THERMAL
ELECTRICAL
MECHANICAL
PHOTOMETRIC
OPTICAL

CREE SERVICES

TEMPO TESTING AND EVALUATION

February 25, 2013
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Title:

TEMPO 24 Report

Prepared for:

Econex

Prepared by:

Cree Durham Technology Center

Ticket Number:

12470-T

CREE

Table of Contents

NVLAP lab code 500070-0

The Cree Durham Technology Center (NVLAP lab code 500070-0) has been accredited by NVLAP to satisfy the requirements of ISO/IEC 17025:2005, IES LM-79-08 and LM-58-94

This report contains data sets that are not covered by NVLAP accreditation.

The measurement data sets contained in this report are related only to the items tested. This report must not be used by the customer to claim product certification, approval or endorsement by NVLAP, NIST or any agency of the federal government.

This report was generated for:

Econex
3-Y Paveletskiy Proyezd D.7 Korp. 1
Moscow 115114
Russia

This report was generated by:

The Cree Durham Technology Center
4600 Silicon Dr
Durham, NC 27703

TEMPO 24 Checklist

Thermal

✓	Solder Point Temperature Measurement
✓	Thermal Imaging With IR Camera

Electrical

✓	Driver Efficiency
✓	Transient Analysis
✓	Power Analysis (PF, THD)
n/a	Dimmer Compatibility Test
✓	Dielectric Breakdown (Hi-pot)
✓	Vf/Current Balancing (Parallel Arrays Only)
n/a	Electrolytic Capacitor Testing

Mechanical

✓	Qualitative Construction Analysis
✓	Chemical compatibility Analysis
✓	X-ray of Printed Circuit Board

Photometric and Optical

✓	Luminous Intensity Distribution (Per IES LM-79-08, section 10)
n/a	Spatial Non-uniformity of Chromaticity (Per IES LM-79-08, section 12.5)
✓	Luminous Flux (Per IES LM-79-08, section 9.1 and/or section 9.3)
✓	Radiant Flux (Per IES LM-79-08, section 9.1 and/or section 9.3)
✓	Chromaticity (CRI, CCT, x-y, u-v, u'-v', duv, Per IES LM-79-08, section 9.1)
✓	Spectral Power Distribution (Visible Range, Per IES LM-79-08, section 9.1)
✓	Luminaire Efficacy (lm/W, Per IES LM-79-08, section 11)
✓	Illuminance (ft-cd or lux, derived from IES LM-63-02 electronic file)
✓	Optical Efficiency
✓	Component Binning and Color Point Evaluation
✓	Additional Photometric Analysis for Luminaire Type (e.g. Indoor, Roadway, etc.)
✓	Visible Flicker Test
n/a	Review Against ENERGY STAR® criteria
✓	TM-21 Lifetime estimate

EXECUTIVE SUMMARY

The Econex Street Light (model Road 80) uses 15 XLamp® XM-L LEDs. The luminaire produces 8009 lumens at a 6042K CCT, while consuming 86.1W of power. With an optical efficiency of nearly 92% the luminaire delivers 93 lumens per watt.

Cree Services' TEMPO24 Evaluation process is a thorough multi-point evaluation and analysis of a customer's lighting product. Cree Application Engineering personnel perform a battery of thermal, electrical, mechanical and photometric tests and provide a comprehensive report that includes all relevant data necessary to confirm the performance of the product.

In addition to this standard set of tests, products will also be reviewed against appropriate Energy Star or DesignLights™ Consortium (DLC) criteria, TM-21 LED Lifetime estimates, and LM-79 conformant tests where applicable. Table 1 below provides a quick summary of the test data. Additional detailed test results are covered in the following pages.

Criteria	Result	Test Compliance
Total Luminous Flux (lm)	8009	IES LM-79-08
Power (W)	86.12	
Tsp and Tj (°C)[1]	65.2 / 78.7	
Power Factor	0.978	
Lumens per Watt (LPW)	93	IES LM-79-08
Optical Efficiency (%)	92	
Driver Efficiency (%)	91	
CCT (K)	6042	IES LM-79-08
CRI (Ra)	68	IES LM-79-08
Chromaticity (x-coord)	0.3201	IES LM-79-08
Chromaticity (y-coord)	0.3462	IES LM-79-08
LED Lumen Maintenance[2]	Projected L_{70}(9K) : 286,000	IES TM-21
	Reported L_{70}(9K) : 36,300	
DLC Criteria	Not Applicable	

Table 1: Summary of Test Results

[1] *Measured at ambient temperature of 23.4ºC.*
[2] *Per IES TM-21-2011*

Incoming Inspection

All samples are subjected to a visual, physical inspection to ensure that the product was not damaged during shipping. One sample was received as shown in Figures 1 through 4. No signs of physical damage were observed.

As received pictures

Figure 1: As-Received Picture #1

Figure 2: As-Received Picture #2

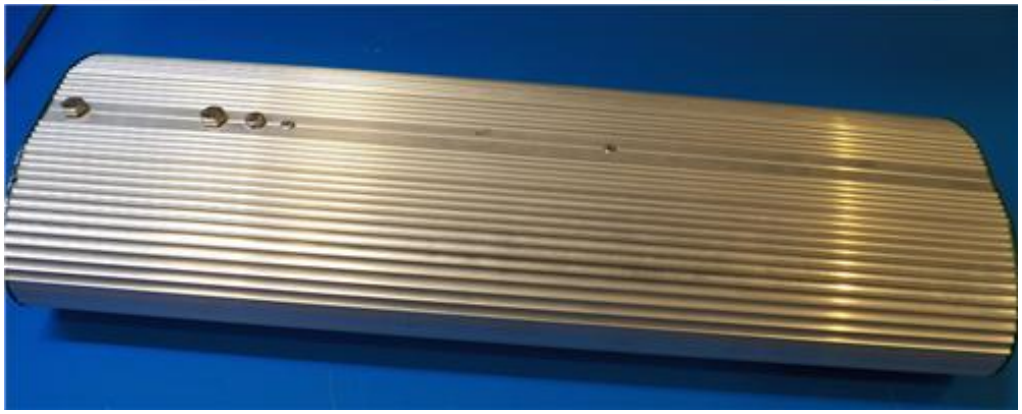

Figure 3: As-Received Picture #3

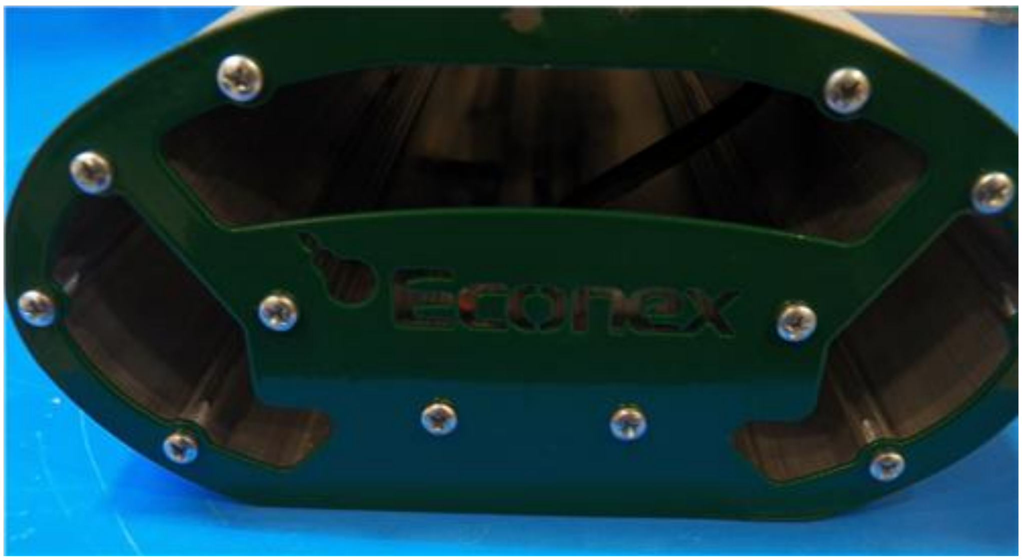

Figure 4: As-Received Picture #4

Photometric Testing

Photometric testing includes luminous flux, radiant flux, chromaticity, correlated color temperature (CCT) and color rendering index (CRI) measurements. Measurements are made at Cree's photometric testing lab in Durham, NC on two test systems: a 2-meter (2m) Labsphere integrating sphere and a Type C Goniophotometer.

The total spectral flux calibration on the 2m sphere is conducted using an omni-directional halogen reference bulb. This calibration is transferred to a Cree solid state working reference standard and used to calibrate this integrating sphere. The total spectral flux of the Cree working reference lamp is directly traceable to NIST-RF0816 (Lamp NIST-844/8592-09) in the visible wavelength range from 360nm to 830nm. The 75W lamps are calibrated in a base-down configuration, and are allowed a warm-up period of 10 minutes prior to measurement and driven at a specific drive current of 2.679A. The spectroradiometer detector is a CCD detector used for collection of the optical data.

This 2m sphere is a Labsphere model CSLMS-7660 using the 4π geometry measurement method with a Photal (Otsuka Electronics) MC 9801 spectroradiometer. Testing is performed per Cree standard photometric testing protocols, which follow IES LM-79-08[3] sections 9.1 and 9.3 and includes procedures such as: absorption correction using a NIST traceable lamp and ensuring the emission plane of the device under test is collinear with the sphere's sensor baffle. The sample is powered using a Chroma Model 61503 AC/DC Power Source and a Xitron model 2801 power analyzer is used to measure the electrical characteristics. Figure 5 is a photograph of the sample mounted in the sphere.

Figure 5: Sample in 2m Integrating Sphere

[3] *IES LM-79-08, Electrical and Photometric Measurements of Solid State Lighting Products*

Luminaire evaluation on a type C goniophotometer system was performed at Cree's photometric testing lab in Durham, NC. This goniophotometer is a UL/Lighting Sciences Inc. model 6440T utilizing, an Inphora photocell model PDET 11, an Elgar AC power supply model CW1251 and a Yokogawa power meter model WT210. A Gooch & Housego spectroradiometer model 770VIS/NIR also allows for spectral irradiance data to be measured.

The illuminance calibration on the type C goniophotometer is performed utilizing 3 EHD Lamps with a 500 Watt rating. The initial values for illuminance are measured with an Inphora photocell model PDET 11 S/N 080901, test no. LSI 29197. The photocell used by Lighting Sciences was calibrated by NIST on 3 September, 2009 with NIST test no. 844/278666-09. The lamps that are utilized at Cree were generated on 14 September, 2011.

To calibrate color on the Type C goniophotometer, a single EHD 120V spectral irradiance calibration lamp with a 500 Watt rating is used. The lamp has a black line placed on the base for alignment and is set up exactly like the calibration for illuminance. This lamp must operate base down and at the specified amperes noted on the test no. LSI 29863. Figure 6 is a photograph of the sample under test on this type C goniophotometer.

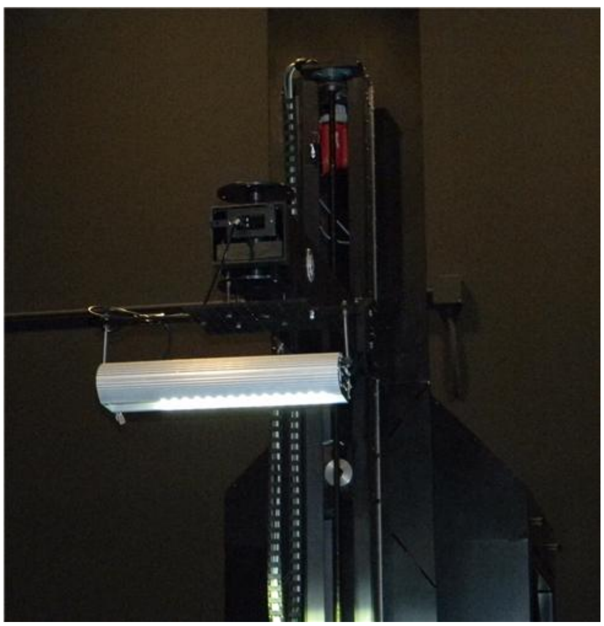

Figure 6: Sample Mounted on Type C Goniophotometer

Tests	Date	Ambient Temp. (°C)	Input Voltage (Volts AC)	Frequency (Hz)
Luminous Flux, Radiant Flux, Chromaticity, Color Rendering, Spectral Power Distribution, Luminaire Efficacy	18-Feb-2013	22.5	230	50
Luminous Intensity	13-Feb-2013	25.4	230	50

Table 2: Photometric Test Conditions

Luminous Flux, Radiant Flux

Radiant flux is a measure of the total power of electromagnetic radiation emitted from the luminaire or lamp, while luminous flux is a measurement that is weighted based on human visual perception. Measurements are recorded once per minute over a sufficient period of time to allow the sample to reach thermal equilibrium. In the case of this luminaire, it took approximately 1.98 hours to stabilize.

Parameter	Stable Data
Radiant Flux (Watts)	24.53
Photopic luminous flux (lumens)	8009
Scotopic luminous flux (lumens)	15314
S/P ratio	1.91

Table 3: Luminaire Radiometric and Photometric Output

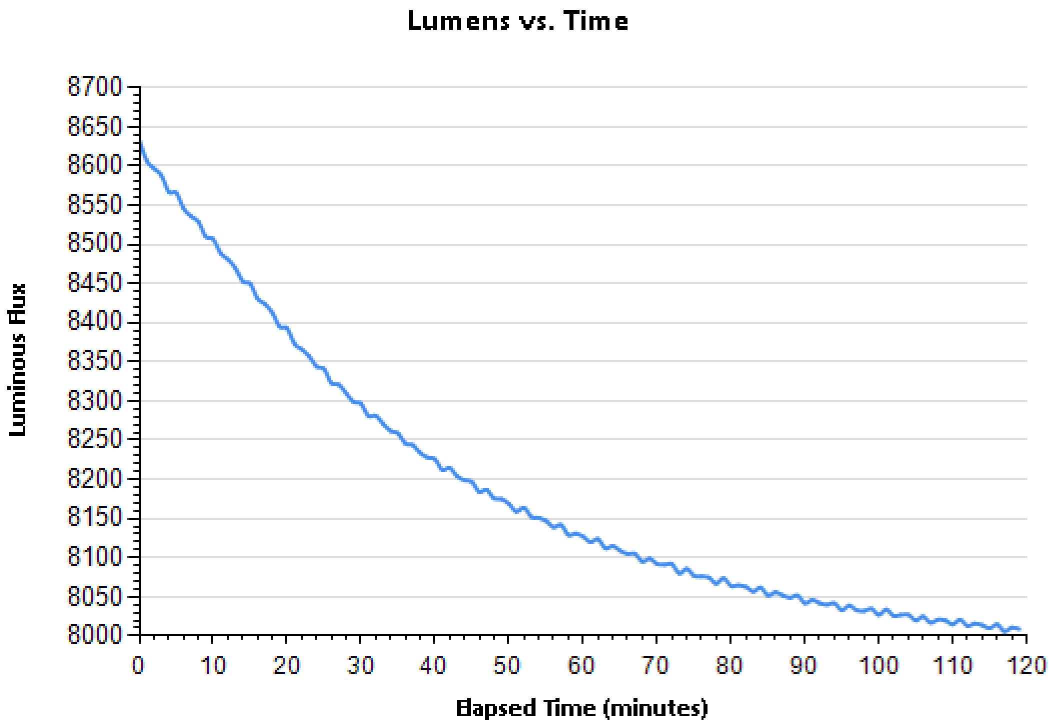

Chart 1: Luminous Flux Plotted Versus Time

Luminaire Chromaticity and Color Rendering

Parameter	Stable Data
x coordinate	0.3201
y coordinate	0.3462
u' coordinate	0.1966
v' coordinate	0.4783
Correlated Color Temperature	6042
Delta uv	0.0082

Table 4: Measured Chromaticity and Correlated Color Temperature (CCT) Data

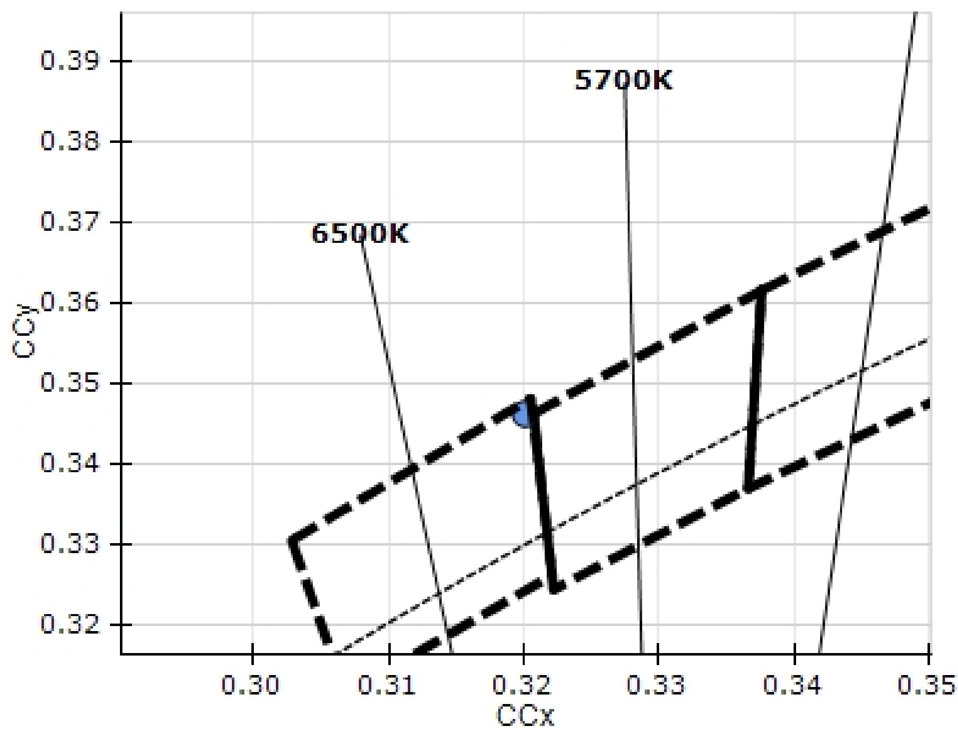

Chart 2: Plot of x-y Coordinates on ANSI C78.377A Diagram

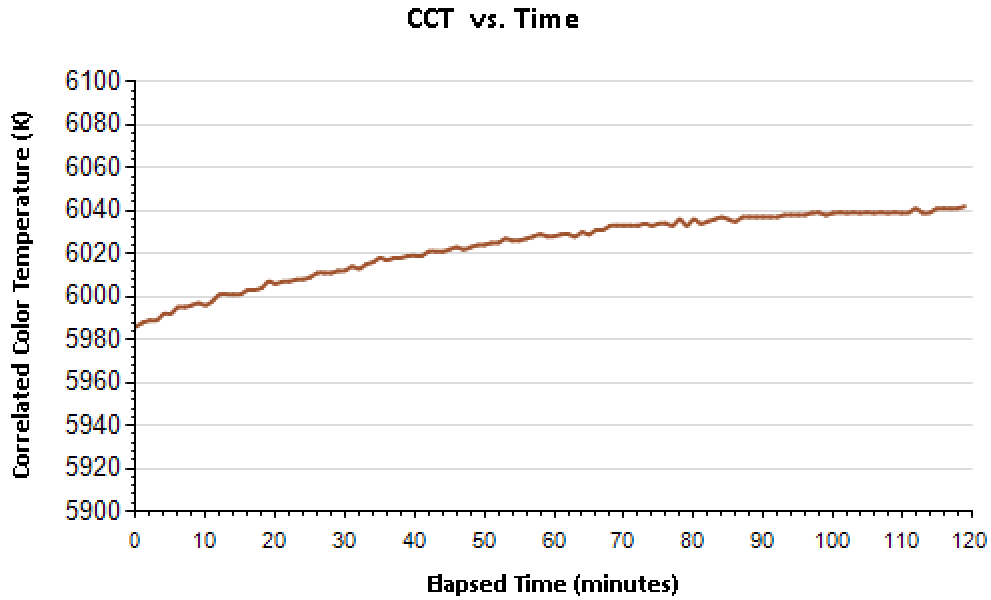

Chart 3: Correlated Color Temperature vs. Time

Color Rendering Index (CRI)	Value
Average (RA)	68
CRI (R1)	66
CRI (R2)	71
CRI (R3)	75
CRI (R4)	70
CRI (R5)	68
CRI (R6)	63
CRI (R7)	77
CRI (R8)	57
CRI (R9)	-41
CRI (R10)	32
CRI (R11)	69
CRI (R12)	43
CRI (R13)	65
CRI (R14)	86

Table 5: Measured Color Rendering Index

Luminaire Spectral Distribution

Parameter	Stable Data
Peak Wavelength (nm)	445
Dominant Wavelength (nm)	505

Table 6: Peak and Dominant Wavelength

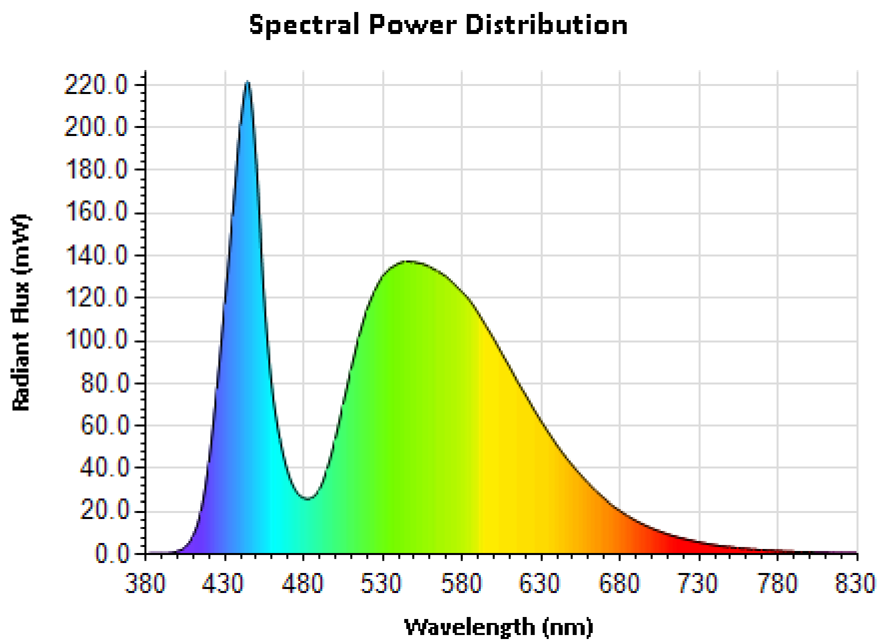

Chart 4: Measured Spectral Power Distribution

nm	mW/nm	nm	mW/nm	nm	mW/nm	nm	mW/nm
380	0.2	490	30.4	600	100.9	710	9.5
385	0.2	495	40.1	605	94.2	715	8.3
390	0.4	500	54.1	610	87.8	720	7.3
395	0.5	505	70.5	615	80.9	725	6.5
400	1.4	510	86.9	620	74.7	730	5.6
405	3.4	515	102.1	625	68.2	735	4.9
410	8.8	520	114.7	630	62.2	740	4.3
415	20.4	525	123.7	635	56.5	745	3.8
420	43.1	530	130.4	640	51.0	750	3.3
425	77.7	535	134.1	645	45.9	755	2.9
430	117.7	540	136.4	650	41.3	760	2.5
435	159.1	545	137.3	655	37.0	765	2.2
440	201.4	550	136.9	660	33.0	770	2.0
445	221.0	555	136.2	665	29.3	775	1.7
450	182.6	560	134.6	670	26.0	780	1.6
455	118.8	565	132.6	675	22.8	785	1.3
460	77.3	570	130.1	680	20.3	790	1.2
465	53.6	575	126.6	685	17.9	795	1.1
470	38.3	580	122.9	690	15.7	800	1.1
475	29.5	585	118.8	695	13.8	805	0.9
480	26.1	590	113.2	700	12.2	810	0.8
485	26.2	595	107.1	705	10.7	815	0.8

Table 7: SPD Numerical Data

Overall Luminaire Efficacy

The overall luminaire efficacy, also referred to as “wall plug efficacy”, is a metric of how well a luminaire or lamp converts electrical energy into photons. The input power was measured at an input voltage of 230 VAC.

Efficacy (At steady state) = Lumens / Total input Power

= 8009 /86.12

= 93 lm/W

Goniophotometer Data

The data shown is based on the luminaire tested in a level orientation with 0 degrees of tilt. The results will vary if the luminaire is mounted on a pole with an angled arm.

Characteristics	Result
IES Classification	Type I
Longitudinal Classification	Short
Luminaire Lumens	7780
Total Luminaire Watts	86.1
Luminaire Efficacy Rating (LER)	90
Maximum Candela	6575.5
Maximum Candela Angle	85H 65V
Maximum Candela At 90 Degrees Vertical	0
Maximum Candela from 80 to <90 Degrees Vertical	52.7

Table 8: Luminaire Summary Data

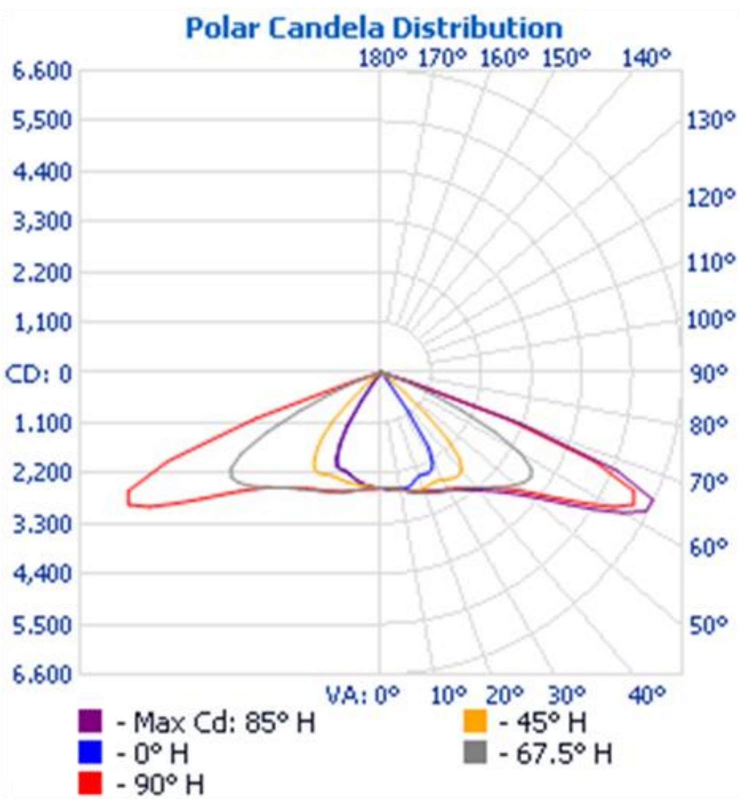

Chart 5: Intensity Distribution

Luminaire Classifcation System (LCS)	Lumens	% Luminaire
FL - Front-Low (0-30)	1113.7	14.3
FM - Front-Medium (30-60)	2269	29.2
FH - Front-High (60-80)	771.3	9.9
FVH - Front-Very High	1.1	0
BL - Back-Low (0-30)	1054.6	13.6
BM - Back-Medium (30-60)	1964	25.2
BH - Back-High (60-80)	604.4	7.8
BVH - Back-Very High (80-90)	1.9	0
UL – Up light-Low (90-100)	0	0
UH – Up light-High (100-180)	0	0
TOTAL	7780	100.0
BUG Rating	B3-U0-G2	

Table 9: Luminaire Classification System

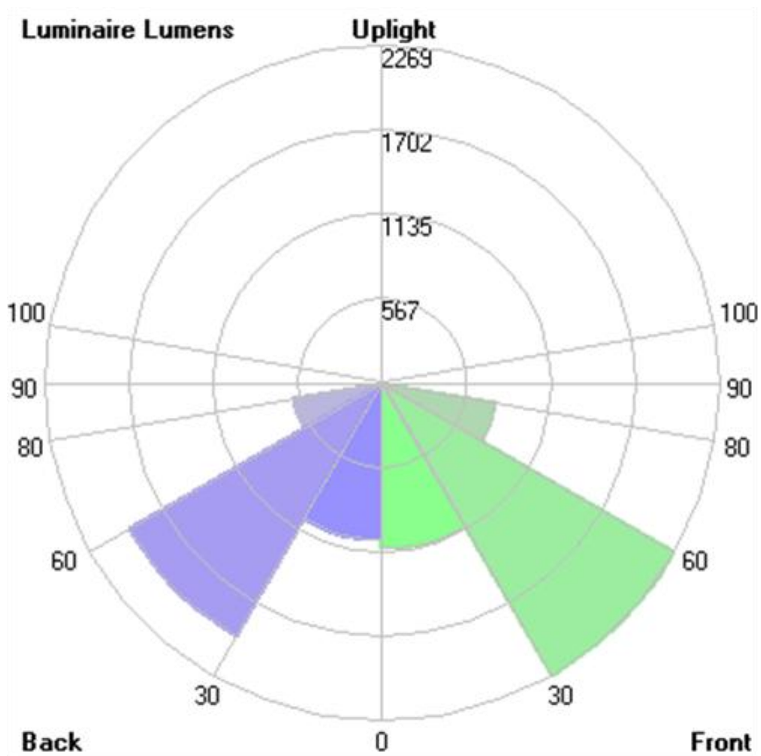

Chart 6: LCS Graph

Flux Distribution	Lumens	% Lamp
Downward Street Side:	4154.3	53
Downward House Side:	3624	47
Downward Total:	7778.3	100
Upward Street Side:	0	0
Upward House Side:	0	0
Upward Total:	0	0
Total Lumens:	7778.3	100

Table 10: Flux Distribution

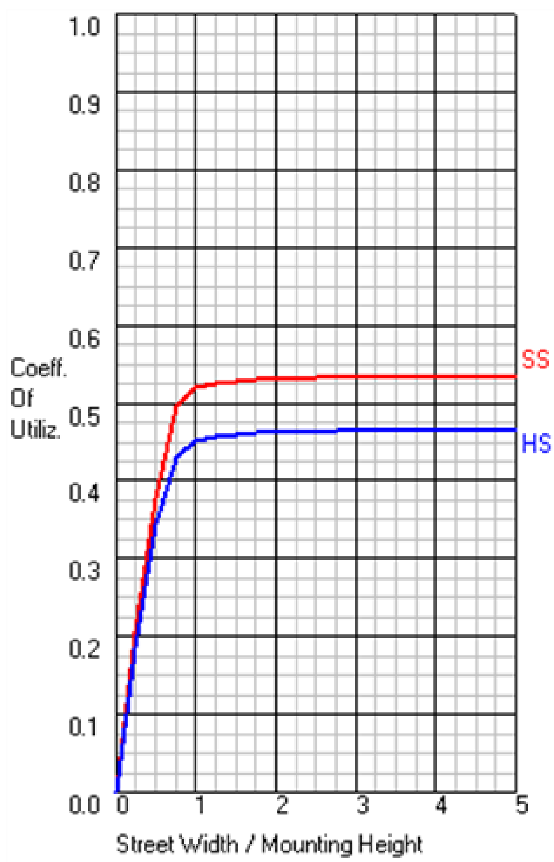

Chart 7: Coefficients of Utilization

Illuminance

The sample was measured on a type C goniophotometer and illuminance measurements were calculated from the IES-63 electronic file using Photometric Toolbox software. The results are shown in Chart 8 based on a level (0 degree tilt) orientation of the luminaire.

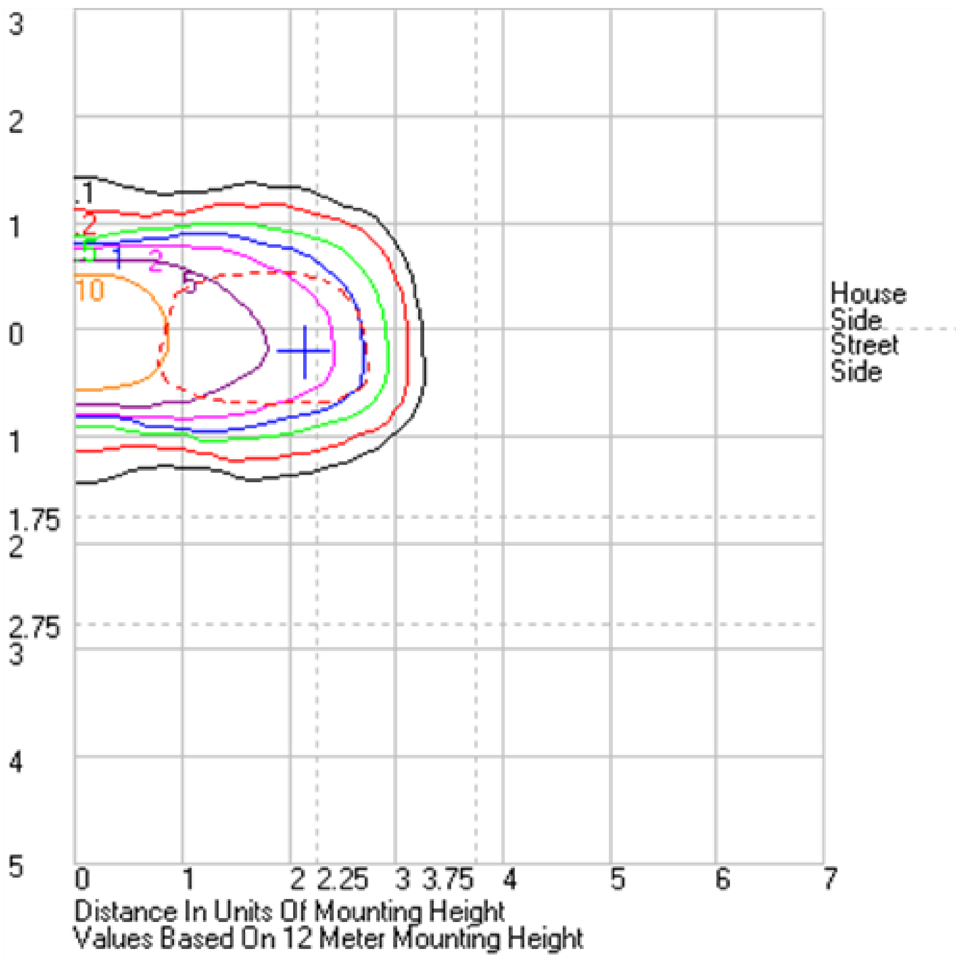

Chart 8: Isolux Plot at 12m Mounting Height

Component Binning and Color Point Evaluation

A total of 8 LEDs were measured at the binning current of 700 mA. Based on the data shown in Chart 9 and Table 11, the LEDs are from the T6 flux bin (280 lm min. +/-7%) and 2S chromaticity bin.

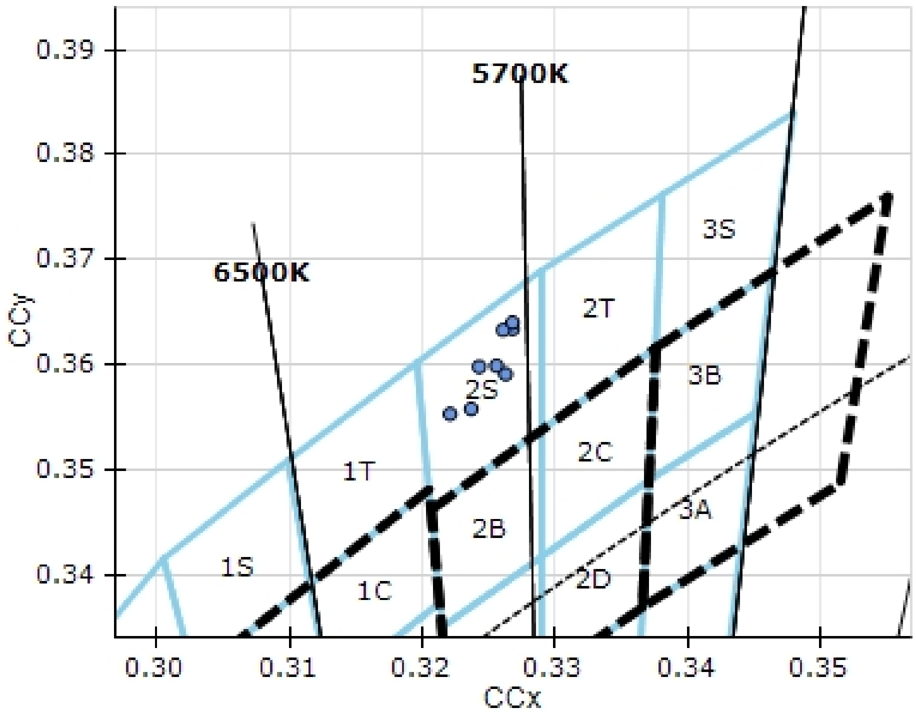

Chart 9: Measured Data Plotted on Cree Binning Chart

Board/Lamp	CCx	CCy	Lum Flux
1	0.3268	0.3640	313.10
2	0.3261	0.3633	312.61
3	0.3221	0.3553	299.16
4	0.3237	0.3558	305.64
5	0.3268	0.3634	304.50
6	0.3243	0.3598	293.85
7	0.3263	0.3591	309.55
8	0.3256	0.3599	298.35

Table 11: Measured Component Data

Optical Efficiency Calculation

The optical components consist of a single plastic lens for each LED, glued to the PCB with a grey potting material. The sample was tested with and without optics and the results are shown below in Table 12. Using this data, the optical efficiency can be calculated. The initial lumen values were used to avoid any effects due to thermal differences with the optics removed.

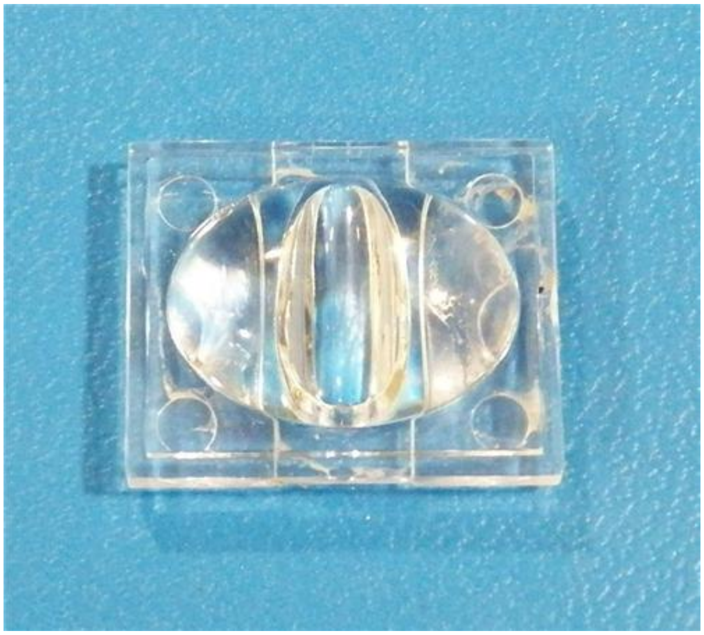

Figure 7: Optical Components

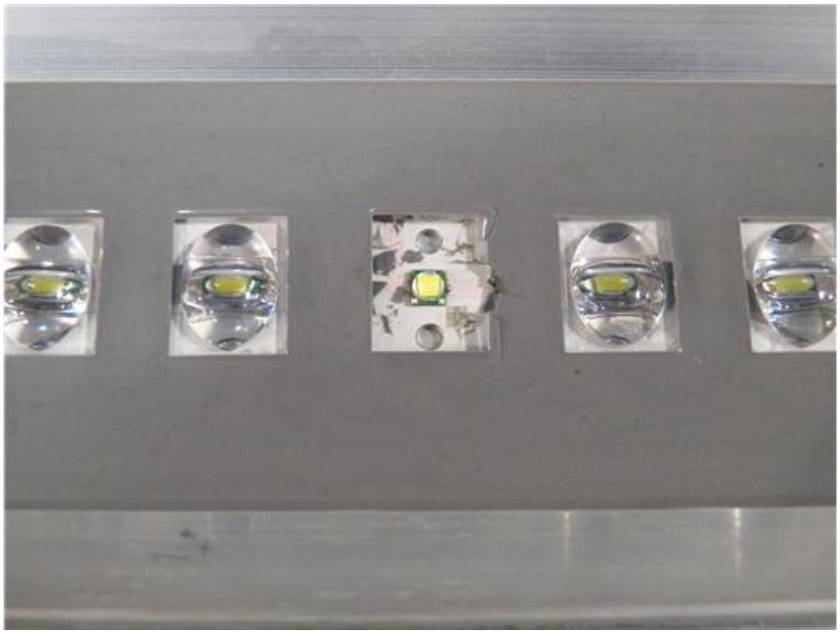

Figure 8: Optical Component attach

Condition	Radiant Flux (Watts)	Luminous Flux (lumens)	% Loss (overall)
With optics	26.24	8679	7.5%
Without optics	28.48	9382	--

Table 12: Measured Optical Efficiency

Optical Efficiency = lumens with optic / lumens without

=8679/9382

=92.5%

Visible Flicker Test

Visible Flicker is defined by the rapid fluctuation of light output in a cyclical manner[4]. The sample was tested with a photodetector to measure the amount of light modulation, or flicker. The detector output was captured using an oscilloscope, and the result is shown in Figure 9.

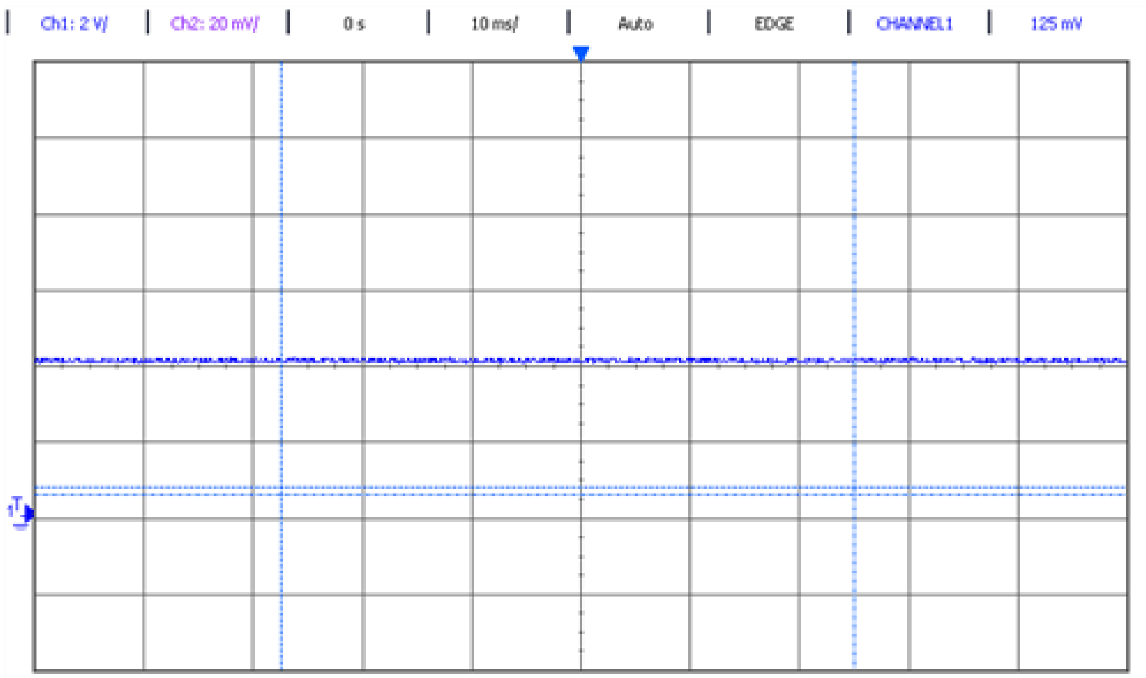

Figure 9: Visible Flicker

Where the percentage of modulation, referred to as flicker, varies from 0% to 100% as defined by the equation:

Flicker (%) = 100 * (max-min) / (max + min)

For this sample the flicker (%) is:

100* (4.15 - 3.96) / (4.15 + 3.96) = 2.3%

As a reference point, a 60W incandescent lamp operating at 60Hz AC voltage has a flicker percentage of 8%. Flicker greater than 50% and at a frequency of less than 150Hz is generally considered unacceptable, while any percentage of flicker at frequencies above 1500 Hz cannot be detected by the human eye.

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[4] Alliance for Solid-State Illumination Systems and Technologies (ASSIST). 2012 ASSIST recommends…Flicker Parameters for Reducing Stroboscopic Effects from Solid-state Lighting Systems. Vol 11, Issue 1. Troy, NY Lighting Research Center http://www.lrc.rpi.edu/programs/solidstate/assist/recommends/flicker.asp

A summary of the frequency and percentage flicker that is considered acceptable by most observers is presented in Chart 10, and the measured result from the sample (the blue data point) is plotted on this chart. The position of the data point within the shaded regions corresponds to an acceptability number between +2 to -2. The lower the number, the less acceptable the level of flicker is to an observer and values below zero are considered unacceptable to most observers.

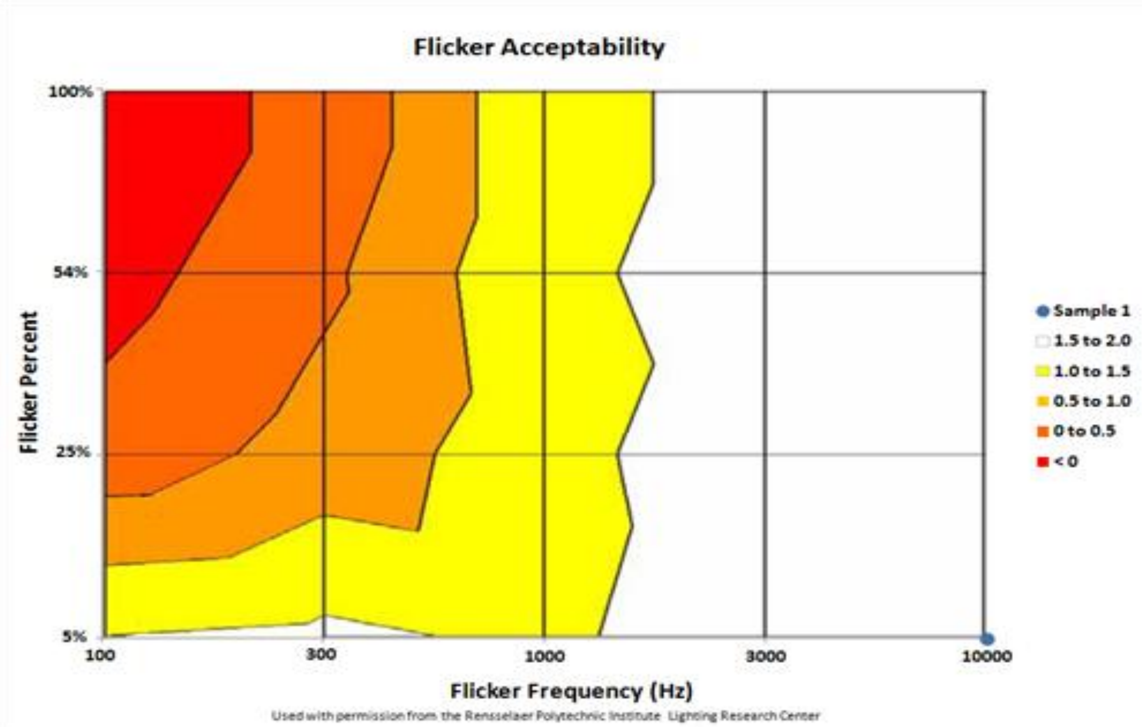

Chart 10: Calculated Flicker Acceptability for Measured Sample

Electrical Testing

Driver Efficiency

Driver efficiency is calculated by dividing the electrical output power supplied to the LEDs by the total input power to the fixture. The output power to the LEDs is the sum of the product of the forward voltage and current for each LED. The input power was measured at an input voltage of 230 VAC.

Driver Efficiency = LED power / Total input power
Driver Efficiency = (Vf*If) / Pin

Driver Efficiency =(45.59 * 1.781) / 89.35

Driver Efficiency =90.9 %

Power Factor and Harmonic Distortion

Power factor is an important metric for LED driver performance, and in the case of street lighting, utility companies may require that luminaires have power factor greater than some specified value. In general the closer the value is to 1, the better the performance. For this luminaire, the power factor is 0.978.

Total harmonic distortion (THD) is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. Harmonic currents are a concern because they can produce problems such as noise interference and overheating of electrical distribution system wiring. The total current harmonic distortion (aTHD) was measured to be less than 15%.

Figure 10: Picture of LED driver

Transient Analysis

Hot plugging and turn-on electrical overstress is occasionally seen with LED Drivers. See Cree Application Note Electrical Overstress for further information on the effects this has on LED performance and lifetime. The driver output current was measured with a current probe and oscilloscope and the waveforms were captured in the following figures. Figure 11 shows the initial inrush current which reaches a maximum amplitude of 1020 mA. Figure 12 shows the continuous output current which has a peak-to-peak ripple of 90 mA with a maximum of 1802 mA.

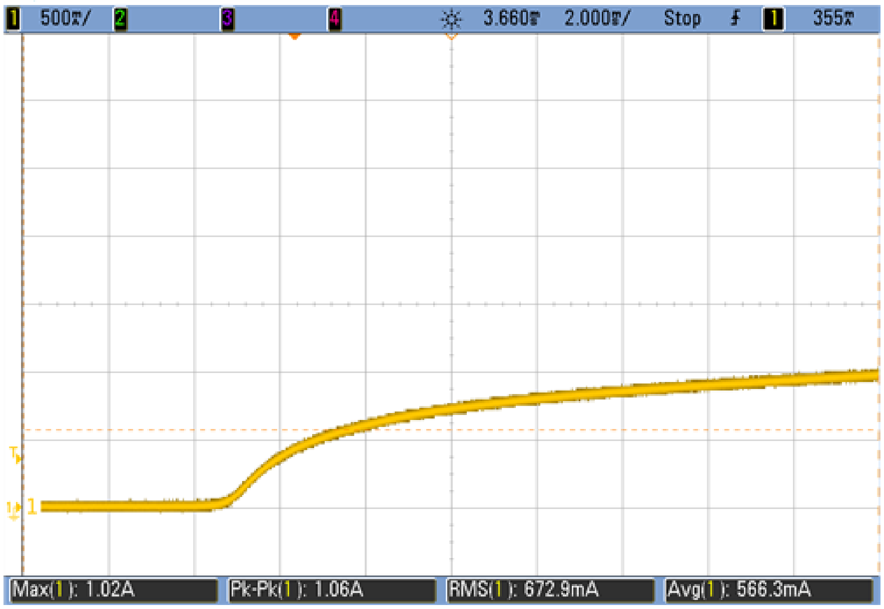

Figure 11: Initial turn-on (inrush) current

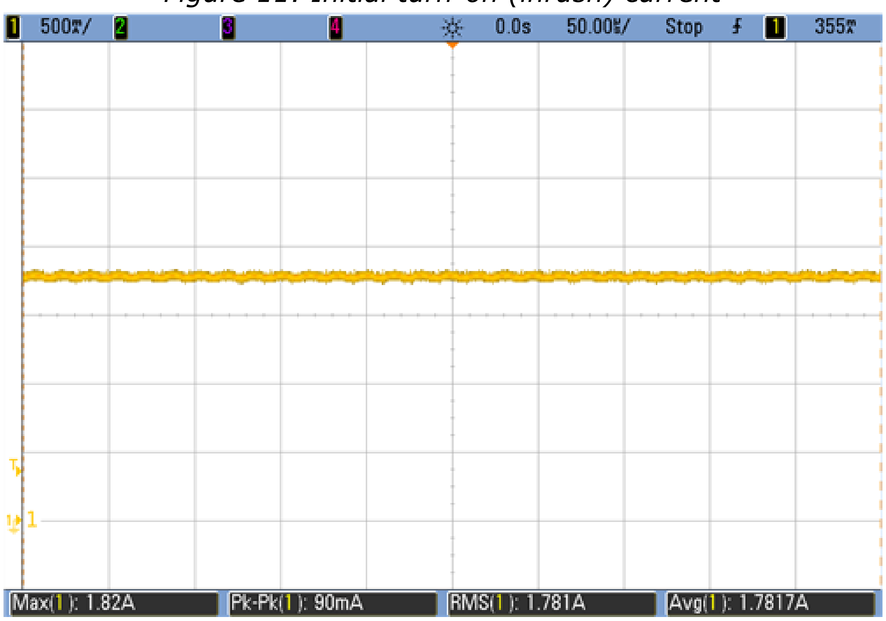

Figure 12: Ripple current

Vf/Current Balance

Luminaires utilizing multiple emitters are often configured using parallel strings which are then driven by a single constant-current source. One drawback to this approach is that careful attention must be paid to minimize the difference in forward voltage between the individual strings; otherwise, the currents will not balance evenly.

The luminaire uses a single string of 15 LEDs in series, therefore current balancing is not applicable.

Driver / String	Current (mA)	Vf	Total LED Wattage
1	1781	45.59	81.2

Table 13: LED Load Current, Forward Voltage, and Power

Dielectric Breakdown Testing

Dielectric withstand testing or "hi-pot" testing is a safety test performed to ensure that the insulation of an electrical device is sufficient to protect humans from electrical shock. A voltage that is several times higher than the working voltage of the device is applied for a period of either one second or one minute. The test is used to verify the mechanical integrity of the insulation and grounding continuity. Typically the voltage applied is 1000V plus 2 times the working voltage.

The hi-pot tester was connected with the positive terminal to the neutral and line inputs and with the negative terminal to the chassis. Ground continuity between the various metal parts was verified. A voltage of 1.46 kVDC was applied for 60s. The result was the sample passed.

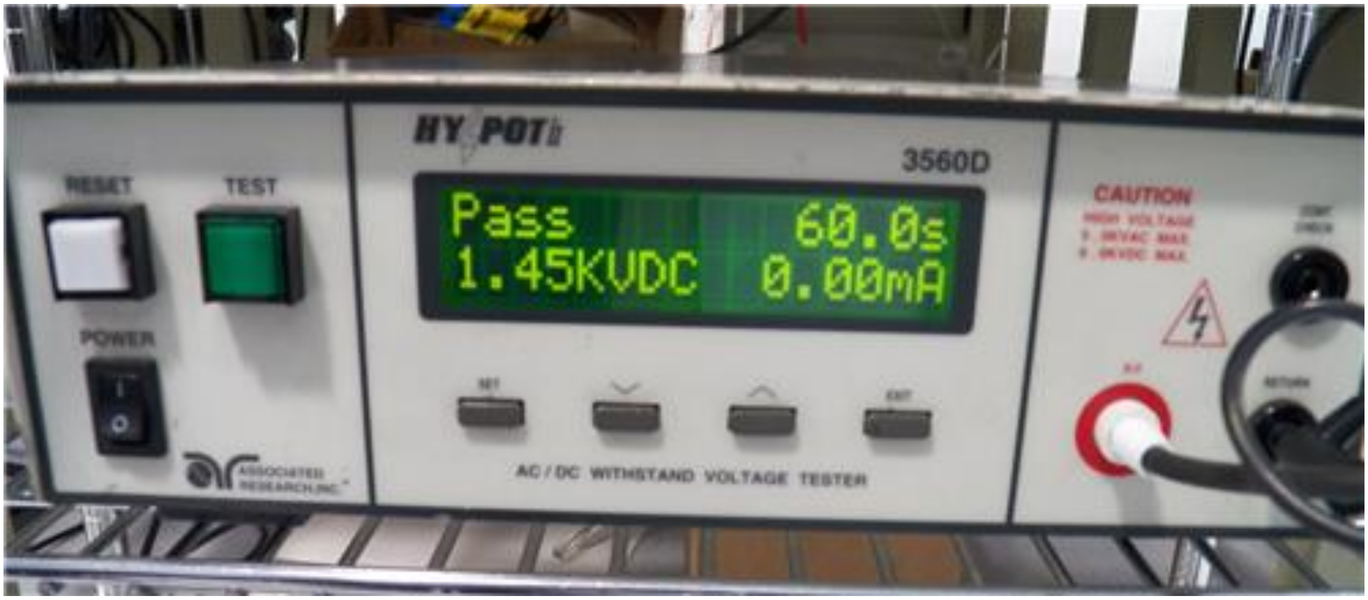

Figure 13: Dielectric Withstand Test Result

Dimmer Compatibility Test

The sample was not tested for dimmer compatibility because it is not intended to be dimmed.

Electrolytic Capacitor Test

Electrolytic capacitor testing was not able to be performed on this luminaire.

Thermal and Mechanical Testing

Solder Point Temperature Analysis

Measuring solder point (case) temperature of the LEDs used in a luminaire is useful for determining the junction temperature and thus predicting lifetime. For more information on measuring case temperature, refer to Cree's Application note on Soldering & Handling.

A thermocouple (TC1) was attached to the solder point of one of the LEDs. A second and third thermocouple (TC2, TC3) were attached to the heat sink and a fourth (TC4) was used to monitor the ambient room temperature, which averaged 23.4°C. Chart 11 shows the measured temperatures over a period of approximately 4 hours. Based on the measured solder-point temperature (Tsp), the operating wattage of the LED and the typical thermal resistance of 2.5°C/W for the XM-L, the resulting calculated junction temperature is 78.7°C.

$T_{sp} = 65.2°C$

$T_j = T_{sp} + (\text{LED power} * 2.5°C/W)$

$T_j = 65.2 + 5.4*2.5$

$T_j = 78.7°C$

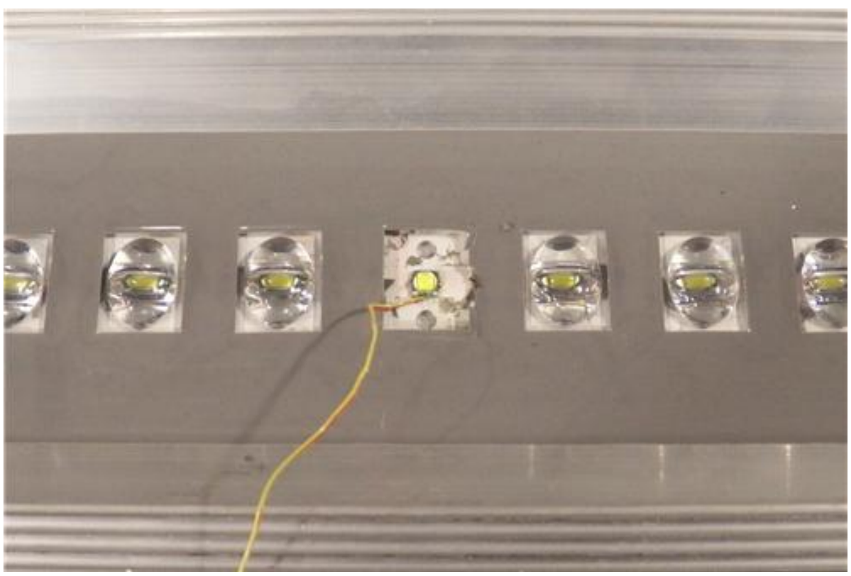

Figure 14: Thermal Testing Set-up

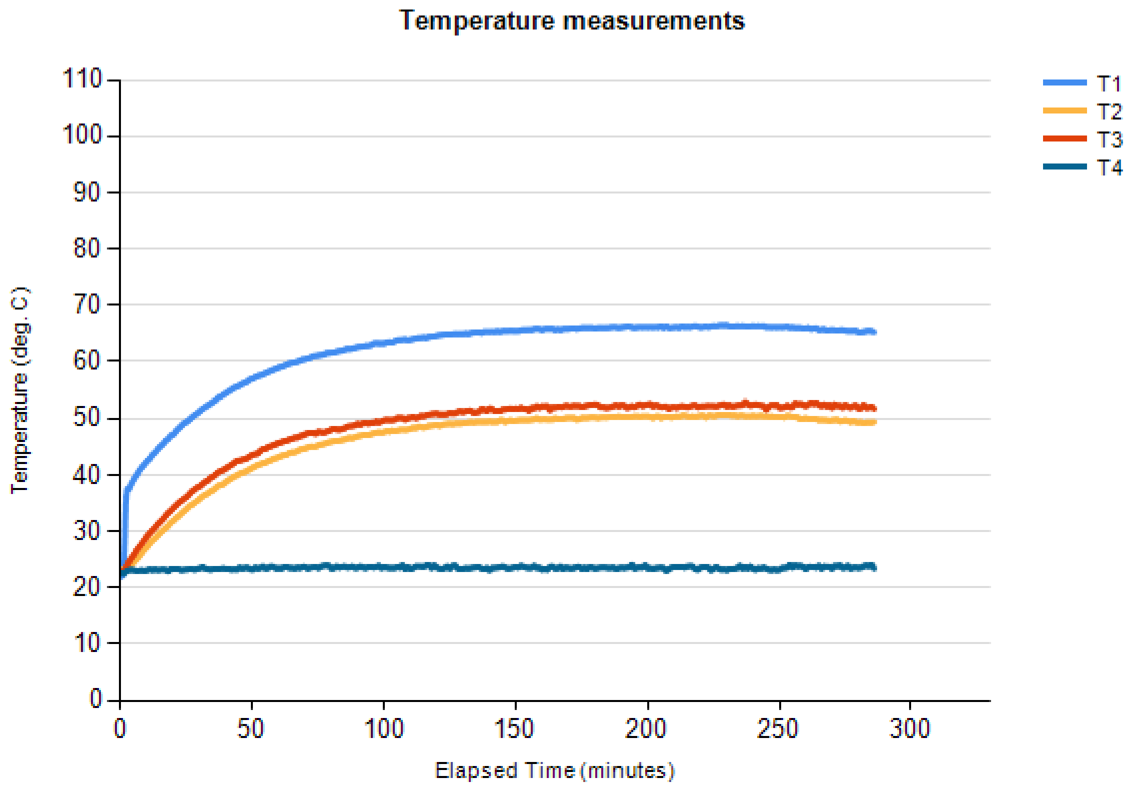

Chart 11: Measured Temperature Graphs

Thermal Imaging Analysis

With the fixture at steady-state temperature, a series of infrared (IR) imaging photographs were taken using a FLIR T300 to evaluate thermal dissipation and areas of concern on the light engine, heat sink, and external housing. The FLIR camera, when used in this way, gives primarily qualitative information. Without precise per-material emissivity calibration, the analysis will not provide exact correspondence to other temperature measurements. The emissivity was set to the default value of 0.95.

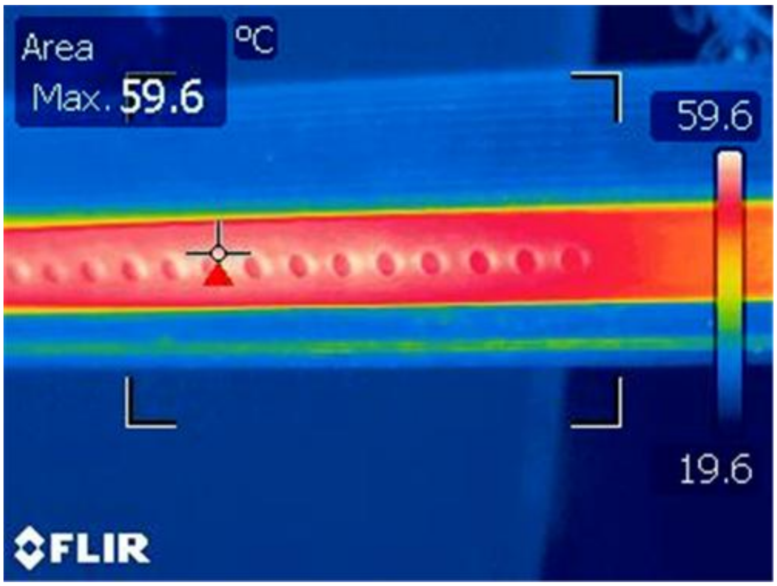

Figure 15: Thermal Image #1

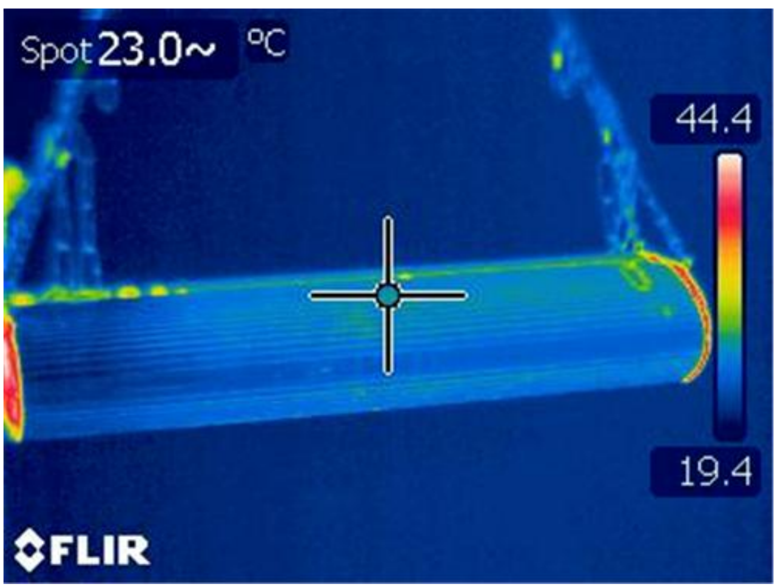

Figure 16: Thermal Image #2

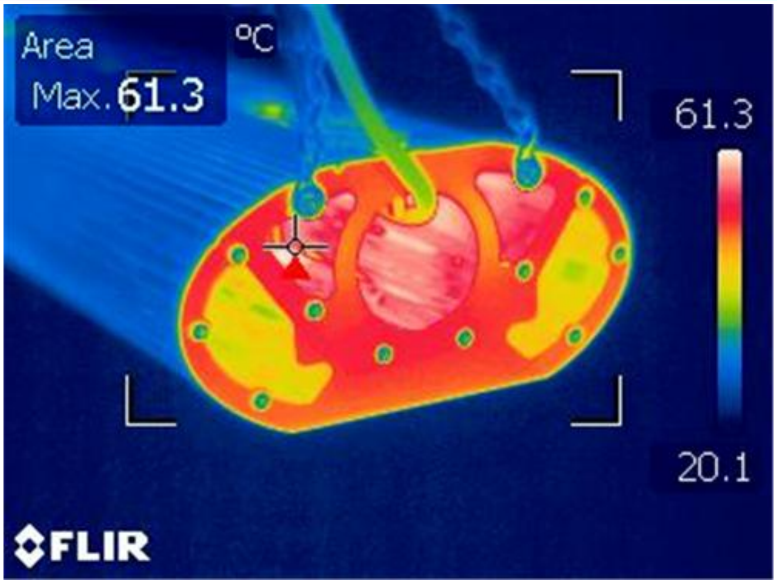

Figure 17: Thermal Image #3

Qualitative Mechanical Construction

The luminaire consists of a 15 XM-L LEDs mounted to multiple MCPCBs. A plastic optic fit over the LED. The MCPCB mates to a large metal heat sink. Grey potting material is coated on top of the MCPCB up to the base of each lens. The LED driver is mounted inside of the heat sink extrusion, with a wire connector protruding from the side of the luminaire.

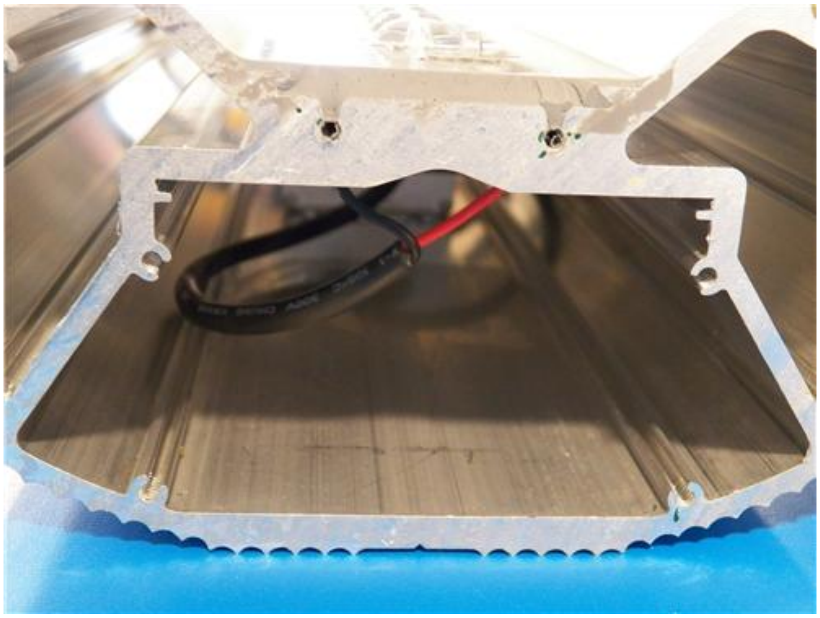

Figure 18: Side view of heat sink

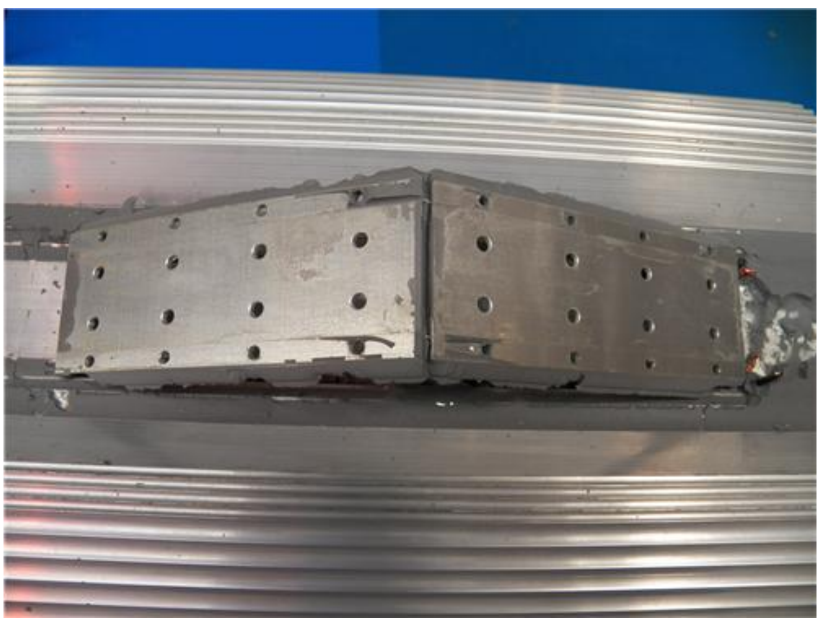

Figure 19: Backside of PCB

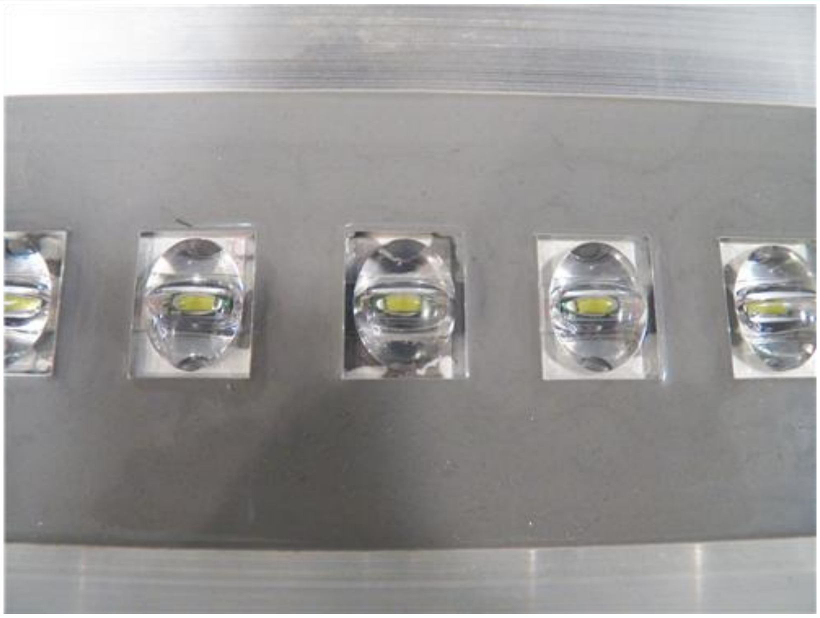

Figure 20: Material under lens

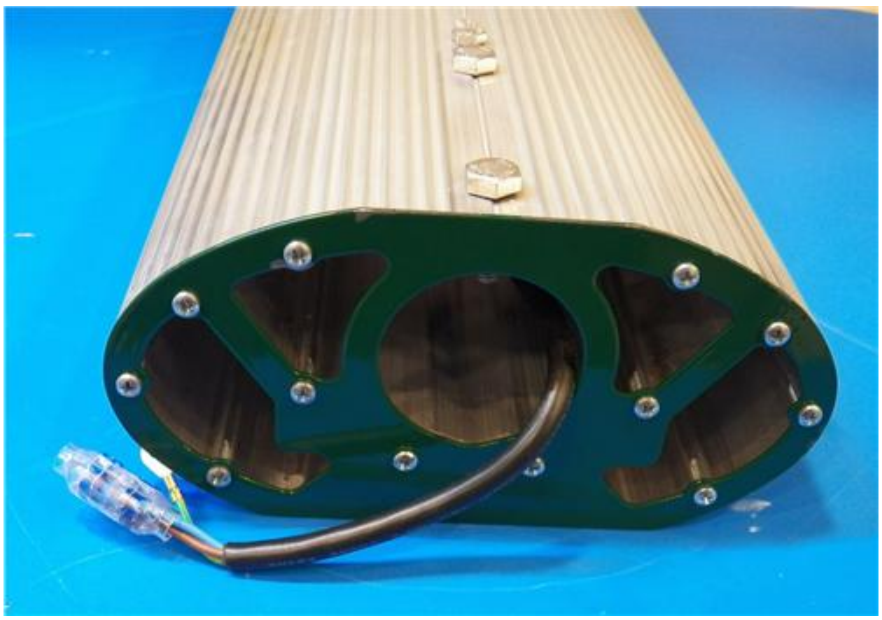

Figure 21: Connector

Chemical Compatibility Analysis

During operation of the luminaire, volatile organic compounds may outgas from materials used in the construction of the luminaire. Testing of these materials is recommended. For more information on chemical compatibility refer to Cree's Application note on Chemical Compatibility[5]

The sample contains a grey potting material, some of which leaked under the individual lenses near the LEDs, as well as below the PCB in some areas.

Based on information provided by the customer, the materials used are manufactured by Dow Corning: 744, PR-1200 RTV prime clear, and Sylgard 160. These materials have not been tested by Cree. The PR-1200 could be a potential concern if not cured properly. According to the datasheet, it contains <0.1% of toluene which is a known chemical that could potentially cause a problem.

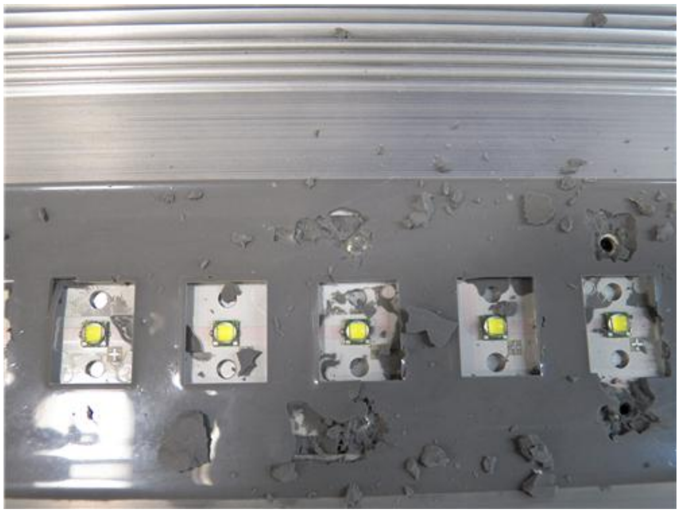

Figure 22: Potting material under lenses

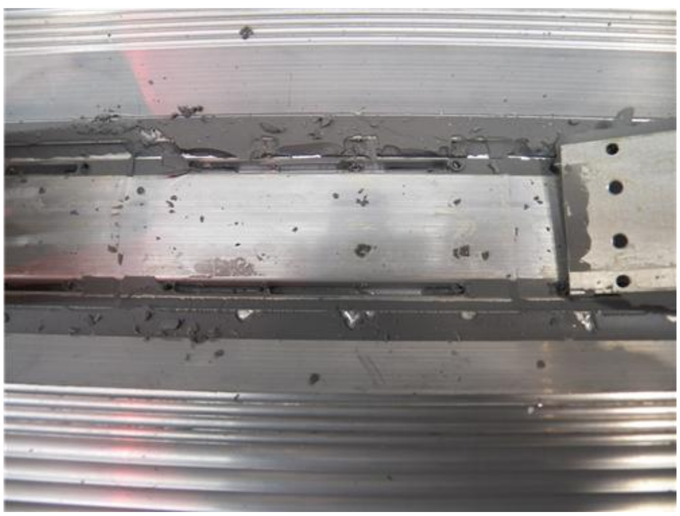

Figure 23:Potting material below MCPCB

[5] http://www.cree.com/products/pdf/XLamp_Chemical_Comp.pdf

X-ray/PCB Analysis

X-ray analysis of a printed circuit board is useful to verify the quality of the soldering process and can determine if there is voiding or excessive solder present. For more information please refer to Cree's application note on soldering and handling.[6]

The images, taken at this angle (camera head positioned above the LED dome with focal plane at the solder pad boundary), show satisfactory coverage with minimal voiding. However, some solder residue is present around each of the LEDs.

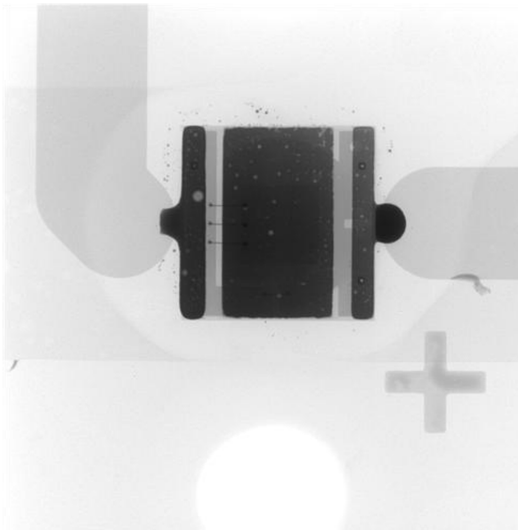

Figure 24: X-ray Image of LED #1

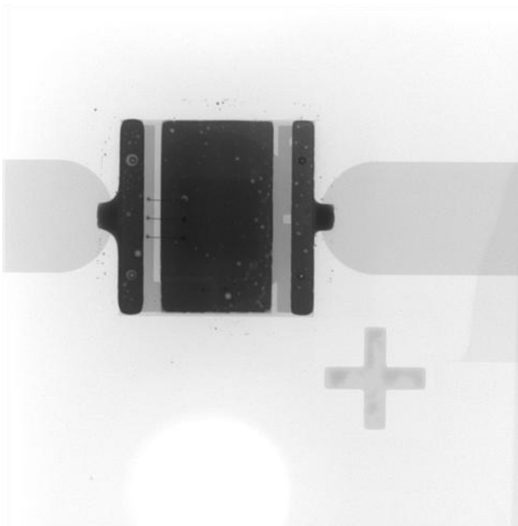

Figure 25: X-ray Image of LED #2

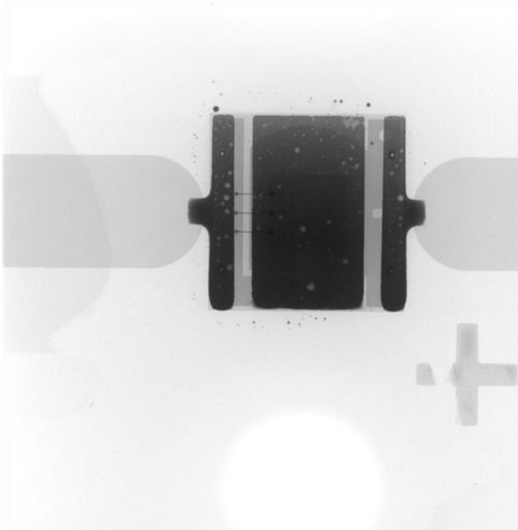

Figure 26: X-ray Image of LED #3

[6] XM Soldering & Handling

LED Lifetime Estimate (per TM-21)

IESNA TM-21-11, "Projecting Long Term Lumen Maintenance of LED Light Sources" is a newly developed Technical Memorandum which provides recommendations for projecting long term lumen maintenance of LEDs using data obtained when testing the LEDs per IESNA LM-80-08, "IES Approved Method for Measuring Lumen Maintenance of LED Light Sources." The TM-21 standard provides an industry-wide, standard and conservative method on which to base lumen maintenance of LEDs. Using TM-21, a projected "L**70**" value can be no greater than six times the actual test duration of the LM-80 data sets.

The TM-21 projections represent the anticipated lumen maintenance of the LEDs and does not account for reliability of all of the other components of the luminaire or of the luminaire as a system.

Cree currently has published 9072 hours of LM-80 on the XLamp XM-L White where If = 2000mA and Tsp = 55°C, 85°C, & 105°C. When using the TM-21 method to determine lumen maintenance of the XM-L based on a measured Tsp of 65°C, the reported L70 is 36,300 hours. This projection is limited by the 6X rule as defined in TM-21. This method also allows lumen maintenance for other L-values to be calculated. In this case, at 32,400 hours the calculated lumen maintenance will be 96%.

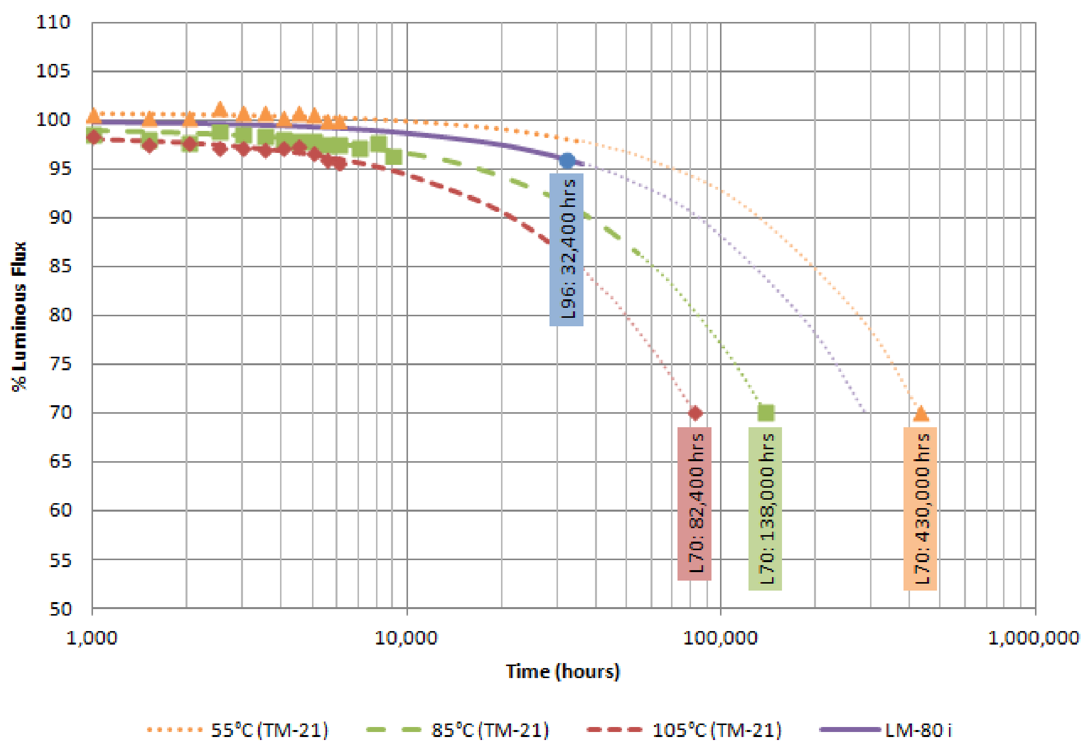

Chart 12: TM-21 projection for XM-L at 2000mA

	Ts1	Tsi (Interpolated)	Ts2
Tsp	**55°C**	65°C	**85°C**
Tsp	328.15 K	338.15 K	358.15 K
Ea/kB		4270.48	
A		3.7998E-01	
α	8.471E-07	1.245E-06	2.520E-06
β	1.008E+00	9.995E-01	9.913E-01
Calculated Lifetime	L70(6k) = 430,000 hours	L70(6k) = 286,000 hours	L70(9k) = 138,000 hours
Reported Lifetime	L70(6k) > 36,300 hours	**L70(6k) > 36,300 hours**	L70(9k) > 54,400 hours

Table 14: TM-21 Calculation Summary

Data Summary

Results in this report are for the sample submitted and used in this evaluation only.

Criteria	Result
Total Luminous Flux	8009
Power (W)	86.12
Tsp and Tj (°C)[7]	65.2 / 78.7
Power Factor	0.978
Lumens per Watt (LPW)	93
Optical Efficiency (%)	92
Driver Efficiency (%)	91
CCT (K)	6042
CRI (Ra)	68
Chromaticity (x-coord)	0.3201
Chromaticity (y-coord)	0.3462
LED Lumen Maintenance[8]	Projected L_{70}(9K) : 286,000
	Reported L_{70}(9K) : 36,300
DLC criteria	Not Applicable

Table 15: Summary of Test Results

[7] Measured at ambient temperature of 23.4ºC.
[8] Per IES TM-21-2011

Lighting Facts® Label

Based on the measured data, an ***unofficial*** U.S. DOE lighting facts label is shown below, and when applicable, an FTC label is provided. To obtain an official label, a formal application must be filed with the respective agencies. Process information can be found at the U.S. Dept. of Energy and Federal Trade Commission websites.

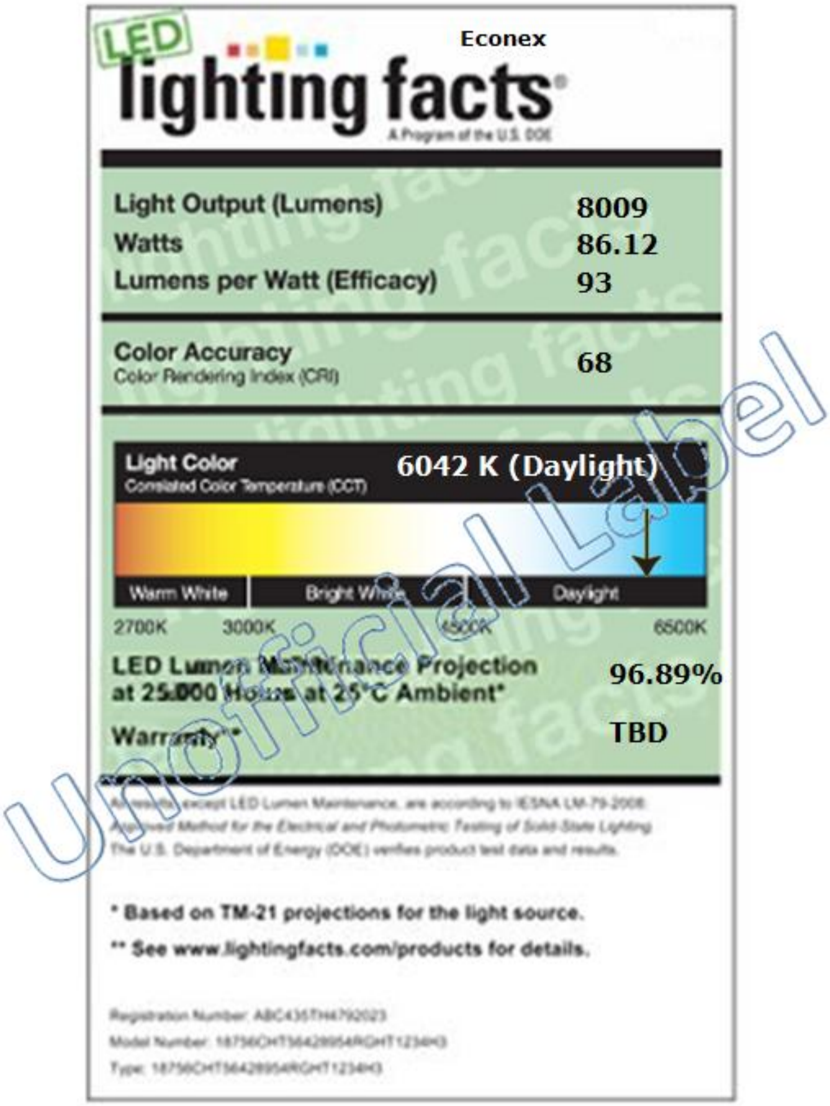

Figure 27: Sample Lighting Facts Label

The LED Lighting Facts label is a registered trademark developed by DOE. Only LED Lighting Facts labels that are provided by and in accordance with the LED Lighting Facts program and LED Lighting Facts product registration process are allowed. Any manufacturer or agent who reproduces, alters, or recreates the LED Lighting Facts label outside the program requirements will be subject to penalties of trademark infringement and may be denied the right to participate in the LED Lighting Facts program.

Measurement Uncertainty

Measurement Parameter	2m Integrating Sphere (+/- %)	Type C Goniophotometer (+/- %)
Total Luminous Flux	1.62	1.52
CCT	0.40	0.50 estimated
CCx	0.14	0.15 estimated
CCy	0.14	0.15 estimated
CRI	0.20	0.30 estimated
Electrical	0.08	0.06
Temperature	1.28	1.28

Table 16: Measurement Uncertainty

Equipment List

Using calibrated, state-of-the-art equipment at Cree Technology Centers across the world, Cree Services reports provide measurements you can trust. Below is a list of manufacturers and equipment that allows Cree to evaluate important aspects of your LED system design and examine areas critical to certifications, as well as cover areas not currently tested by regulatory bodies but vital to quality LED system design. That's lighting-class.

Equipment Used	Manufacturer	Model
Two-meter integrating sphere	Labsphere	CSLMC-7660
Oscilloscope	Agilent Technologies	MS0-6034A
Current probe	Agilent Technologies	1147A
Dielectric breakdown tester	Hypot II	3560D
Infrared camera	FLIR	T300
Digital multimeter	Fluke	289
Thermocouple	Omega	Type K
X-ray Machine	Yxlon	Cougar
250mm integrating sphere	Instrument Systems	ISP250-110
Spectrometer for 250mm sphere	Instrument Systems	CAS 140B-151
Software	N/A	Quickspec Version 1.002.0000
AC Power Source (Type C Goniometer)	Elgar	CW1251
Type C Goniophotometer	LSI / UL	6440T
Software	LSI / UL	Photometric Suite
Spectrometer (2m sphere)	Otsuka Electronics	MC-9801:3683
AC power source	Chroma	61503
Power analyzer	Xitron	2801
Amplifier	UDT Instruments	Tramp
Photosensor	UDT Instruments	211
USB Oscilloscope	Agilent	U2702A
Software	Labsphere	TOCS Version 3.41
Thermometer	Omega	HH147U
Software	jSolutions, Inc.	Photometrics Pro Version 1.3.14

Table 17: List of Equipment Used in Testing

Regulatory Submittals

The Cree Durham Technology Center (NVLAP lab code 500070-0) has been accredited by NVLAP to satisfy the requirements of ISO/IEC 17025:2005, IES LM-79-08, and LM 58-94.

Additional tests beyond IES LM-79-08 with data sets from approved testing labs may be required by certain regulatory bodies. A summary of the Energy Star, Design Lights Consortium and DOE Lighting Facts submittals with web links and required tests is provided. Tests highlighted in yellow are contained within this report and the data from the Cree Durham Technology Center is accepted by the listed regulatory body.

ENERGY STAR Luminaires 1.1 (Final_Luminaires_Program_Requirements.pdf)

- IES LM-79-08 Photometric Report w/ Sphere and Gonio Data (including Color Angular Uniformity)
- Electrical Performance Data
  - Start up time, Run up Time, Dimming, Power Factor, Off State Power Consumption, UUT Operating Frequency
- Noise Test Data
- Transient Protection (Ring Wave) Test Data
- EMI / RFI Test Data
- In-Situ Test Data
- Safety Report
- Color / Lumen Maintenance
  - Option #1 – Customer needs full set of LM-80 data, in-situ test data and TM-21 report
  - Option #2 – Customer needs to put actual luminaires onto Lifetime Testing

ENERGY STAR Integral LED Lamps 1.4 (Note Lamps 1.0 is currently in draft which may change these requirements slightly) (Integral_LED_Lamps_Program_Requirements.pdf)

- IES LM-79-08 Photometric Report w/ Sphere and Gonio Data (including Color Angular Uniformity)
- Electrical Performance Data
  - Dimming, Power Factor, UUT Operating Frequency
- Noise Test Data
- Transient Protection (Ring Wave) Test Data
- EMI / RFI Test Data
- In-Situ Test Data
- Safety Report
- Minimum Operating Temperature Validation (Outdoor Only -20C)
- Rapid Cycle Stress Testing
- Color / Lumen Maintenance
  - Option #1 – Customer needs full set of IES LM-80-08 data, in-situ test data and TM-21 report
  - Option #2 – Customer needs to put actual lamps onto Lifetime Testing

DesignLights Consortium (http://www.designlights.org/solidstate.manufacturer.instructions.php)

- IES LM-79-08 Photometric Report with Sphere and Gonio Data
- In-situ temperature measurements test (ISTMT) report.
- Electrical Performance Data
  - Power Factor, THD-A / THD-V
- Noise Test Data
- Color / Lumen Maintenance
  - Option #1 – Customer needs full set of LM-80 data, in-situ test data and TM-21 report
  - Option #2 – Customer needs to put actual product onto Lifetime Testing

U.S. DOE Lighting Facts http://www.lightingfacts.com/content/manufacturers and
FTC label information at: http://www.lightingfacts.com/ftclabel

- IES LM-79-08 for total flux and color (required label metrics; LM-79 sections 9 and 12)
- IES LM-79-08 for intensity distribution (optional metrics; LM-79 section 10)

In-situ Temperature Measurement Test (ISTMT): IES LM-80-08

Report Review

This report has been reviewed by:

Date: 2/25/2013

Shawn Keeney for
Richie Richards
DTC Manager of Applications Engineering

If there are any questions or concerns on the information or content of this report, please contact your Cree sales representative or your local Cree field application engineer. If you do not know these points of contacts or require additional assistance, please contact Cree Product Support.

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https://www.research.net/s/temposurvey