C3 - LED Lifetime

A Real World look at issues affecting LED lifetime.

Background

The introduction of LED lighting technology provoked an industry paranoia around fixture lifetime.

Since their development, LEDs have been used in high reliability aerospace and military applications. Recently, they have become commonly used in automotive applications ... due to their high reliability. So why is it that have many LED luminaires fail and continue to fall well short of their expected lifetimes? It turns out that the LED lifetime is the least of your worries when it comes to fixture lifetime.

The LED Operating Environment

Light that appears white, is in fact made up from a spectrum of colours (frequencies). The LED is a semiconductor diode that emits photons when excited in the blue wavelength. This light must be frequency shifted with the use of phosphors to add other frequencies that add to produce what appears to be "white" light.

The LED itself has an almost infinite life, so long as it is operated in its "safe operating area". This operating environment for the LED will include safe limits in temperature, operating current, mechanical stress and electrical stress.

Authorities have attempted to promote lifetime performance standards, most notably the industry wide LM80 and TM21 type standards. These standards are based upon a sample size test (typically 25) of the LEDs used in the luminaire. The test is conducted under laboratory conditions for several thousand hours, with the LED operated at constant temperature and drive current. Any change in the output of the LED is noted and this data drives a lifetime projection, *based upon the assumption that the LED output will decline exponentially*. In order to derive this projection, the last 5 useful data points are used which is curve fitted to an exponential decay. It is not uncommon for this projection to predict infinite life (rising output over time) or extremely long life (250,000+ hours). In this event, the standard requires the projection to be ignored and a statement made to the effect "life in excess of X,XXX hours" based upon no more the 5 times the longest test data.

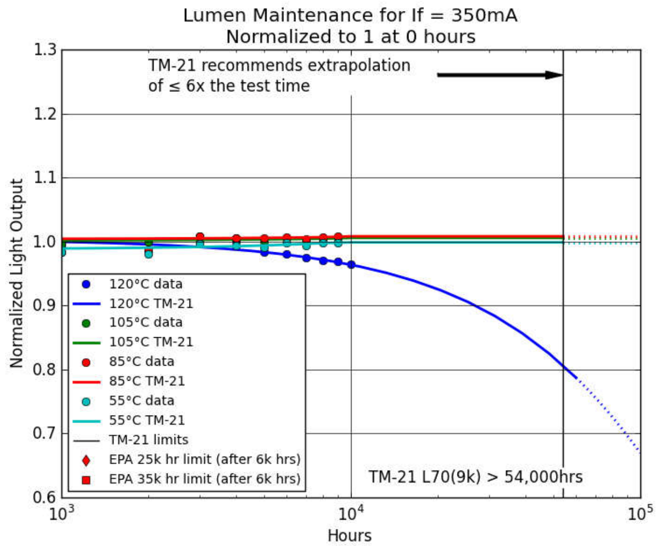

Figure 1. Lifetime projections with 9,000 hr test data for a ceramic LED

It is important to note that these tests *do not measure the operational stress of the LED in real world applications.*

Market Drivers and Operating Lifetime

The market focus on the cheapest possible fixture demands that manufacturers use as few LEDs as possible in their fixture. They must drive fewer LEDs harder to meet the total required light output. This also drives a demand for smaller fittings using less materials which provides less heat sinking.

As a result, LEDs must operate hotter, often at the very limits of their designed maximum operating envelope. In hot ambient conditions, the smaller heat-sinks and harder driving conditions may well push the LED into critical operating areas severely effecting lifetime. Additionally, because LED output drops as it runs hotter, these cheaper fittings will also be less efficient.

A quality fitting will use more LEDs driven less hard and utilise better heat sinking, providing the LED with an environment conducive to long lifetimes and higher overall efficiency.

Ceramic versus Plastic LEDs

Much of the early "lighting class" LED development was around the LED substrate, whether sapphire or diamond. Regardless of the substrate, the LED was termed "ceramic" and able to withstand considerable operating temperatures (typically 150°C) with little adverse effect.

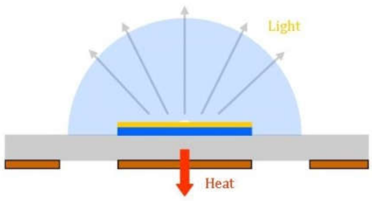

Figure 3. Ceramic LED - Direct light path and rear heat path

The television industry drove the use of plastic LEDs for backlighting. Consequently, "plastic" LEDs became very cheap and over supplied. These LEDs are structurally different and rely on internal reflector surfaces, pushing the light through a phosphor. Without a direct heat path from the die, plastic LEDs cannot withstand the higher operating temperatures of the ceramic LED. The mechanical structure is more prone to crazing, aging effects and discolouration, making for a LED with substantially shorter lifetimes than a ceramic LED. As a result of its low tolerance for heat, the plastic LEDs tend to be "medium" or "low" power and therefore a manufacturer must use a lot of them and run them cool, to make the required total output of the fitting.

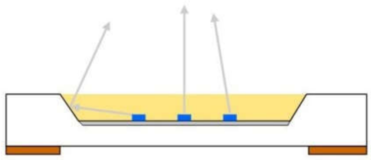

Figure 2. Plastic LED - Side reflectors and no rear heat path

The market demand for low cost fittings has driven the price equation away from the ceramic LED. The manufacturer can now use more low cost plastic LEDs and deliver a solution at lower cost than one using a few high power ceramic LEDs. The consequence of this is shorter LED lifetimes.[3]

It is worth noting that 6,000 hour LM80 data on a plastic LED may show adequate lifetime when extrapolated to 36,000 - 40,000 hrs. However extended testing to 12,000 hours can show this same LED will actually have rapid degradation of output and colour by as little as 20,000 hours.

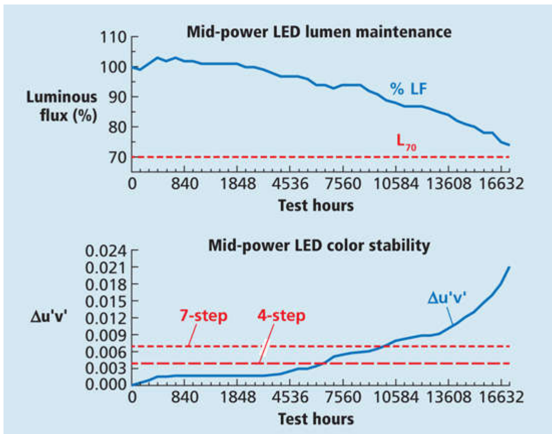

Figure 4. Plastic LED stability

[3] Understanding the True Cost of LED Choices in SSL Systems. Ralph Tuttle & Mark McClear, Cree Inc.