Today’s purpose

- Engineers and end users want confidence in their choices
- Tools to help establish guidelines for quality
  - There is no standard parameter, let’s start talking about it
- Market erosion for cheapening the system
  - Look what happened to CFL

NOT ALL LEDs ARE CREATED EQUAL
How to compare LED light fixtures

- Lumen output
- energy efficiency (lumens per watt)
- watts consumed

DUH, you already know that!

Agenda

- Why do Light Loss Factors matter?
- LED Fixture life and expectations for life
- L70 and TM21 what do they mean?
  - But really...practically, what do they mean?
- What is the HID “equivalent” fixture
- Where is the light going?
- Driver life
- Optics
- Temperature and why it matters
- The challenge: get what you spec
- Expectations for your vendor
Let’s start with a project (Design 1)

Receiving Warehouse
Building dimensions

- 30’ ceiling, 20’ stack, 23’ mounting height
- 17’ wide aisle. 20’ between fixtures

How much light will the fixture provide?

Let’s design it!

Design 1

Rep: “Great! We can do it! Look how good the light levels are!!”

Customer: “We’re not at 50….can you get to 50FC?”

Highbay LED 25,000L
Design 1 - 50FC

Rep: “Great! We can do it! Look how good the light levels are!!”

Customer: “Yay! What did you do? Same fixture? Cool! How about 100?”

Design 1 - 100FC

Same fixture... MAGIC!

Rep: “Where’s the PO?”
What was missing???

Where was the light loss factor?

**Luminaire Schedule**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Label</th>
<th>Manufacturer</th>
<th>Catalog Number</th>
<th>Description</th>
<th>Lamp</th>
<th>Number of Lamps</th>
<th>Filename</th>
<th>Lumens Per Lamp</th>
<th>Wattage</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>Highbay LED 25,000L</td>
<td></td>
<td></td>
<td>28 LED Boards</td>
<td>1</td>
<td></td>
<td></td>
<td>25173.34</td>
<td>253.4</td>
</tr>
</tbody>
</table>

**Statistics**

<table>
<thead>
<tr>
<th>Description</th>
<th>Symbol</th>
<th>Avg</th>
<th>Max</th>
<th>Min</th>
<th>Avg/Hi</th>
<th>Min/Hi</th>
<th>Avg/Hi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor</td>
<td>+</td>
<td>1.0</td>
<td>54.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Light Loss Factors and LED

Will it pass the test of time?

- LED Light Loss Factors LLF
  - LLD: Lamp Lumen Depreciation (LED L70 / TM21)
  - LDD: Luminaire Dirt Depreciation
  - BF/DF: Ballast Factor (LED Driver Factor DF = 1)
  - TF: Thermal Factor (** BIG DEAL IF HOT)

Traditional: Lumens Out = Lamp rated lumens * LLD * LDD * BF * TF
LED: Lumens Out = Initial Lumens * TM21 * LDD * DF * TF
Fixture life - parts of an LED fixture

LED is a whole new ball game. This is NOT HID

- Light Emitting Diodes (lamps)
- When will the lights go out? STOP! With LED they don’t go out (unless there is a problem)
- Driver (ballast)
  - 50,000 hours, 100,000 hours. It’s the SAME driver. Tcase temperature matters!
- Optic Life
- Surge Protector
  - Make sure there is one. Class “C” for outdoor
- Housing - Will it last?

LED Lamp Lumen Depreciation

Lumen Maintenance curves define LED life. And this varies with temperature.
With LED it is not just life – it’s light!

- L70 is when Lumen Maintenance has reached 70% initial output
  - Usually tested at 25°C
  - 50,000; 60,000; 100,000; 500,000???

- TM21 is a new way to measure output (L70 > 100,000 hours)
  - Specify temperature and your timeframe

⭐ Quality Differentiator
⭐ Choose the correct fixture

What fixture LLD value should I use?

- TM21 input
- Thermal report
- Specific fixture performance
<table>
<thead>
<tr>
<th>Time (hours)</th>
<th>Lumen Maintenance (%)</th>
<th>Test Data for 55°C Case Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>100.00%</td>
<td>Tested drive current (mA): 1000</td>
</tr>
<tr>
<td>1.00</td>
<td>99.90%</td>
<td>Tested case temperature 1 (Tc, °C): 55</td>
</tr>
<tr>
<td>2.00</td>
<td>99.80%</td>
<td>Tested case temperature 2 (Tc, °C): 85</td>
</tr>
<tr>
<td>3.00</td>
<td>99.70%</td>
<td>Tested case temperature 3 (Tc, °C): 105</td>
</tr>
<tr>
<td>4.00</td>
<td>99.60%</td>
<td>Lumen maintenance at time (t) (%): 87.95%</td>
</tr>
<tr>
<td>5.00</td>
<td>99.50%</td>
<td>Calculated L70 (hours): 220,000</td>
</tr>
<tr>
<td>6.00</td>
<td>99.40%</td>
<td>Reported L70 (hours): &gt;60000</td>
</tr>
</tbody>
</table>

In-Situ Inputs

- Drive current: 1000 mA
- In-situ case temperature (Tc, °C): 73

Results

Lumen maintenance at time (t) (%) = 87.95%

**See thermal test report**
Thermal Test Results – Your vendor should have this specific to fixture, # of LEDs and driver current specific to temperature. Use worst case to determine LLD for TM21.

<table>
<thead>
<tr>
<th>Loc</th>
<th>Temp</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>633</td>
<td>74</td>
<td>LED #1</td>
</tr>
<tr>
<td>634</td>
<td>67</td>
<td>LED #1 lens</td>
</tr>
<tr>
<td>635</td>
<td>78</td>
<td>LED #2</td>
</tr>
<tr>
<td>636</td>
<td>67</td>
<td>LED #2 lens</td>
</tr>
<tr>
<td>637</td>
<td>79</td>
<td>LED #3</td>
</tr>
<tr>
<td>638</td>
<td>68</td>
<td>LED #3 lens</td>
</tr>
<tr>
<td>639</td>
<td>62</td>
<td>LED driver A test point</td>
</tr>
<tr>
<td>640</td>
<td>66</td>
<td>LED driver B test point</td>
</tr>
</tbody>
</table>

American Electric

TM-21 Inputs

Instructions

LM-80 Test Inputs

In-Situ Inputs

Results

This is just the first step. This is incomplete if it’s all you get.
Your specification determines LLD

**LLD: Lamp Lumen Depreciation aka: Lumen Maintenance**

**This is L70 / TM21-- quality differentiator**

- Many diode choices
- Higher TM21 means it last longer
- Directly dependent on quality of the fixture
- Ask for fixture performance, not diode performance
The Low Bidder - do we use the $400 fixture or the $200 one?

**Maintained Light output = initial lumen output * LLD**
(not including dirt or thermal factor)

Example:
Fixture initial lumens = 18,642
LLD at 100,000 hours at 25C from graph is = .85

**Maintained output at 100,000 hours at 25C :**

\[
18642 \times 0.85 = 15,845
\]

**Fixture Efficacy (relative light efficiency)**
**Lumens Per Watt (LPW)**

As the LED dims, LPW decreases

Direct multiple of TM21 value

**Ex:**  Initial Lumens = 10900
System Watts = 100
TM21 @ 40C @ 100K hours = 89%

Initial LPW = 109 LPW
100K hour LPW = 109*.89 = 97 LPW
Why TM21 matters…….

- Life
- Maintained Lumen output
- Fixture Efficacy LPW

Think LONG TERM performance

Which fixture should I use?
Design 2
46’w x 32’l x 18’h room, 16’ MH

<table>
<thead>
<tr>
<th>Luminous Schedule</th>
<th>Lumens</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>10L</td>
<td>10,000L lowbay</td>
<td></td>
</tr>
<tr>
<td>12L</td>
<td>12,000L lowbay</td>
<td></td>
</tr>
</tbody>
</table>

Statistics

<table>
<thead>
<tr>
<th>10,000L lowbay</th>
<th>12,000L lowbay</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 fc</td>
<td>18 fc</td>
</tr>
<tr>
<td>9 fc</td>
<td>5 fc</td>
</tr>
<tr>
<td>2.0:1</td>
<td>2.0:1</td>
</tr>
<tr>
<td>1.6:1</td>
<td>1.0:1</td>
</tr>
<tr>
<td>0.8:1</td>
<td>0.8:1</td>
</tr>
</tbody>
</table>
Choose the right LLF - don’t forget the dirt factor!

<table>
<thead>
<tr>
<th>Label</th>
<th>Quantity</th>
<th>Manufacturer</th>
<th>Catalog Number</th>
<th>Description</th>
<th>Lumens Per Lamp</th>
<th>Light Loss</th>
<th>Wattage</th>
</tr>
</thead>
<tbody>
<tr>
<td>10L</td>
<td></td>
<td></td>
<td></td>
<td>10,000L lowbay</td>
<td></td>
<td>0.8</td>
<td>98.8</td>
</tr>
<tr>
<td>12L</td>
<td></td>
<td></td>
<td></td>
<td>12,000L lowbay</td>
<td></td>
<td>0.63</td>
<td>120.3</td>
</tr>
</tbody>
</table>

Actual: 0.88 * 0.9 = 0.8
Generic: LLF = 0.7 * 0.9 = 0.63

Results are basically identical - you can use the less expensive fixture!

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Description</th>
<th>Avg</th>
<th>Max</th>
<th>Min</th>
<th>Max/Min</th>
<th>Avg/Min</th>
<th>Avg/Max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10,000L lowbay</td>
<td>14 fc</td>
<td>18 fc</td>
<td>9 fc</td>
<td>2.0:1</td>
<td>1.6:1</td>
<td>0.8:1</td>
</tr>
<tr>
<td></td>
<td>12,000L lowbay</td>
<td>14 fc</td>
<td>18 fc</td>
<td>8 fc</td>
<td>2.3:1</td>
<td>1.8:1</td>
<td>0.8:1</td>
</tr>
</tbody>
</table>

What about the light distribution???

Narrow  | Medium  | Wide

[Graphs showing light distribution for Narrow, Medium, and Wide]
Where is the light going? Is it uniform?

*20% higher

*40% higher
Does Distribution and Uniformity Matter?

- How fast are you moving?
- How fast are objects moving?
- How big is the object?
- Where are you trying to see?
- Retail? Industrial? etc

Uniformity and Task vs Volumetric lighting

<table>
<thead>
<tr>
<th>Avg (fc)</th>
<th>Max (fc)</th>
<th>Min (fc)</th>
<th>Max/Min</th>
<th>Avg/Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>86.9</td>
<td>118.4</td>
<td>35.4</td>
<td>3.3:1</td>
<td>2.5:1</td>
</tr>
<tr>
<td>86.3</td>
<td>87.7</td>
<td>36.0</td>
<td>2.4:1</td>
<td>1.9:1</td>
</tr>
</tbody>
</table>

One has a higher Avg, but arguably lesser coverage and worse uniformity.

What is most important to you?
What is an equivalent?

- **FIXTURE** Lumen output - Initial / Maintained
- Distribution
- Match initial install or end of life

Who is liable?

How to compare LED light fixtures

OPTICS

- Glass vs Acrylic vs Poly Carbonate
- Prisms vs Frosted vs Clear/Flat
- Distribution Options
Distribution Pattern Options

Do you have choices?

- reflector, symmetric
- refractor, symmetric
- reflector, asymmetric

Flood beam spreads, same total lumens

[Graphs showing luminance distributions for different beam spreads]
Spectral Density Curves vs CRI

- SUNLIGHT
- LED
- INCANDESCENT
- CFL

WAVELENGTH (nanometers)

Driver life

- Component Quality
- Heat sink matters
- Don’t just look at the driver spec sheet
driver life varies
Thermal Test Results - Your vendor should have this

<table>
<thead>
<tr>
<th>Catalog Number:</th>
<th>Thermocouple Readings:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thermocouples Corrected</td>
</tr>
<tr>
<td><strong>Loc:</strong></td>
<td><strong>Temp:</strong></td>
</tr>
<tr>
<td>633</td>
<td>74</td>
</tr>
<tr>
<td>634</td>
<td>67</td>
</tr>
<tr>
<td>635</td>
<td>78</td>
</tr>
<tr>
<td>636</td>
<td>67</td>
</tr>
<tr>
<td>637</td>
<td>79</td>
</tr>
<tr>
<td>638</td>
<td>68</td>
</tr>
<tr>
<td>639</td>
<td>62</td>
</tr>
<tr>
<td>640</td>
<td>66</td>
</tr>
</tbody>
</table>

Specific to temperature

Use worst case to determine life

---

Thermal Factor!

Why HOT matters:

- TM21 --- DUH
- INSTANTAEOUS Thermal Cutback
- \[ LLF = LLD \times LDD \times DF \times TF \]
Thermal Factors

Thermal Factor Comparison

<table>
<thead>
<tr>
<th>PHZ 18L</th>
<th>Competitor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixture A 18,000L</td>
<td>Fixture B 17,500L</td>
</tr>
<tr>
<td>Lumens at 25C</td>
<td>18,428</td>
</tr>
<tr>
<td>Lumens at 40C</td>
<td>18,198</td>
</tr>
<tr>
<td>Lumens at 55C</td>
<td>17,875</td>
</tr>
<tr>
<td>Lumens at 65C</td>
<td>15,135</td>
</tr>
</tbody>
</table>

Max Ambient Temperature rating

- Just like Wet location or HAZ rating

**Warranty & Standards**
- Rated for -40C to 40C ambient
- UL 1598 A wet location, UL 1598A Marine (pending)

- Affects component life.
Comparing LED fixtures

THE FIXTURE

- Do you have the wattage I need?
- Robust, durable, corrosion resistant, correct classification
- Optics that make sense
- Long life components
- Durable heat sink
- Easy to install and maintain
- Temperature rating

Specifiers - UPSELL YOUR SERVICES

- You are the expert - it's high tech
- Tools to validate what you do
- Review the submittals
  - Make sure the product submitted meets the specs
  - Police the photometry - LLF to include TM21 and thermal factor

Customer is assured they get what they expect
What the manufacturer should provide

ASK FOR IT!

NO GENERIC or INCORRECT LIGHT LOSS FACTORS ON PHOTOMETRICS

- Temperature reports to validate LED and driver performance
- TM21 output data specific to the luminaire
- Driver information for performance in the fixture
  - Not just the driver spec sheet
- Photometric analysis using the actual fixture performance data for calculations
- Easily identified packages submitting 1 quote with supporting documents

NO DATA DUMP!

Understanding and Using LED Light Fixtures

Thank you!!

Kellie Koedel, LC
Portland, OR
Kellie.Koedel@Holophane.com
503-201-5350