

THERMAL
ELECTRICAL
MECHANICAL
PHOTOMETRIC
OPTICAL

CREE SERVICES
**TEMPO TESTING
AND EVALUATION**

July 31, 2019

Title:

TEMPO 24 Report

Prepared for:

LED Roadway

Prepared by:

Cree Durham Technology Center (DTC)

Ticket Number:

20110-T

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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:

LED Roadway

This report was generated by:

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

TEMPO 24 Checklist

Thermal

- ☒ In-situ Temperature Measurement Test (ISTMT)*
- ☐ n/a Thermal Imaging With IR Camera*

Electrical

- ☒ Driver Efficiency*
- ☒ Transient Analysis*
- ☒ Source Start Time Test
- ☒ Power Analysis (PF, aTHD) (Per IES LM-79-08, sections 7 and 8)
- ☐ n/a Dimmer Compatibility Test*
- ☒ Dielectric Breakdown (Hi-pot)*
- ☒ Vf/Current Balancing (Parallel Arrays Only)*
- ☐ n/a Electrolytic Capacitor Testing*

Mechanical

- ☐ n/a Qualitative Construction Analysis*
- ☐ n/a Chemical compatibility Analysis*
- ☒ X-ray of Printed Circuit Board*

Photometric and Optical

- ☒ Luminous Intensity Distribution (Per IES LM-79-08, section 9.3)
- ☐ 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*
- ☐ n/a Component Binning and Color Point Evaluation*
- ☒ Additional Photometric Analysis for Luminaire Type (e.g. Indoor, Roadway, etc.)*
- ☐ n/a Visible Flicker Test*
- ☒ Review Against DesignLights™ Consortium (DLC) criteria*
- ☒ LED Lumen Maintenance Estimate (per TM-21)*

* Data sets that are not covered by NVLAP accreditation.

Executive Summary

The LED Roadway QB 00 H16S X 5 40 X 4G2S uses 16 XLamp® XHP35 LEDs. The luminaire produces 9260 lumens with a 3979K CCT while consuming 79.5W of power. With an optical efficiency of 82% the luminaire delivers 116 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)	9260	IES LM-79-08
Power (W)	79.5	
Tsp and Tj(°C) ¹	81.6 / 89.9	
Power Factor	0.925	
Lumens Per Watt (LPW)	116.5	IES LM-79-08
Optical Efficiency (%)	82	
Driver Efficiency (%)	90	
CCT (K)	3979	IES LM-79-08
CRI (Ra)	71	IES LM-79-08
Chromaticity (x-coord)	0.3849	IES LM-79-08
Chromaticity (y-coord)	0.3905	IES LM-79-08
LED Lumen Maintenance	Reported L ₇₀ (9k) :> 60,500	IES TM-21

Table 1: Summary of Test Results

²Measured at ambient temperature of 21.9°C and normalized to 25°C

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 and 2. No signs of physical damage were observed. The sample was powered and appeared to be operating normally.

As Received Pictures



Figure 1: As-Received Picture #1



Figure 2: As-Received Picture #2

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.

This 2m sphere is a Labsphere model CSLMS-7660 using the 4π geometry measurement method with a Photol (Otsuka Electronics) MC 9801 spectroradiometer. Testing is performed per Cree standard photometric testing protocols, which follow IES LM-79-08³ sections 9.1 and 9.3 and includes procedures such as performing absorption correction using a NIST traceable lamp and aligning the emission plane of the device under test with the sphere's sensor baffle. The sample is powered using a programmable regulated AC Power Source (or DC when applicable) and a Xitron model 2801 power analyzer is used to measure the electrical characteristics. Figure 3 is a photograph of the sample mounted in the sphere.



Figure 3: Sample in 2m Integrating Sphere

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

Luminaire evaluation on a goniophotometer system was performed at Cree's photometric testing lab in Durham, NC on a type C goniophotometer. This goniophotometer is a UL/Lighting Sciences Inc. model 6440T utilizing, an Inphora photocell (model PDET 11), an AC power supply (or DC supply when applicable) and a power meter. A Gooch & Housego spectroradiometer (model 770VIS/NIR) also allows for spectral irradiance data to be measured over the range of 380 to 780 nm. The testing distance is 28.5 feet (8.69 meters).

The illuminance calibration on the type C goniophotometer is performed utilizing 3 STD-EHD Lamps with a 500 Watt rating. The initial values for illuminance are measured with a Spectroradiometer, STS Certificate of Calibration #2082. The lamp serial numbers are: 12C066, 12C067, and 12C068. The lamps that are utilized at Cree were generated on 11, February 2013.

To calibrate color on the Type C goniophotometer, a single STD-EHD 120V spectral irradiance calibration lamp with a 500 Watt rating is used. The lamp (Serial Number: 13C072) is positioned with the serial number facing away from the spectroradiometer just like the intensity standards. This lamp must operate base down and at the specified amperes noted on STS Certificate of Calibration #2084. Figure 4 is a photograph of a fixture under test on this Type C Goniophotometer.



Figure 4: 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	12-Jul-2019	24.3	277	60
Luminous Intensity	30-Jul-2019	24.8	277	60

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 1.47 hours to stabilize.

Parameter	Stable Data
Radiant Flux (watts)	26.43
Photopic Luminous Flux (lumens)	9260
Scotopic Luminous Flux (lumens)	13683
S/P ratio	1.48

Table 3: Luminaire Radiometric and Photometric Output

Lumens vs. Time

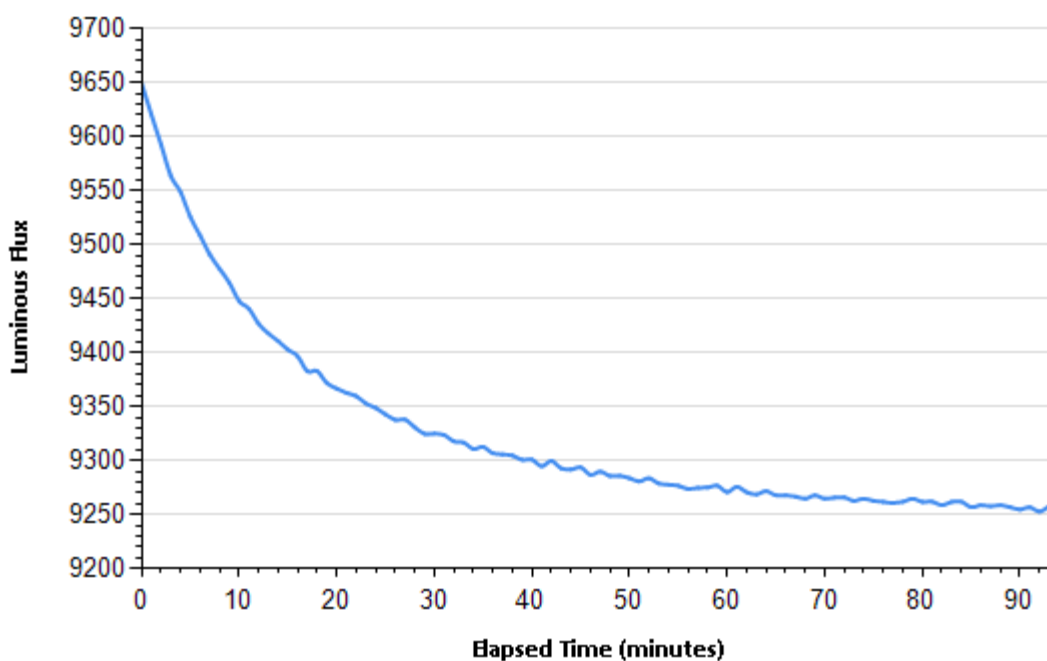


Chart 1: Luminous Flux Stabilization Over Time

Luminaire Chromaticity and Color Rendering

Parameter	Stable Data
x coordinate	0.3849
y coordinate	0.3905
u' coordinate	0.2226
v' coordinate	0.5082
Correlated Color Temperature	3979
Duv	0.0051

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

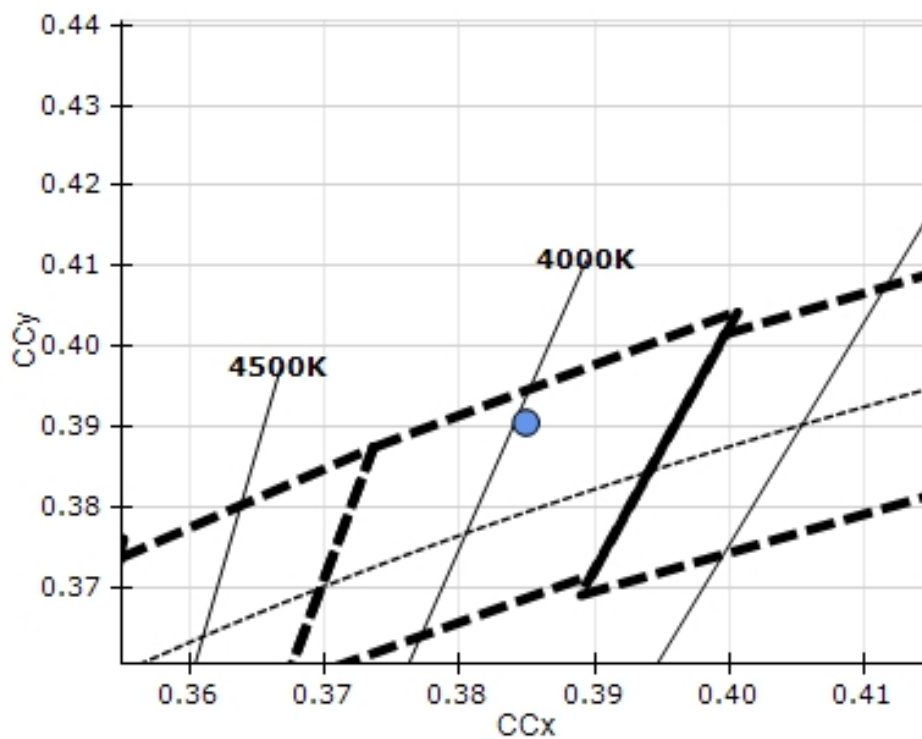


Chart 2: Plot of x-y Coordinates on ANSI C78.377A Diagram

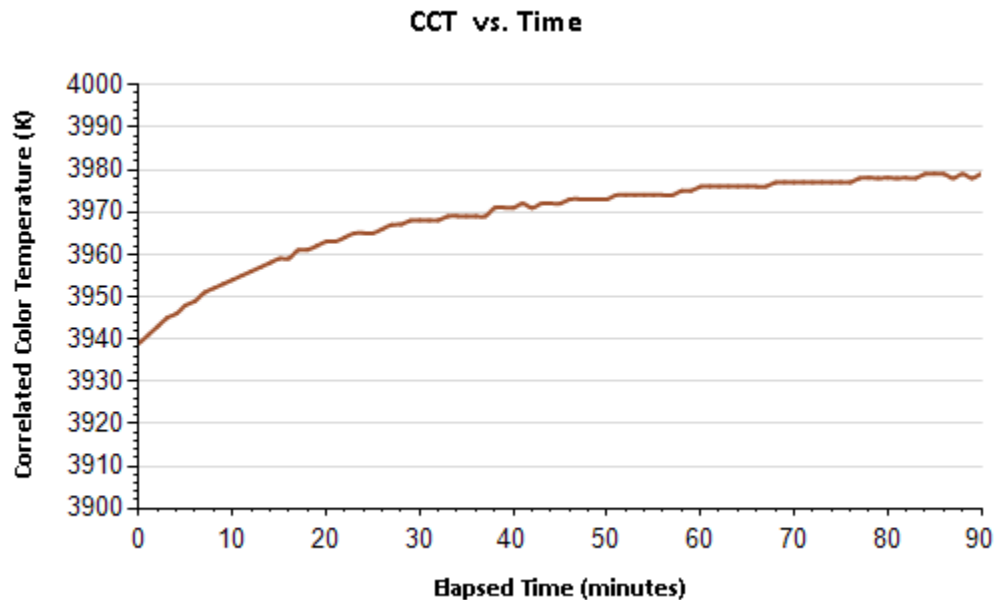


Chart 3: Correlated Color Temperature Stabilization Over Time

Color Rendering Index (CRI)	Value
Average (RA)	71
CRI (R1)	67
CRI (R2)	76
CRI (R3)	84
CRI (R4)	71
CRI (R5)	67
CRI (R6)	67
CRI (R7)	81
CRI (R8)	52
CRI (R9)	-32
CRI (R10)	44
CRI (R11)	66
CRI (R12)	39
CRI (R13)	68
CRI (R14)	91

Table 5: Measured Color Rendering Index

Luminaire Spectral Distribution

Parameter	Stable Data
Peak Wavelength (nm)	580
Dominant Wavelength (nm)	576

Table 6: Peak and Dominant Wavelength

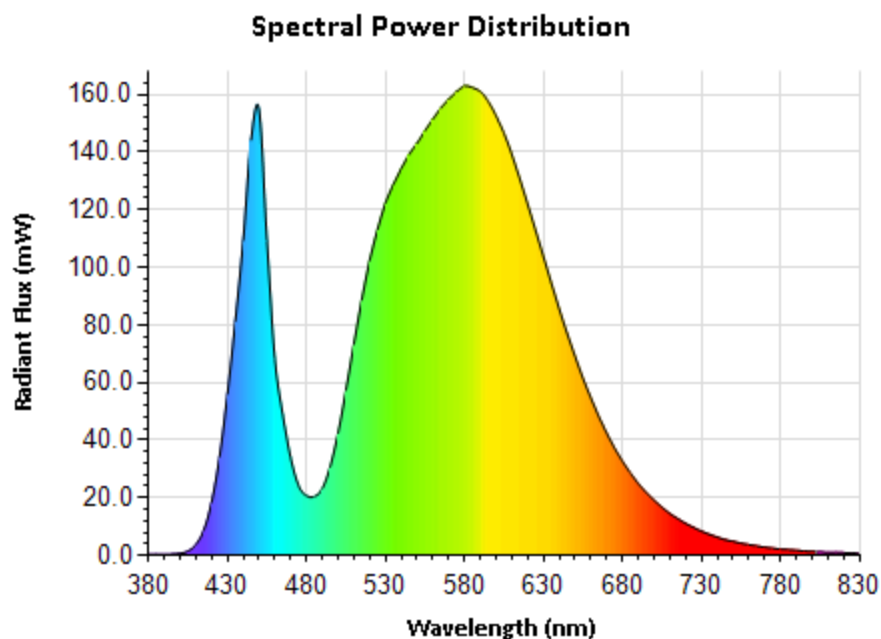


Chart 4: Measured Spectral Power Distribution

nm	mW/nm	nm	mW/nm	nm	mW/nm	nm	mW/nm
380	0.3	490	23.2	600	152.5	710	14.5
385	0.4	495	30.6	605	146.5	715	12.7
390	0.2	500	42.4	610	139.1	720	11.0
395	0.4	505	57.3	615	130.8	725	9.6
400	0.6	510	73.2	620	121.8	730	8.3
405	1.4	515	88.7	625	112.8	735	7.3
410	3.7	520	102.3	630	103.7	740	6.3
415	8.7	525	113.1	635	94.4	745	5.4
420	18.4	530	122.3	640	85.5	750	4.8
425	34.2	535	128.7	645	76.9	755	4.2
430	56.0	540	134.2	650	69.0	760	3.7
435	81.4	545	139.2	655	61.4	765	3.2
440	109.3	550	143.0	660	54.6	770	2.8
445	144.2	555	147.4	665	48.2	775	2.4
450	154.6	560	151.4	670	42.3	780	2.1
455	109.0	565	155.2	675	37.1	785	1.9
460	68.2	570	158.3	680	32.6	790	1.7
465	48.9	575	160.9	685	28.5	795	1.5
470	33.9	580	162.9	690	24.9	800	1.3
475	24.2	585	162.3	695	21.8	805	1.2
480	20.7	590	161.0	700	19.1	810	1.0
485	20.3	595	157.6	705	16.6	815	1.0

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 277 Vac.

$$\begin{aligned}
 \text{Efficacy (at steady state)} &= \text{Lumens} / \text{Total Input Power} \\
 &= 9260 / 79.5 \\
 &= \mathbf{116.5 \text{ lm/W}}
 \end{aligned}$$

Goniophotometer Data

Characteristics	Result
IES Classification	Type II
Longitudinal Classification	Medium
Luminaire Lumens	9,123.0
Total Luminaire Watts	79.5
Luminaire Efficacy Rating (LER)	115
Maximum Candela	3,947.0
Maximum Candela Angle	70H70V
Maximum Candela At 90 Degrees Vertical	.2(0.0%Lum)
Maximum Candela from 80 to <90 Degrees Vertical	1159.5(12.8%Lum)

Table 8: Luminaire Summary Data

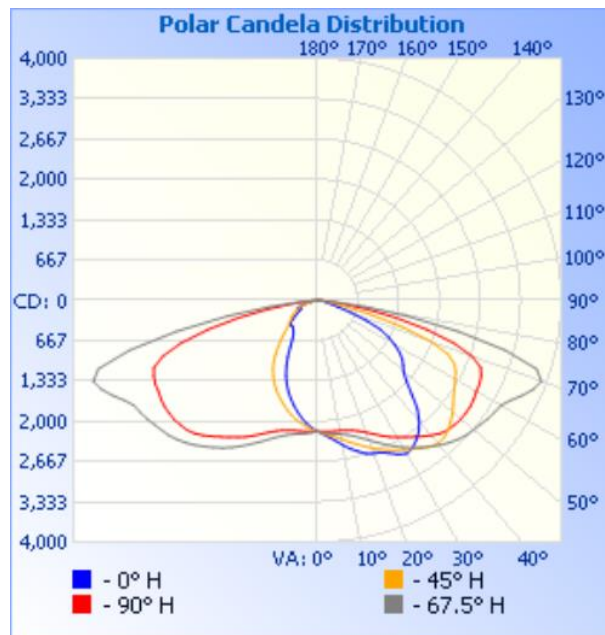


Chart 5: Intensity Distribution

Luminaire Classification System (LCS)	Lumens	% Luminaire
FL - Front-Low (0-30)	1081.3	11.9
FM - Front-Medium (30-60)	3179	34.8
FH - Front-High (60-80)	1892.2	20.7
FVH - Front-Very High	106	1.2
BL - Back-Low (0-30)	764.1	8.4
BM - Back-Medium (30-60)	1447.8	15.9
BH - Back-High (60-80)	630	6.9
BVH - Back-Very High (80-90)	20.5	0.2
UL – Up light-Low (90-100)	0.5	0
UH – Up light-High (100-180)	1.7	0
TOTAL	9123.1	100
BUG Rating	B2-U1-G2	

Table 9: Luminaire Classification System

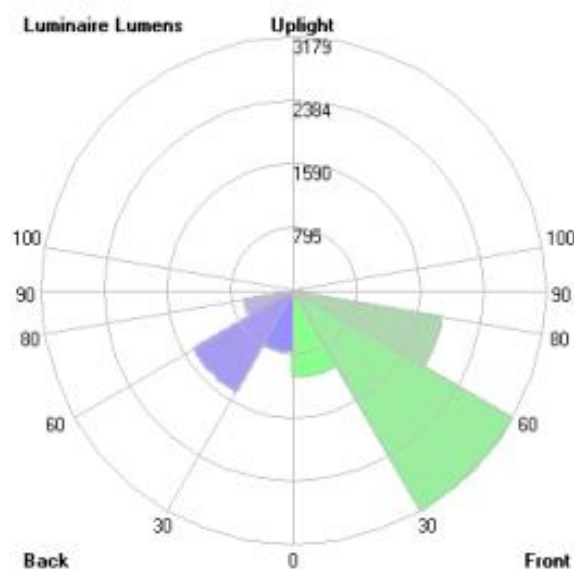


Chart 6: LCS Graph

Flux Distribution	Lumens	% Luminaire
Downward Street Side:	6258.6	69
Downward House Side:	2862.4	31
Downward Total:	9121	100
Upward Street Side:	0.7	0
Upward House Side:	1.6	0
Upward Total:	2.3	0
Total Lumens:	9123.3	100

Table 10: Flux Distribution

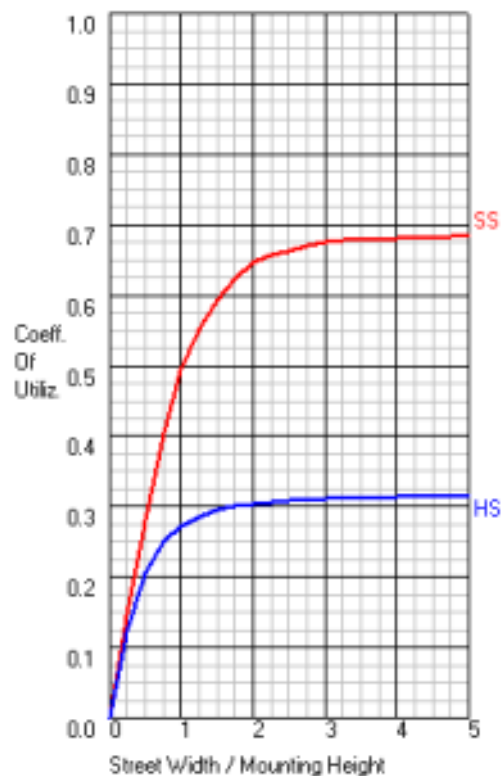


Chart 7: Coefficients of Utilization

Illuminance

The sample was measured on a type C goniophotometer and illuminance measurements were calculated from the IES-63 electronic file using Photometrics Pro software. The results are shown in Charts 4 and 5.

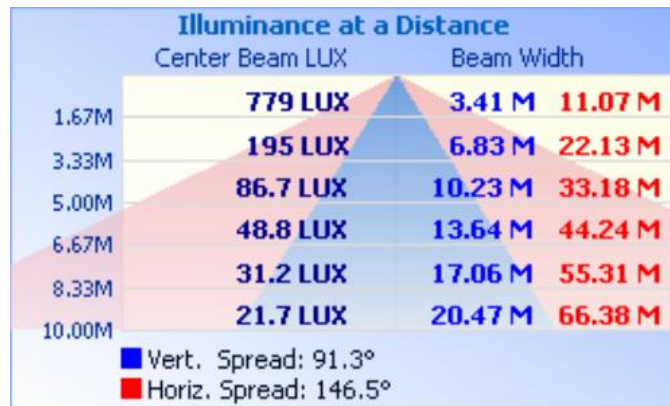


Chart 4: Cone of Light Diagram

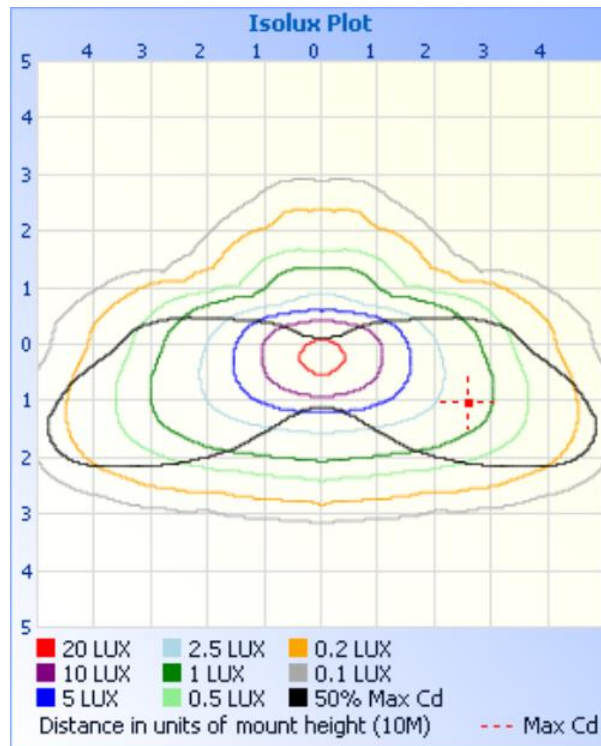


Chart 5: Isolux Plot

Optical Efficiency Calculation

The sample was tested with and without optics and the results are shown below in Table 11. 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 5: Optical Components

Condition	Radiant Flux (Watts)	Luminous Flux (lumens)	% Loss (overall)
With Optics	26.9	9343	17.6%
Primary Optic Removed	29.42	10187	10.2%
No Optics	32.59	11340	--

Table 11: Measured Optical Efficiency

$$\begin{aligned}
 \text{Optical Efficiency} &= \text{Lumens With Optic} / \text{Lumens Without Optic} \\
 &= 9343 / 11340 \\
 &= 82.4\%
 \end{aligned}$$

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 277 Vac.

Driver Efficiency = LED power / Total input power

Driver Efficiency = ($V_f \times I_f$) / P_{in}

Driver Efficiency = ($90.6 \times 0.402 + 90.6 \times 0.402$) / 80.87

Driver Efficiency = 90.1 %

Power Factor and Harmonic Distortion

Power factor (PF) is an important metric for LED driver performance, and certain regulations may require that luminaires or lamps have power factor greater than some specified value. In general the closer the value is to 1, the better the performance.

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 measured PF and THD results are shown in Table 12.

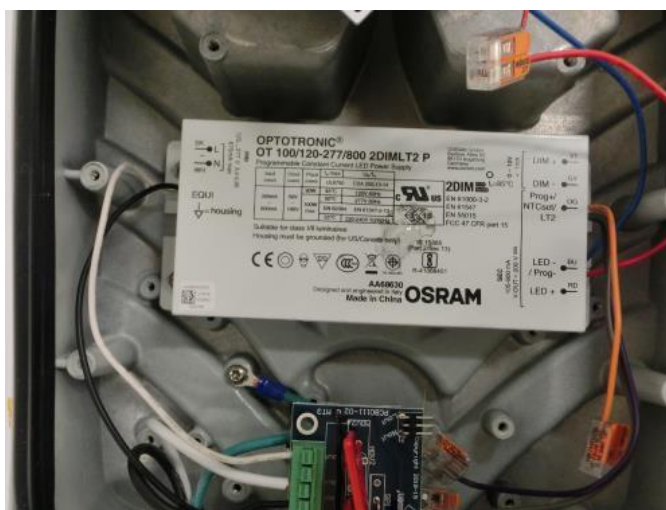


Figure 6: Picture of LED driver

Power Results

Parameter	Stable Data at 277VAC
Total Wattage	79.5
Power Factor	0.925
Input Voltage (Vac)	277
Input Frequency (Hz)	60.0
Input Current(A)	0.31
vTHD (Voltage Total Harmonic Distortion)	0.06%
aTHD (Current Total Harmonic Distortion)	15.92%

Table 12: Measured Power Test Results

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 7 shows the initial inrush current which reaches a maximum amplitude of 799mA. Figure 8 shows the continuous output current which has a peak-to-peak ripple of 63mA with a maximum of 836 mA. Figure 9 shows an open circuit voltage of 41.9 volts.



Figure 7: Initial Turn-on (inrush) Current

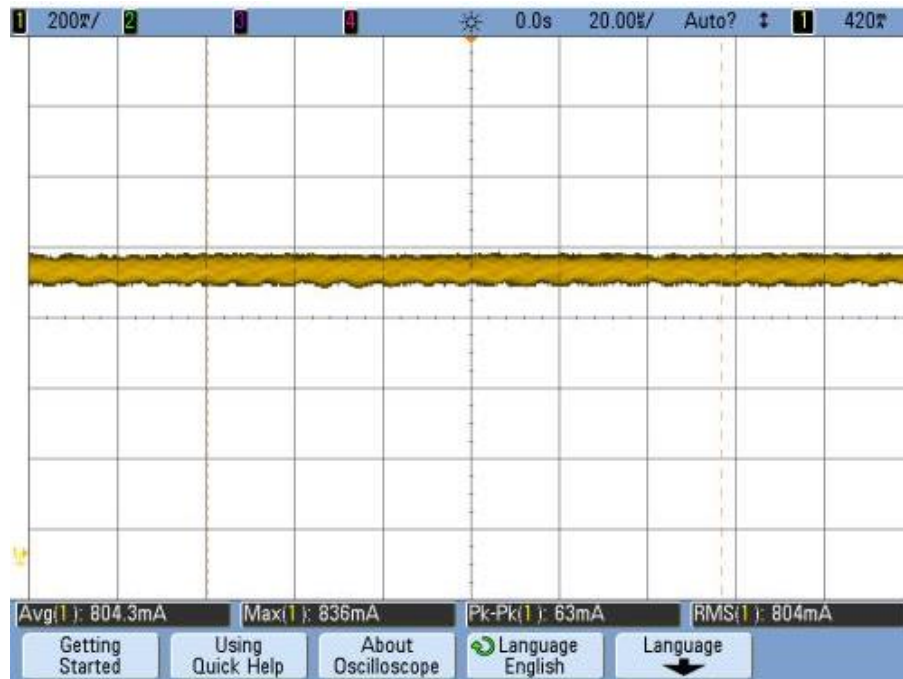


Figure 8: Driver Output Ripple Current



Figure 9: Open circuit voltage

Source Start Time Test

The source start time test measures the delay between when power from the mains is applied and when the luminaire output reaches 98% of full output. In the figure below, the yellow trace is the AC input current and the purple trace is the output of a photodetector. A delay of approximately 1.2 seconds was observed prior to the LEDs reaching 98% of full output.

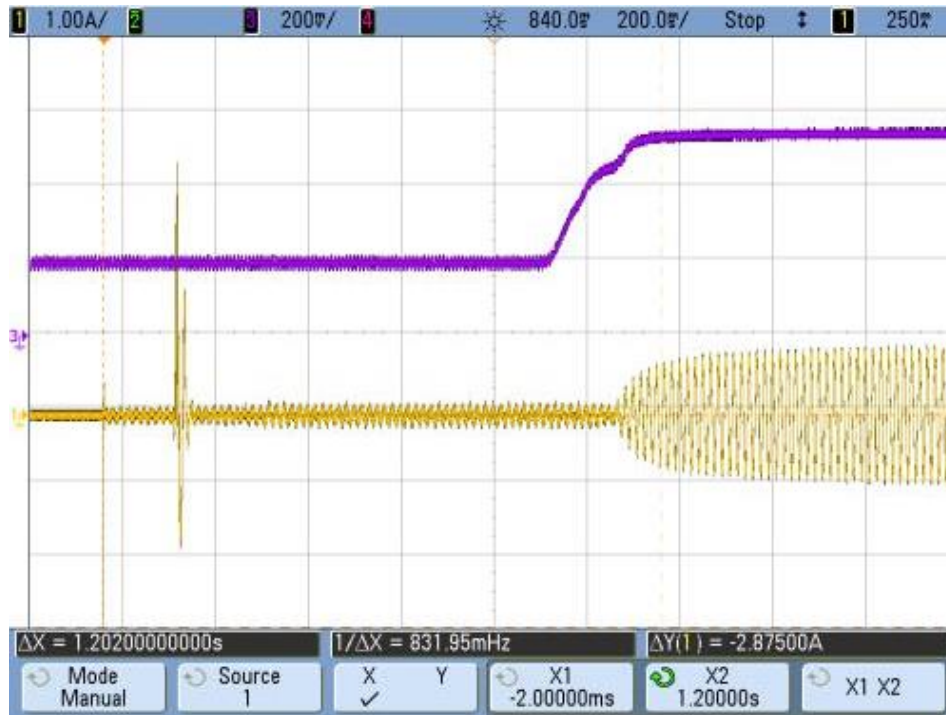


Figure 10: Turn-on Delay

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.

Driver / String	Current (mA)	Vf	Total LED Wattage
1	402	90.6	36.4
2	402	90.6	36.4

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 1.554kVDC was applied for 60s. The result was the sample passed.



Figure 11: Dielectric Withstand Test Result

Thermal and Mechanical Testing

In-situ Temperature Measurement Test (ISTMT)

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.

One thermocouple (TC1) was attached to the solder point of one of the LEDs. A second thermocouple (TC2) was attached to the heat sink. A third (TC3) was attached to driver and a fourth (TC4) was used to monitor the ambient room temperature, which averaged 21.9°C. Chart 8 shows the measured temperatures over a period of approximately 3 hours. Based on the measured solder-point temperature (Tsp), the operating wattage of the LED and the typical thermal resistance of 1.8°C/W for the XHP35, the resulting calculated junction temperature is 86.8°C.

$$T_{sp} = 78.5^{\circ}\text{C}$$

$$T_j = T_{sp} + (\text{LED power} * 1.8^{\circ}\text{C/W})$$

$$T_j = 78.5 + 4.6 * 1.8$$

$$T_j = 86.8^{\circ}\text{C}$$

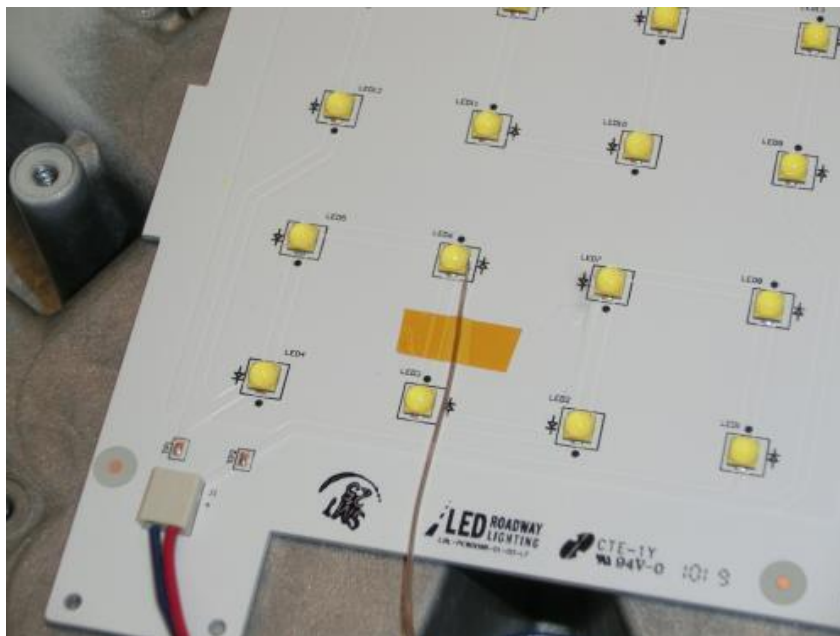


Figure 12: Thermal Testing Set-up

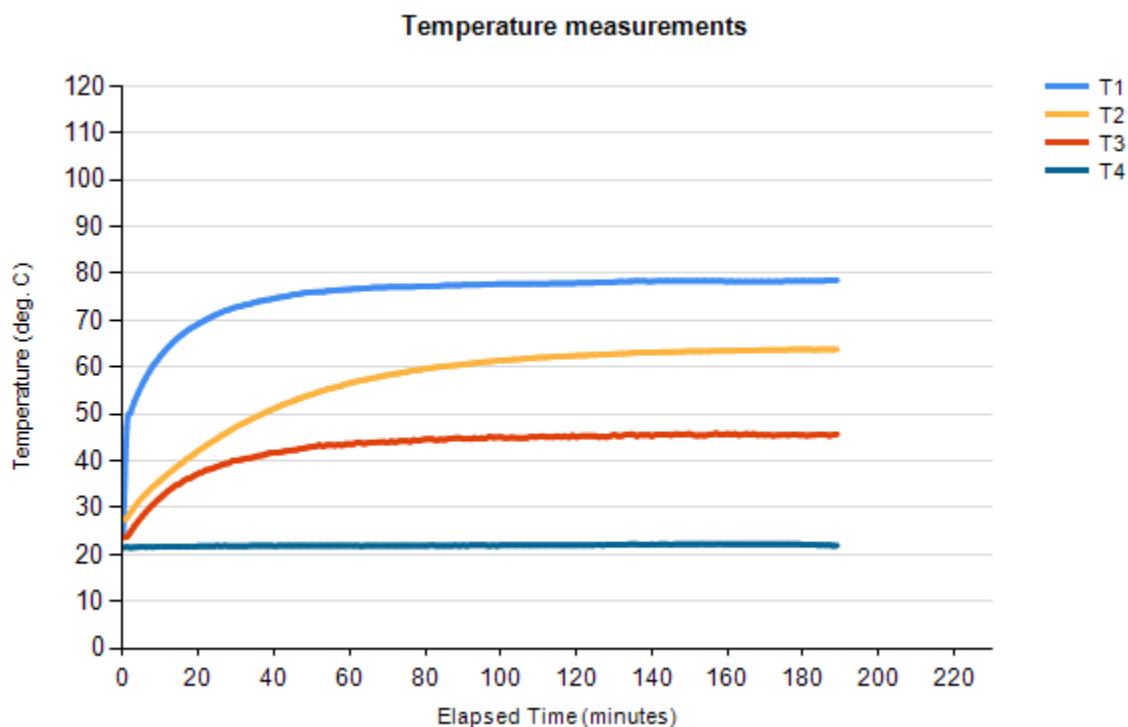


Chart 8: Measured Temperature Graphs

Recorded Tsp (°C)	Recorded Ta (°C)	Calculated Tj	Tsp Adjusted to 25° Ambient	Tj Adjusted to 25° Ambient
78.5	21.9	86.8	81.6	89.9

Table 14: Normalized ISTMT result

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 handling¹.

The images, taken at this angle (camera head positioned above the LED dome with focal plane at the solder pad boundary), show inconsistent application of solder over the contact areas between the circuit board and LED. The figures show a moderate amount of voiding. No excess solder particles between or near the solder pads were observed.

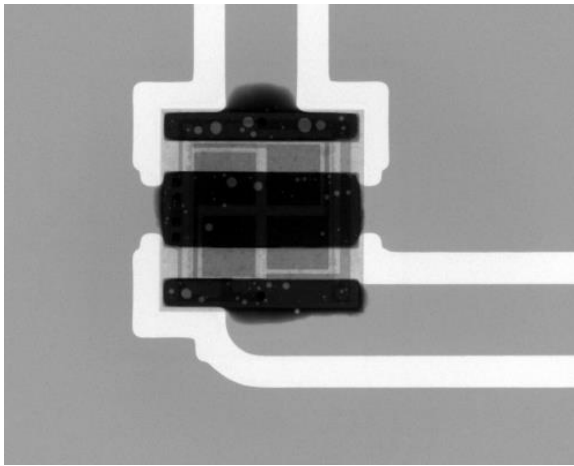


Figure 13: X-ray Image of LED

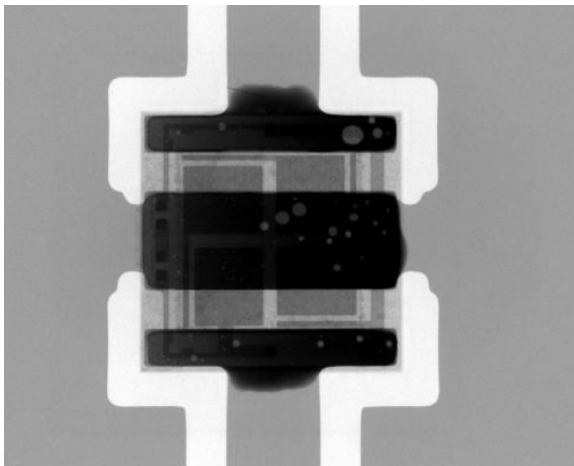


Figure 14: X-ray Image of LED

¹ <https://www.cree.com/led-components/media/documents/sh-XHP.pdf>

LED Lumen Maintenance 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 is the industry-standard calculation method on which to base lumen maintenance of LEDs. Using TM-21, a projected "L70" 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 8568 hours of LM-80 data² on the XLamp XHP35 White where $I_f = 700\text{mA}$ and $T_{sp} = 85^\circ\text{C}$. When using the TM-21 method to determine lumen maintenance of the XHP35 based on a normalized T_{sp} of 82°C , the reported L70 is $> 60,500$. 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.

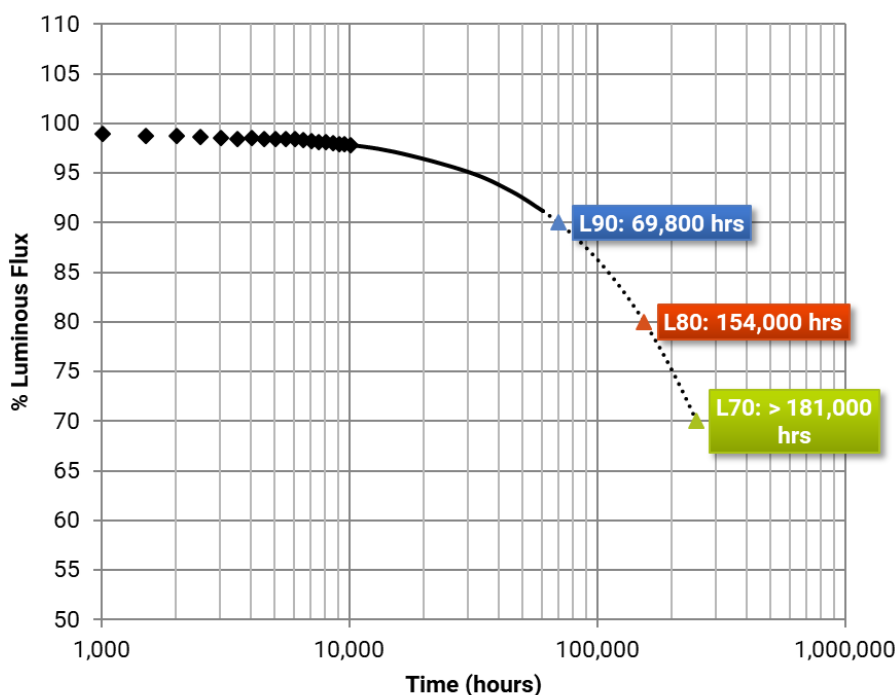


Chart 1: TM-21 projection chart

Description of LED light source tested	XLamp XHP35 White Data Set 1
Sample size	24
LED drive current used in the test	700 mA
Tested case temperature	85°C
Test duration	10,080 hours
Test duration used for projection	t=5,040 to t=10,080
α	1.396E-06
β	9.921E-01
Reported Lifetime	L70(10k) > 181,000 hours

Table 15: TM-21 calculation summary table

³LM-80 data set(s) provided by Cree SSL Reliability Lab, accredited under NVLAP Lab Code: 500041-0.

Review Against Appropriate DLC Criteria

Outdoor Pole/Arm-Mounted Area and Roadway Luminaires		
Criteria	Requirement	Tempo Result
Minimum Light Output	5000 - 10000 lm	Meets requirement, 9260 lm
Zonal Lumen Density	$\approx 100\%$ 0–90°, $<10\%$ 80–90°	Meets requirement
Minimum Luminaire Efficacy	95 lm/W	Meets requirement, 116 lm/W
Allowable CCTs	$<5700\text{k}$	Meets requirement, 3979k
Minimum CRI	65	Meets requirement, 70.6529
L70 Lumen Maintenance	50000 hours	$\approx 33,200$ hours
L90 hours	36,000 hours	$\approx 69,800$ hours
Power Factor	≥ 0.9	Meets requirement, 0.925
aTHD	$<20\%$	Meets requirement, 15.92%

Table 16: DLC Requirements Summary

The sample was reviewed against the requirements for the DesignLights™ Consortium for Outdoor Pole/Arm-Mounted Area and Roadway Luminaires. In addition to these technical specifications, products must have a minimum warranty of 5 years.

Data Summary

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

Criteria	Result
Total Luminous Flux	9,260
Power (W)	79.5
Tsp and Tj(°C) ⁶	81.6 / 89.9
Power Factor	0.925
Lumens per Watt (LPW)	116.5
Optical Efficiency (%)	82
Driver Efficiency (%)	90
CCT (K)	3979
CRI (Ra)	71
Chromaticity (x-coord)	0.3849
Chromaticity (y-coord)	0.3905
LED Lumen Maintenance	Reported L ₇₀ (10k) :> 60,500

Table 17: Summary of Test Results

⁷Measured at ambient temperature of 21.9°C and normalized to 25°C

Measurement Uncertainty

Measurement Parameter	2m Integrating Sphere (+/-)	Goniophotometer
CCx	0.0012	
CCy	0.0013	
Total Luminous Flux (lm)	3.9%	2%

* Denotes the values for these color parameters are estimates based on calibration lamp uncertainty and test correlation results

Table 18: 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	ID No. / Serial No.
Software	Lighting Analysts, Inc.	Photometric Toolbox Pro. Ed.	
Software	jSolutions, Inc.	Photometrics Pro Version 1.3.14	
USB Oscilloscope	Agilent	U2702A	
Digital multimeter	Fluke	289	
Type C Goniophotometer	LSI / UL	6440T	TEMPO-0026 / SN: 6440TE0192T
Software	LSI / UL	Photometric Suite	
Power Meter	Yokogawa	WT210	
AC Power Supply	Adaptive Power Sys.	FC210	
Dielectric Breakdown Tester	GW Instek	GPT-9802	
Spectrometer (2m sphere)	Otsuka Electronics	MC-9801:3683	TEMPO-0034 / SN: 98010162
Two-meter integrating sphere	Labsphere	CSLMC-7660	TEMPO-0023 / SN: 128090799
Software	Labsphere	TOCS Version 3.41	
Three-meter integrating sphere	Labsphere	CSTM-CSLMS-3M98-HDS	
AC power source	Chroma	61503	TEMPO-0038 / SN:615030000243
Power analyzer	Xitron	2801	
Thermocouple	Omega	Type K	
Thermometer	Omega	HH147U	Temop-0083 / SN:150504132
Current probe	Agilent Technologies	1147A	
Oscilloscope	Agilent Technologies	MSO-6034A	
X-ray Machine	Yxlon	Cougar	

Table 19: List of Equipment Used in Testing

Regulatory Submittals

The Cree Durham Technology Center (DTC) (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.

The Cree DTC is recognized under the LED Lighting Facts® Approved Labs List.
<http://www.lightingfacts.com/approvedlabs>

The Cree DTC is recognized by Underwriters Laboratories (UL) in accordance with their Third Party Test Data Program (TPTDP) for in-situ temperature measurement testing (ISTMT), DA file DA1054.

The data in this report that conform with LM-79-08 may be used for submittal to the EPA Energy Star® Program, Design Lights Consortium (DLC) and DOE Lighting Facts® Label. However, Cree does not guarantee qualification to the requirements of these programs based solely on the results from this test report.

Additional tests beyond the scope of IES LM-79-08 with data sets from approved testing labs are required by these regulatory bodies. Note that for many of the criteria listed in the Energy Star Program requirements, a sample size of 10 units is required.

Links to the specific requirements for each program are listed below:

ENERGY STAR® Luminaires 1.1 ([Final Luminaires Program Requirements.pdf](#))

ENERGY STAR® Integral LED Lamps 1.4* ([Integral LED Lamps Program Requirements.pdf](#))

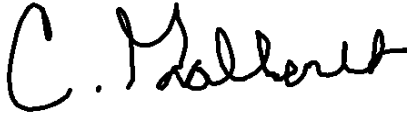
DesignLights Consortium (<http://www.designlights.org/Content/QPL/ProductSubmit>)

U.S. DOE Lighting Facts <http://www.lightingfacts.com/About/manufacturers>

* These requirements will be superseded by Lamps Version 1.0 effective September 30, 2014.
([Lamps Version 1.0 Requirements](#))

Report Review

This report has been reviewed by:



Date: 7/31/2019

Calvin Galberth
Manager, Cree Durham Technology Center

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.

For support of all Cree products, send an e-mail to productsupport@cree.com or call:

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Additionally, please provide us feedback on how we are doing by completing the survey at:
<https://www.research.net/s/temposurvey>