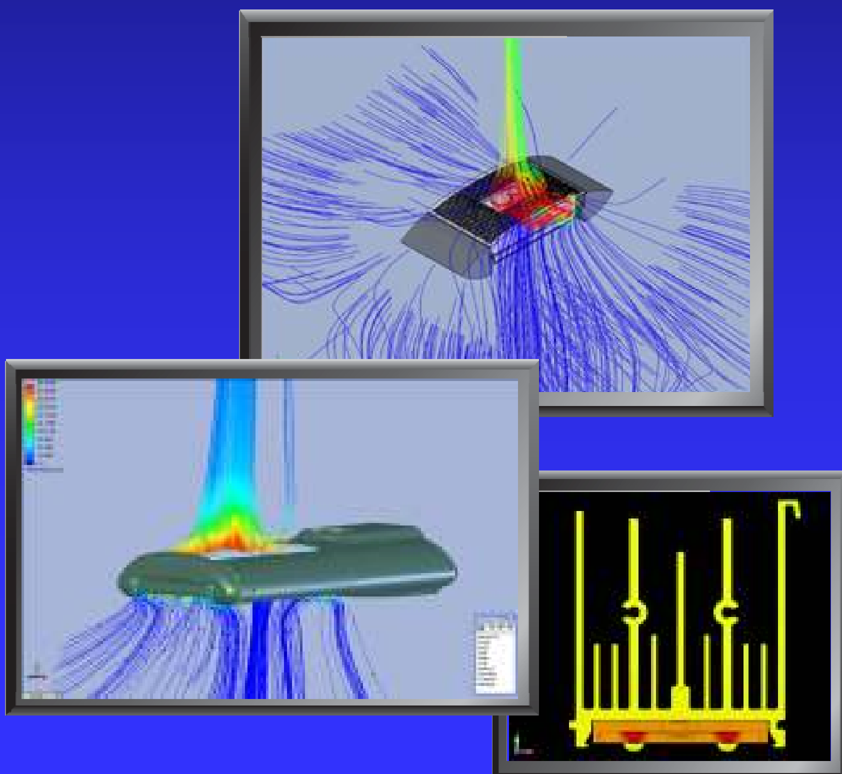
Optimizing Integration for Luminaire Design and Applications

Thermal Management



Optical Control

Thermal Management

- Goal
  - Maximize Light Extraction From LED Package
  - Minimize Lumen Depreciation
    - Maximize Lumen Maintenance

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Optical Control

- Goal
  - Maximize Target Lighting Performance

What is L_{70}?

- As it Applies to LED Luminaires
  - L_{70} defines a time duration, in hours, to which an LED luminaire reaches 70% of it's initial output.
  - Defines End of Life for the LED Luminaire
    - The DOE, IESNA and others have reached consensus on this

What Affects L_{70} Values?

- LED Junction Temperature
- LED Drive Current
  - For Beta Luminaires
    - 350 mA, 525 mA, 700mA
      (175 mA for 2 – Level Low Mode)

The L_{70} value is routinely quoted to answer the question "What is your LED product life?"

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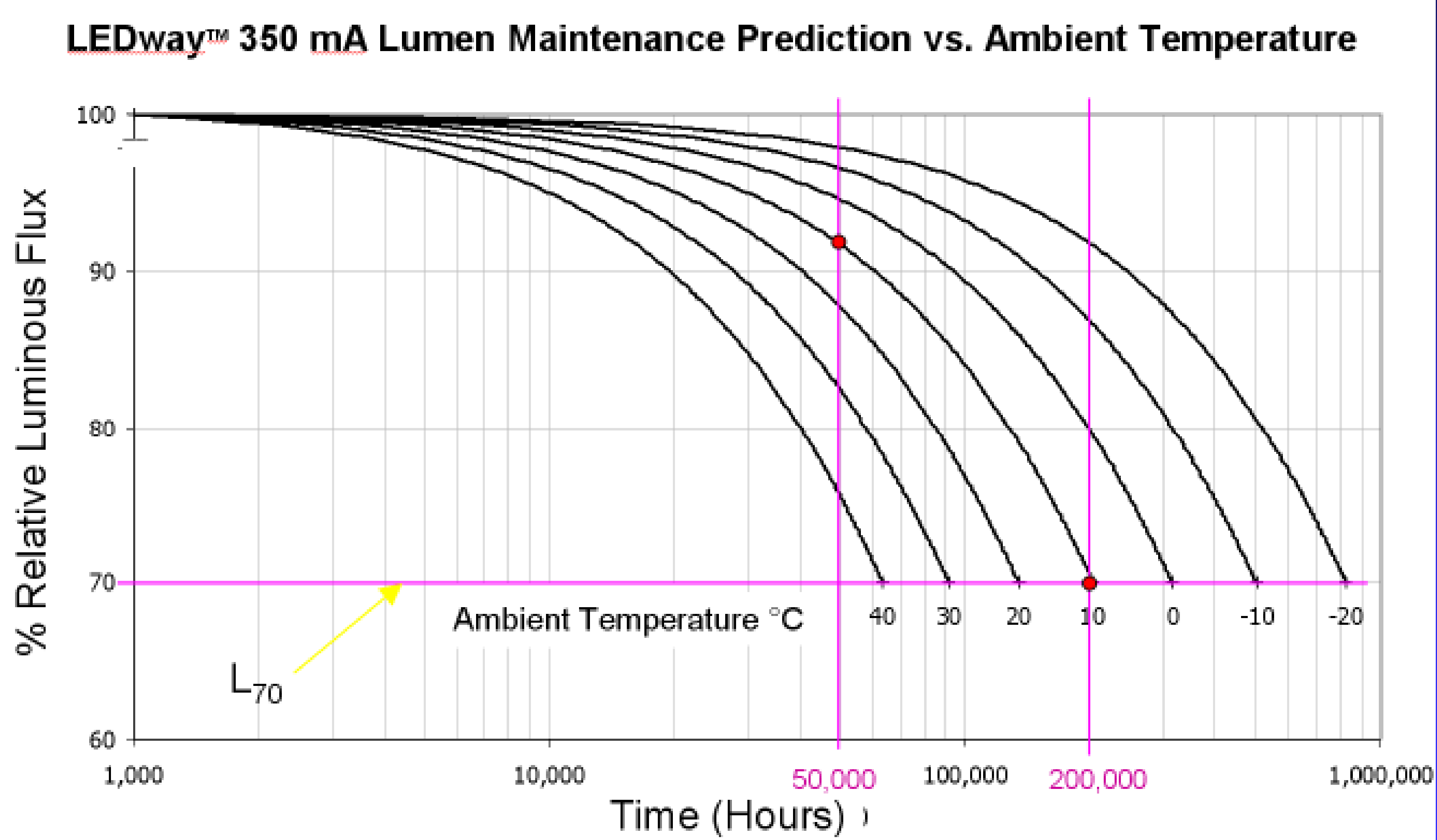
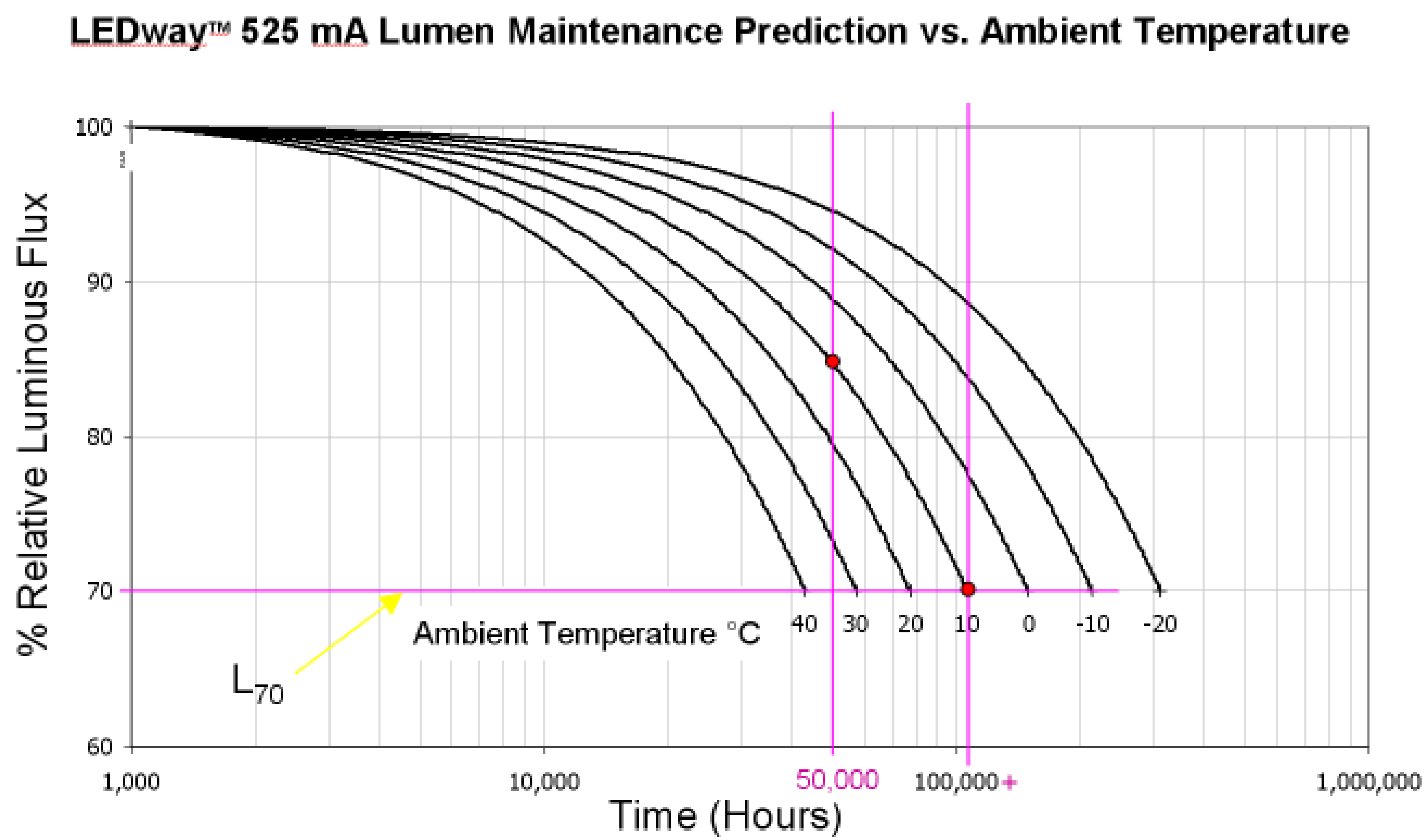
Derived Lumen Depreciation Data

(From LED Manufactures LM-80 Data)



Derived Lumen Depreciation Data

(From LED Manufactures LM-80 Data)



Optical Control

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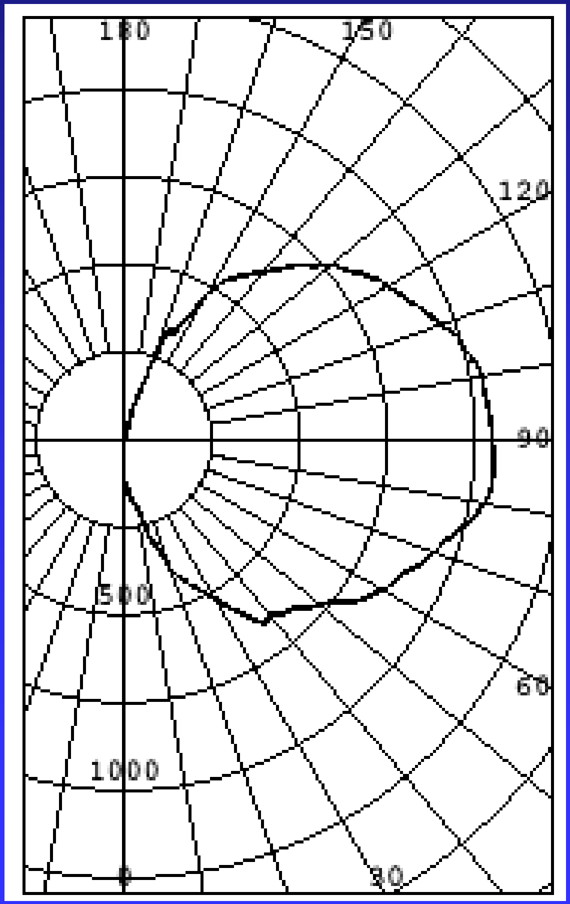
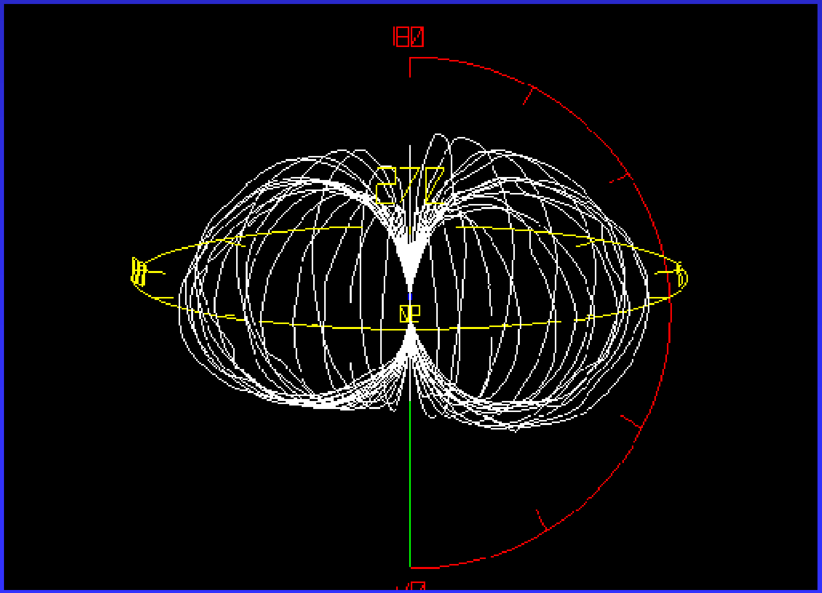
HID Bare Source Photometry

Commercially Available MH Lamp
Polar Candela Plot





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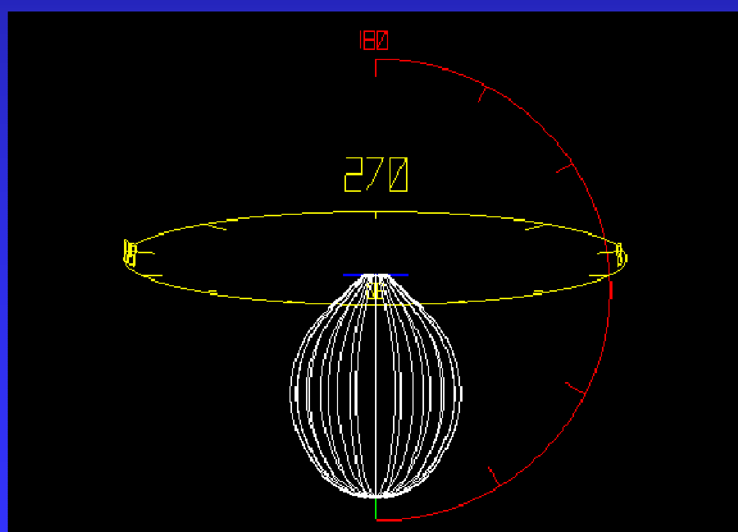
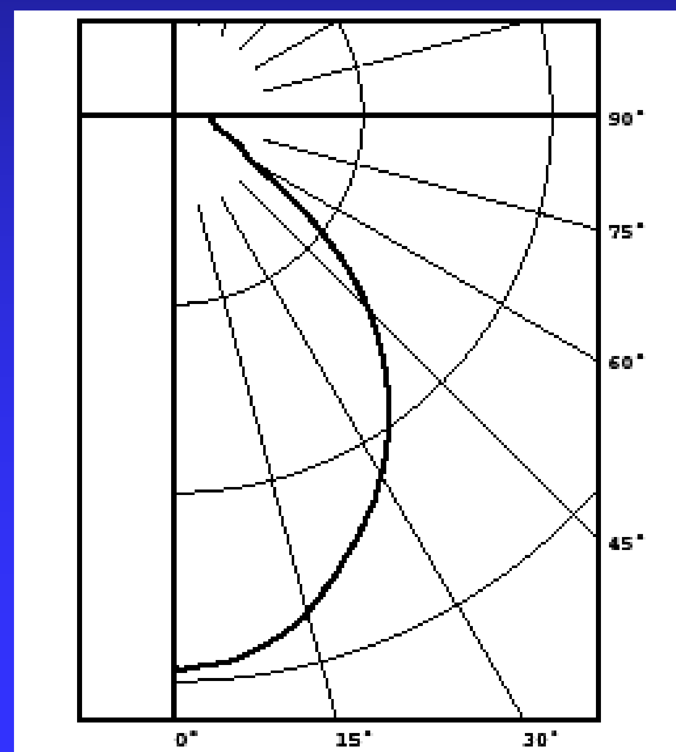
LED Bare Source Photometry



Commercially Available HB
White LED
Polar Candela Plot



LED

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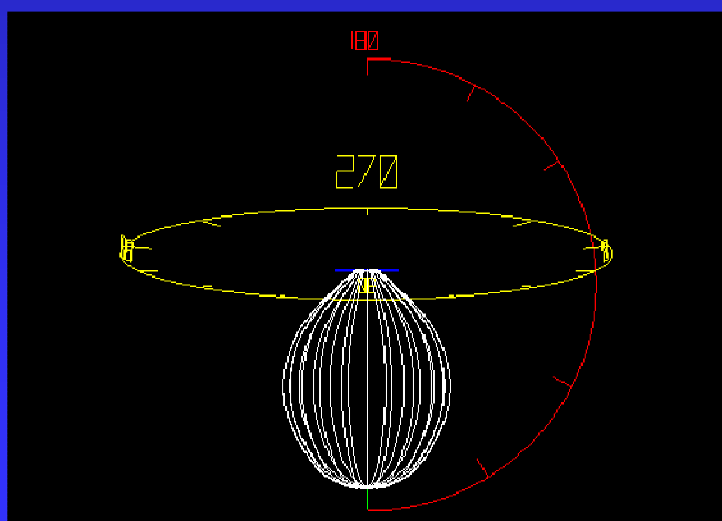
Optical Control

Bare LED Package Illustration



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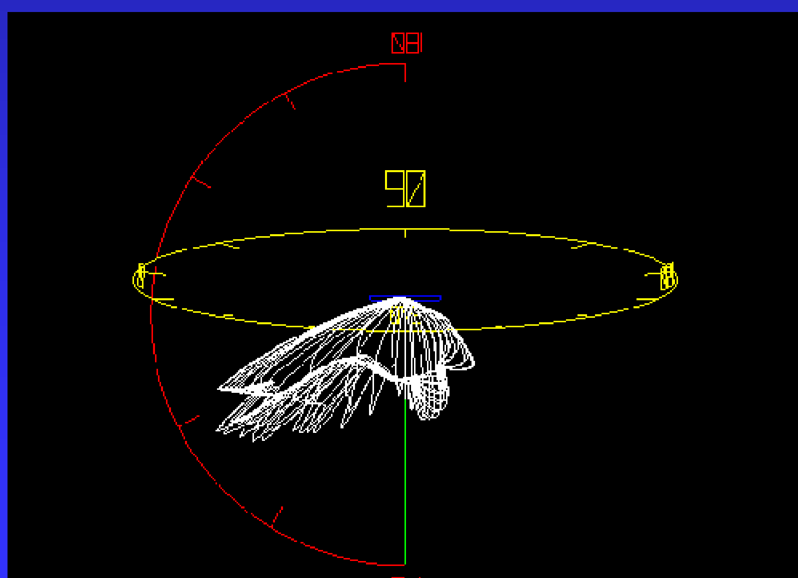
Optical Control

Illustration of Altered Distribution (Secondary Optic Added)



Dramatically Improved Uniformity

Alternate Optical control Methods For LEDs

- Reflection
  - Disadvantages
    - Full Reflection Method
      - Emitter assembly (i.e. LED Chip Package) becomes an obstruction to reflected light
      - Challenges in providing power to LEDs
      - Thermal management challenges
    - Partial Reflection Method
      - significant portion of the light is delivered direct from the LED (uncontrolled)
      - Secondary lens requirement

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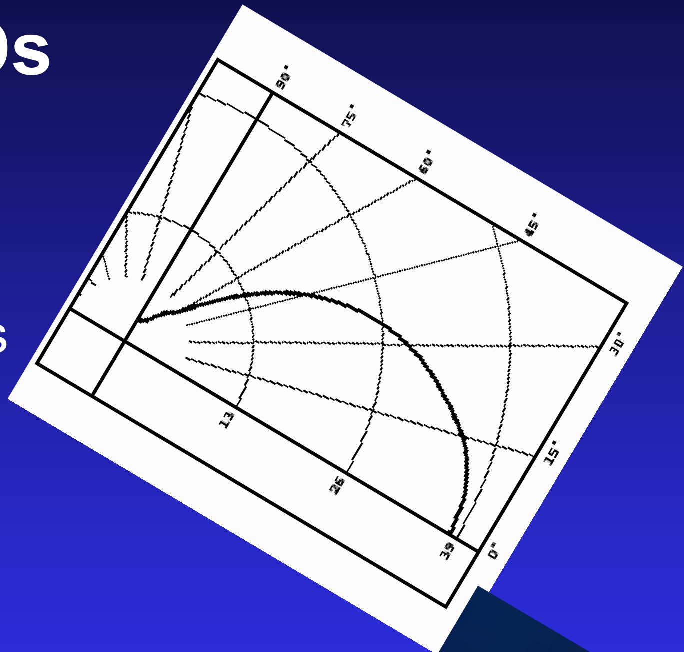
Alternate Optical control Methods For LEDs

- Aiming
  - Creating required distribution by aiming packaged LEDs at various angles for desired performance.
    - Disadvantages
      - Light spill at high angles
      - Light spill at low angles
      - Difficult to provide scalar output with no change to distribution



Mechanical Life

- Load Testing
  - Vibration Testing to 1g Infinite Fatigue Life
- Marine Grade Low Copper Aluminum
- DeltaGuard Finish
  - Accelerated Salt Fog Testing to 5000 hrs.
  - South Florida Sun Exposure Testing
- Backed by a 10 Year Finish Warranty

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Mechanical Integrity & Performance

- Colorfast DeltaGuard® Finish
  - Accelerated Salt Fog Testing to 5,000+ hours

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Environmental Ratings
Ingress Protection (IP)

Dust / Water / Impact
- Higher Value = Higher Resistance

- IP 65 Protected against dust, low pressure jets if water from all directions - limited ingress permitted
- **IP 66 Protected against dust and strong jets of water e.g. for use on ship decks**
- IP 67 Protected against dust and the effects of temporary immersion between 15cm and 1m. Duration of test 30 minutes

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Power Systems

HID Magnetic Ballasts

LED Drivers

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What is an LED driver/power supply and how does it differ from a transformer or ballast?

- A ballast is the power supply for fluorescent, compact fluorescent and HID light sources.
- A transformer is the power supply for incandescent, halogen and neon.
- A driver is a constant current supply for LED loads
  - Constant Current is the simplest and most efficient solution. Primarily series wired LEDs.

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Class I vs. Class II Drivers

- Class I Drivers
  - Advantages
    - Higher Efficiency at Higher Power Demands
    - Higher Power Limits (no practical limit)
      - Less Drivers for Desired Output
        - » Cost / performance optimized
- Class II Drivers
  - Advantages
    - Construction Method Simplicity (UL requirements)
        - » Cost / performance optimized
  - Disadvantages
    - 100W Power Limit
    - Efficiency Challenges

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LED Driver Advantages

- Power Regulation (near perfect)
- Input Voltage Range
- High Efficiency Possibilities
- Protection
- Life
- Control Possibilities
  - Photo Control
  - Occupancy Control
  - Dimming
  - Step, Continuous (0-10V, etc.)
  - Wireless
  - Power Line Carrier
  - Etc.

Driver Life….

- For all outdoor applications (22ºC average Ambient or less), the expected failure rate of the driver is less than 0.5% at 150,000 hours.

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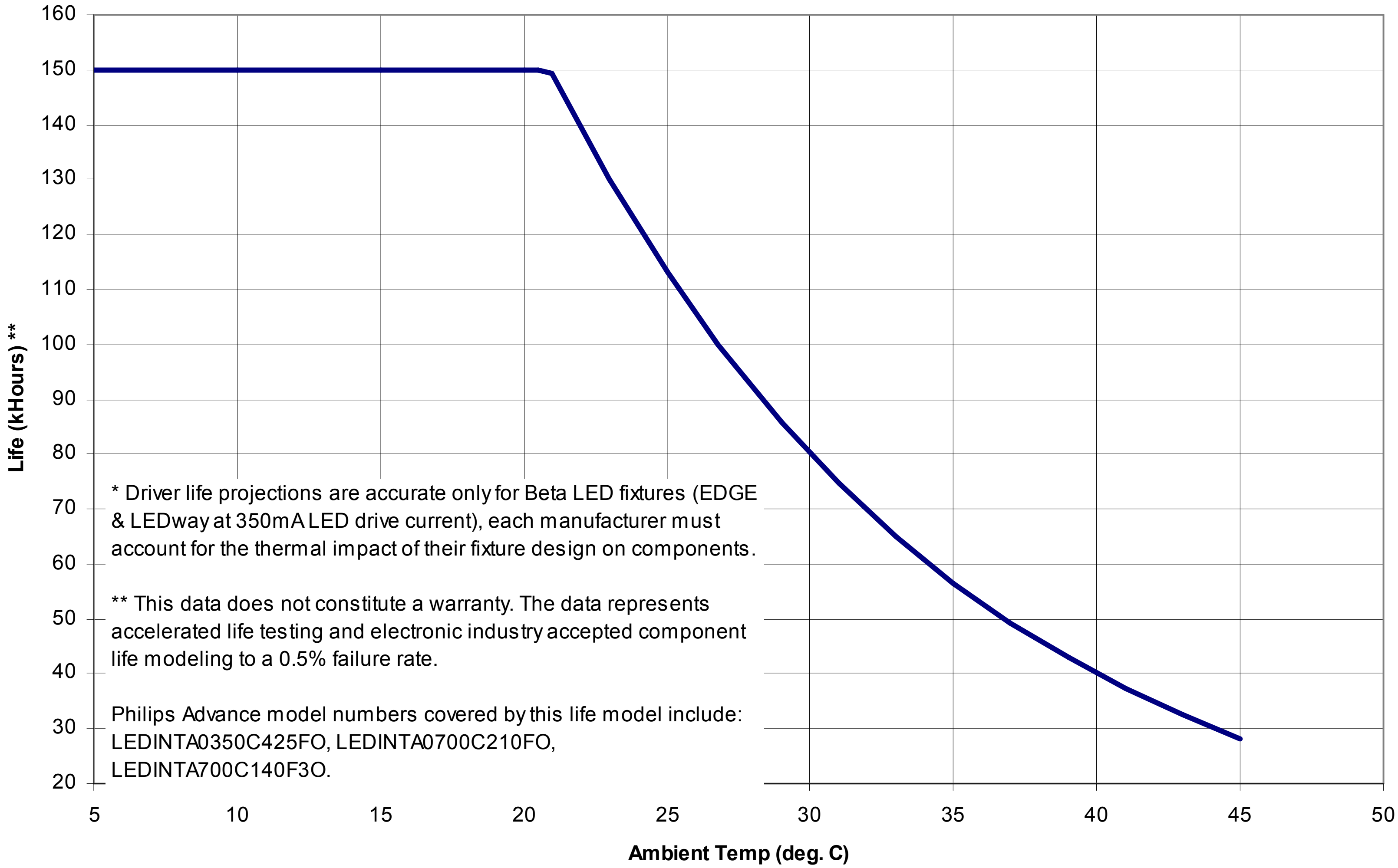
Driver Life/Reliability

Data Approved for Use By Advance

Beta LED / Philips Advance Driver Life Projections *



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LED System Reliability

LED Failure Rates

- 3 or more LED failures in a fixture constitutes a failed product.

  (Assume 50 LEDs per Fixture)

  – Probability at 10,000 Hours = 1 in 1.25E-10
  – Probability at 25,000 Hours = 1 in 1.95E-9
  – Probability at 50,000 Hours = 1 in 1.56E-8
  – Probability at 100,000 Hours = 1 in 1.25E-7

  At 250,000 Hours **=** 1 in 1 Million (1 in 1.0 E-6)
- One LED failure does not take out the others in the string.
- The remaining LEDs in the string are proportionately over driven (~5-10%) to compensate for the lost LED

Application Performance Comparisons

Beta LED

- Data
- Standards

LED Photometric Performance Measurement

- Initial Photometric Performance
  - IESNA **LM-79** Testing Standard (early 2008)
    - Approved Method: Electrical and Photometric Measurements of Solid-State Lighting Products
      - Requires Absolute Photometry Methods
    - IES Data File
    - All Beta LED IES files comply with LM-79

Accounting for LED Luminaire Lumen Depreciation

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LED Luminaire Lumen Depreciation

- Lumen Maintenance Performance Testing Standard
  - IESNA **LM-80** (late 2008)
    - Approved Method: Measuring Lumen Maintenance of LED Light Sources
    - LED Package Level Test and Measurement
      - Lumen depreciation prediction based on LED Junction Temperature (T_J)
      - Multiple T_J data sets available from LED manufacturers
      - Luminaire manufactures can accurately correlate "in fixture" LED performance to LED manufacturers data

What is Needed for a Fair Comparison?

1. Side-by-Side Performance Evaluation
   - At the Application Level !!!

2. Certified Photometric Report From an Independent Testing Agency
   - LED System (per IESNA LM-79)
   - Competing Systems (per appropriate IESNA Standards)

3. Life Data (Lumen Depreciation Value) for the LED System
   - Supported by IESNA LM-80
     - Based On the Life of the Application
     - L_{70} = end of life limit (Do not use a 0.7 Light Loss Factor Universally)

4. Appropriate Maintenance Factors/Light Loss Factors for the Competing Systems

5. Cost/Value Analysis
     - Lighting Performance, Total Power Consumption, Maintenance, etc.

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Five Tips for a Fair Comparison of LED Luminaires

1 Compare Performance at the Application Level

Conduct "in field" application level performance evaluations using IESNA recommended practices and standards.

Utilize the best available design software and application engineering practices to predict application level performance.

Evaluate relevant and credible case studies such as the Department of Energy's CALiPER and GATEWAY programs.

2 Request Certified Photometric Data

Make sure the LED luminaire manufacturer provides a certified photometric report (per IESNA LM-79) from an approved DOE lab to validate the manufacturer's photometric performance claims.

3 Validate Lumen Depreciation

Obtain lumen depreciation (life) data for the LED luminaire supported by the LED chip manufacturer's IESNA LM-80 test data that is directly correlated to luminaire level performance.

4 Apply the Appropriate Light Loss Factors

An accurate application comparison must account for the light levels at the end of the application life. Using the manufacturer's LED luminaire lumen depreciation data, apply the correct light loss factor to the application.

For example, a typical outdoor dusk-to-dawn application may be evaluated at a 50,000 hour (~11 - 12 year) application life. Based on this example, you would conduct an evaluation based on each manufacturer's 50,000 hour lumen depreciation values.

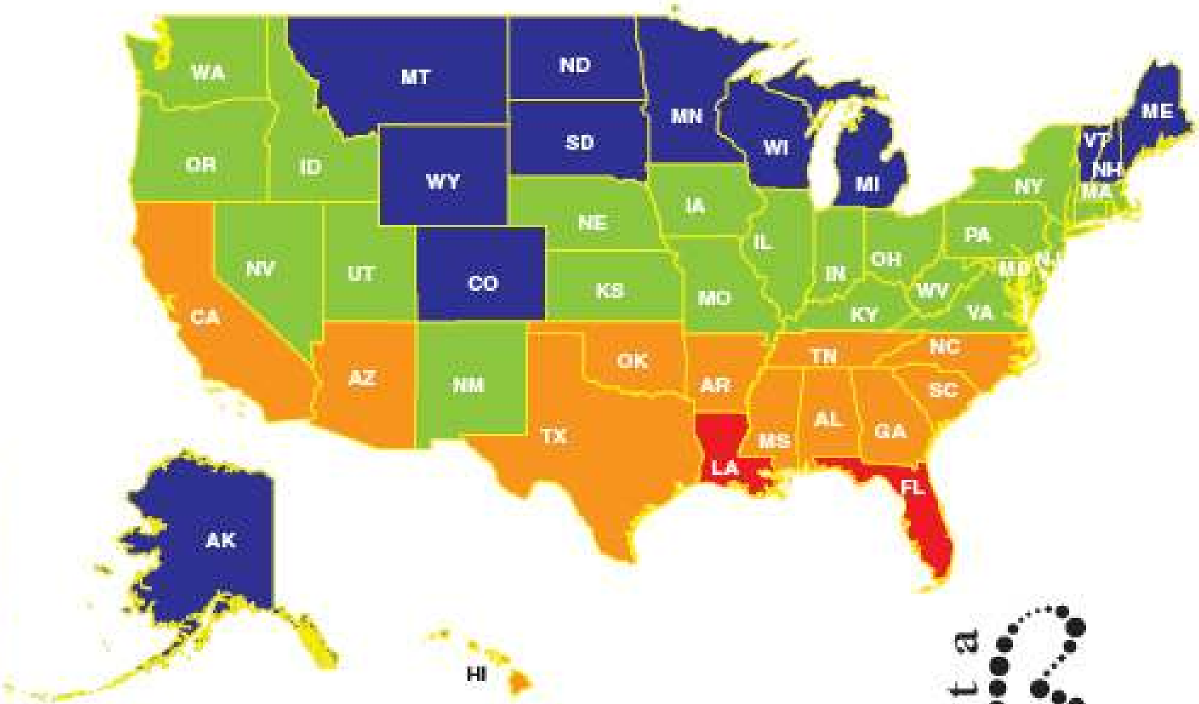
5 Evaluate Lifetime Luminaire Value

Analyze initial investment versus lifetime value by considering all LED fixture benefits such as lighting performance, total power consumption, maintenance and warranty. The entire luminaire must be built to last for the length of the application life.

These Five Tips are a starting point for you to better understand LED comparisons. We know it can be confusing, especially when you add in unique market application variables. Please contact us for guidance in understanding and implementing the tips, regardless of manufacturer or brand. We can be reached at (800) 236-6800 or sales@betaled.com.

www.BetaLED.com/CompareLEDs

Recommended BetaLED® Lumen Depreciation (LD) Factors



Zone*	Drive Current (mA)	Initial LD	25K hr LD	50K hr LD	100K hr LD
5°C (41°F)	350mA	1.05	1.02	0.98	0.92
	525mA	1.05	0.97	0.89	0.76
	700mA	1.05	0.91	0.77	0.57
10°C (50°F)	350mA	1.04	1.00	0.95	0.88
	525mA	1.04	0.95	0.86	0.71
	700mA	1.04	0.88	0.74	0.52
15°C (59°F)	350mA	1.03	0.98	0.93	0.83
	525mA	1.03	0.92	0.82	0.65
	700mA	1.03	0.85	0.70	0.48
20°C (68°F)	350mA	1.01	0.95	0.90	0.78
	525mA	1.01	0.89	0.78	0.60
	700mA	1.01	0.83	0.66	0.43
25°C (77°F)	350mA	1.00	0.93	0.86	0.73
	525mA	1.00	0.86	0.74	0.54
	700mA	1.00	0.79	0.63	0.39

*Average Nighttime Temperature

Use the LD values in this chart when performing lighting calculations for BetaLED products ONLY.

Rev. B Expires: 9/09

beta LED®

THE EDGE

LEDway™ STREETLIGHTS

DOE Commercial Product Testing

CALiPER

Beta LED

U.S. Department of Energy
Energy Efficiency and Renewable Energy

www.ssl.energy.gov/caliper.html

CALiPER: Commercially Available LED Product Evaluation and Reporting

- Anonymous testing of commercially-available products
- Product selection based on expected performance, visibility, market impacts, and specific design characteristics
- Tests include efficacy, color temperature, illumination pattern, lumen depreciation (for some products), etc.
- Official DOE reports issued on each product and downloadable from the SSL website
- Testing program initiated in Aug 06; >100 products tested to date (7/15/2008)

Bruce Kinzey
August 6, 2008

Beta LED

Department of Energy (DOE)
SSL Product Technology Demonstration Program

a.k.a. GATEWAY Demonstration Program

www.ssl.energy.gov/gatewaydemos.html

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DOE GATEWAY Program

U.S. Department of Energy
Energy Efficiency and Renewable Energy

www.ssl.energy.gov/gatewaydemos.html

DOE GATEWAY Demonstration Program

- Current situation and lack of field experience complicates investment decisions in SSL technology.
- GATEWAY provides case studies of tested, high-performance SSL products in real world applications.
- Purpose is to demonstrate new SSL products that:
  - save energy
  - match or improve lighting quality
  - are cost effective for the user

Bruce Kinzey
August 6, 2008

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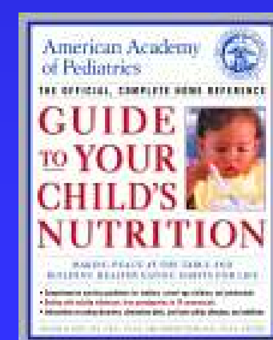
Hg: a Persistent, Bioaccumulative Neurotoxin(1)



http://www.state.nj.us/dep/dsr/research/mercury-bulbs.pdf

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Effects of Mercury on the Environment

One teaspoon of mercury can contaminate a 20 acre lake forever *.

Each year, an estimated 600 million fluorescent lamps are disposed of in U.S. landfills amounting to 30,000 pounds of mercury waste.*

The mercury from one fluorescent bulb can pollute 6,000 gallons of water beyond safe drinking levels.*

* www.lightbulbrecycling.com

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Mercury Content by Traditional Lamp Type

Lamp Type	mg per Lamp Min	mg per Lamp Max	Lamps/ Fixture	Mg/Fixt. Max	Rated Life (10k hrs)	EOL Fixt. 10k lum.	mg/RL/ 10k lum
160W Induction	**8**	**18**	**2**	**36**	**10**	**1,44**	**2,50**
F540 T5HO	**1,4**	**5**	**4**	**20**	**2,4**	**1,86**	**4,48**
400W Ceramic PS MH	**12**	**35**	**1**	**35**	**2**	**3,2**	**5,47**
F32 T8	**3,5**	**8**	**6**	**48**	**2,8**	**1,968**	**8,71**
250W Cer. PS MH	**15**	**25**	**1**	**25**	**1,5**	**1,92**	**8,68**
42W CFL	**2,7**	**5**	**8**	**40**	**1,4**	**2,56**	**11,16**
400W Quartz PS MH	**50**	**70**	**1**	**70**	**2**	**2,975**	**11,76**
250W Quartz PS MH	**34**	**41**	**1**	**41**	**1,5**	**1,645**	**16,62**
400W Std. MH	**50**	**70**	**1**	**70**	**2**	**1,71**	**20,47**
250W Std. MH	**34**	**41**	**1**	**41**	**1**	**0,95**	**43,16**

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Either Way, Lighting Generates Lots of Dangerous Hg Waste…Little is Safely Disposed of…

	Typical Hg Content (mg/lamp)	Lamps per year (2009, EMEA)	Mercury per year (kgs)	Kg of Mercury/yr released in EU if xx% are recycled					
				30%	20%	10%	5%	2%	1%
Incandescent 	0	2,814,952,558	0	0	0	0	0	0	0
Halogen 	0	411,929,619	0	0	0	0	0	0	0
Compact Fluorescent 	3.9	1,225,940,728	4,743	3,320	3,794	4,269	4,506	4,648	4,696
Linear Fluorescent 	5	765,504,870	3,828	2,679	3,062	3,445	3,636	3,751	3,789
HID 	35	102,602,193	3,591	2,514	2,873	3,232	3,412	3,519	3,555
	Total (kgs/year):		**12,162**	**8,513**	**9,729**	**10,945**	**11,554**	**11,918**	**12,040**

"If CFLs are not recycled properly, up to 25 per cent of the mercury contained in CFLs could be released into the atmosphere, [through] Bulb breakage during transport, vaporisation during incineration [and] evaporation from landfills. … For the EU, the study reports a mercury distribution factor, stating that 9.2 per cent of mercury contained in CFLs is eventually emitted to the atmosphere. "

http://ec.europa.eu/environment/integration/research/newsalert/pdf/129na1.pdf

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Thank You