Apple and Oranges
Comparing LED and HID Roadway Lights

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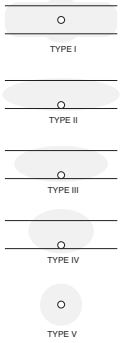
HID "Cobra Head" Luminaires

- Primarily high pressure sodium (HPS),
- Available in fixed wattages, i.e. 100W, 250W, 400W.
- Available in fixed lighting patterns, e.g. Type II, Type III, Type V
- Available from established manufacturers like GE, AEL, Cooper Lighting, etc.
- HID lighting is a mature technology.
- HPS street lights are a commodity item.
- 3-4 min. start up, 1-3 min. restrike.
- HPS lamps contain mercury. Must be disposed of as hazardous waste.



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HID "Cobra Head" Luminaires

- Conforms to ANSI C136.14-2004, *American National Standard for Roadway and Area Lighting Equipment — Elliptically Shaped, Enclosed Side-Mounted Luminaires for Horizontal-burning High-intensity Discharge Lamps.*
- Within a particular lamp wattage and lighting pattern, luminaires built to C136.14 will be interchangeable.
- ANSI C136.17 covers interchangeability of refractors.
- ANSI C136.10 covers interchangeability of photocontrols.

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LED Roadway Luminaires

- New to the market, < 5 years.
- Promise higher efficacy and lower maintenance than HPS.
- There is no fixed wattage designation; wattage depends on #LED's and drive current.
- As newer, more efficient LED chips are introduced, the luminaire manufacturers are re-designing their fixtures.
- Offer very precise control over lighting patterns.
- Too many manufacturers to count.
- New ANSI standard C136.37-2011 — *Solid State Light Sources Used in Roadway and Area Lighting*

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Photometric Testing

SSL (Solid State Luminaires) tested per IESNA LM-79-08

- Total Luminous Flux (lumens)
- Luminous Efficacy (lm/W)
- Chromaticity, Correlated Color Temperature (CCT), Color Rendering Index (CRI)
- Luminous Flux Distribution
- Isofootcandle Curves
- BUG Rating
- Output from LM-79 test includes test report and .ies file.
- Absolute Photometry
  - LED chips and fixture tested as a unit
  - Referenced to a calibrated standard lamp

Relative Photometry

- HID fixtures are tested using "relative" photometry (fixture is measure, then lamp and ballast are removed and measured).

HPS vs. LED Efficacy

- Luminous Efficacy — measure of light output/input power (lm/W)
- Source Efficacy — efficacy of bare lamp at room temperature
- HPS Source Efficacy ~ 120 lm/W
- LED Source Efficacy ~ 130 lm/W
- 100W HPS Source Efficacy = 9500 lm/133 W = 71 lm/W
- 100W HPS Fixture Efficacy = 71 lm/W x 74% fixture eff. = 53 lm/W
- 66W LED Fixture Efficacy = 5037 lm /66 W = 76 lm/W
- HPS DSS[1] ~ 43%, DHS[2] ~ 31%, Light Loss ~ 26%
- LED DSS[1] % ~ 67%, DHS[2] ~ 33%, Light Loss ~ 0%
- HPS DOE FTE[3] ~ 35 lm/W
- LED DOE FTE[3] ~ 50 lm/W

[1] Downward Street Side (DSS)
[2] Downward House Side (DHS)
[3] Fitted Target Efficacy (FTE) — See http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/fte_performance_metric.pdf

LED Efficacy

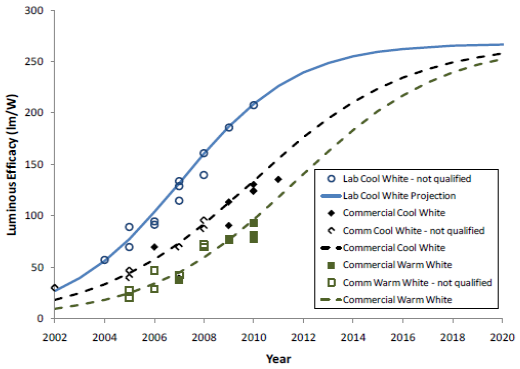
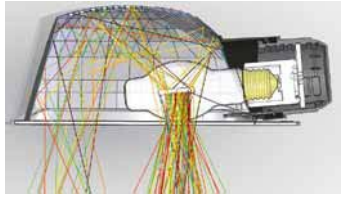


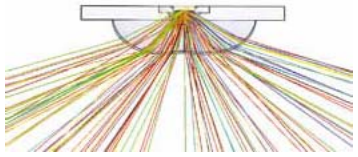
Figure 5.4: White Light LED Package Efficacy Targets[0,3], Laboratory and Commercial

Notes:
1. Cool White: CRI 70-80; CCT 4746-7040 K
2. Warm White: CRI 80-90; CCT 2580-3710 K
3. Current density: 35A/cm^2
4. These results are at 25°C package temperature, not steady state operating temperature. Thermal sensitivity will reduce efficacies by 24% or so in normal operation, depending on luminaire thermal management.

HPS vs. LED Optics

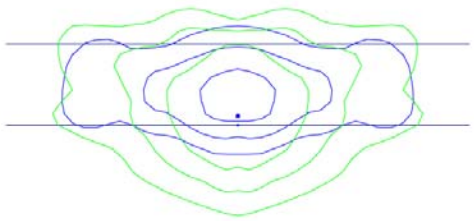


An HID lamp is a single large point source that relies on the reflector/refractor assembly to direct the light in the required pattern. A large portion of the lamp's light output is lost or uncontrolled.



With LEDs the light is already traveling down and the small point source allows for precise optical control with very little waste.

HPS vs. LED Optics



Isofootcandle horizontal illuminance graph

- **150W GE Cobrahead**
- **60 LED 72W Luminaire**

35' wide roadway with fixtures at 30' mounting height on a 4' arm

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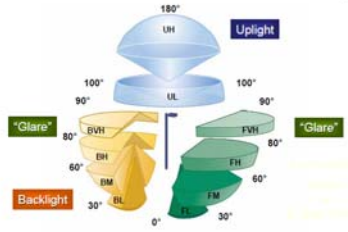
Dealing with Light Trespass

The LCS System



Luminaire Classification System (LCS) — IES Standard TM-15-11

- **Backlight, Uplight & Glare (BUG) Rating System**
- **Replaces obsolete IESNA cutoff classification system**
- **HID light trespass is usually controlled with shields and/or partially obscured refractors**

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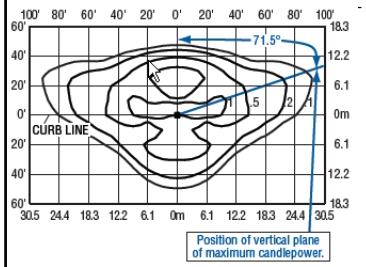
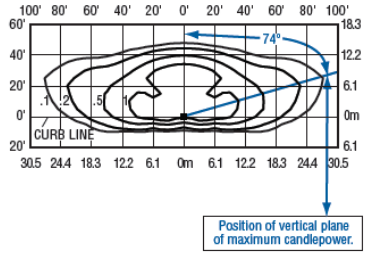
Dealing with Light Trespass

- **Accuracy of LED photometrics allows more control over BUG rating and light trespass.**
- **May require stocking multiple lights of the same nominal wattage with different patterns.**



LED Type II Light



LED Type II Light w/Backlight Control

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Color

HPS

- **CCT ~ 2,100°K**
- **CRI ~ 22**
- **S/P[1] ~ 0.6**

LED

- **CCT ~ 4,500°K**
- **CRI ~ 75**
- **S/P[1] ~ 1.5-2.0**

[1]Scotopic/Photopic Ratio – See http://www.ecofitlighting.com/files/Photopic%20vs%20Scotopic%20technical%20paper.pdf

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LED Reliability

HPS
- Rated lamp life ~ 24,000 hours — 40,000 hours (5.5 — 9.1 years)
- Failure mode — lamp cycles on and off

LED
- Claimed lamp life of 50,000 – 100,000+ hours (11.4 — 22.8+ years)
- Failure mode — LED's slowly darken with age
- End of life when light reaches 70% of initial output (L_{70})
- Heat management is critical to ensuring long life

LED Reliability

Standards

- IESNA LM-80-08 — *ESNA Approved Method for Measuring Lumen Maintenance of LED Light Sources*
  - Test procedure for LED chip, not fixture
  - Provided by chip manufacturer
  - 6,000 hour minimum test at various temperatures and drive currents
- IESNA TM-21 — *IESNA Lumen Method Extrapolation*
  - Methodology to extrapolate LM-80 data beyond 6,000 hours
  - Still focuses on LED chip, module or array, not the entire luminaire
  - The luminaires' driver, optics, thermal management or housing design may limit actual service life

Luminaire Reliability

Other Potential Sources of Failure
- Surges
- Mechanical Vibration
- Corrosion
- UV
- Ingress Protection
  - IP 65 for fixture
  - IP 54 for electrical components
- Vandalism
- Driver Failure

HID Electrical Components

HID Ballast & Starter

- **Tapped Input Voltage 120V – 277VAC**
- **~ 55V secondary voltage w/new lamp**
- **~ 84V secondary voltage @ end of life**
- **Starter supplies 2500-4000V needed to strike the gas arc. Once arc is struck, starter turns off.**
- **~ 80% efficiency**
- **0.90 power factor**

Wiring Diagram:

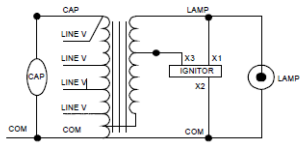
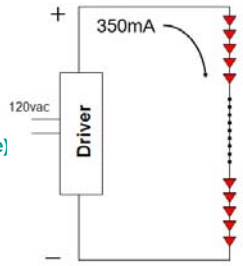


Fig. K

LED Electrical Components

LED Driver

- 120V – 277VAC Input Voltage
- Constant Current Output, Fixed or Multiple
- 350mA, 525mA & 700mA
- Secondary voltage "floats"
- ~ 90% efficiency
- 0.99 power factor
- 20% Max. THD
  - ANSI & Energy Star require PF >0.9 & THD < 32%
- > 50,000 hour service life T <= 75°C (5% failure rate)
- > 100,000 hour service life T<= 65°C



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Things You Can't Do With HID

- Dimmable Drivers (1-10VDC Control)
- Programmable Drivers
  - Constant Light Output
  - Built-in Photocontrol
  - Temperature Monitoring
  - Motion Sensing
- Communicating Drivers (IEEE 802.15.4, ZigBee)
  - Adjust illuminance based on conditions (road work, weather, 911, etc.)
  - Notifications of failures
  - Reporting of power usage, temperature
  - Predictive maintenance

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References & Resources

Reference Standards

- ANSI/IES RP-8-00 — *Roadway Lighting*
- ANSI C136.37-2011 — *Solid State Light Sources Used in Roadway and Area Lighting*
- IESNA LM-79-08 — *Electrical and Photometric Measurements of Solid-State Lighting Products*
- IESNA LM-80-08 — *ESNA Approved Method for Measuring Lumen Maintenance of LED Light Sources*
- IESNA TM-21 — *IESNA Lumen Method Extrapolation*
- IES Standard TM-15-11 — *Luminaire Classification System (LCS)*
- NEMA SSL 1-2010 — *Electronic Drivers for LED Devices, Arrays or Systems*

Resources

- Department of Energy Solid-State Lighting Website
  http://www1.eere.energy.gov/buildings/ssl/
- DOE Municipal Solid-State Street Lighting Consortium
  http://www1.eere.energy.gov/buildings/ssl/consortium.html
  - Model Specification for LED Roadway Lighting

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Questions??

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