LumeLEX™ 2000 Series
Reliability Datasheet_IS-0328 Rev. A
Reliability Data

INTRODUCTION

This Technical Datasheet summarizes the Reliability performance of the specification grade LumeLEX™ 2000 series fixtures (LSI brand name for Xicato XTM LED Module, Corrected Cold Phosphor Technology).

As with all Solid-State Lighting Fixtures, the overall product reliability is determined by the integration of packaging and assembly of LED components, also defined as a Luminaire(s) into a final product. Reliability documentation ensures that each of the Original Equipment Manufacturers (OEM) guidelines on operating conditions and certificate of product compliance are adhered to. The LumeLEX™ 2000 series of products primarily integrates Xicato Spot Module (XTM) and typically can also integrate in LSI Luminaires, Philips Lumileds LUXEON Royal-Blue Rebel LEDs. Therefore, to fully demonstrate the reliability of the fixture, the reliability of the LED Module must be detailed, evaluated within context to each related integrated component and to the specified configuration of the Luminaire fixture(s).

Most LED components experience a gradual reduction in light output during operation, known as Lumen Depreciation. The reliability of the LED to maintain its light output during operation is known as Lumen Maintenance. As such, any degradation can be either from a reduction in the light-emitting efficiency of the LED chip or a reduction in the light transmission of the optical path within the LED component, package module, or integrated fixture. Other factors that play a critical role in lumen maintenance and lumen depreciation – Temperature conditions, phosphor quality, driver failure, and other electrical conditions such as voltage, current, wattage, or material.

The Xicato XTM product family uses remote, corrected cold Phosphor Technology to keep the phosphor layer at a relatively cool temperature during operation, therefore retaining its light output transmission, and color properties throughout the life of the product. All LumeLEX™ 2000 fixtures use reflectors with a High-Quality Coating that does not degrade over time, due to the Light's wavelength and the heat of the fixture.

Key factors establishing performance and reliability that play a significant role in operating conditions of the fixture are: time, current applied and sustained temperatures. Therefore, Lumen Maintenance will be provided at specific current and temperature points for a LED component, LED Module, and/or Luminaire Fixture. These three composite data points provide a practical manner to establish compliance with testing for LM-80-08 standards.

The ambient temperature for all LM80-08 testing mentioned in this Reliability documentation is 25°C (77°F). However, Lighting Services Inc conducts specified tests of Xicato XTM Module LEDs at elevated temperatures to ensure sustained product performance from the rated maximum operating temperature(s) of 55°C (131°F) and 90°C (194°F), to ensure reliability confidence. *An independent LM-80-08 test of the XTM Module has been performed by XICATO internally to validate these parameters (LED Lumen Maintenance, Color Consistency).*

DEFINITIONS

Lumen Maintenance
Lumen maintenance is the luminous flux output remaining (typically expressed as a percentage of the maximum output) at any selected elapsed operating time.

Rated Lumen Maintenance Life, (L_{70})
The elapsed operating time over which the LED light source will maintain the percentage of 70% of its initial light output. Lifetime measurement criteria (developed by IESNA) of solid-state lighting source degrading past 70% of its initial lighting source output during useful operational hours of LED Module package. Units of measurement is in hours.

Product Lifetime (L_{70}, B_{50}, F_{YY})
The combined metric of the elapsed operating time when the average light source will reach 70% lumen maintenance (reference value) and where **XX**% of the population have reached 70% lumen maintenance and where **YY**% of the population have experienced a conventional lights-out failure, i.e. - L_{70}, B_{50}, F_{25} (in units of hours). Industry metric standard of two nomenclature to description of the minimum of 80% Luminous Flux for a specified period in Maximum Ambient Temperature.
Industry metric standard of two nomenclature to description of the minimum of 90% Luminaire to the level of maintenance defining the Luminous flux (B_{50})

Ambient Temperature, T_{AMB}
The Temperature immediate surrounding air that Luminaire equipment is exposed to and stored for the purpose of testing

Case Temperature, T_C
The Temperature of the casing within the LED light source package defined by the OEM Manufacture

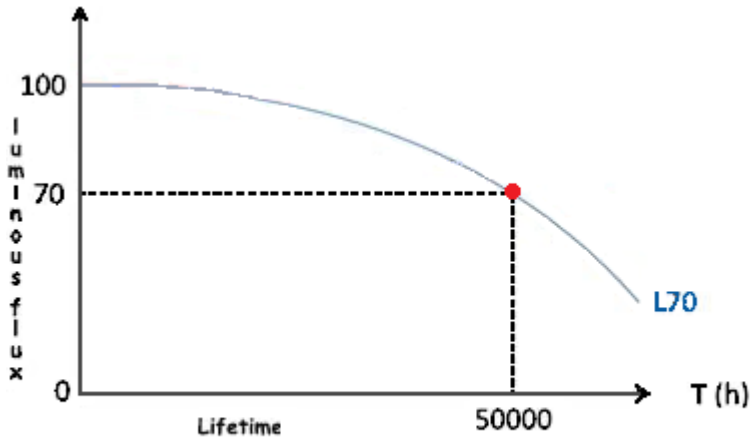


Figure 1 - L_{70}, Actual Lifetime of LED Luminaire – Luminous Flux Description (*Refer to Reliability – Product Lifetime section*)

Mean-Time Between Failure, MTBF
A defined period of elapsed time between failures of an individual electronic component or system specific to LED Luminaires

$$MTBF \equiv \frac{Hours\ of\ Operation}{Number\ of\ Failures} = \frac{\Sigma\ (Start_{DOWNTIME} - Start_{UPTIME})}{Number\ of\ Failures}$$

Lifetime Lumen Maintenance Projection

$$L_p(Dk) = \frac{ln(100 \times \frac{B}{p})}{\alpha} \cong \frac{ln(\frac{B}{0.7})}{\alpha}$$

$L_p \equiv$ *Lumen maintenance output expressed in hours, where p is in % of initial lumen output maintained*

$D \equiv$ *Total duration of time divided by 1000*

Normalized Luminous Flux
Luminous Flux output at time (t), operating hours which derives a decay rate constant of when the calculated output reach to 70% Lumens

$$\Phi(t) = Be^{-\alpha t}$$

$t \equiv$ *operating time, (hours)*
$\Phi(t) \equiv$ *Average Normalized Luminous Flux output, (%)*
$B \equiv$ *projected initial constant, derived from the least squared curved fit*
$\alpha \equiv$ *decay rate constant derived from the least squared curved fit*

LM80-08, Testing Protocol
IES standard that utilizes a test method to measure lumen depreciation of operated solid-state lighting source such as LED integrated component, modules, and auxiliary current drivers. Results recorded details clarifications for better understanding of LED Product Lifetime and product performance overtime

Technical Memorandum – TM-21-11 Test Method Report
Technical Memorandum IES recommended Industry metric standard, by IESNA, to specify how to extrapolate data generated from internal LM-80 Protocol lumen maintenance tests results conducted by LED manufacturers

DRIVE CURRENT

The LumeLEX™ 2000 series operates the XTM module and LUXEON LEDs at $I_{LM\text{-}80,\ Test} = 1000mA$ and above depending on the LED package module and Lighting application. Supported documentation on qualifying components used in LumeLEX 2000 Series is available for viewing that is within the parameter scope of operating Xicato XTM LED modules. The driver, LED module, and optical reflectors components are all key criteria of the Luminaire's Overall Product Reliability and lifetime Lumen Maintenance. LumeLEX 2000 series luminaires all have electronic drivers that have been critically selected due to their performance requirements and specificized component compatibility.

The fixture design also ensures that the electronic driver meets the electric, thermal requirements that the driver manufacturer sets to prevent the possibility of unexpected "lights out" failure. Test results will detail from samples tested of Luminaire having a 70% Lumen Maintenance and the sample fixtures having a 50% success rate at sustaining 70% through product Lifetime. The reflector suppliers are also under constant surveillance by LSI for optical coating quality and efficiency.

LSI LumeLEX™ 2000 series uses MAGTech LED Drivers. Drivers integrated into our Luminaire fixtures are **M-series** (M18-U XP, M28-XP) & **Q-series** (Q12-XP, Q22-XP). The MTBF (referenced in the

definition section) of which LED Drivers' operating specification >100,000 *hrs* at full load and $\boldsymbol{T_{AMB}}$*=25°C* conditions. (TELC3, Telcordia SR-332, Issue 3 references results documented on MAGTech LED Drivers Datasheet.

CASE TEMPERATURES

Drive current and operating temperature are the two most important variables affecting long-term lumen maintenance of high-power LED's. These two variables have the most influence on the "Junction Temperature" which is equivalent to the "heart" of the LED Luminaire. The LM-80-08 and TM-21-11 protocols define $\boldsymbol{T_{CASE}}$ to be the temperature at the thermocouple attachment point on the LED light source package as defined by the manufacturer. Case Temperature is therefore the most critical factor for ensuring sustained performance and product lifetime as that is how the LM-80-08 testing is performed to investigate.

Published LED Driver specifications for all their case temperatures:

$$\boldsymbol{T_{CASE}} \equiv \textit{case temperature of LED Luminaires tested}$$

Specifications for driver current and $\boldsymbol{T_{CASE}}$ will be detailed in reported results.

RELIABILITY TESTING

LM80-08 STANDARDIZED TESTING

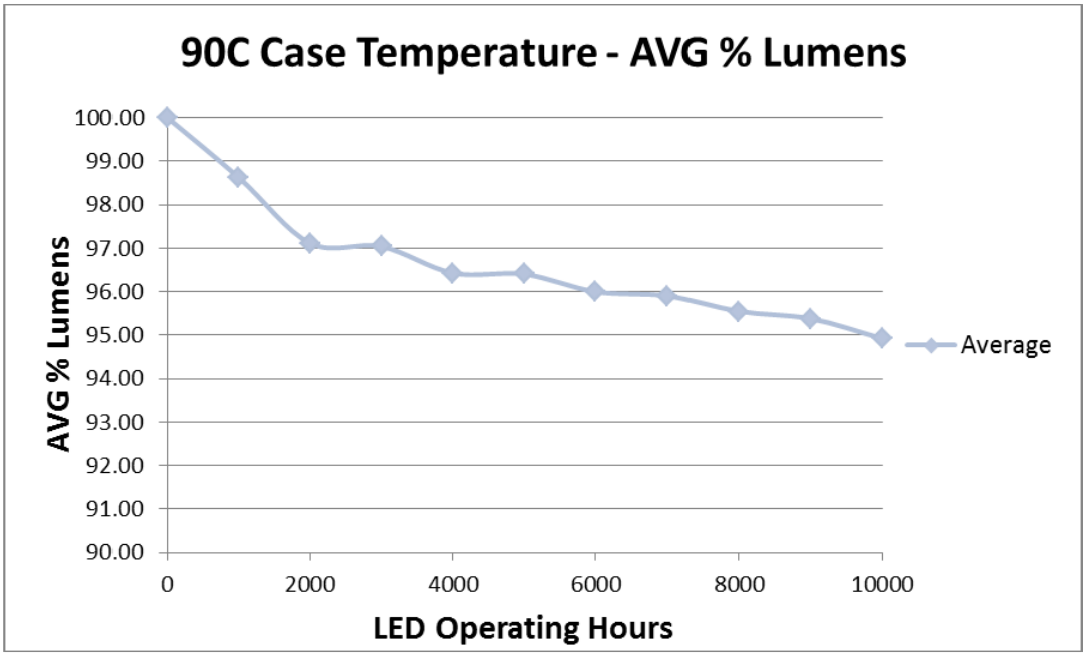
The scope of our focus is Xicato XTM Artist Series under LM-80-08 testing on XCA (Xicato Core Array). Stationed into an exclusive holder to the modules' design allows a variety of lenses and heatsinks to integrate into different configurations of Luminaire design option. LM-80-08 testing is an industry wide testing standard that measures Lumen Maintenance and Color Consistency of an LED lighting source or a Luminaire. Bay Area Compliance Laboratories Corp is the 3rd Party responsible for facilitating testing capacity for Xicato internally testing their LED Modules. The report that documents the findings of data recorded in LM-80-08 testing are listed below:

1. *LM-80-08 Report* - ***10,000 hrs.***
    a. Report Number: R1409229
    b. Report Date: May 11th, 2016
    c. Product Type: LED Module
    d. LED Model: XCA19803050CCA (19mm LED)
    e. Test Duration: 0 hours – 10,000 hours, in increments of 1000 hours
2. *LM-80-08 Report* - ***6,000 hrs.***
    a. Report Number: R1512141
    b. Report Date: January 31st, 2017
    c. Product Type: LED Module
    d. LED Model: XCA090803020CCA (9mm LED)
    e. Test Duration: 0 hours – 6,000 hours, in increments of 1000 hours

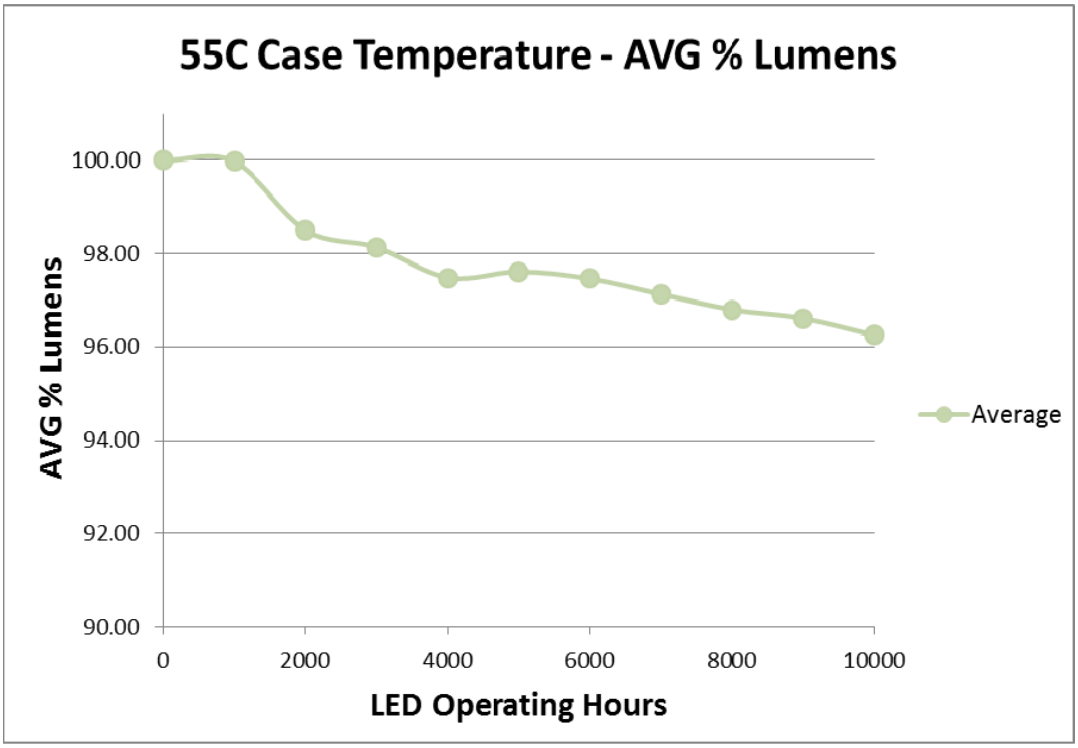
Each LM-80-08 reports are the standard testing results published most recent to date.

The format of testing is that each LED Modules is operating at $\mathbf{T_{AMB}}$= 25°C. The operating temperature of each LED Lighting source is 55°C and 90°C. Lumen output is measured in percentage from the beginning operating hours to the end. The average Lumen (%) is then measured every 1000 hours to check for Lumen Depreciation over the course of time assessed. Testing temperatures point should never exceed temperature point(s) stated above for testing at operating condition to avoid system damage in

Luminaires. Below is a graph illustrating LM-80-08 testing results obtained from Xicato's 9mm and 19mm LED Modules at each operating temperature(s):



Graph 1 – 90°C Case Temperature, Lumens Maintenance (Tested at 10,000 Hours)



Graph 2 – 55°C Case Temperature, Lumens Maintenance (Tested at 10,000 Hours)

The Graphs above display the Lumen Depreciation (%) overtime of operating test conditions, which is running 7 and 10 LED samples at 2 different Case Temperatures, $T_{C,1} = 90\ °C$ and $T_{C,2} = 55\ °C$. From

the data sample populated over the course of 6,000hrs for the 9mm LED and of the 10,000hrs for the 19mm LED, the product lifetime of each LED Module(s) was found by extrapolating the measured data recorded in the LM-80-08 testing from the TM-21-11 Calculator.

TM-21-11 Test Report

TM-21-11 provides recommendations for projecting the long-term lumen maintenance of LED light sources to estimate overall product longevity. Lumen Depreciation is the key factor being calculated to give a predictive measure of Lumen Maintenance. The TM-21 rationale was determined using statistically significant long-term tests to produce mathematical models that predict lumen maintenance. The maximum limitation making a "Reported L_{70}" data claim by using the TM-21-11 formulas, is only six (6) times the total test duration (Max. Hours).

Therefore, to claim 50,000 hrs., data would be required at a minimum of 8,333 testing hours, however these models can "interpolate" a theoretical life as well.

From the reported date(s) mentioned in the LM80-08 section, Xicato has achieved 6,000 hours and 10,000 hours of LM-80-08 testing in which Figure No. 3 and Figure No. 4 displays results of the predicted Lumen Maintenance and at what period the Lumen output will reach

$$L_{70} \equiv \textit{ 70\% Lumen output}$$

At this point in time, we can only use the TM-21 formula for the Xicato Module testing to substantiate a reported claim of 6 x 10,000 = L_{70} > 60,000 hours. Calculations can be made utilizing TM-21 formula to "interpolate" data from documented LM80-08 results. TM-21-11 results are displayed in Figure No. 3 at 90°C where the LED Module will reach a 70% Lumen Maintenance output (L_{70}) at an estimate 112,000 hrs. and at 55°C, a calculated $L_{70} = 110{,}000\ hrs$. These values calculated represent the Luminaires that were tested for 10,000 hrs. Luminaire results that were tested at 6,000 hrs. were calculated to be as follows: $L_{70} = 91{,}000\ hrs$ at 90°C, and $L_{70} = 172{,}000\ hrs$ at 55°C. (Seen on Figure No. 4)

Table 1: Report at each LM-80 Test Condition				
Case Temperature 1			Case Temperature 2	
Temperature (°*C*)	90		Temperature (°*C*)	55
Temperature (°*K*)	363.15		Temperature (°*K*)	328.15
Calculated L_{70} (hrs.)	112,000		Calculated L_{70} (hrs.)	110,000
Reported L_{70} (hrs.)	> 55,000		Reported L_{70} (hrs.)	> 55,000

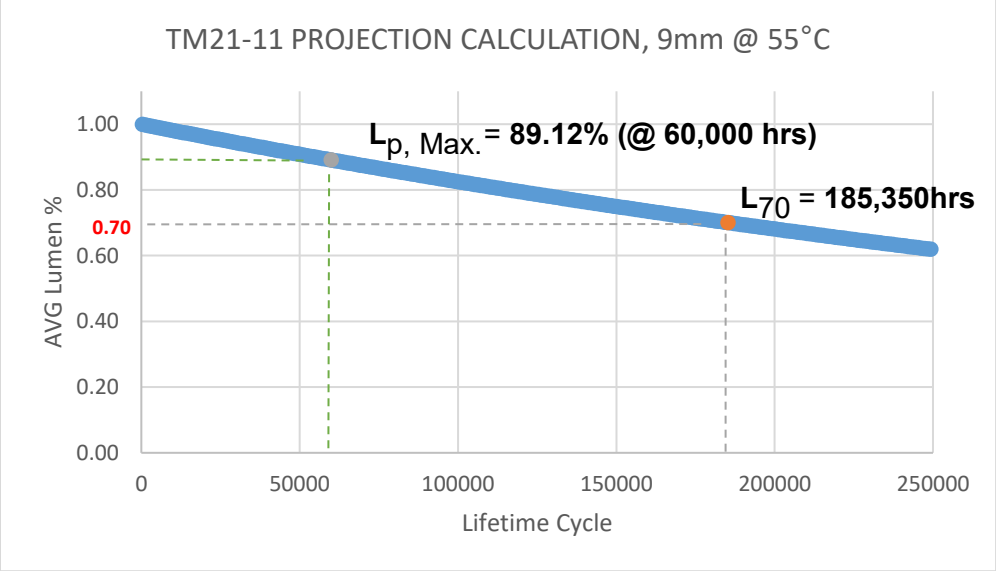
Table 1 – TM-21-11 Reported Projections of 10,000 Hrs. Test from LM-80-08 Xicato test

Table 2: Report at each LM-80 Test Condition				
Case Temperature 1			Case Temperature 2	
Temperature (°*C*)	90		Temperature (°*C*)	55
Temperature (°*K*)	363.15		Temperature (°*K*)	328.15
Calculated L_{70} (hrs.)	91,000		Calculated L_{70} (hrs.)	172,000
Reported L_{70} (hrs.)	Not Reported		Reported L_{70} (hrs.)	Not Reported

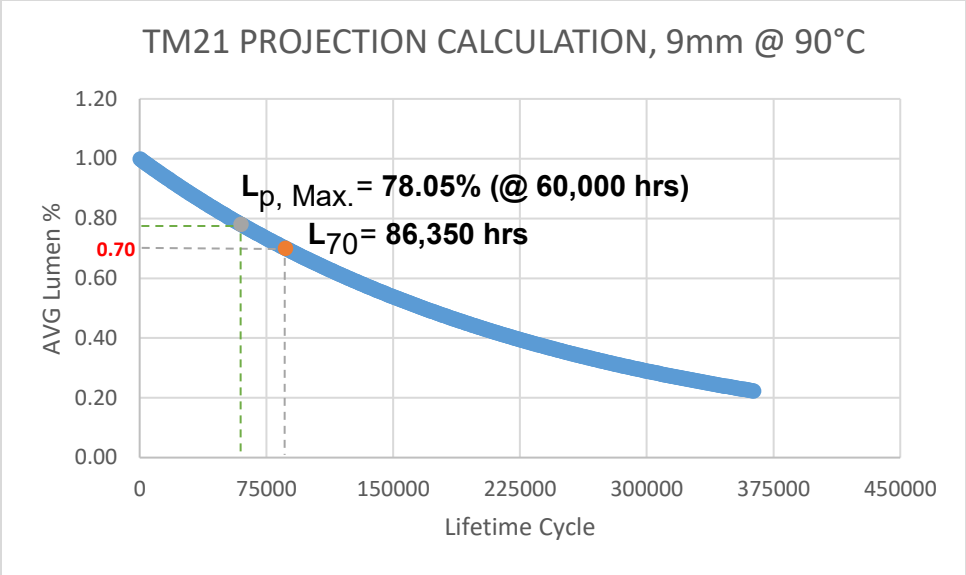
Table 2 – TM-21-11 Reported Projections of 6,000 Hrs. Test from LM-80-08 Xicato test

PRODUCT LIFETIME

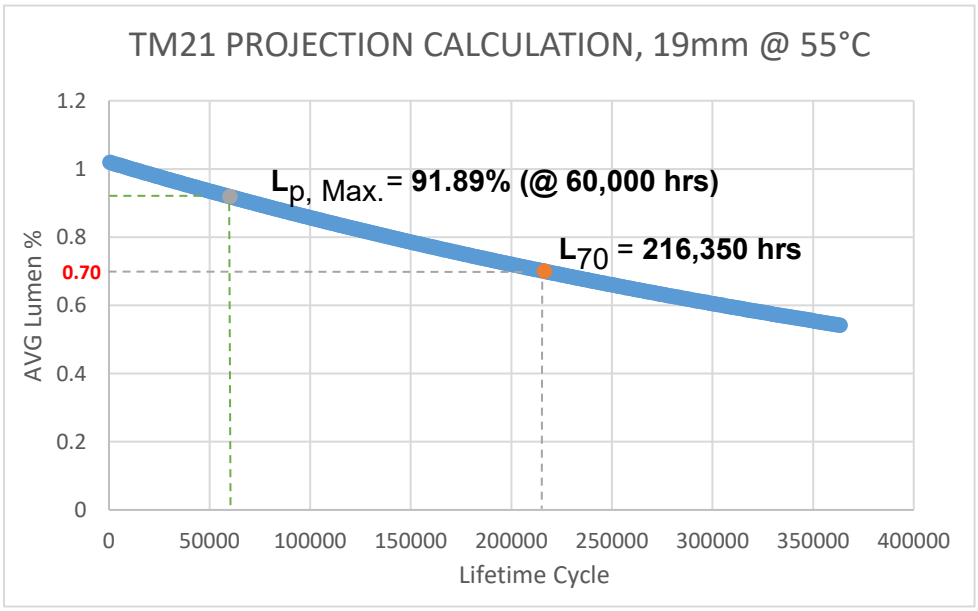
Below are graph charts detailing test results from Reported $\boldsymbol{L_{70}}$ Claims from LM-80-08 Testing collected, and from said data gathered, using them to calculate Operating Hours Luminaire fixtures will maintain a 70% and greater Lumen Maintenance quality over the course of its Lifetime. The data also illustrates over the course of a Luminaires Lifetime what the degradation of the LED Module from Xicato XTM models will be. The intervals of the operating hours used to calculate $\boldsymbol{L_{70}}$, were in increments of $t = 350$ *hrs.*



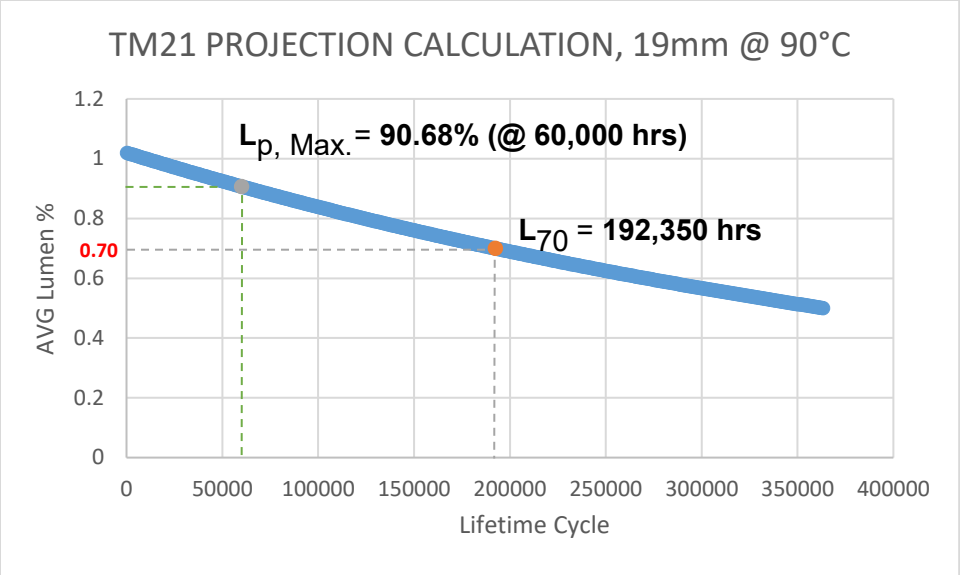
Graph 3 – 9mm Xicato XTM Module, @ $T_{Operating}$ = 55°C Lumen Maintenance Calculation



Graph 4 – 9mm Xicato XTM Module, @ $T_{Operating}$ = 90°C Lumen Maintenance Calculation



Graph 5 – 19mm Xicato XTM Module, @ $T_{Operating}$ = 55°C Lumen Maintenance Calculation



Graph 6 – 19mm Xicato XTM Module, @ $T_{operating}$ = 90°C Lumen Maintenance Calculation

CONCLUSION

Based on the above data and testing, the LumeLEX™ 2000 series Luminaires is expected to exceed a Rating Lumen Maintenance of

- $L_{70,\ @\ 90°C\ and\ 10{,}000hrs}$*=60,000 hrs ≤~86,350 hrs*. (9mm, Graph 4)
- $L_{70,\ @\ 55°C\ and\ 10{,}000hrs}$*=60,000 hrs ≤~185,350 hrs.* (9mm, Graph 3)
- $L_{70,\ @\ 90°C\ and\ 6{,}000hrs}$*= 60,000 hrs ≤~192,350 hrs*. (19mm, Graph 6)
- $L_{70,\ @\ 55°C\ and\ 6{,}000hrs}$*=60,000 hrs≤~216,350*. (19mm, Graph 5)

Lighting Services Inc is projecting that the LumeLEX™ 2000 series fixtures will have a minimum **Product Lifetime of $L_{70} \geq$ 60,000 Hours** at which time 50% of the population will fall below L_{70} nominal initial Lumen output value, and less than 10% would experience conventional “lights-out” failure.

WARRANTY:

LSI has a full 5-year warranty to ensure customer satisfaction for our product. Contact LSI for more details are required.