False Lifetime Claims & Expectations Are a Real Issue

Menno Schakel, **Erik Swenson**
Nichia Corporation

Are you ready for the shocking truth?...

LED Products and LEDs <u>DO NOT</u> last forever!

Company	NICHIA Corporation
Location	Anan, Tokushima, Japan
Established	December 1956

Main Products

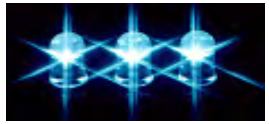
1. Optical semiconductor / LED・LD
2. Chemicals / Phosphors
3. Lithium Ion Battery Cathode Materials

President, COO	Hiroyoshi Ogawa
Employees	8,776 (Nichia Group)

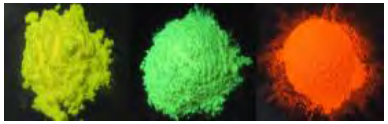
Turnover EUR 2.9 B (2017)

3 Core Competencies

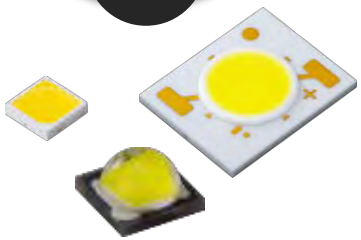
Advanced Chip Technology

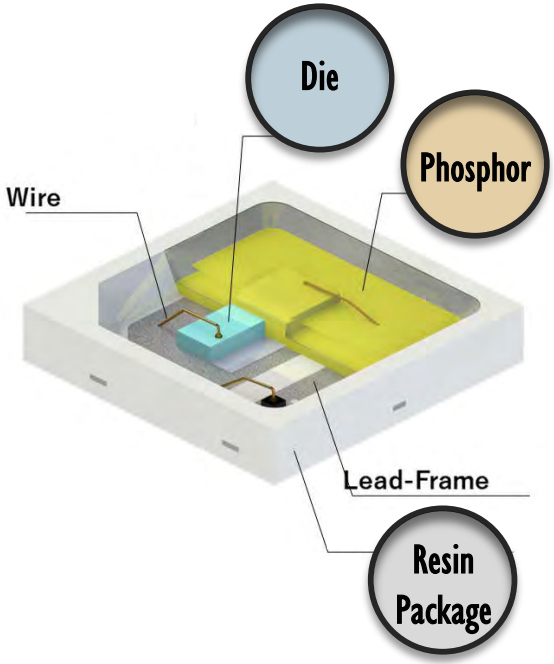


Phosphor Converter Technology



Advanced Packaging Technology





Integrated Manufacturing of LED packages

Agenda

1. What is LM-80? What is TM-21?
2. TM-21 can be misleading
3. Are LM-80 / TM-21 being misused?
4. New proposals for lifetime prediction beyond LM-80
5. Wrap up

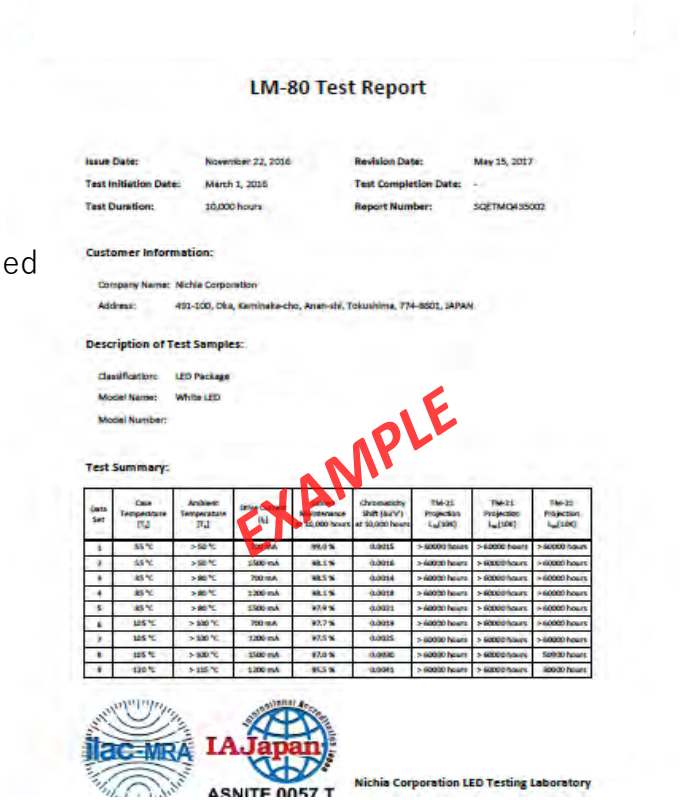
What is LM-80?

Overview

- LM-80 is the Illuminating Engineering Society of North America (IESNA) approved testing standard for measuring Lumen Maintenance, Color Shift and Forward Voltage of LED's.
  - To qualify for DLC or Energy Star certifications, testing must be performed by an accredited Laboratory
  - LM-80 does not state how to predict lifetime.
  - LM-80 does not have a pass / fail criteria.

Key Points

- Testing must now be conducted at a minimum of 2 different temperatures (T_S); 55^{0}C or 85^{0}C plus a 2nd T_S point selected by the LED Manufacturer.
  - The T_A must be within -5^{0}C of T_S.
  - The T_C must be within -2^{0}C of T_S.
- Testing must continue for a minimum of 6k hours.
  - Per TM-21, measurements must be taken every 1k hours.


LM-80 Test Report

Issue Date: November 22, 2016 Revision Date: May 15, 2017
Test Initiation Date: March 1, 2016 Test Completion Date: -
Test Duration: 10,000 hours Report Number: SQETMO435002

Customer Information:

Company Name: Nichia Corporation
Address: 491-100, Oka, Kaminaka-cho, Anan-shi, Tokushima, 774-8601, JAPAN

Description of Test Samples:

Classification: LED Package
Model Name: White LED
Model Number:

EXAMPLE

Test Summary:

Lots Set	Case Temperature [T_C]	Ambient Temperature [T_A]	Drive Current [IF]	Lumen Maintenance at 10,000 hours	Chromaticity Shift ($\Delta u'v'$) at 10,000 hours	TM-21 Projection (L_{70}(10K))	TM-21 Projection (L_{80}(10K))	TM-21 Projection (L_{90}(10K))
1	55 °C	> 50 °C	350 mA	99.0 %	0.0015	> 60000 hours	> 60000 hours	> 60000 hours
2	55 °C	> 50 °C	1500 mA	98.1 %	0.0016	> 60000 hours	> 60000 hours	> 60000 hours
3	85 °C	> 80 °C	700 mA	98.5 %	0.0014	> 60000 hours	> 60000 hours	> 60000 hours
4	85 °C	> 80 °C	1200 mA	98.1 %	0.0018	> 60000 hours	> 60000 hours	> 60000 hours
5	85 °C	> 80 °C	1500 mA	97.9 %	0.0021	> 60000 hours	> 60000 hours	> 60000 hours
6	105 °C	> 100 °C	700 mA	97.7 %	0.0019	> 60000 hours	> 60000 hours	> 60000 hours
7	105 °C	> 100 °C	1200 mA	97.5 %	0.0025	> 60000 hours	> 60000 hours	> 60000 hours
8	105 °C	> 100 °C	1500 mA	97.0 %	0.0030	> 60000 hours	> 60000 hours	58930 hours
9	135 °C	> 115 °C	1200 mA	95.5 %	0.0041	> 60000 hours	> 60000 hours	40030 hours

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Nichia Corporation LED Testing Laboratory

LM-80 was the industry's first standard for performing lifetime tests.

It was a good 1st step to standardize test conditions.

What is TM-21?

Overview

- TM-21 is the IESNA approved method for using LM-80 test data to extrapolate lumen maintenance lifetime estimations.
  - Standardized equations are used to calculate the lumen maintenance.
  - The output is an estimate referenced as “Lxx Y hours” where:
    - xx = % lumen maintenance (i.e. 70 = 70%, 90 = 90%)
    - Y = calculated extrapolation value (i.e. 60 = 60k hours)

Key Points

- When > 6k hours of LM-80 testing has been conducted, the most recent 5k hours must be used to calculate the lumen maintenance (“Calculated” Lxx)
  - The TM-21 Addendum clearly states to never use Calculated TM-21 Values.
  - Unfortunately, this “Calculated” value is too often used for false marketing claims.
- Industry certifications (i.e. DLC, Energy Star) require a “Reported” TM-21 value, which is restricted to 6x the amount of hours actually tested because of the limitations to this mathematical extrapolation and lack of confidence in the data beyond 6x.
  - The 6x extrapolation cannot be applied to all length of tests. “Just test longer and then multiply by 6.”
- TM-21 is purely a mathematical prediction of lifetime.

TM-21 Projection

Time	4513 h	5251 h	6014 h	6797 h	7609 h	8443 h	9181 h	10012 h	
ln(Avg.)	-0.0053	-0.0063	-0.0046	-0.0058	-0.0062	-0.0083	-0.0059	-0.0070	

Test duration used	4513 h to 10012 h
B	0.9962
α	3.2532E-07
R^2	0.3325
Calculated L_{70} (10K)	1080000 hours
Reported L_{70} (10K)	> 60100 hours

Curve-fit equation:
$\Phi(t)=Bexp(-\alpha t)$

Lumen maintenance life eqation:
$L_{70}=ln(B/0.7)/\alpha$

EXAMPLE

TM-21 Projection

Time	5000 h	6000 h	7000 h	8000 h	9000 h	10000 h			
ln(Avg.)	0.0027	0.0019	-0.0013	0.0007	-0.0026	-0.0025			

Test duration used	5000 h to 10000 h
B	1.0079
α	1.0732E-06
R^2	0.7821
Calculated L_{70} (10K)	340000 hours
Reported L_{70} (10K)	> 60000 hours
Calculated L_{80} (10K)	215000 hours
Reported L_{80} (10K)	> 60000 hours
Calculated L_{90} (10K)	106000 hours
Reported L_{90} (10K)	> 60000 hours

Curve-fit equation:
$\Phi(t)=Bexp(-\alpha t)$

Lumen maintenance life eqation:
$L_{70}=ln(B/0.7)/\alpha$

$L_{80}=ln(B/0.8)/\alpha$

$L_{90}=ln(B/0.9)/\alpha$

TM-21 was the industry’s first standard for predicting lumen maintenance.

It was a great 2nd step to establish a baseline, but was never intended to compare LEDs above this baseline.

TM-21 Example Calculation

Example Lifetime Report Prior to LM-80 / TM-21)

Reference 参考資料

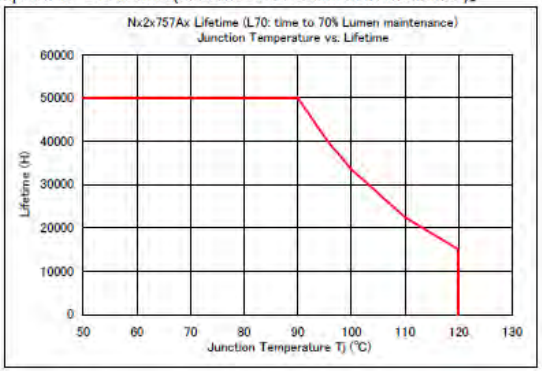
Nx2x757Ax Presumption of Lifetime

NS2x(W,L)757A / NF2x(W,L)757AR

【Presumption of Lifetime / 推定寿命】

Type 型名	Current Value(mA) 電流値(mA)	Junction Temperature Tj(℃) ジャンクション温度 Tj(℃)	Lifetime (H) 寿命 (H)	Lumen maintenance (%) 光束維持率 (%)
NS2x757A	120	90	50000	70
NF2x757AR	200			

【Junction Temperature vs. Lifetime (L70: time to 70% lumen maintenance)】



Example LM-80 / TM-21 Report For the same LED

n	25	25	25	25	25	25	25	25	25	25	25	25
Avg.	100.0	99.3	99.2	98.9	99.1	99.0	98.7	98.7	98.5	98.3	98.0	97.9
Med.	100.0	99.3	99.2	98.9	99.1	99.0	98.7	98.7	98.5	98.3	97.9	97.9
σ	0.00	0.15	0.14	0.13	0.14	0.15	0.15	0.13	0.14	0.14	0.16	0.18
Min.	100.0	99.1	98.9	98.7	98.8	98.7	98.5	98.5	98.3	98.1	97.6	97.5
Max.	100.0	99.6	99.5	99.2	99.3	99.2	99.0	98.9	98.8	98.6	98.2	98.3

TM-21 Projection

Time	5000 h	6000 h	7000 h	8000 h	9000 h	10000 h						
ln(Avg.)	-0.0128	-0.0134	-0.0150	-0.0167	-0.0206	-0.0210						

Test duration used	5000 h to 10000 h	
B	0.9973	
α	1.8532E-06	
R^2	0.9424	
Calculated L_{70} (10K)	191000	hours
Reported L_{70} (10K)	> 60000	hours
Calculated L_{80} (10K)	119000	hours
Reported L_{80} (10K)	> 60000	hours
Calculated L_{90} (10K)	55400	hours
Reported L_{90} (10K)	55400	hours

Curve-fit equation:

$$\Phi(t)=Bexp(-\alpha t)$$

Lumen maintenance life eqation:

$$L_{70}=ln(B/0.7)/\alpha$$

$$L_{80}=ln(B/0.8)/\alpha$$

$$L_{90}=ln(B/0.9)/\alpha$$

Product lifetime claims beyond the amount of LM80 hours tested are only a calculation from a limited test set.

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2. TM-21 can be misleading
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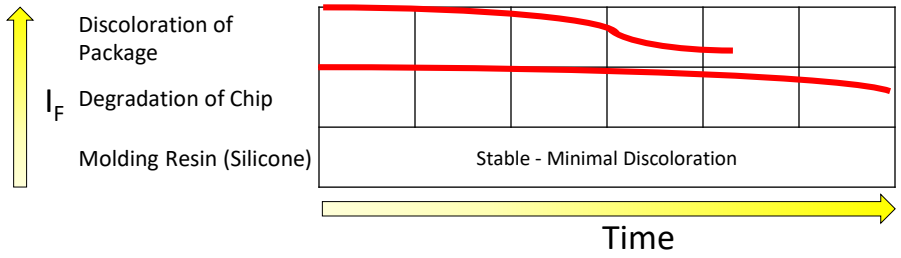
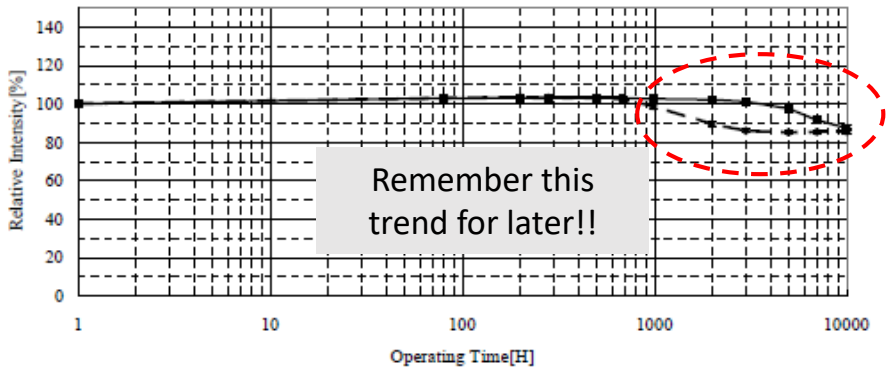
TM-21 can be misleading

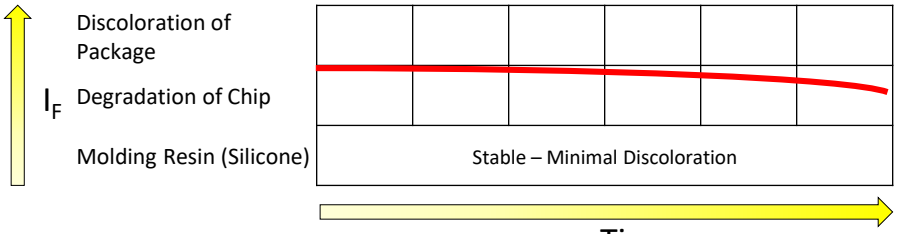
First, we must understand the breakdown mechanisms of an LED

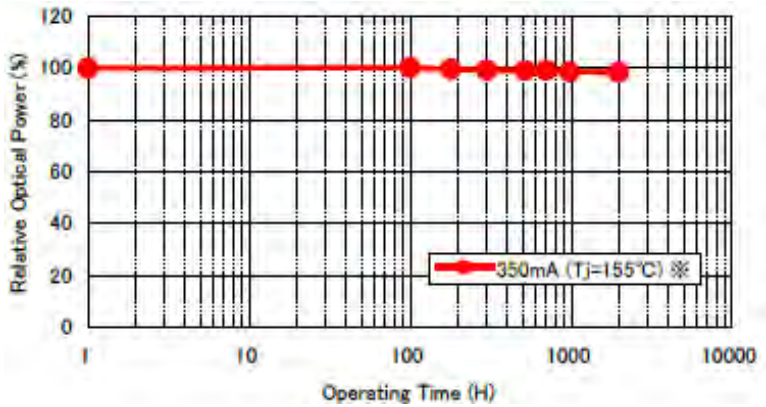
Heat Resistant Polymer Type





Flip Chip Ceramic Type





TM-21 can be misleading

Is a calculated value truly feasible in real life?

TM-21 Projection

Time	4513 h	5251 h	6014 h	6797 h	7609 h	8443 h	9181 h	10012 h	
ln(Avg.)	-0.0053	-0.0063	-0.0046	-0.0058	-0.0062	-0.0083	-0.0059	-0.0070	

Test duration used	4513 h to 10012 h
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Curve-fit equation:

$$\Phi(t)=B\exp(-\alpha t)$$

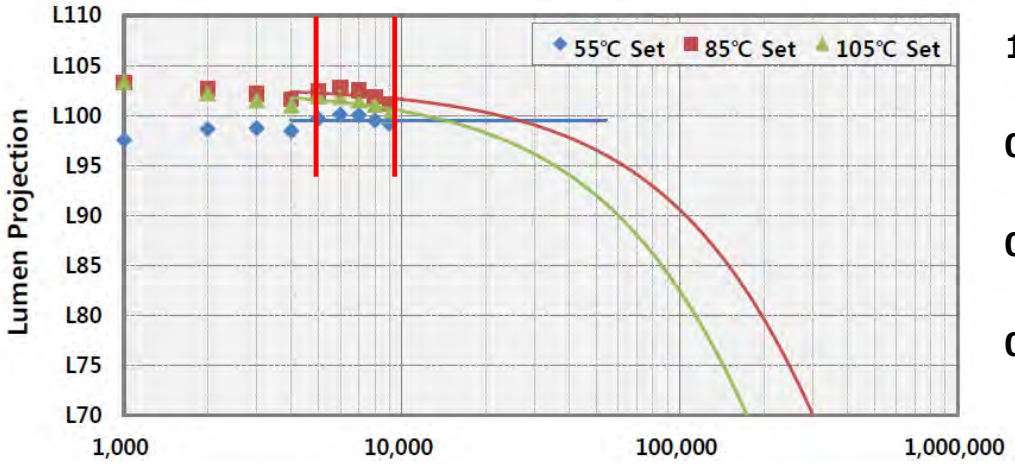
Lumen maintenance life eqation:

$$L_{70}=\ln(B/0.7)/\alpha$$

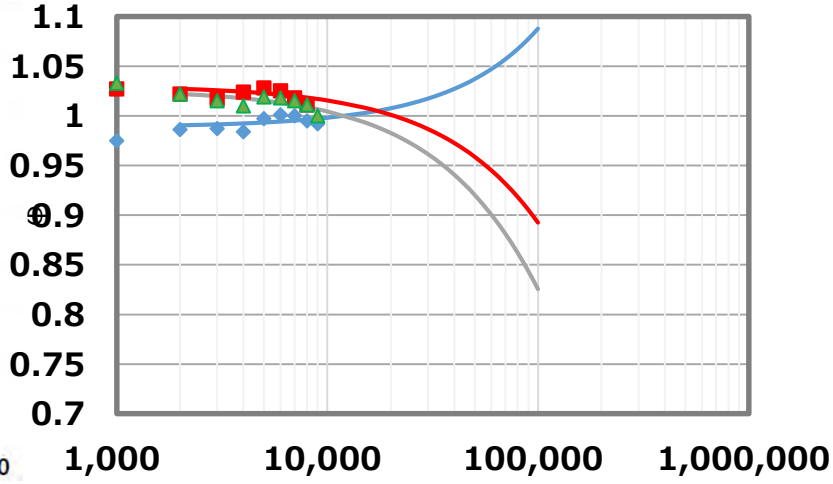
L70 = 1 Million hours or 114 years!?!
or
L90 = 312,000 hours or 35 years!?!

TM-21 can be misleading

Measurements have tolerance and fluctuate, especially with a limited test set



Per the Reported TM-21 Value,
at 55^{0}C the LED will last forever!

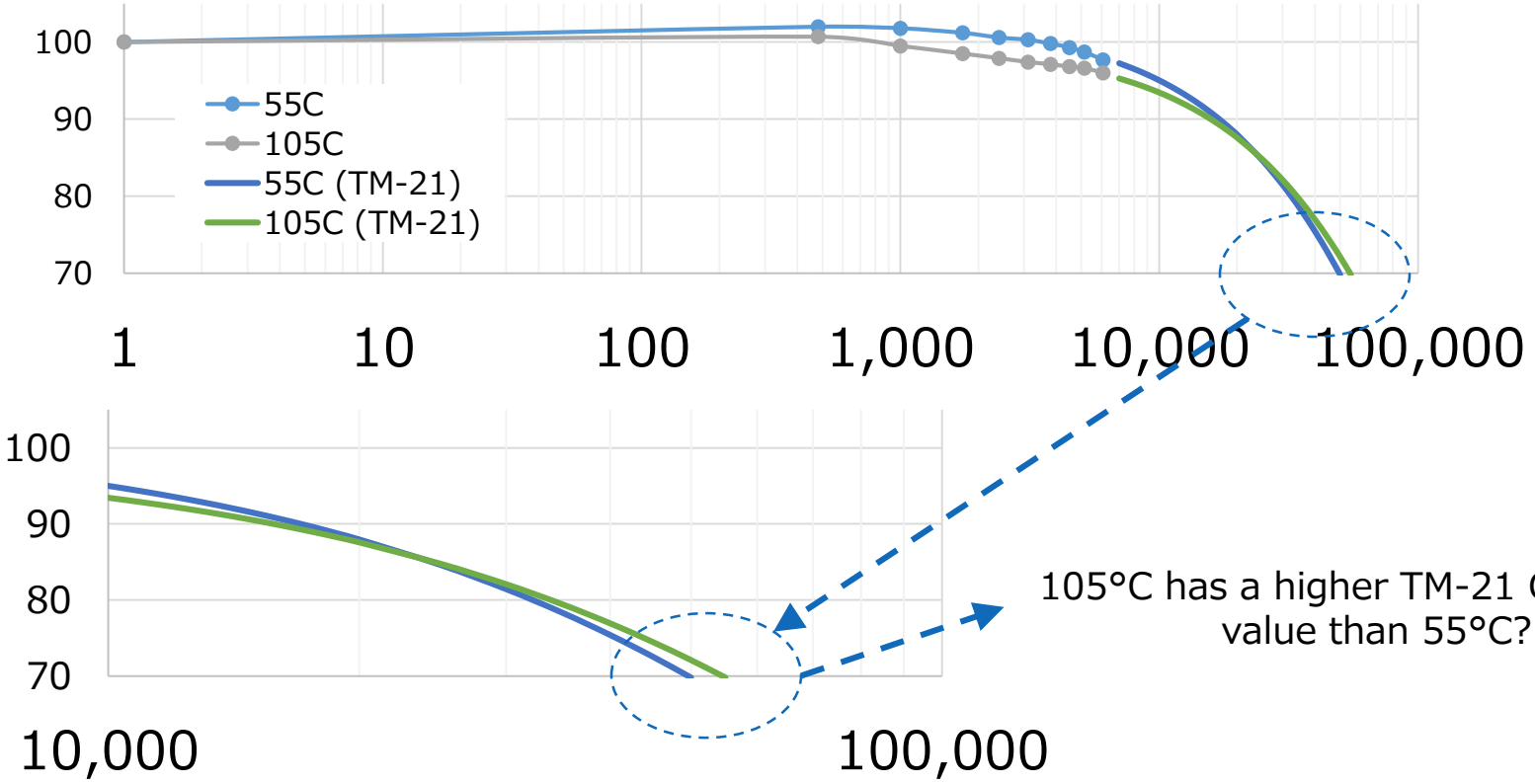


However, per the TM-21 Calculation,
the LED will actually get brighter
over time!

TM-21 Calculated Lifetime is only an internal TM-21 value
which should never be used for actual lifetime estimations

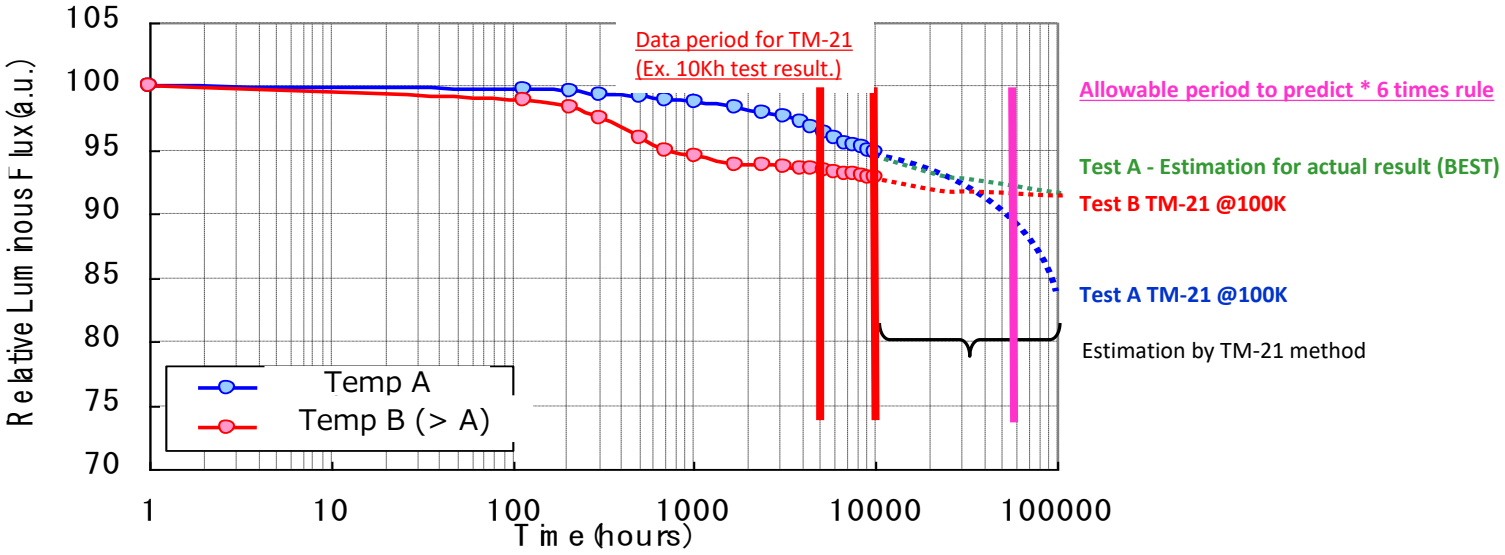
TM-21 can be misleading

Shouldn't a test at a higher T_S reflect lower lifetime?



TM-21 can be misleading

Why are these anomalies happening?

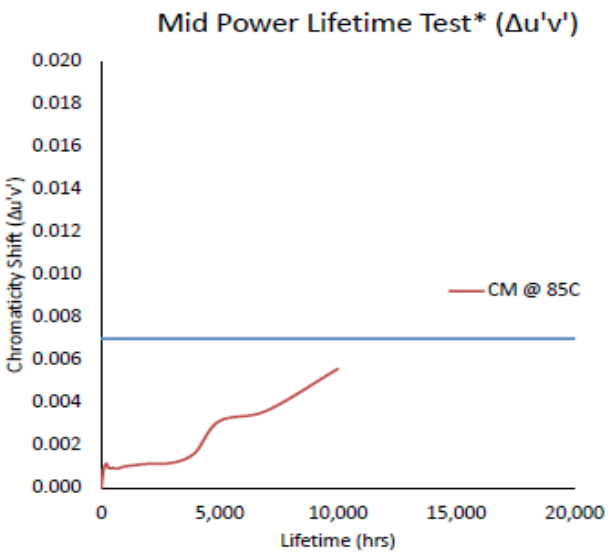


The reasons for lumen depreciation in this situation are the same.
However, when this breakdown occurs has a dramatic effect on the final TM-21 value.

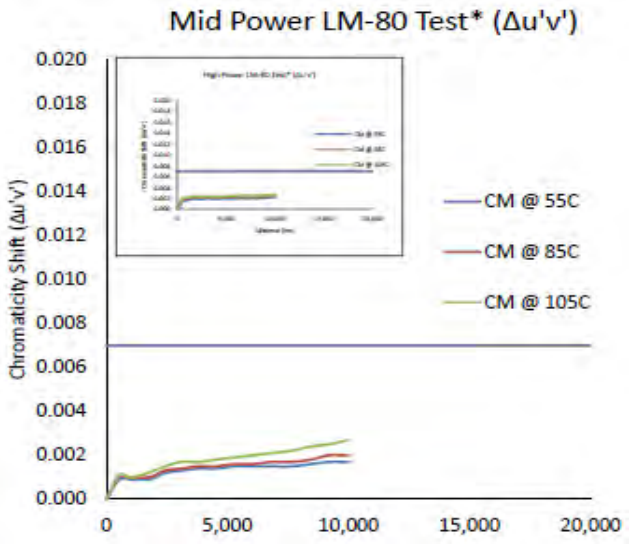
TM-21 can be misleading

What about color shift?

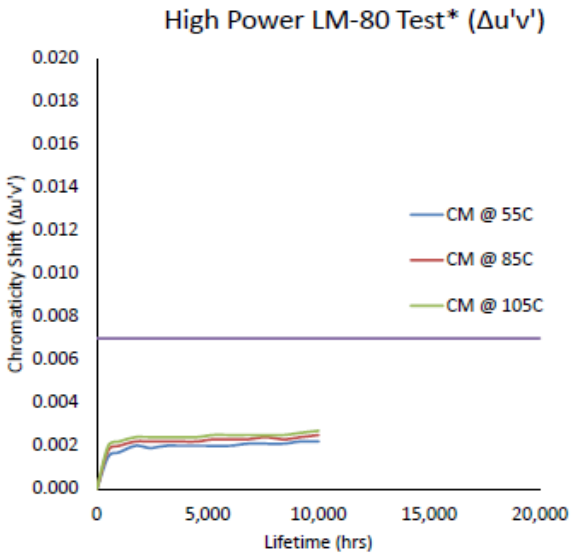
Thermo “Plastic”



Thermoset



Ceramic



There is not yet a good method to predict color shift over the lifetime of an LED.
IESNA is developing a method, but just like TM-21, it won’t be perfect.

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Are LM-80 / TM-21 being misused?

Excerpts from US DOE SSL 2017 Suggested Research Topics Supplement*

3.1.3 Reliability

"While the lifetime of an LED source is one important indicator of LED luminaire life, lifetime claims should consider the whole luminaire system, not just the LEDs."

"Developing accurate lifetime claims, the DOE SSL Program formed an industry consortium with the Next Generation Lighting Industry Alliance (NGLIA), the LED Systems Reliability Consortium (LSRC)"

"It should be noted that LM-80 measurements are taken with the LED packages operating continuously… This does not necessarily reflect real-world operating conditions, so there may not be a perfect match between predictions based on laboratory results and practical experiences…"

LM-80 / TM-21 alone is not good enough to accurately judge an LED's reliability, let alone a finished product's reliability

* US Department of Energy, Solid-State Lighting 2017 Suggested Research Topics, September 2017

Misused – or misunderstood?

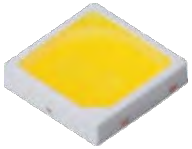
An LED's TM-21 extrapolations do not equal an LED's actual lifetime.

LEDs' actual lifetimes do not equal an LED Luminaire's actual lifetime.

TM-21 extrapolations do not equal an LED Luminaire's actual lifetime.

Secondary Optics

Can discolor, lose reflectiveness. Heat and Optical energy will accelerate this , thus lower light output



LED

Package and die degradation, etc.

PCB

Solder joints fail = catastrophic failure. PCB's can discolor, specifically solder resist, becoming less reflective and lower lumen maintenance

Drivers

Capacitors are one of the main factor for LED driver life. Because of the electrolyte's volatilization, generally even high quality grade capacitor rated life is 40KH@85C. Higher temperatures accelerates this.

Housing

Chemical Resistance, reflectivity, thermals

Heat Sink

Chemical Resistance

And more components…

While an LED does have it's depreciation, we all know it is not the weakest link.
So why pretend otherwise and reference an LED's calculated lifetime as a fixture's lifetime?

Are LM-80 / TM-21 being misused?

Manufacturer's Claims vs. Actual field studies DOE Caliper Report 20-4 PAR38

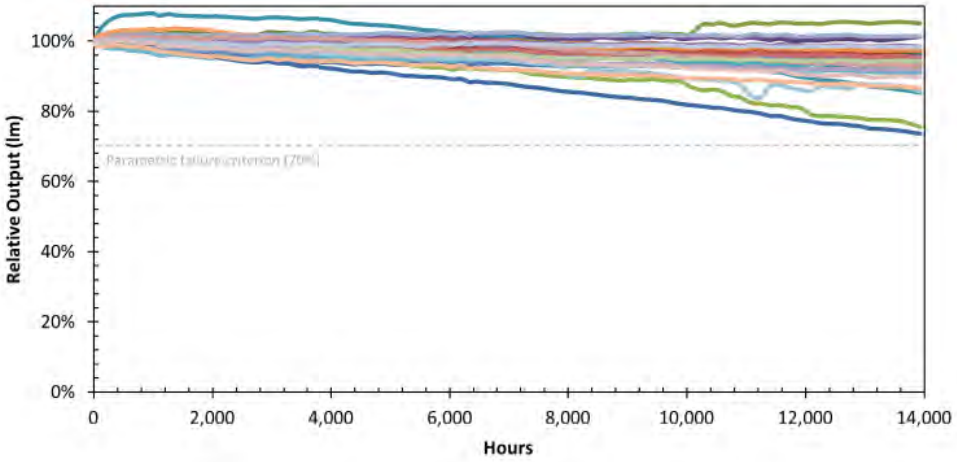


Figure 3. Average lumen maintenance for each of the 32 LED lamp models. There were a few lamps with better or worse performance, but a majority of the lamp types emitted between 90 and 98% of their initial lumens at the final measurement point. The cause of the sudden jump for 12-92 (green line) at approximately 10,000 hours was not identified; it occurred for only one of the five lamp samples. The line colors are consistent for each product in all charts throughout this report.

Rated lifetime (Estimated by LM-80/TM-21)

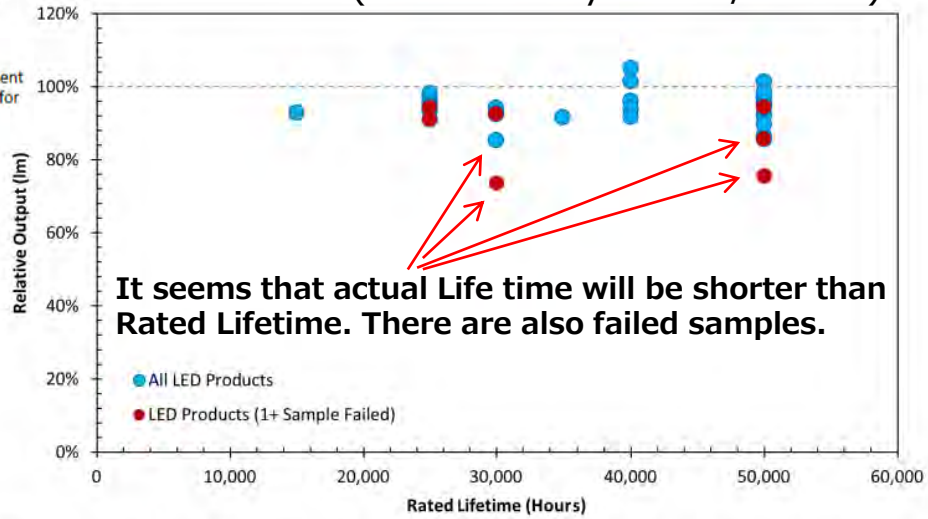


Figure 5. Lumen maintenance (final measurement) versus rated lifetime. There was no correlation between manufacturer rated lifetime and the final measured relative output.

Are LM-80 / TM-21 being misused?

Comments heard in the industry…

"I understand and agree the lifetime is not real, but my competitor is doing it so we must do it too."

"LM-80 / TM-21 is just a 'check-the-box metric' for us. Just give me a report that shows L70 1M hours. I don't care if its realistic."

"This TM-21 value shows L70 100k hours so it must be better than this report that shows L70 80k hours."

"Our end-customers do not really understand lifetime, but they are requiring L90 100k because it is 'better.'"

"5 years, 10 years, 20 years, no difference. In the end, I'd rather they buy more fixtures anyways…"

With no policing or further testing requirements, this mindset will continue!

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New Proposals for Lifetime / Robustness Testing

Test	Reference Standard	Purpose (to evaluate)
High Temperature Operating Life (HTOL)	JESD22-A108	Accelerated test for LED life time
Wet High Temperature Operating Life (WHTOL)	JESD22-A101C	Accelerated test for LED life time
Temperature Cycling (TMCL)	JEITA ED-4701 100 105 Or JESD22-A108	Solder joint reliability btw PCB and LED LED structure robustness (ex. Solder crack, Delamination, etc.)
Resistance to Soldering Heat (RSH)	JEITA ED-4701 300 301	Robustness of LED materials against heat.
Electrostatic Discharge	JEITA ED-4701 300 304	Robustness against ESD
Sulfuration Test	-	Robustness against Harmful gas

Creating LM-80 was a great 1st step.
Establishing TM-21 was a great 2nd step.

The industry now deserves a 3rd step to more accurately predict product lifetime so better comparisons can be made vs. just establishing a minimum bar

Wrap up

- ✓ **LM-80** was a **great 1st step** to standardize lifetime tests. **TM-21** was a **great 2nd step** to establish a calculation for estimating lifetime, but both have their limitations.

- ✓ Since **TM-21** is based only off a **calculation** of a limited test set:
  - ✓ It can, and does, frequently go against theory / logic.
  - ✓ It is not meant to be used as a comparison beyond a minimum threshold value, i.e. L70 60k hours.
  - ✓ Calculated TM-21 values are not to be used in any way (i.e. marketing).

- ✓ **Additional robustness testing** beyond LM-80 must be required and implemented (i.e. LM-87 or others).

- ✓ The LED is just a piece of the puzzle and is not necessarily the weakest link.
  - ✓ TM-21 calculations do not equal an LED's actual lifetime.
  - ✓ An LEDs actual lifetime does not equal an LED Fixtures actual lifetime.
  - ✓ TM-21 calculations do not equal an LED Fixture's actual lifetime.

To best manage lifetime expectations:

- We must better educate the market
- Be realistic with lifetime claims

Thank you for your attention!

ありがとう

Questions?

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