LED High Bay reliability and performance over time

Flex Lighting Solutions

CHOOSING THE BEST LED HIGH BAY

LED lighting has become the preferred option for low and high bay lighting. The benefits are multiple—longer lifetimes, reduced energy costs, less maintenance, higher quality of light, better lighting distribution, better color consistency and instant full light output. The promise of never having to worry about your lighting again is compelling, but it is a little more complicated than that. In order to make the most of your investment you need to know what to look for, and how to best make LED technology work for you in your application.

The energy and maintenance savings of LED lighting are attractive benefits, but you must remember the primary purpose of lighting – to provide proper light levels in your space and ensure a safe and productive work environment.

LED luminaires are not created equal. LEDs will fade over time, leading to reduced light levels. With the projected lifetime of LED luminaires, it is easy to believe they will last forever. It is important to understand projected L70 lifetime is the point when the luminaire produces 70% of the original light output. The Department of Energy has determined L70 is the point when the luminaire no longer produces an acceptable quantity of light.

It is critical when selecting an LED luminaire to understand this purchase is an investment in your infrastructure for 5, 10 or more years. The luminaire will perform differently in your environment than it does in a clean lab at 25°C, which are the conditions for the data typically reported in a specification sheet. This paper will explore the luminaire design details and test data you should review in order to determine how a given LED luminaire is going to perform in your application and environment.

LUMINAIRE DESIGN

General

The design of the luminaire should include materials engineered for long life and performance. The use of aluminum extrusions with vertical surfaces produces rigid luminaires with excellent thermal properties. Rigid luminaires will not transfer the stress of transportation, installation and building movements to the relatively delicate LED boards and LEDs inside. This stress may not show as a failure for some time. The use of aluminum extrusions tied firmly to the LED boards will allow the LEDs to run at the coolest possible temperature for a given drive current, resulting in the best combination of output, life and efficacy. Specific care should be taken to tie the LED board thermally to the heat sink such that the LED can effectively transfer heat from the board to the heat sink. Just using screws will not give an adequate thermal bond.

Lenses can be a weak point for luminaires as they are often made from inferior materials to reduce cost. Look for polycarbonate or PMMA lenses when using a luminaire in a harsh environment. They will stand up to strikes from material, sports equipment, etc. much better than less expensive acrylic and no-lens luminaires. They will also protect the delicate LED’s from dust and airborne particles (oils, solvents, etc.). No-lens options are not recommended for an industrial environment.

LED luminaires should be designed as a complete unit with the optimal design having integrated LEDs. LED lamps are very popular, but fail to take advantage of the full benefits of LED technology in a high bay application. LED tubes, bulbs etc. do not properly tie into the luminaire thermally, resulting in the LED's running hotter and therefore having a shorter life. The integrated LED drivers used in LED tubes and LED bulbs are not as robust and use lower quality components due to space constraints, which translates into lower efficacies, substantial ripple causing flickering of the light and a lower lifetime due to a poor lumen maintenance and premature driver failures. When used in a plug and play configuration to retrofit conventional luminaires, although the efficiency of the LED tubes may be high, the existing ballast of the luminaire adds 10 to 20% efficacy losses to the luminaire and will suffer from premature failure when this aged ballast fails.

LED

Choosing LEDs from well-known manufacturers is recommended. LEDs should first and foremost be of high quality, backed up by verified data. This data is presented in an LM-80 report.

LM-80

LM-80 is an industry standard for measuring the reliability of an LED over time. It is critical to note it only measures the LED package by itself in a very controlled environment. How this data is interpreted and how it is applied to a luminaire is important for realistic LED life claims.

LM-80 includes the following:

- Minimum 3,000 hours for a successor LED package.
- Minimum 6,000 hours for a new LED package.
- Multiple drive currents.
- Most vendors end at 6,000 hours.
- Three temperatures: 55°C, 85°C and one selected by the manufacturer, with relative humidity (RH) less than 65%.
- Data is collected at 25°C (allowed to cool for measurement).
- Measures Output, Chromaticity, Forward Voltage (sometimes) and notes any failures (rare).
- One LED package is usually allowed to cover a wide range of similar LEDs in a product family.

It should be noted that:

- LM-80 does not predict failures.
- LM-80 does not take into account any facets of luminaire design.
- LM-80 is NOT directly relatable to luminaire performance in any way.

What Should You Look for in an LM-80 Report?

- Large changes in Lumen Maintenance at elevated temperatures or current.
    - It is typical the life of an LED is reduced at elevated temperatures and currents, but a sharp drop can indicate an LED is cheaply constructed and may fail more rapidly than planned, even at lower

temperatures and currents.

- Make sure the LM-80 data has a minimum of 6,000 hours.
- Understand at what temperature the LEDs were tested.
- Verify the LED package in the report is the same as the LED being used in application, or it is a verified successor package.
    - It is common for a single LED part number to cover a wide range of LEDs since they are similar. Unfortunately, some luminaire manufacturers take advantage of this, and the LEDs in the report may perform better by 10% or more versus the LEDs used in their actual luminaires.
- Verify the Chromaticity drift is acceptable.
- Verify if the luminaire is DLC or Energy Star listed and adequate for your industry.

TM-21

TM-21 calculates the lumen maintenance of an LED luminaire based on IESNA's approved method to use LM-80 data. It is a standard way to calculate projected data from LM-80 by applying defined algorithms to achieve consistent results across all manufacturers. More details of TM-21 can be found in page 8.

CHOOSING AN LED

LEDs should be selected in such a way they are driven well below the maximum drive current. When an LED is pushed to its maximum drive current it is unlikely to survive favorably against TM-21 calculations. Due to variations in production, the LEDs may actually end up being driven beyond their maximum current. It is also critical in high stress environments the LEDs are robust and properly designed for the application. Even if the TM-21 calculations look favorable, look at how the LED operates at elevated temperatures.

High quality LEDs are made with more robust materials, and stand up to elevated heat better than inferior LEDs, resulting in real world life improvement despite TM-21 claims. Only high quality LEDs are suited for high bay applications due to the conditions of the environments where they are usually installed. Some companies use the less expensive LEDs typically used in troffers for office lighting and expect them to perform well in high bay applications. The TM-21 for those LED's might provide an acceptable lifetime, but when running in the typical environment of high bay applications the result can be catastrophic as the harsher conditions in terms of ambient temperature, quality of air (dust, vapors, chemicals, etc.) and running time will reduce the lifetime of those inexpensive LEDs drastically. Only high quality LEDs from respected manufacturers should be taken into consideration to ensure the expected and required lifetime, lumen maintenance and performance of a professional high bay LED luminaire.

Be sure when reviewing the TM-21 report

It includes the in situ ambient temperature in which your luminaires will be installed.

Standard TM-21 reports only account for performance at 25°C ambient. Your light calculations on Day 1 should take into account the ambient temperature effects which may reduce light output in addition to a reduction of L70 lifetime.

Note: LM80, LM79 and TM-21 calculators do NOT take into account any temperature other than 25°C.

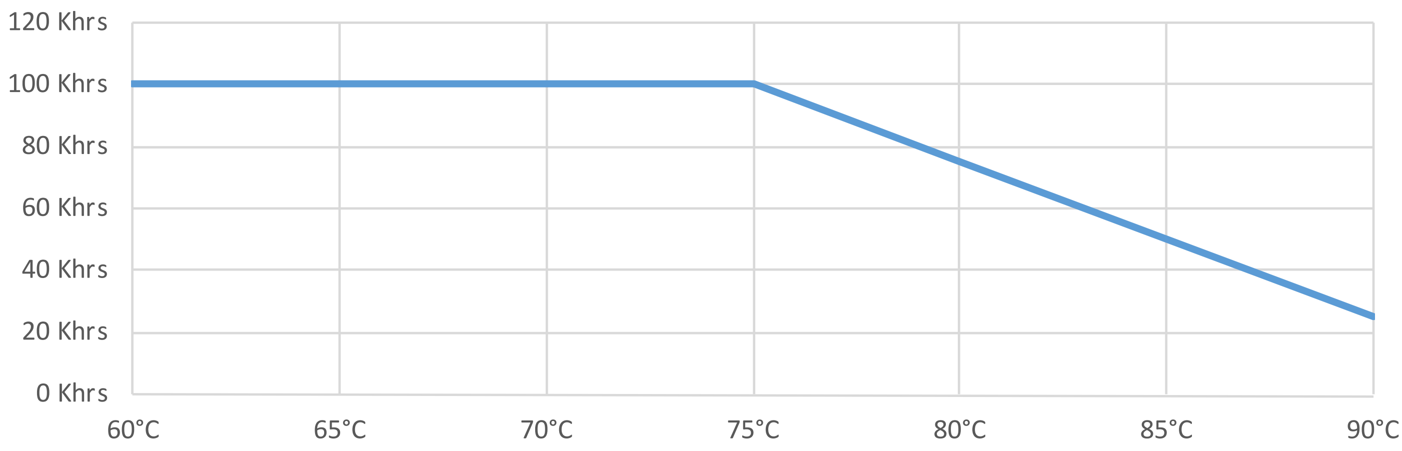
DRIVER

Drivers are one of the most important parts of an LED light luminaire as they may have the shortest life of all components.

What good does it do if the LEDs are projected to last for 100,000 hours if the driver will only last 40,000 hours?

As with LEDs, the biggest enemy of a driver is heat, which drastically shortens its life. Aluminum extrusions tied directly to the driver help dissipate heat, which is key to keeping the operating temperature of the driver within the recommendations of the manufacturer in order to achieve the expected lifetime. Look for luminaires with maximum ambient temperatures well above your need. Typically, the maximum ambient temperature of a luminaire is related to the maximum allowable safe temperature of the driver. There is a problem with this thinking. At maximum driver temperature, the life of the driver my fall from 100,000+ hours to as little as 25,000 hours. DLC, Lighting Facts, etc. do NOT account for this. Users should ask for lifetime data in the form of graphs or tables for driver case temperature estimates at elevated ambient temperatures, along with the life curve for the driver, like this one below.

Driver Lifetime (Khrs) vs. Driver Case Temperature (°C)



If the data is not available, the best way to estimate this is to use the in situ case temperature of the driver in the luminaire at an ambient temperature of 25°C, and add the degrees above 25°C at which the luminaire will operate. Make sure the requested temperatures are for the driver inside the luminaire as it will operate in the field.

For further simplicity, please note the common abbreviations used in the industry:

- Driver case temperature = TCASE = TC
- Ambient temperature = TAMB = TA

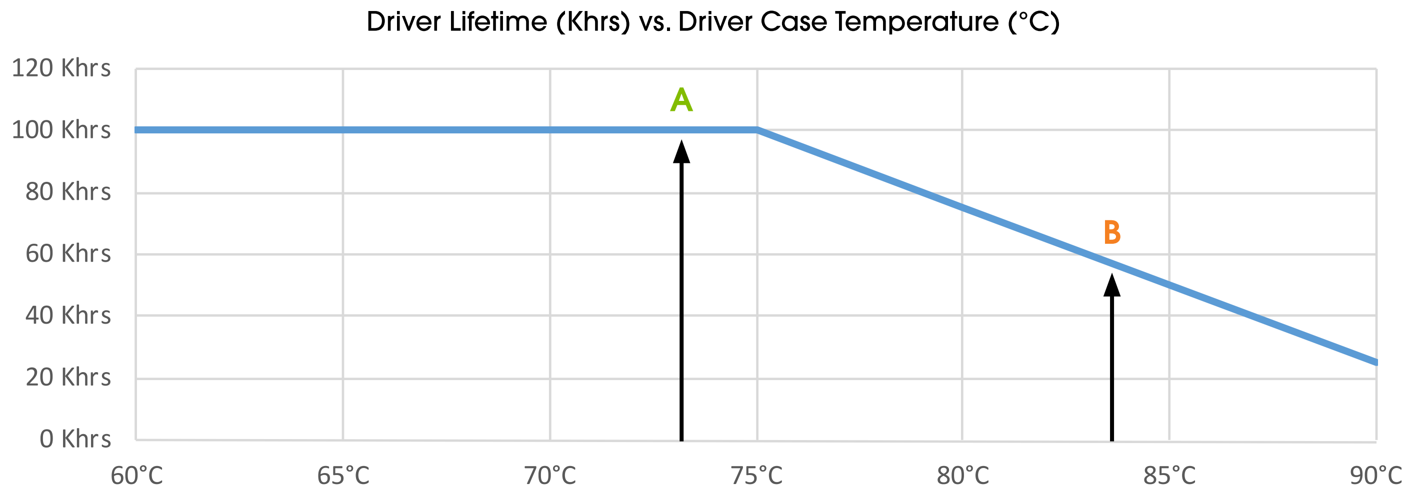
Luminaire life in environments with an ambient temperature of 25°C would be still 100,000 hours, but when the product is used in a more realistic scenario, for example a 55°C ambient temperature, we can predict that the lifetime will be impacted negatively.

How to calculate the driver TCASE and expected lifetime for more realistic enviroment, for example 55°C?

1) Use the formula: TCASE @ AMB. XX°C = TCASE @AMB.25°C + Difference of ambient temperatures
2) Find the corresponding lifetime in the provided graph by the manufacturer

Let's take a look at two scenarios with different drivers and calculate their estimated lifetime with the assistance of the formula above and the graph below.

Scenario	Ambient Temperature = 25°C	Ambient Temperature = 55°C
A	TCASE @ AMB.25°C = 43°C	Calculate TCASE @ AMB.55°C
B	TCASE @ AMB.25°C = 57°C	Calculate TCASE @ AMB.55°C



Scenario A

43°C	+	(	55°C	−	25°C	)	=	73°C	→	100,000h
TCASE @ AMB.25°C			Difference of ambient temperatures					TCASE @ AMB.55°C	From graph	Expected driver lifetime

With an ambient temperature (TAMB) of 55°C the driver case temperature (TCASE) will be 73°C.
It should be noted this is a WORST CASE scenario as the driver case temperature does not scale linearly with the ambient temperature 1:1 but it is a good and commonly used estimate.

Scenario B

57°C	+	(	55°C	–	25°C	)	=	87°C	→	~40,000h
TCASE @ AMB.25°C			Difference of ambient temperatures					TCASE @ AMB.55°C	From graph	**Expected driver lifetime**

In this case the driver is not managed as well thermally, and the case temperature (TCASE) is 57°C when operating at an ambient temperature of 25°C. As we can see, that leads to a 60% loss of lifetime.

Why does this matter?

In order to reduce cost many LED products do not invest is good thermal management, pushing driver case temperatures to their maximum rating, TCASE = 90°C for the driver represented in the graph. A 90°C case temperature would result in only a 25,000-hour driver life. A luminaire with a theoretical L70 of 100,000 hours will require 3 driver replacements during that span.

It should be noted most environments fluctuate and don't sustain the maximum ambient temperature, so the life calculations shown here may seem pessimistic. However, the luminaire MUST be rated for the maximum ambient temperature even if it is only seen for 1 hour per day.

Drivers rated for outdoor use should be used even for indoor high bay applications when longevity in industrial environments is required. An outdoor driver will have higher surge capability without additional devices and will be fully potted (sealed) to ensure environmental conditions don't cause chemical reactions with the various metals in the driver. This sealing also ties together the internals of the driver for thermal reasons, allowing sensitive components to dissipate heat to a larger surface area, which improves lifetime.

If the installation has voltage surge inducing devices in close proximity (even located in a different building) additional surge suppression devices should be installed on each luminaire. Sources of damaging levels of surge could be a poorly maintained air conditioner, or even well maintained commercial equipment. Make sure the luminaire vendor offers this additional protection. Surges can also be caused by exterior forces such as line surges and lightning strikes.

ENVIRONMENT

As noted above, temperature control of the driver and LEDs is critical to the performance of the luminaire over time. All calculations should be done based on the actual operating environment of the luminaire. The temperature in which the luminaire operates may differ from the temperature measured at the floor due to rising warm air, a hot roof, or machinery generating heat. The temperature in the ceiling should be measured to ensure proper care is taken to select the right product.

Other factors may be more obvious like dust, chemicals or dangerous environments and should also not be overlooked. High concentrations of certain chemicals floating in the air can damage plastics, circuit boards and even the LEDs themselves.

When protection from dust, humidity and water splashes is required, choose a luminaire offering seals for dust and water as required. If the environment is a hazardous location or it has a high concentration of chemicals, it is best to choose a luminaire that is completely sealed such as one offering an IP68 rating, or one with a hazardous location rating as required.

LM-79

LM-79 testing provides data on the luminaire itself. LM-79 is an approved method of measuring the various electrical and photometric characteristics impacting the performance of a luminaire. Additionally, driver and LED temperature will often be listed in order to formalize data used to calculate the life of the driver and LED via TM-21. LM-79 includes 5 basic tests; total flux, electrical (power, THD, PF), efficacy, chromaticity and distribution.

- Total flux is the sum of all the light emitted from the luminaire in all directions. Measured in Lumens.
- Electrical power is the amount of energy the luminaire uses. Measured in Watts.
- Electrical THD is the amount of harmonic distortion the luminaire creates. Measured in percent. Look for less than 20%
- Electrical PF is the power factor of the luminaire, which in simplest terms is an additional efficiency of the luminaire. Measured in a decimal ratio. Look for greater than 0.90.
- Efficacy is the ratio of light output to power. Measured in lumens per watt (lm/W). Premium products produce over 150 lm/W. Anything below 130 lm/W is not a wise investment for most commercial applications and could indicate the luminaire has been designed either with low quality LEDs or with a low quantity of LEDs in order to save costs, and driven at very high drive currents to maintain a similar light output. Unfortunately, this practice reduces the lumen maintenance of the LEDs and the life of the luminaire.

TM-21

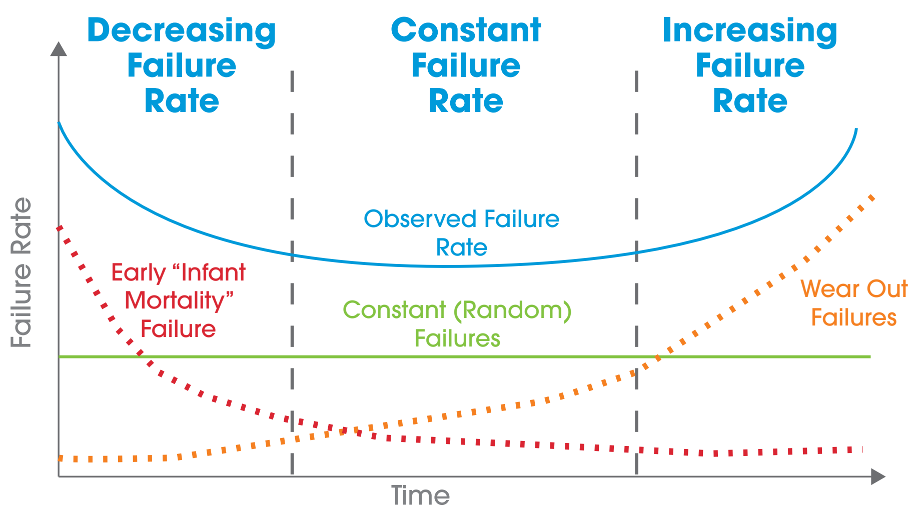
TM-21 is the IESNA approved method for predicting the output of an LED in application over time, or Lumen Maintenance. It is in the form of a spread sheet where LM-80 data from the LED manufacturer and luminaire specific temperature and drive current are input, and predicted Lumen Maintenance is extrapolated.

- TM-21 Reports the output of the LED in the luminaire over time at 25°C by default.
  - Reported as % of original flux at a certain time period.
  - L70 is the term used for the light luminaire having 70% of its initial light output. This is an important term as L70 is the point when "…human observers began to notice diminished light levels at 70% of initial (LRC 2006). Thus, if a product reaches that output level, it would be considered to no longer be delivering an acceptable quantity of light." (DOE report Lumen Maintenance and Light Loss Factors, 2013).
  - L70 @ 50,000 hours would mean the product will retain 70% of the original light output at 50,000 hours.

TM-21 Projected vs Reported

- Reported hours are limited to 6x the actual testing done in LM80 and is considered highly reliable.
- Projected hours are extrapolated well past what experts consider credible. Projected hours are considered high risk. However, this can be a tool for comparing competitive luminaires.
- TM-21 takes into account LED drive current for the luminaire and actual operating temperature of the LED in the luminaire at 25°C.
- Although TM-21 interpolates for temperature between LM-80 testing, it does not interpolate drive current, so the next higher current tested via LM-80 must be used.
- **TM-21 predicts change of light output over time, not output on Day 1.**
- The newest TM-21 tool from energy star does not show calculated values in the report.
- By changing the LED case temperature to one consistent with elevated ambient temperatures, fixture life can be predicted at ambient temperatures other than 25°C reliably.

Always request the TM-21 report with lumen maintenance at the actual amb. temperature of your application



Typical relative failure rate and cause for an electronic component.
Orange "wear out failure" collaborates with TM-21 Lumen Maintenance.
(graphic source: Wikipedia)

Sample TM-21 Report

It is common for the manufacturer to remove the LED from this block and replace with the fixture to protect intellectual property.

Table 1: Report at Each LM-80 Test Condition					
Description of LED Light Source Tested (manufacturer, model, catalog number)					
Test Condition 1 - 55°C Case Temp		**Test Condition 2 - 85°C Case Temp**		**Test Condition 3 - 105°C Case Temp**	
Sample Size	25	Sample Size	25	Sample Size	25
Number of Failures	0	Number of Failures	0	Number of Failures	0
DUT Drive Current Used in the Test (mA)	150	DUT Drive Current Used in the Test (mA)	150	DUT Drive Current Used in the Test (mA)	150
Test Duration (Hours)	6,000	Test Duration (Hours)	6,000	Test Duration (Hours)	6,000
Test Duration Used for Projection (Hour to Hour)	1,000 - 6,000	Test Duration Used for Projection (Hour to Hour)	1,000 - 6,000	Test Duration Used for Projection (Hour to Hour)	1,000 - 6,000
Test Case Temperature (°C)	55	Test Case Temperature (°C)	85	Test Case Temperature (°C)	105
α	1.383E-06	α	2.523E-06	α	6.568E-06
β	0.997	β	0.994	β	0.994
Calculated L70 (6K) (Hours)	256,000	Calculated L70 (6K) (Hours)	139,000	Calculated L70 (6K) (Hours)	53,000
Reported L70 (6K) (Hours)	>36000	Reported L70 (6K) (Hours)	>36000	Reported L70 (6K) (Hours)	>36000

This data is just the raw LM80 data.
It as no direct bearing on the fixture. The case temperature is completely meaningless in fixture context and does not in any way relate to ambient conditions.

Table 2: Interpolation Report (Projection Based on *in-situ* Temperature Entered)	
$T_{3,1}$ (°C)	55.00
$T_{3,1}$ (K)	328.15
α_1	1.383E-06
β_1	0.997
$T_{3,2}$ (°C)	85.00
$T_{3,2}$ (K)	358.15
α_2	2.523E-06
β_2	0.994
E_α/K_o	2.35E+03
A	1.806E-03
β_o	0.996
$T_{3,t}$ (°C)	67.30
$T_{3,t}$ (K)	340.45
α_t	1.793E-06
Projected L70 (6K) at 67.3°C (Hours)	197,000
Reported L70 (6K) at 67.3°C (Hours)	<36000

This data is about the fixture.

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Sample Size	25	Sample Size	25	Sample Size	25
Number of Failures	0	Number of Failures	0	Number of Failures	0
DUT Drive Current Used in the Test (mA)	150	DUT Drive Current Used in the Test (mA)	150	DUT Drive Current Used in the Test (mA)	150
Test Duration (Hours)	6,000	Test Duration (Hours)	6,000	Test Duration (Hours)	6,000
Test Duration Used for Projection (Hour to Hour)	1,000 - 6,000	Test Duration Used for Projection (Hour to Hour)	1,000 - 6,000	Test Duration Used for Projection (Hour to Hour)	1,000 - 6,000
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α	1.383E-06	α	2.523E-06	α	6.568E-06
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$T_{3,2}$ (°C)	85.00
$T_{3,2}$ (K)	358.15
α_2	2.523E-06
β_2	0.994
E_α/K_o	2.35E+03
A	1.806E-03
β_o	0.996
$T_{3,t}$ (°C) (case temp)	**67.30**
$T_{3,t}$ (K)	340.45
α_t	1.793E-06
Projected L70 (6K) at 67.3°C (Hours)	**197,000**
Reported L70 (6K) at 67.3°C (Hours)	**<36,000**

! A great check to see if the calculator has been manipulated is to verify the calculated L70 falls between the calculated L70 in the LM80 data for the temperatures that bracket the LED case temperature.

This data passes this quick check because 67.3°C is between 55°C and 85°C roughly proportional to 197,000 being in between 256,000 and 139,000.

It should be noted:

- TM-21 is not an exact science.
  - Anything beyond the LM-80 data is predicted, and anything beyond 6x the LM-80 data input is considered high risk.
  - Even the LM-80 data is a prediction since the EXACT LED package was probably not tested.
  - Although calculated life can be used as a comparison tool, it should be used with caution. It is the result of several predictions layered on top of each other.

- TM-21 does not include other luminaire wear factors such as reflector or lens degradation over time.
- Does not include acute failures such as a broken wire, or even an LED that just stops working.
- Does not include failures from LED drivers, which can actually become the leading cause of LED fixture maintenance issues.
- Does not predict chromaticity drift.

Example

TM-21 is the Lumen Maintenance calculation for the luminaire. The case temperature of the LED ($T_{s,i}$) is used to predict the life of the LED by interpolating the temperature points given in the LM-80 data. Remember, the LM-80 data must be at an equal or higher drive current than the used in the actual luminaire and is not interpolated.

In this example we are assuming the luminaire was tested at 25°C ambient temperature. The reported L70 is 36,000 hours because the LED was only tested for 6,000 hours (6x factor). On the other hand, the projected L70 is nearly 200,000 hours.

The 200,000 hours should be highly suspect, but IS correct per the TM-21 method. Simply put, predicting the life of an LED over 20 years from now is statistically irrelevant.

If the viewer of this report wanted to know how this luminaire would perform at an ambient temperature of 55°C, they could request that data to the luminaire manufacturer, who will run a simulation to calculate the projected L70 at the requested conditions. In this example, with the new ambient temperature (T_{AMB} = 55°C), the new LED case temperature (Ts,i) will be 97.3°C (30°C higher) and the simulation tool will return a projected L70 of 76,000 hours. As expected, the higher the temperature, the lower the lumen maintenance. (Note: this is a worst case calculation. If the manufacturer has actual test data, it is better to use that value).

$T_{3,\iota}$ (°C)	97.30
$T_{3,\iota}$ (K)	370.45
α_{ι}	4.600E-06
Projected L70 (6K) at 97.3°C (Hours)	76,000
Reported L70 (6K) at 97.3°C (Hours)	<36000

At 55°C in this example projected L70 is 76,000 is still great...
but VERY different from 197,000!

TYING IT ALL TOGETHER

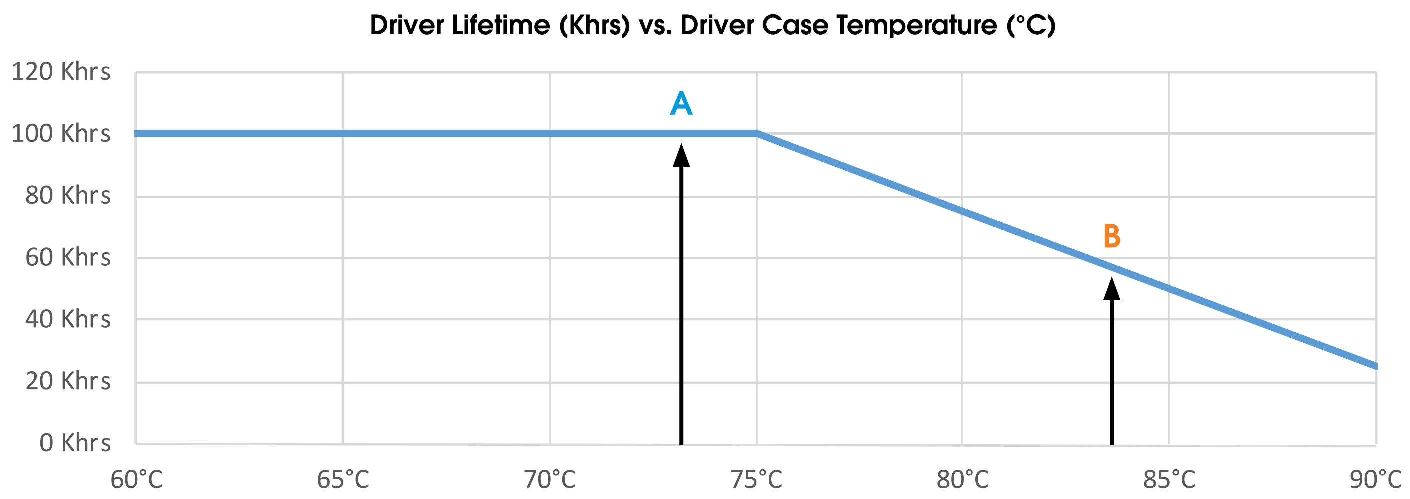
Armed with this information, we can quickly review a luminaire's construction and component selection to determine if the product we are considering is high quality. The next step is to actually calculate the output of the luminaire on Day 1 and calculate the life of the luminaire in the environment it will be used in. The manufacturer can help you do this by providing the correct TM-21 report, and output modification factors at elevated temperatures. Let's look at a real example of two luminaires.

	Ambient Temperature	Light Output Day 1	L70
Luminaire 1	25°C	20,000 lm	113,000 hrs
Luminaire 2	25°C	20,000 lm	97,000 hrs

The above is simple data taken from a manufacturer's spec sheet. At first glance, we would possibly buy luminaire 1. However, we are operating in an environment with an ambient temperature of 55°C, so we ask for the following:

1. Datasheet of the driver
2. Data of the driver case temperature T_{CASE} @ T_{AMB} = 25°C, and T_{AMB} = 55°C if they have it (typically about 25°C greater than at 25°C due to that non-linear relationship we discussed above
3. TM-21 @ T_{AMB} = 55°C
4. Luminaire Ambient Temperature Factor (LATF)

For the sake of simplicity, let's assume Luminaire 1 and Luminaire 2 both use the same driver.



- **Luminaire 1** is constructed of sheet metal, so the driver runs hotter as indicated by arrow "B".
- **Luminaire 2** uses extruded aluminum so the driver runs much cooler as shown by "A".

Luminaire 2 suddenly looks much better. In theory the LEDs on Luminaire 1 MIGHT last 10,000 hours longer, but you will be on driver #2 by that time.

Additionally, make sure the driver temperature doesn't exceed the maximum allowed (in this example T_{CASE} = 90°C). This will be noted in the data sheet clearly.

The next consideration will be the Luminaire Ambient Temperature Factor (LATF) of the LED.
For luminaire 1, we found the LATF at 55°C is 0.90 (this means the lumen output is 10% less than stated on Day 1 when used in a 55°C ambient temperature environment) and luminaire 2 has a LATF of 0.97 (only 3% less) under the same 55°C ambient temperature.

The light output on Day 1 for Luminaire 1 is now 18,000 lm and for Luminaire 2 is 19,400 lm. You may now need to go to a higher lumen luminaire from the manufacturer of Luminaire 1 to reach the desired light level.

	Luminaire Ambient Temperature Factor (LATF)	
	Ambient Temperature = 25°C	**Ambient Temperature = 55°C**
Luminaire 1	1.00	0.90
Luminaire 2	1.00	0.97

Now, we will **consider the lumen maintenance of the LED using TM-21**. Remember TM-21 calculates light output at a given point in time as a percentage of light output on Day 1 at T_{AMB} = 25°C.

We asked for TM-21 at T_{AMB} = 55°C and received the following information:

- Luminaire 1 has an L70 of 65,000 hours @ T_{AMB} = 55°C
- Luminaire 2 has an L70 of 82,000 hours @ T_{AMB} = 55°C

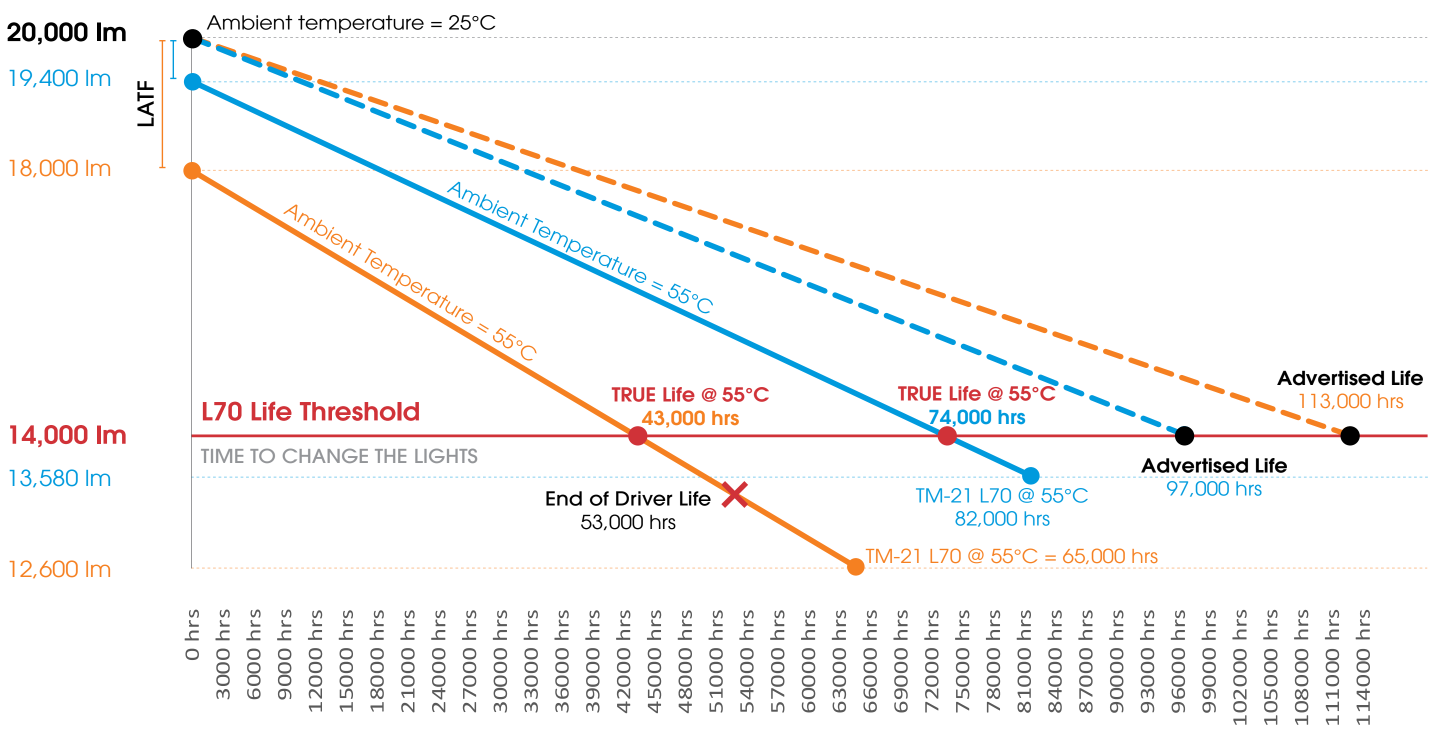
TM-21 does not take into account Day 1 losses from elevated temperature.
The flux factor must be applied to see the actual lumen depreciation value.

Example: Impact of ambient temperature on lumen maintenance, stated vs. real L70 lifetime.

- **Luminaire 1** has a LATF of 0.90 for T_{AMB}=55°C. This means the light output of Day 1 is 18,000 lm instead of the advertised 20,000 lm. The TM-21 value we received for L70 @ 55°C is 65,000 hours but it does not include this 10% loss. At 65,000 hours, we actually get 12,600 lm at 55°C. We need to calculate the point at which we will see 14,000 lm (target L70). In this case, it is at ~43,000 hours, well below the advertised 65,000 hours.
- **Luminaire 2** only loses 3% light output at T_{AMB}=55°C thanks to a much better LATF (0.97). Applying this to the advertised L70 of 82,000 hrs we obtain the real L70 which is at ~74,000 hrs.

	Light Output Day 1 (LATF applied)		Light Output at Stated L70 Lifetime (based on TM-21)		Real L70 Lifetime (LATF applied)	Driver Life	
	@ 25°C	**@ 55°C**	**@ 25°C**	**@ 55°C** (below L70)	**@ 55°C**	**@ 25°C**	**@ 55°C**
Luminaire 1	20,000 lm	18,000 lm	14,000lm @ 113,000 hrs	12,600lm @ 65,000 hrs	14,000lm @ ~43,000 hrs	100,000+ hrs	53,000 hrs
Luminaire 2	20,000 lm	19,400 lm	14,000lm @ 97,000 hrs	13,580lm @ 82,000 hrs	14,000lm @ ~74,000 hrs	100,000+ hrs	100,000+ hrs

LUMEN OUTPUT



This example demonstrates luminaire 2 will perform better for a longer period of time

CONCLUSION

The engineering and construction of an LED luminaire is important to its reliability and performance over time. LED luminaires should be considered technology products, and scrutiny of the engineering design should be as such. A properly designed LED luminaire will be a fantastic investment, generating years of energy and maintenance savings. If a poorly designed luminaire is selected, there is a high likelihood the entire installation will have to be replaced far sooner than anticipated. Most manufacturer warranties don't cover lumen maintenance. This is why it's critical to review luminaire design and test data, so you can better predict the performance of your investment over time.

You will need to know the lumen output required to reach your desired light levels, as well as the maximum ambient temperature of your operating environment. You should then obtain LM80 data as well as TM-21 data for the LED's at the required ambient temperature. You will also want to see LM79 data for the luminaire, which should provide the case temperature of the driver and LED's within the luminaire. The specification sheet for the driver should provide the expected life curve for the driver. Armed with this information, you will be able to compare the projected performance of different LED luminaires in your actual environment, not just the conditions they see in the lab or marketing claims.

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