LED Lighting - State of the Art

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Customer Expectations for LED Lighting

• **Energy Savings**
  – Good Rule of Thumb – 40% to 60% Savings Typical When Replacing Incumbent High Efficiency Technologies
    • Metal Halide
    • High Pressure Sodium
    • Fluorescent
  – Much Higher Savings When Replacing any Type of Incandescent or Halogen Technology
    • 60% to 90% Energy Reduction Depending Upon the Application

• **Long Life**
  – Expectation of at Least 50,000 Operating Hours in Most Applications
Thermal Management

• Goal
  – Maximize Light Extraction From LED Package
  – Maximize Lumen Maintenance
    • Minimize Lumen Depreciation
Thermal Management

- Heat kills LEDs
  - Minimal IR, heat must be conducted away
- LED junction temperature must be kept below manufacturer specified levels to achieve long life
- An integrated thermal management approach is required
  - Every thermal interface must be considered and optimized
Step #1 - continued

Lumen Maintenance Factors Must Be Applied!

BetaLED provides Lumen Maintenance Factors in a user-friendly format in its TD-13 Document.
Optical Control
HID Bare Source Photometry

Commercially Available MH Lamp
Polar Candela Plot
LED Bare Source Photometry

Commercially Available HB White LED Polar Candela Plot
Optical Control

Bare LED Package Illustration
Optical Control

Illustration of Altered Distribution (Secondary Optic Added)
Dramatically Improved Uniformity
Optimizing the Specification Process...
Application Efficacy

• Meeting the **Maintained** Lighting Performance Requirements With:
  – Lower Lighting Power Density
    • Higher Lumens/Watt on the Application Target

  …**Maintained**

Light Loss Factors Must be Applied
Lowest In-Service Lighting Performance Threshold
Essential Elements

A Specification Development Process That:

1. Defines the Required Sustainable Illumination Performance

2. Defines the Required Sustainable (Risk Managed) Economic Performance
   - Life Cycle Cost Analysis Elements/Variables
     - Evaluation Timeframe / Desired Application Life
     - Product Durability Performance Requirements
     - Standards Compliance / Reliability / Warranty
     - Etc.
Step #1

**Always!**

Establish the Required **Maintained** Illumination Performance Requirements

- Lighting Performance Specification
  - Vertical and Horizontal Illumination Requirements
  - Uniformity
  - Color Quality
  - Light trespass
  - Glare Metrics...
  - Etc.
Illumination Performance

Define the Variables:

- Define the Lighting Application Geometric Target(s)
  - Boundaries
- Luminaire Position Constraints
  - New vs. Retrofit
- Service Life (i.e. Application Life)
  - Years of Expected Near Maintenance Free Operation (i.e. Hours of Operation)
  - Required Economic Assessment Period (5 - 15 yrs...?)

Lumen Maintenance Factors Must Be Applied!
Required Product Characteristics “Must Haves”

- Designed to mount on 1.25” IP (1.66” O.D.) and/or 2” IP (2.375” O.D.) horizontal tenon
- Adjustable Horizontal tenon mounting capable of (+/- 5 Degrees) in 2.5° vertical increments
- Finish Color shall be silver
- Luminaire EPA shall not exceed 0.90 / maximum weight not to exceed 30 LBS
- Meets Buy American requirements within the ARRA
- UL Listed for Wet Locations
- RoHS Compliant
- Meets CALTrans 611 Vibration Testing Requirements
Required Product Characteristics

“Must Haves”

• Driver: UL Listed, Power Factor > 90% and THD < 20% at full load; Complies with FCC rules and regulations, Title 47 CFR Part 15 Non-Consumer (Class A), 100,000 hours expected life (≤ 0.5% failure at 100,000 hours of operation in 25°C ambient).

• Integral 10kV Surge Protection
  – Tested in Accordance With IEEE/ANSI C62.41

• Exposed hardware shall be Stainless Steel

• Light Engine must meet IP66 requirements

• Serviceable and upgradable light engine

• Passive thermal management (heat sink)
Step #2 - continued

Required Product Characteristics “Must Haves”

• International Dark-Sky Association (IDA) approved
• Suitable to operate in -40°C to +40°C ambient environments
• Minimum 5 year Luminaire Warranty
• Minimum 10 year Finish Warranty
  – Luminaire and finish endurance tested to withstand 5,000 hours of elevated ambient salt fog conditions as defined in ATSM Standard B 117 testing standard
  – Greater than 90% Gloss Retention per ASTM G154 (UV Exposure Test)
• Etc.
Optional Product Characteristics

“Nice Haves”

• Manufactured in an ISO9001 facility
• Tool-less Entry
• Minimum 70% recyclable content (by weight)
• Scalable: Luminous increments of no more than???
• Field selectable/adjustable drive current (range???)
• Leveling Indicator
• Power supply quick disconnect harness(s) suitable for mate-and-break under load on power feed
• Minimum XX years LED luminaire manufacturing experience and XX installed LED projects (XX References Required)
• Etc.
Do **NOT** Specify Product Performance Variables That Directly or Indirectly Affect Illumination Performance

For Example:

- Total Luminaire Efficacy
- Optical Efficiency
- Driver Efficiency
- Specific Lumen Maintenance (i.e. 80% at 50,000 hours)
- A Specific $L_{70}$ Value (i.e. 50,000 hours)
  - $L_{70}$ Limits are OK
- Specific IES Types (Type I, II, III, IV, V)
- Etc.
Other Economic Variables
Outside the Scope of the Spec

• Energy Costs
• Maintenance Costs
• Cost of Capital
• Etc.
A Specification Development Process That:

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     - Etc.
LED Exterior Lighting Applications
How Does LED Performance Compare to Incumbent Lighting Technologies?
LED Comparison to Incumbent Technologies

Pseudo Color Renderings

High Pressure Sodium

Metal Halide

Induction

LED

Cree – 35th WEEC – Bob Roller - 11-1-2012

CONFIDENTIAL - Cree Proprietary
LED Comparison to Incumbent Technologies

Luminaire Schedule

<table>
<thead>
<tr>
<th>Technology</th>
<th>Number of Poles</th>
<th>Number of Fixtures</th>
<th>Arrangement</th>
<th>Lamp Lumens</th>
<th>LLF</th>
<th>Total Watts</th>
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<tbody>
<tr>
<td>High Pressure Sodium</td>
<td>10</td>
<td>20</td>
<td>Back to Back @ 90°</td>
<td>51000</td>
<td>.88</td>
<td>9200</td>
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<tr>
<td>Induction</td>
<td>15</td>
<td>60</td>
<td>4 per pole</td>
<td>11000</td>
<td>.70</td>
<td>8820</td>
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<tr>
<td>Metal Halide</td>
<td>10</td>
<td>20</td>
<td>Back to Back @ 90°</td>
<td>33100</td>
<td>.67</td>
<td>9100</td>
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<tr>
<td>LED</td>
<td>10</td>
<td>20</td>
<td>Back to Back @ 90°</td>
<td>10178</td>
<td>.91</td>
<td><strong>2780</strong></td>
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</table>
## LED Comparison to Incumbent Technologies

### Illuminance Calculation Results

<table>
<thead>
<tr>
<th>Technology</th>
<th>Units</th>
<th>Average</th>
<th>Max Fc</th>
<th>Min Fc</th>
<th>Avg/Min Ratio</th>
<th>Max/Min Ratio</th>
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<tbody>
<tr>
<td>HPS</td>
<td>Fc</td>
<td>4.34</td>
<td>9.1</td>
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<td>Fc</td>
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<td>Fc</td>
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<td>Fc</td>
<td>1.13</td>
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<td>0.6</td>
<td>2.26</td>
<td>3.2</td>
</tr>
</tbody>
</table>

LED Light Levels calculated at Grade using predicted lumens after 50K hours assuming a 10°C average night time temperature. MH and HPS light levels calculated at grade using mean lumens. Induction light levels calculated at grade using lumens at 60 K hours.
The Bottom Line

• 70% less energy than HPS
• 68% less energy than Induction
• 69% less energy than Metal Halide

AND...

A Superior Lighting Project with an Average to Minimum Ratio of only 2.26
Cub Foods Parking Lot, Minneapolis, MN
George Mason University, Fairfax, VA
North Star Commuter Rail, Minneapolis, MN
Floodlighting Application
Security Lighting Application
Petroleum Station Canopy Application

HID

BetaLED

30% Energy Savings
Petroleum Canopy, Hamburg, Germany
LED Parking Structure Duke University
Milwaukee Technical College - Wisconsin
Street Lighting, Los Angeles, CA
LED Products For Interior Lighting Applications
Innovation

- LR6 has been in the market 2 years longer than any other credible LED downlight
  - Millions sold
  - Tremendous amounts of data gathered
  - Lessons learned....
Cree TrueWhite® Technology

- A unique way to generate white light with LEDs
  - Proprietary mix of unsaturated yellow (blue + phosphor) and red
  - Color management (thermistor)
- High CRI and high Efficacy
  - 110 LPW at 90 CRI
  - 80 LPW at 94 CRI
- Each product is optimized before shipment by sophisticated tuning equip.
- Color maintained over time and temperature
  - Thermistor (all)
  - Optical sensor (some)
Cree TrueWhite® Technology

Yellow/Green + Red = Cree TrueWhite Technology
Color Quality: Cree TrueWhite

- Non-white PC LED (BSY) and add red LED
  - Very good efficacy (100LPW)
  - Most suitable for WW CCT ~2700K
  - High CRI (>90 Ra)
  - Some control requirements
  - Color mixing at fixture level
FIRST LOOK…Computer Lab Before (2400W)
FIRST LOOK – Computer Lab After (640W)
Hotel Installations
RESTAURANTS

The place for Smiles

est. 2010
Residential Installations
CR24: systems level approach

High Efficiency Mixing Chamber
Uniform, low brightness lens

Next Generation Driver
Reduced Cost, Increased Efficiency

One Piece Reflector
Creates Quiet Ceiling

Cree TrueWhite® Technology
Beautiful Consistent Color

Room-side Heat Sink
Maximized cooling effectiveness
**Controls Options**

- **S = Step Dimming 50% - Standard / Available Now**

  The “S” option is for Step Dimming 50%. This option allows the luminaire to deliver either 100% light output (both switches ON), 50% light output (either switch ON and the other OFF) or 0% light output (both switches in the OFF position). It could also be named *Step Switching 50%*, because it does not actually require a dimmer, just (2) common, every day toggle switches or occupancy sensors.

![Wiring Diagram](image)

*Note: Line (HOT) inputs must be connected to the same phase of the line voltage.*

- **10V = 0-10V dimming optional**
Power Supply

Power Supply efficiency

- 12W product with a 75% efficient power supply generates 3W worth of heat in the power supply compartment

- 12W product with an 88% efficient power supply generates 1.5W worth of heat in the power supply compartment

The power supply is just as important to the life of the fixture as the LEDs
Thank You

Questions, Comments???