Understanding Reliability Metrics

L, B, and F

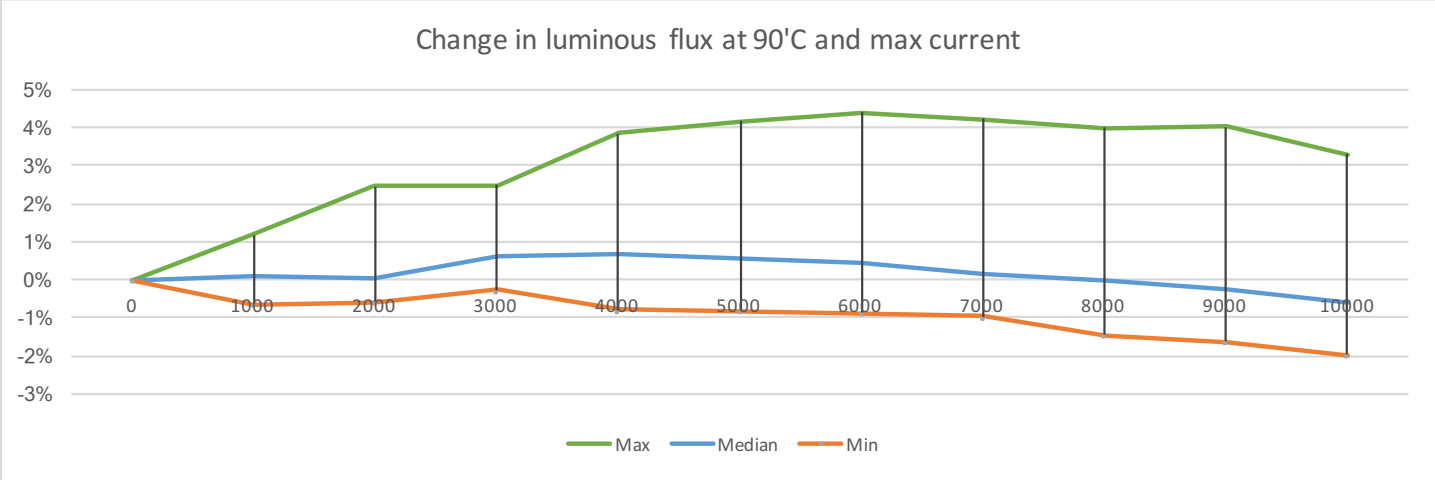
LED reliability terminology can seem cryptic to those not directly involved in LED manufacturing. The most common set of specifications uses L and B, such as "50,000 hours, L70/B50", where the L stands for Lumens – the percentage lumen maintenance threshold – and B essentially stands for "Bad" – the percentage of the population of units that are allowed to exceed that threshold over the stated period. Therefore, 50,000h L70/B50 means that no more than 50% of a population of units will have depreciated below 70% of their original output within 50,000 hours. 70% is often chosen because that is the point at which the average human eye can begin to detect a difference between two sources shining side-by-side, such as a newly replaced unit amongst a group of older units. This is important because inconsistent lumen output often compels expensive group replacements, to make everything look the same.

But the B number does not account for catastrophic failures. In other words, L70/B50 means that no more than half of the units that do not fail catastrophically will be below 70% of original lumens. This is where the F rating comes into play. F stands for Failure of any kind – either catastrophic or through lumen depreciation.

Defining Failure

But there is a third, usually unaccounted way that a lighting installation can fail – color shift. Color shift can be even more offensive than lumen depreciation. Delta u'v' (or du'v') is frequently used as a measure of color shift. It should be noted that this measure only describes the amount of color shift – distance, not direction. Two parts can both have a du'v' of 0.003, but if one shifts pink and the other green, the difference between them can be as large as 0.006. This is totally unacceptable to most end users, much less lighting designers, and it is absolutely possible that two parts from the same manufacturer will shift in opposite directions. But most manufacturer warranties make no claims at all about color shift.

So Failure should really include catastrophic failure, lumen depreciation, *and* color shift.



10,000 hour LM-80 lumen maintenance for entire population of independently tested Xicato 5000LM Standard Series products. Notice that some units "burn in" and actually get brighter for several thousand hours. This is not unusual for high quality LEDs.

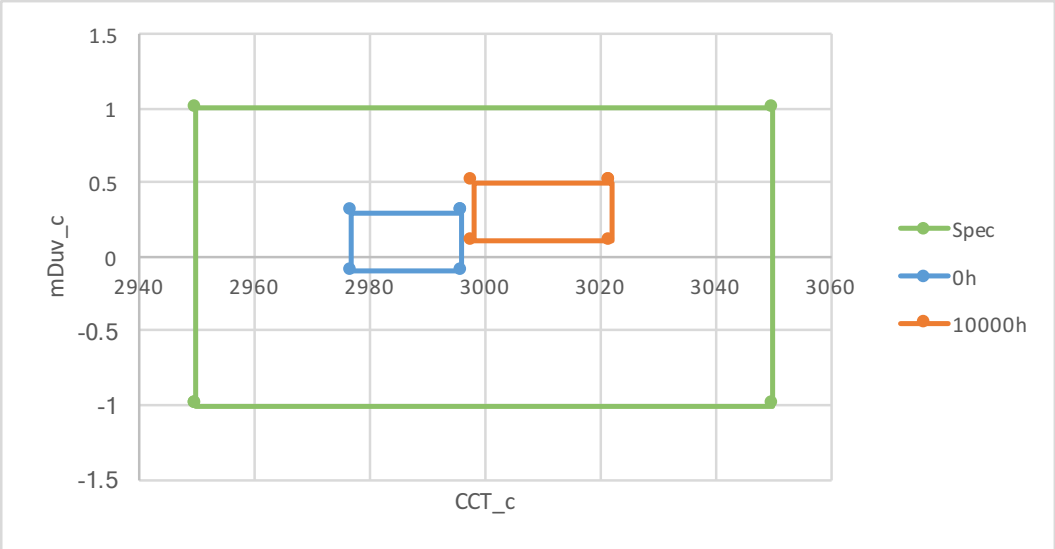
B0 vs. B50

Now, let's think about the number for a minute. Do you really think it is okay for nearly half of your units to fail within the warranty period? What kind of warranty is that? How about B10 (10%)? Is that okay? Do you really want to be replacing 1 out of every 10 luminaires before the warranty is up? And under what conditions is the warranty valid?

Xicato guarantees 70% lumen maintenance after 50,000 hours (XIM) or 5 years (XTM), for every single module. This is a B0 and F0 statement. Similarly, Xicato warrants that any 2 modules will not differ more in color than 3 McAdam ellipses, also a B0 and F0 statement. No failures. Of any kind.

Furthermore, Xicato life predictions are worst case predictions. Xicato provides stability over life predictions at maximum temperature and maximum

current (power) rating. It is up to the fixture makers, when incorporating Xicato modules, to ensure that the actual conditions stay within the maximum current and temperature envelope.



Xicato color change in both CCT and Duv at maximum current and temperature over 10khrs of entire population of tested units. LM80 testing 2016 by BACL (Bay Area Compliance Laboratory). Notice that even after 10khrs, all of the modules were still well within Xicato's initial 1x2 MacAdam ellipse specification, and all moved in the same direction.

Preventing Failure

To ensure long life, Xicato XIM products contain integrated sensors and electronics that enhance stability over life in multiple ways. For example, XIM automatically reduces its LED current if the LED reaches its specified maximum temperature, eliminating the risk of shortened life due to overheating. In addition, XIM counts its operating hours and stores internally its operating hours, as well as histograms of its intensity and temperature. This enables a true 50,000h warranty, as opposed to the common year-based warranty. Should a unit fail, it has its operating hours and temperature diagnostics saved to its memory to confirm whether it is within warranty.

Xicato XIM Gen4 products report their operating status on a regular basis over a Bluetooth Low Energy wireless network. This allows facilities managers to proactively manage situations that might shorten the life of a luminaire. This data includes current LED and driver temperature, input voltage, and total operating hours. it also includes input voltage and ripple, which can provide clues to power issues and power supply health that might lead to failure.

To provide long term stability, Xicato has focused first on color stability. It is often easier to notice small color differences than it is to see small light output differences, making color consistency and stability more important to the appearance of a lighting installation. Fortunately, ensuring good color stability also ensures good light output stability. It does not necessarily work the other way around.

For good color stability, it is fundamental that the phosphors and the encapsulants that are used in an LED package remain at a relatively low temperature. Under operation, both the blue LED chips and phosphor particles generate heat. By placing the phosphor remotely from the LED chips, and by using carefully selected materials and an optimized design, Xicato efficiently cools the phosphor particles and their encapsulant. As a result, the phosphor temperatures are substantially lower than in a comparable LED package.

Because of the importance of phosphor temperature for the stability of the LED, Xicato defines its operating temperature (Tc) measurement point on the ring that supports the phosphors. It is common for LED manufacturers to define chip junction or package case as the temperature reference point. The problem with this approach that the critical phosphor temperature is not directly known, and can be as much as 15'C to 40'C higher than the referenced temperature.

Reporting and Evaluating

Xicato believes that it is not good engineering practice to report lifetime data based on statistics like percentiles, average, or median. For example, would you walk across a river that is on average 1m deep? Or one that is for 95% of its width not deeper than 1m? It is obviously more important to know its maximum depth before deciding to walk across. Similarly, Xicato reports the maximum color shift between any two parts and the maximum light output reduction of any single part, instead of averages, medians or percentiles.

The Xicato Specification

Xicato's warranty guarantees that your lit environment stays beautiful for the life of the installation. This includes initial color point consistency, lumen maintenance, and color consistency over time at MAXIMUM drive current and temperature. In the case of the XIM, it also includes the LED driver, which is integrated into the unit!

Warranty: 5 years (XCA/XTM). 7 years or 50,000 hours (XIM) verifiable by internal data collection in each module, on EVERY module (B0/F0).

- Initial color consistency: 1x2 MacAdam ellipse (SDCM)
- Lumen maintenance: L70/B0/F0
- Color maintenance: units will remain within 3 SDCM of each other
- XIM: integrated deep dimming driver
- XIM Gen4: Integrated driver and Bluetooth control module

Xicato XIM tracks and reports many operating parameters, and stores internally its operating hours and histograms of its lifetime temperature and intensity. Users can perform proactive maintenance, and Xicato can verify compliance with its warranty.

	Xicato	Other LED Manufacturers
Operating condition at which reliability is specified	*Maximum temperature and maximum current*	*Typically at a nominal current or temperature combination below max*
Temperature measure ment point directly correlated to phosphor temperature	*Yes*	*No*
Lumen maintenance based on highest degraders	*Yes*	*No*
Color maintenance specified	*Yes*	*No*
Color maintenance based on biggest possible difference	*Yes*	*No*
Lumen maintenance warranty	*5 years (XTM & XCA)* *7 years or 50,000 hr verifiable (XIM)*	*Typically L70/B50* *50,000 hrs unverifiable*
1x2 MacAdam ellipse initial color point warranty	*Yes*	*No*
Warranty for "dead" LEDs	*Yes*	*No*
Over temperature protection	*Yes*	*No*
Reports maximum degradation in its LM80 testing	*Yes*	*No*