

LumeLEX<sup>TM</sup> 2000 Series  
Reliability Datasheet IS-0112 A

# Reliability Data

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## INTRODUCTION:

This datasheet summarizes the reliability performance of the specification grade LumeLEX<sup>TM</sup> 2000 series fixtures.

As with all Solid-State Lighting Fixtures, the overall product reliability is determined by the integration of packaging and assembly of LED components into a final product, ensuring that each of the Original Equipment Manufacturers (OEM) guidelines on drive conditions and assembly practices are adhered to. The LumeLEX<sup>TM</sup> 2000 series of products use a Xicato Spot Module (XSM) that can typically contain Philips Lumileds LUXEON Royal-Blue Rebel LEDs.

Therefore, to fully demonstrate the reliability of the fixture, the reliability of the LED and of the XSM Module must be detailed and tested within context to each other and to the fixture.

Most LEDs 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 package, module or fixture.

The Xicato XSM product uses remote-phosphor technology to keep the phosphor layer cold during operation, therefore retaining its light transmission and color properties throughout the life of the product. All LumeLEX<sup>TM</sup> 2000 fixtures use reflectors with a high quality Aluminum Coating that does not degrade over time, (as the heat of the fixture and the wavelength of light do not impact the Aluminum coating).

The most important drive conditions of the fixture are current applied and operating temperature, as these are the key factors on establishing performance and reliability. Therefore, Lumen Maintenance will be provided at specific current and temperature points for the LED, the Module and the Fixture. These three composite data points provide objective evidence to establish compliance with LM-80-08.

The ambient temperature for all testing mentioned in this report is 25°C/77°F, however, LSI, Xicato and Philips are all conducting elevated temperature testing to ensure product performance to meet our reliability statement.

## REFERENCES:

IESNA Testing Procedures Committee. IESNA LM-80-08 *Approved Method for Lumen Maintenance Testing of LED Light Sources*, New York: Illuminating Engineering Society of North America, 2008.

Lumileds. RD07 Reliability Datasheet RD07 *LUXEON Rebel Reliability Data*, Philips 2007.

Xicato, *LM80 Test Data*, San Jose: Xicato, 2010

Next Generation Lighting Industry Alliance with the U. S. Department of Energy. Solid-State Lighting Product Quality Initiative *LED LUMINAIRE LIFETIME: Recommendations for Testing and Reporting*: First Edition May 2010.

## DEFINITIONS:

**LED** – Light Emitting Diode

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

**Lumen Depreciation** – Lumen depreciation is the gradual reduction of light output from the packaged LED over time, and is the converse of lumen maintenance.

**Rated Lumen Maintenance Life, ( $L_p$ )** – The elapsed operating time over which the LED light source will maintain the percentage, p% (e.g. 70%), of its initial light output e.g.  $L_{70}$ (hours).

**Lumen Maintenance Lifetime, ( $B_{xx}$ )** – The elapsed operating time over which xx% (e.g. 50%) of the products light output falls below 70% of the nominal initial value e.g.  $B_{50}$ (hours).

**Electrical Failure Time ( $F_{yy}$ )** – The elapsed operating time over which yy% (e.g. 25%) of the population has experienced conventional lights-out failure e.g.  $F_{25}$ (hours).

**Product Lifetime ( $L_{70}/B_{xx}/F_{yy}$ )** – 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 experience a conventional lights-out failure; e.g.  $L_{70}/B_{50}/F_{25}$  (hours).

**Case Temperature, ( $T_x$ )** –  $T_x$  is the temperature of the thermocouple attachment point on the LED light source package (x) as defined by the manufacturer of the package (OEM or x).

**High Temperature Operating Life (HTOL)** – the temperature that life testing is performed at.

CONSTRUCTION OF LumeLEX™ 2000 SERIES FIXTURES:

The LumeLEX™ 2000 series of products, as shown in Figure 1, are Composite Fixtures that start with Philips Lumileds LUXEON Rebel LEDs which are then packaged into Xicato Spot Module (XSM) LED Modules and then integrated by Lighting Services Inc into our LumeLEX™ 2000 series fixtures.

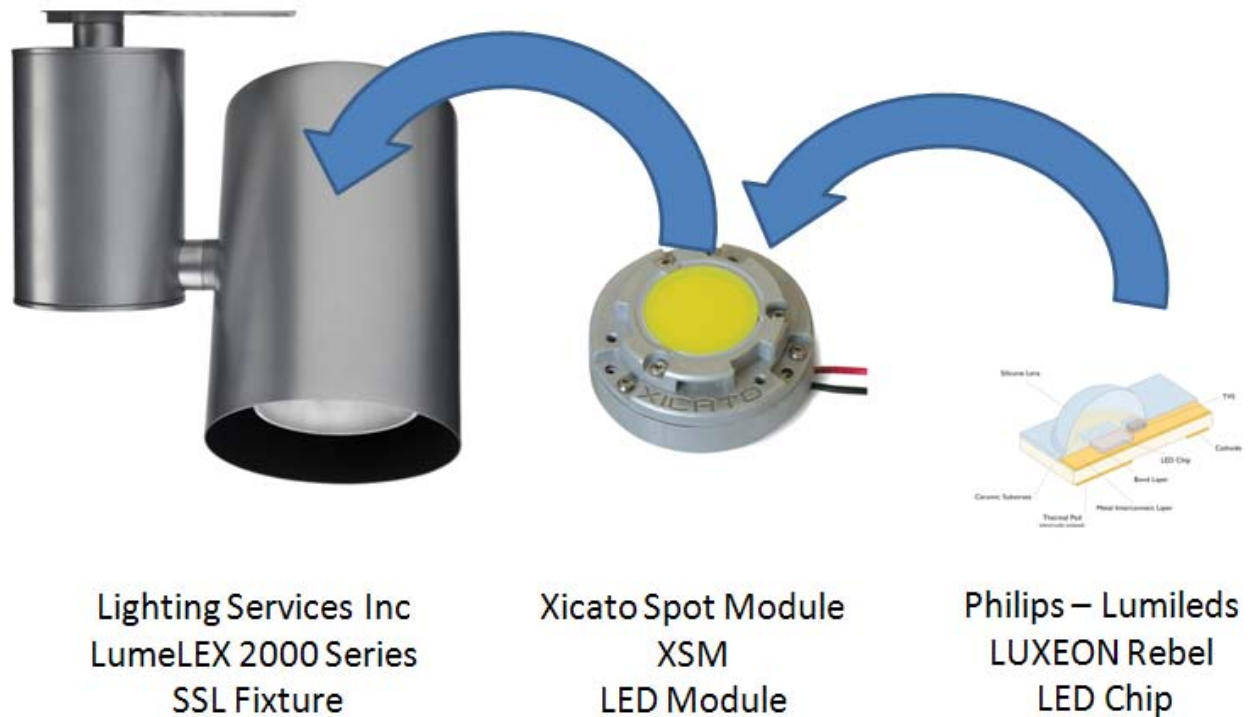


Figure 1 – the Composite Fixture – LSI, Xicato, and Philips

The specific Philips Lumileds LUXEON Rebel, is the Royal-Blue Indium Gallium Nitride (InGaN) LED. Figure 2 illustrates the internal construction of the Royal-Blue InGaN LUXEON Rebel package. Note that the LED chip is mounted on top of the metalized ceramic substrate using gold-to-gold interconnects. A separate InGaN chip is then mounted on the metalized ceramic substrate, with a clear silicone lens molded over the LED package and InGaN chips.

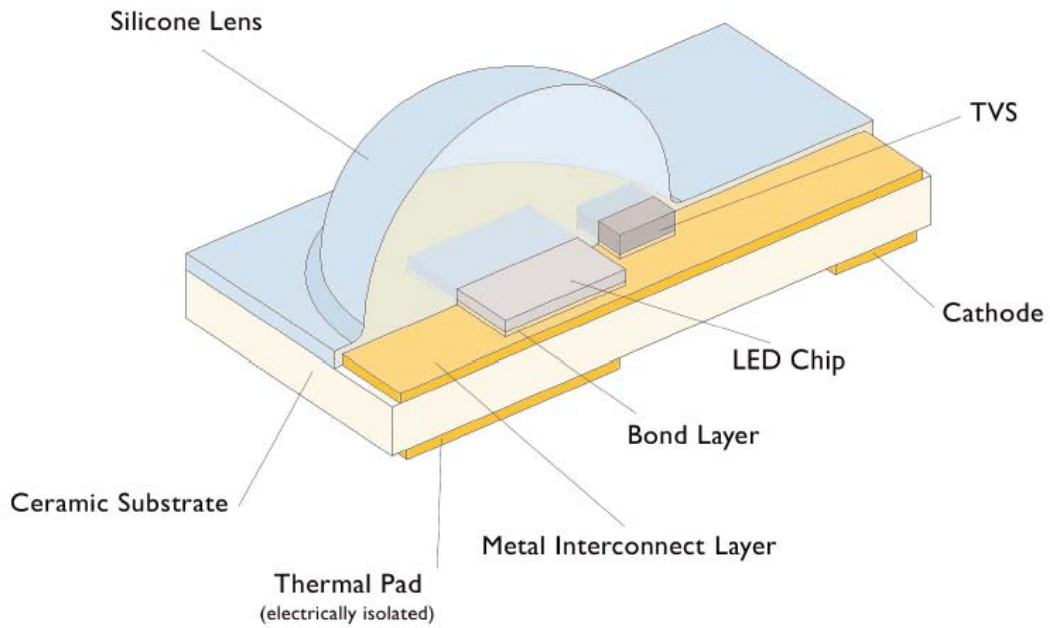


Figure 2 – Philips Lumileds LUXEON Rebel Construction

The Xicato Spot Module (XSM) LED module, Figure 3, packages the LUXEON Rebel LEDs. Utilizing remote phosphor technology the XSM keeps the phosphor colder than other solid State products that have the phosphor directly applied to the top of the LED InGaN chip.



Figure 3 – Xicato Spot Module (XSM) packages several Lumileds LUXEON Rebels

## DRIVE CURRENT:

The LumeLEX™ 2000 operates the XSM module and Rebel LEDs at 700mA.

## CASE TEMPERATURES:

Philips and Xicato have published specifications for all of their case temperatures:

- Tc = XSM Module Case Temperature
- Tj = LED Junction Case Temperature
- Tp = LED Thermal / solder pad Temperature

These specifications are verified by measurements in the module and in the fixture. The combined Drive Currents and Temperatures are shown in Table 1, as both Specifications and as verified Measurements.

Component	Drive Current	Case Temperature		SPECIFICATION / VERIFICATION
LumeLEX™ 2000	700ma	Tc	80°C - XSM Module Case Temp - Measured	Measurement
Xicato XSM	700ma	Tc	85°C - XSM Module Case Temp - Maximum	SPECIFICATION
	700ma	Tj	116°C - Junction Temp - Measured	Measurement
	700ma	Tp	95°C - Thermal / solder pad Temp - Measured	Measurement
LUXEON Rebel	1000ma	Tj	125°C - Junction Temp – Figure 4	SPECIFICATION
	700ma	Tj	135°C - Junction Temp – Figure 5	SPECIFICATION
	700ma	Tp	111°C - Thermal / solder pad – Figure 6	SPECIFICATION

Table 1 – Specification and Measurement Summary of Case Temperatures of LumeLEX™ 2000

In order to ensure long life of this product, each manufacturer has a factor of safety already built into the design elements. For example, Philips specifies their Tj (LED Junction Case Temperature) to not exceed 125°C at 1000mA, and Xicato's XSM has a measured Tj = 116°C at 700mA. Philips specifies their Tp (LED Thermal / solder pad Temperature) to not exceed 111°C, and Xicato XSM has a measured Tp = 95°C. Xicato achieves these temperatures by specifying their Tc (XSM Module case temperature) not to exceed 85°C, while in the final LumeLEX™ fixture the Tc measures below 80°C.

## RELIABILITY TESTING:

With the Construction, Drive Current and Case Temperatures defined, it is now possible to demonstrate the LumeLEX™ 2000 series reliability to IESNA LM-80-08 (Lxx) and per the LED LUMINAIRE LIFETIME:

Recommendations for Testing and Reporting (L70/Bxx/Fyy).

Starting with the Royal-Blue LUXEON Rebel LED, Figure 4 shows the long-term lumen maintenance of the royal-blue LUXEON Rebel at Tj (LED Junction Case Temperature) of Tj = 125°C. Note: this is running at 1000mA (1A), whereas the LumeLEX™ / XSM are running at 700mA. Philips notes that operation at a lower drive current (specifically 700mA for the XSM) is expected to further improve the long-term lumen maintenance of the LED.

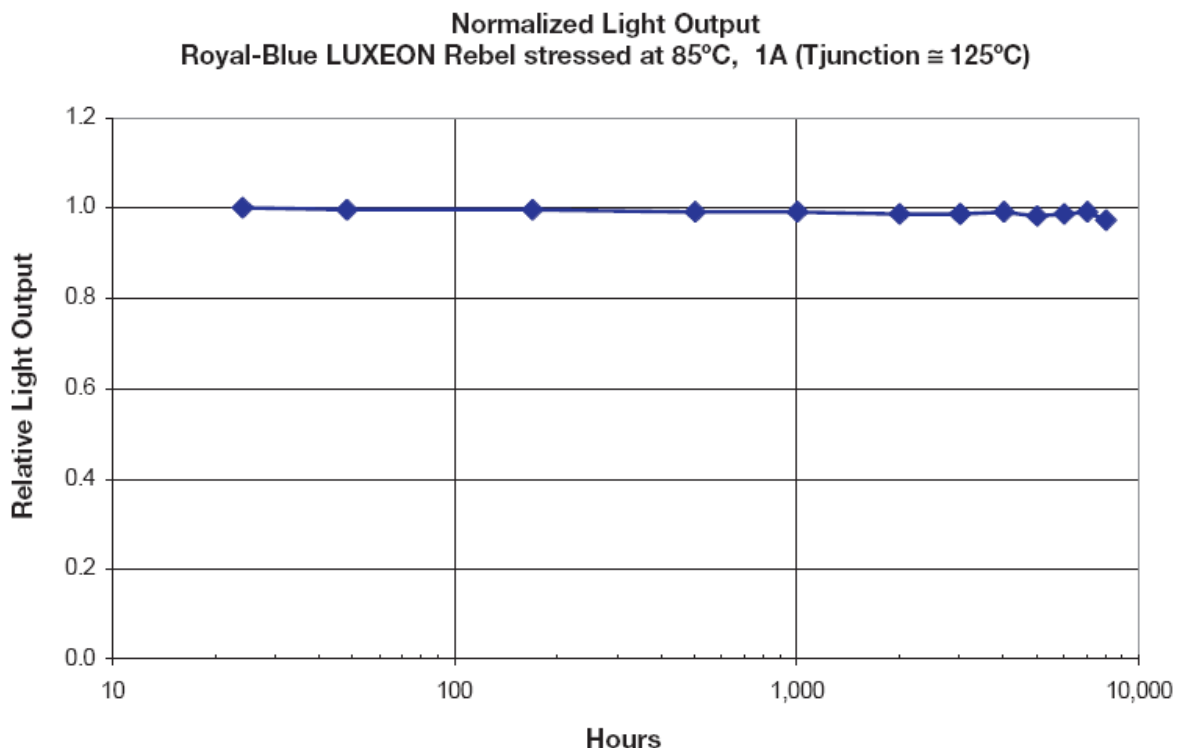


Figure 4 – Lumen maintenance of royal-blue LUXEON Rebel.

As you can see in Figure 4, there is less than 5% drop in lumen maintenance in the first 10,000 hours of life. The following is per Lumileds RD07 - “The LUXEON Rebel product family was stressed over a wide range of drive currents and junction temperatures in order to predict useful lifetimes under various operating conditions. To aid understanding, these predictions incorporate the same terminology applied to conventional lighting technologies. For example, many light sources display little change in light output as the lamp is stressed, until the unit fails catastrophically. As a result, failure rates are often expressed in terms of the time by which a certain percentage of the population is expected to have failed.” For example, a B10 value for any given lamp denotes the time by which 10% of the population is expected to fail.” Note – this B10 value is a 0% light output failure, as defined by Philips.

“However, noting that the light output of an LED tends to degrade gradually as the device is stressed, its efficacy may fall to an unacceptable level long before total failure occurs. Such a condition may be described as lumen maintenance failure. To facilitate comparison of the LUXEON Rebel family with other lighting devices using conventional technologies and other LEDs Philips Lumileds also expresses LUXEON reliability with reference to a threshold for lumen maintenance failure. For example, L70 defines a lumen maintenance failure as any unit producing less than 70% of its initial output. Since light output degradation is defined as  $(1 - \text{lumen maintenance})$ , a failure criteria of L70 means that any unit with more than 30% light output degradation would be classified as a failure.”

“Using this terminology, Philips Lumileds has estimated the expected lifetimes of the LUXEON Rebel product family as a function of drive current and junction temperature. For example, the lifetime at (B10, L70) is the expected stress time at which 10% of the population is expected to have either failed catastrophically (i.e. opens or shorts) or has degraded by more than 30% from the initial light output.”

Figure 5 and 6 show the expected (B50, L70) lifetimes at a 90% confidence interval for the InGaN LUXEON Rebel as a function of the T<sub>j</sub> (junction temperature of LED) and the T<sub>p</sub> (Thermal / solder pad temperature LED), respectively. Note the blue arrows that indicate the measured T<sub>j</sub> and T<sub>p</sub> values.

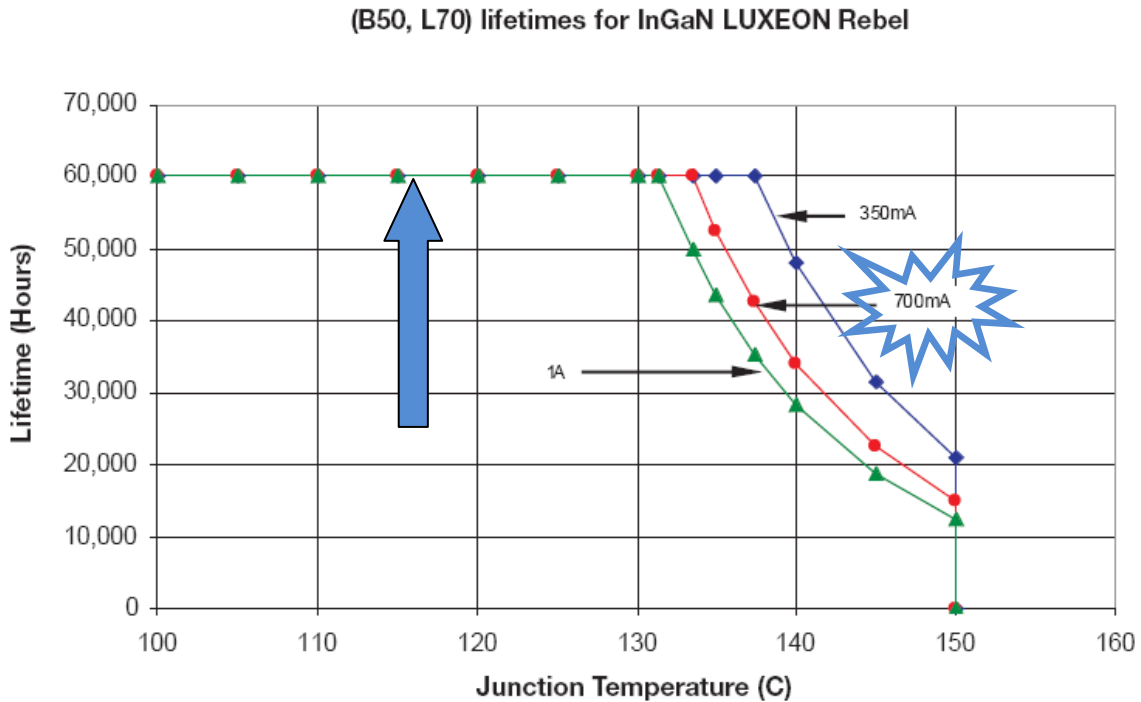


Figure 5 – Expected (B50, L70) lifetimes for InGaN LUXEON Rebel – note XSM runs at 116°C at 700mA

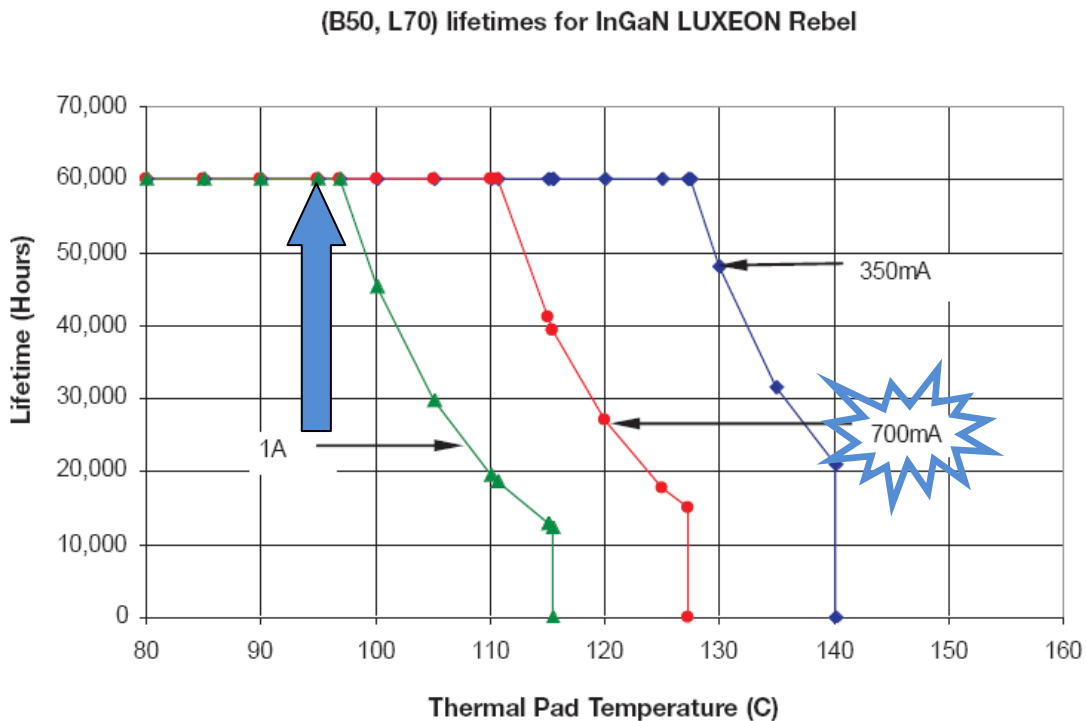


Figure 6 – Expected (B50, L70) lifetimes for InGaN LUXEON Rebel – note XSM runs at 95°C at 700mA

## PRODUCT LIFETIME

Nomenclature in this report in the format of (Bxx, Lyy) was taken directly from Philips 2007 Lumileds LUXEON Rebel *Reliability Data*, which pre-dates the May 2010 *LED LUMINAIRE LIFETIME: Recommendations for Testing and Reporting* that recommends the more comprehensive use of Product Lifetime expressed as (L70/B<sub>xx</sub>/F<sub>yy</sub>) – which is a 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 experience a conventional lights-out failure; e.g. L70/B50/F10 (hours).

Note that the May 2010 *LED LUMINAIRE LIFETIME: Recommendations for Testing and Reporting* has not yet been adopted by any Standards making bodies, as it is only a guide by which LSI is reporting the LumeLEX™ 2000 reliability information on as well.

Per the recommendation report, this comprehensive “Product Lifetime” figure is to address both the complexity and ambiguity between a single luminaires lumen maintenance, and the median lumen maintenance of an installation group. This “Product Lifetime” is a comprehensive expression of gradual lumen depreciation, accelerated degradation and catastrophic failures – as this figure covers some of the following conditions as an example:

1. All LEDs light up, but at a reduced light level (defined by time to B<sub>xx</sub>)
2. A single catastrophic LED failure occurs, but other LEDs in the Modules are still functional, perhaps running at a reduced light level (defined by time to B<sub>xx</sub>)
3. Multiple catastrophic failures, but other LEDs are still functional, perhaps running at a reduced light level (defined by time to B<sub>xx</sub>) – defined by time to F<sub>25</sub> if 25% of the LED Modules or the output of the Driver has reduce drive current.
4. No LEDs light up, due to system failure (defined by time to F<sub>100</sub> as an example)

Figure 7 is Xicato's Lumen Maintenance Testing, showing 6,000 hours at a Tc (XSM module case temperature) of 85°C, whereas the LumeLEX™ 2000 is only running at maximum Tc = 80°C.

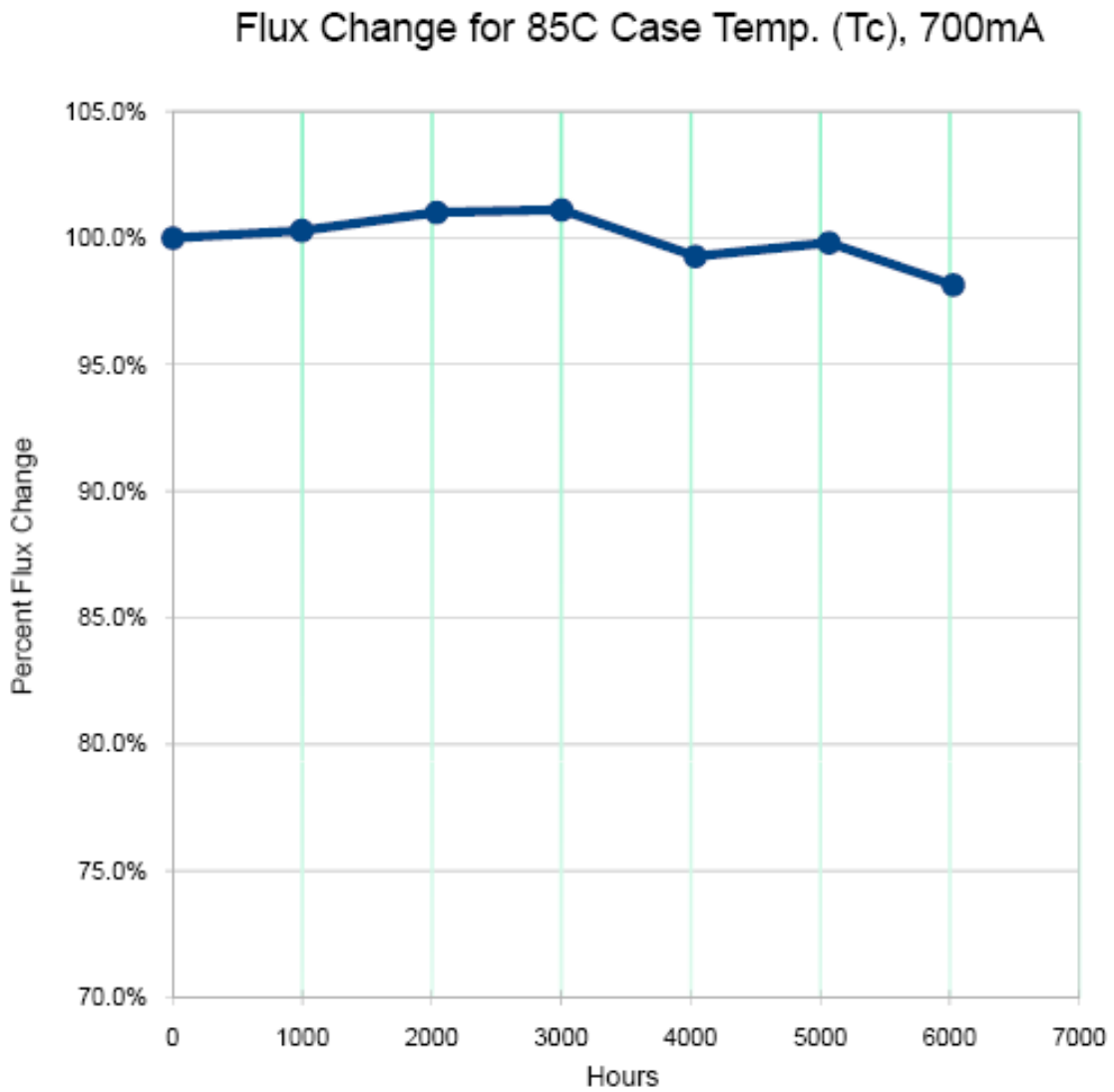


Figure 7 is Xicato's Lumen Maintenance at Tc = 85°C and at 700mA

Figure 8 is Xicato's Color Maintenance results, showing 4000 hours at a Tc (XSM module case temperature) of 85°C. The remote phosphor technology that the XSM utilizes results in a very tight color maintenance. The Blue ellipse represents a 4-step Standard Deviation of Color Matching (SDCM), whereas the magenta parallelogram represents the Xicato 2-step specification. All data points at 4000 hours are still within a 1-step SDCM.

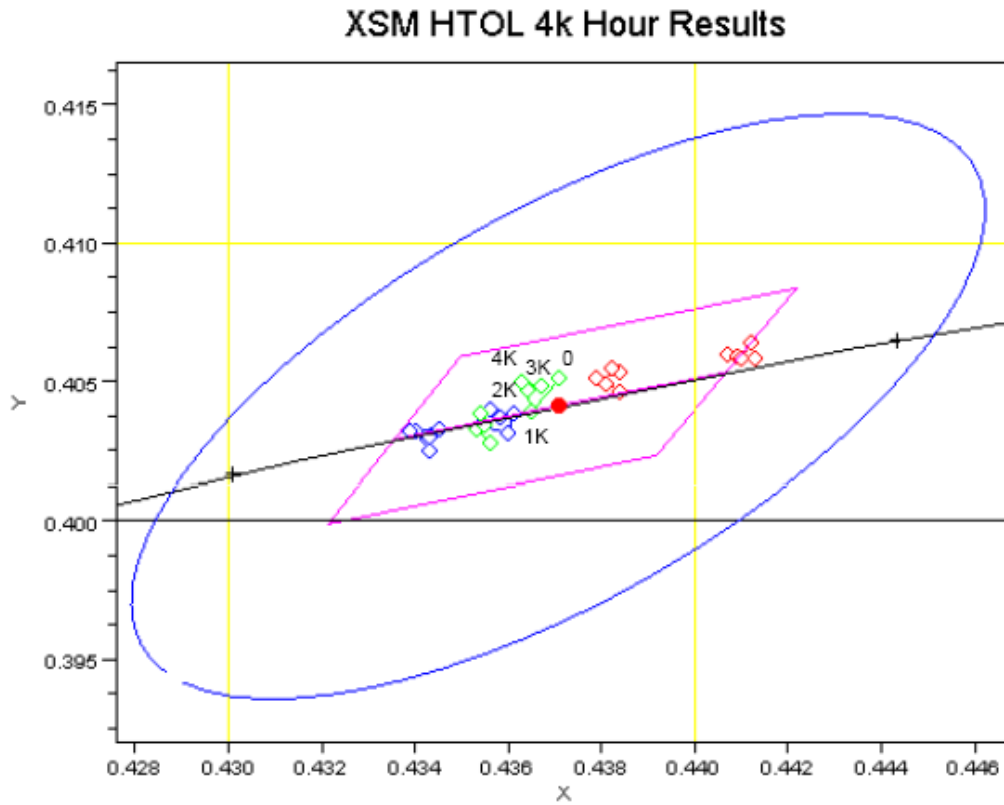


Figure 8 – 4000 hours Color Maintenance Results for XSM at 85°C.

Figure 9 is Xicato’s extrapolation of Lifetime depreciation based on 6,000 hours of testing, which shows L85 = 50,000 hours (85% lumen maintenance at 50,000 hours life). This figure also shows the ENERGY STAR lumen maintenance requirements.

85C Tc, 700mA	Test Time (Hours)						
	1	1000	2000	3000	4000	5000	6000
<b>XSM Lumen Maintenance</b>	100.0%	100.3%	101.0%	101.1%	99.3%	99.8%	98.2%

XSM Lifetime Data Results for 85C Tc, 700mA

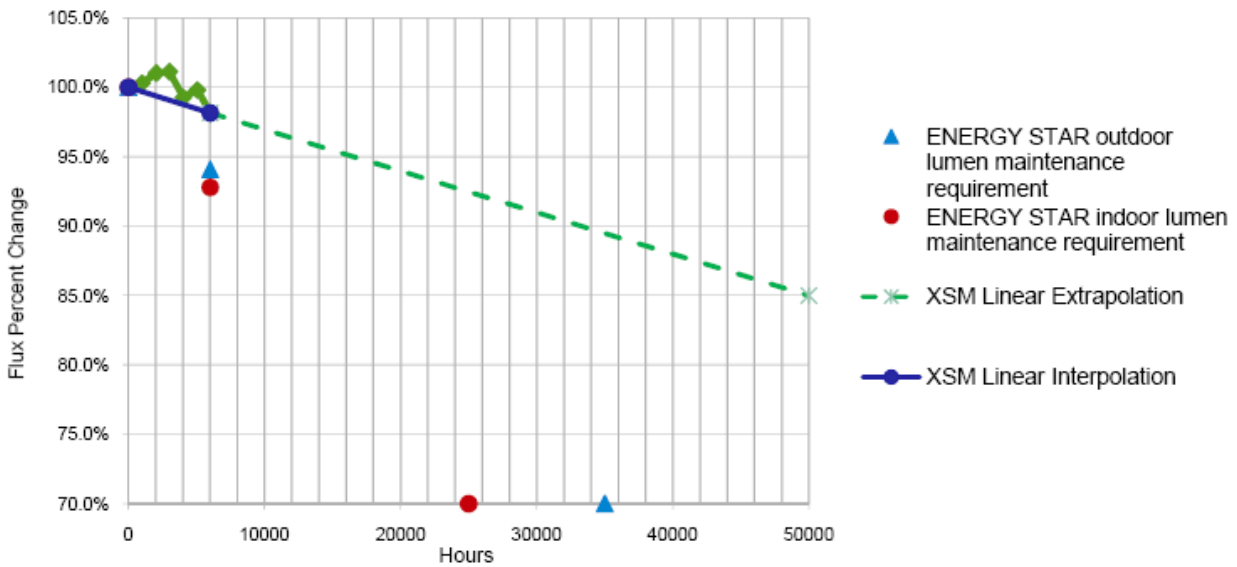


Figure 9 – XSM Lifetime Data and Extrapolation and Energy Star Requirements

PRODUCTION TESTING:

Per the CALiPER program and per recommendation of the *LED LUMINAIRE LIFETIME: Recommendations for Testing and Reporting* Lighting Services Inc performs routine production Burn-In testing to at least 1000 hours of a small number of products continuously to ensure our product quality.

CONCLUSION:

Based on the above data and testing, the LumeLEX™ 2000 series fixtures **shall exceed a Rated Lumen Maintenance Life of L70 = 50,000 Hours** (time to 70% Lumen Maintenance).

Lighting Services Inc is projecting that the LumeLEX™ 2000 series fixtures will have a **Product Lifetime of (L70/B50/F10) = 60,000 Hours** at which time 50% of the population will fall below 70% of the nominal initial value, and less than 10% will have experienced conventional lights-out failure.

WARRANTY:

LSI has a full 5 year warranty to ensure customer satisfaction with our product.

The LSI warranty not only covers conventional (lights-out) failures, but also lumen depreciation not meeting our **Rated Lumen Maintenance Life of L<sub>70</sub> = 50,000 Hours** (time to 70% Lumen Maintenance).