Designers Light Forum

"The Fish Was Thiiiiis BIG!"

The Realities of LM-80 / TM-21 & Setting False Lifetime Expectations

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handling, using, distributing, or dealing in any material or product.
_____
Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Learning Objectives

At the end of the this course, participants will be able to:

1. Understanding of how LM-80 is conducted and TM-21 is calculated / represented.

2. Understanding of when LED lifetimes should and when it is inappropriate.

3. Understanding of how an LED's lifetime is just a piece of an LED Luminaire's lifetime.

4. "Understand new proposals for more accurate lifetime testing at the LED and fixture levels.

We all know the jokes about fishing...
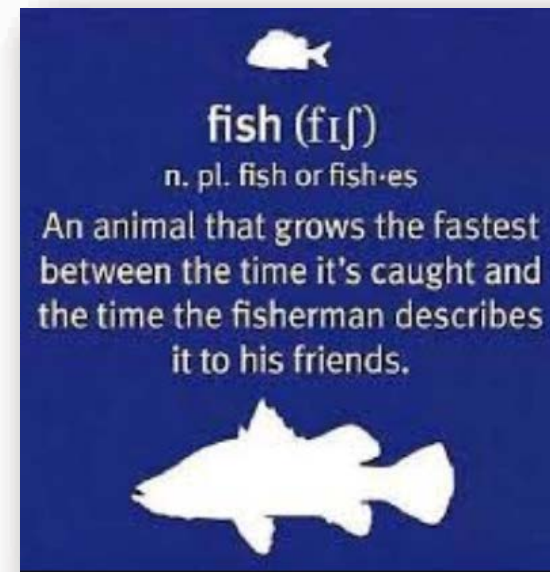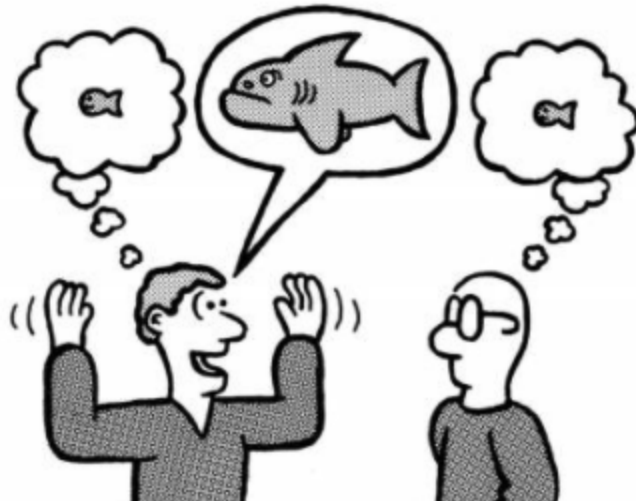
Unfortunately, it has carried over into LED lighting...

Are you ready for the shocking truth?...

LED Products and LEDs DO NOT last forever!

Agenda

1. What is LM-80? What is TM-21?

2. TM-21 can be misleading

3. TM-21 is being misused

4. New proposals for lifetime prediction beyond LM-80

5. Questions

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.
  - Testing must be performed by an EPA recognized Laboratory.
  - LM-80 <u>does not</u> state how to predict lifetime.
  - LM-80 <u>does not</u> have a pass / fail criteria.

Key Requirements

- Testing must now be conducted at a minimum of 2 different temperatures (T_S); 55^0C <u>or</u> 85^0C plus a 2nd T_S point selected by the LED Manufacturer.
  - The T_C must be within 5^0 of T_S
- Testing must continue for a minimum of 6k hours, with measurements 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:	SQETMQ435002

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:

Test Summary:

Data Set	Case Temperature [T_c]	Ambient Temperature [T_a]	Drive Current	Lumen Maintenance 10,000 hours	Chromaticity Shift [$\Delta u'v'$] at 10,000 hours	TM-21 Projection $L_{70}(10k)$	TM-21 Projection $L_{70}(6k)$	TM-21 Projection $L_{70}(6k)$
1	55 °C	> 50 °C	700 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	50900 hours
9	130 °C	> 115 °C	1200 mA	95.5 %	0.0041	> 60000 hours	> 60000 hours	30000 hours

EXAMPLE

Approved Signatory:

Hitoshi TOHYAMA, Lab Manager
Nichia Corporation LED Testing Laboratory

ilac-MRA   IAJapan   ASNITE 0057 T

LM-80 was the industry's first standard for performing lifetime tests.
It was a great 1st step to standardize conditions.

What is TM-21?

Overview

- TM-21 is the IESNA approved method for using LM-80 test data to extrapoloate lifetime estimations of lumen maintenance.
  - Standardized extrapolation equations are used to calculate the lifetime.
  - The output calculation 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 Requirements

- When > 6k hours of LM-80 tests have been conducted, the most recent 5k hours must be used to calculate the lumen maintenance ("Calculated Lxx")
  - Many are using this "Calculated Lxx" as a false marketing gimmick.
- *TM-21 is purely a mathematical prediction of lifetime.*
- ***Industry certifications (i.e. DLC, Energy Star) limit the reported TM-21 value to 6x the amount of hours actually tested ("Reported Lxx") because of the limitations of this mathematical extrapolation***

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

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:
$$L_{70}=ln(B/0.7)/\alpha$$
$$L_{80}=ln(B/0.8)/\alpha$$
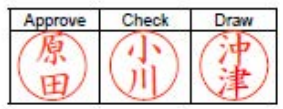$$L_{90}=ln(B/0.9)/\alpha$$

EXAMPLES

TM-21 was the industry's first standard for predicting lumen maintenance (i.e. Lxx).
It was a great 2nd step to set a baseline, but is not to compare LEDs above this baseline.

Example Calculation

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

| Approve	Check	Draw
原田	小川	沖津

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)】

Nx2x757Ax Lifetime (L70: time to 70% Lumen maintenance)
Junction Temperature vs. Lifetime

Example LM-80 / TM-21 Report
For the same LED
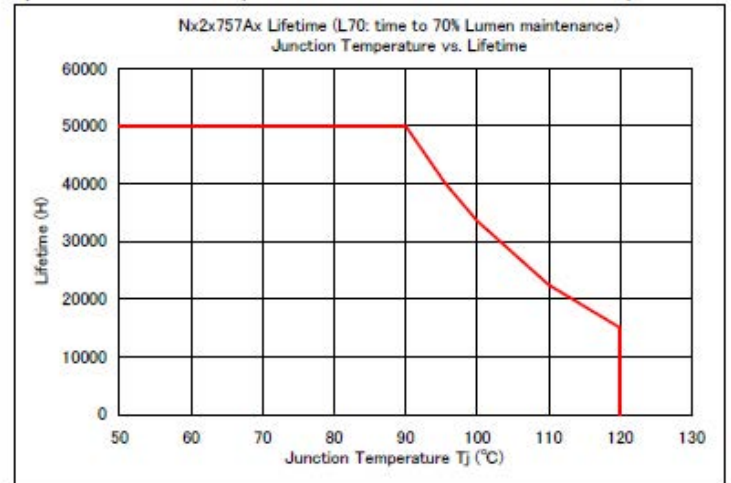
n	25	25	25	25	25	25	25	25	25	25	25	25
Avg.	100.0	99.3	99.2	98.9	99.1	99.0	98.7	98.7	98.5	98.3	98.0	97.9
Med.	100.0	99.3	99.2	98.9	99.1	99.0	98.7	98.7	98.5	98.3	97.9	97.9
σ	0.00	0.15	0.14	0.13	0.14	0.15	0.15	0.13	0.14	0.14	0.16	0.18
Min.	100.0	99.1	98.9	98.7	98.8	98.7	98.5	98.5	98.3	98.1	97.6	97.5
Max.	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		Curve-fit equation:
B	0.9973		$\Phi(t) = B\exp(-\alpha t)$
α	1.8532E-06		
R^2	0.9424		
Calculated L_{70} (10K)	191000	hours	Lumen maintenance life eqation:
Reported L_{70} (10K)	> 60000	hours	$L_{70} = \ln(B/0.7)/\alpha$
Calculated L_{80} (10K)	119000	hours	
Reported L_{80} (10K)	> 60000	hours	$L_{80} = \ln(B/0.8)/\alpha$
Calculated L_{90} (10K)	55400	hours	
Reported L_{90} (10K)	55400	hours	$L_{90} = \ln(B/0.9)/\alpha$

Product lifetime claims beyond the amount of LM80 hours tested are only a calculation from a limited test set, potentially even just a guess.
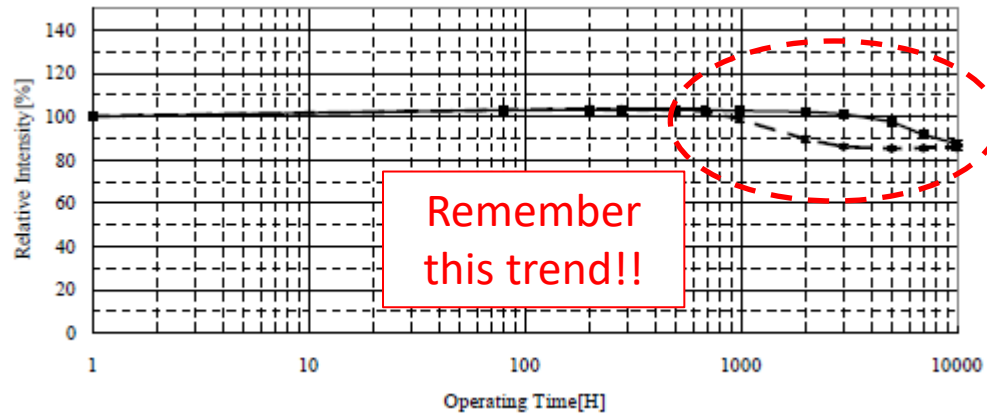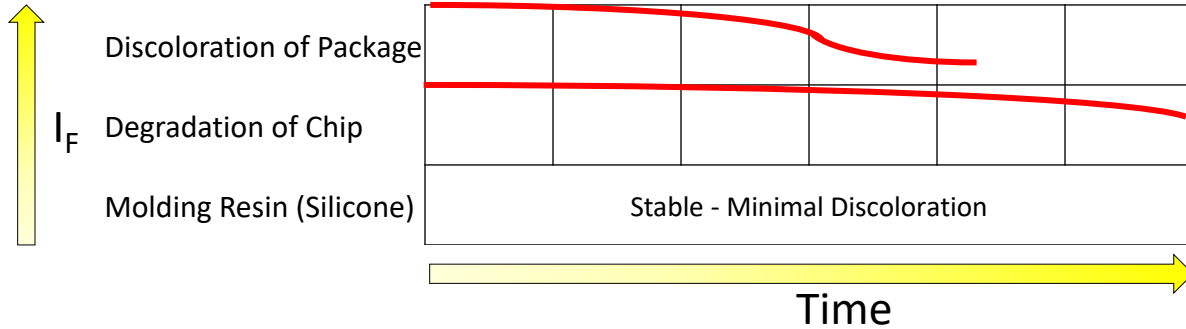
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3. LM-80 / TM-21 is being misused

4. New proposals for lifetime prediction beyond LM-80
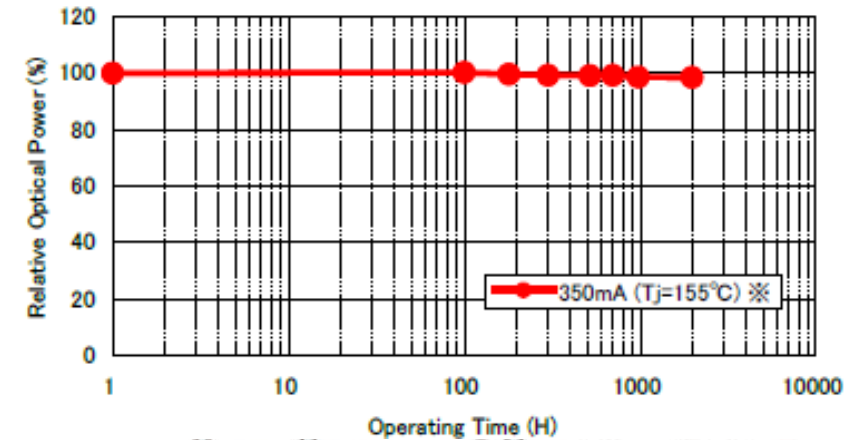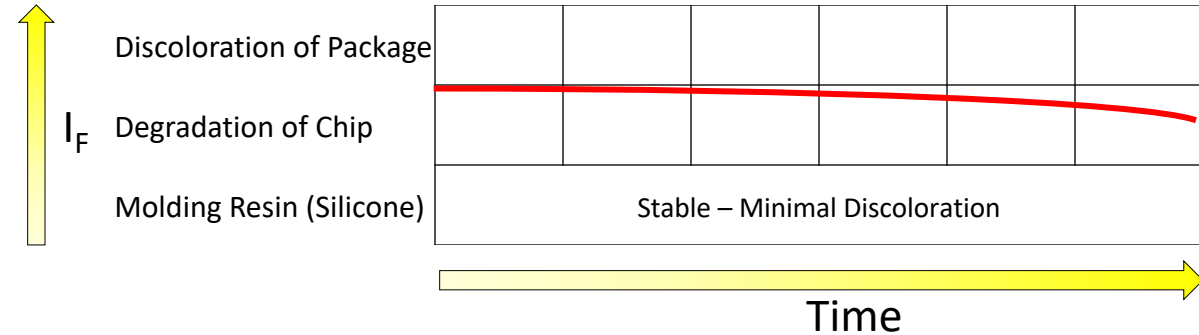
5. Questions

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	

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Curve-fit equation:

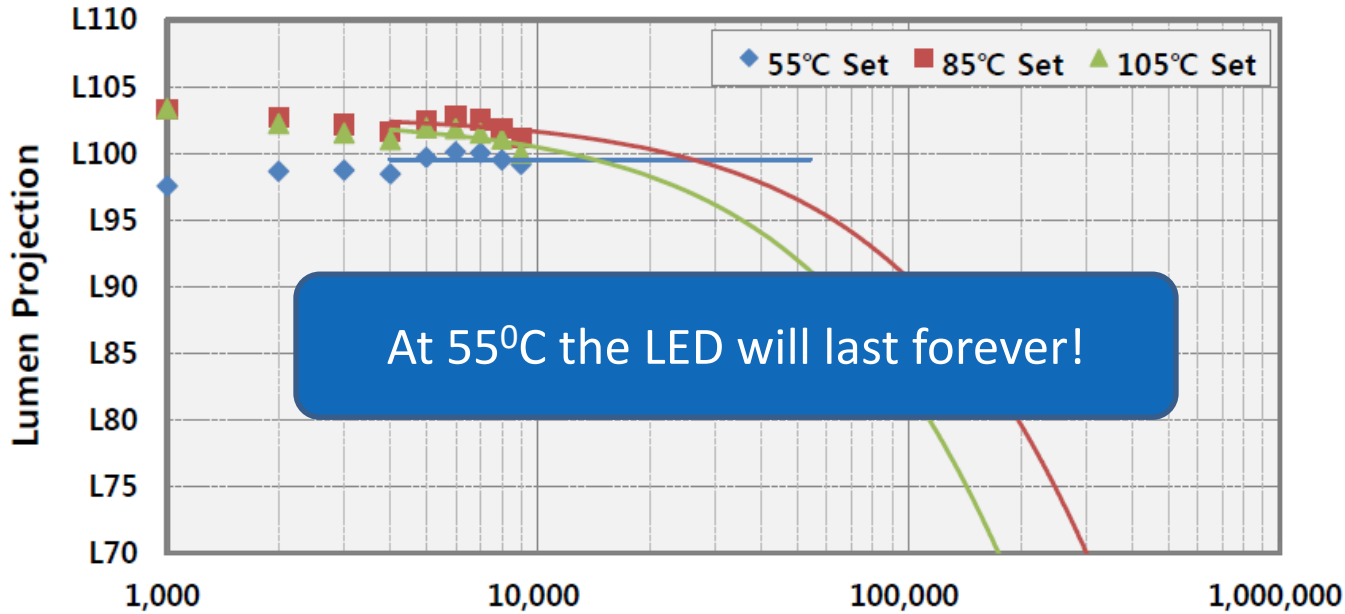$$\Phi(t) = Bexp(-\alpha t)$$

Lumen maintenance life eqation:

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

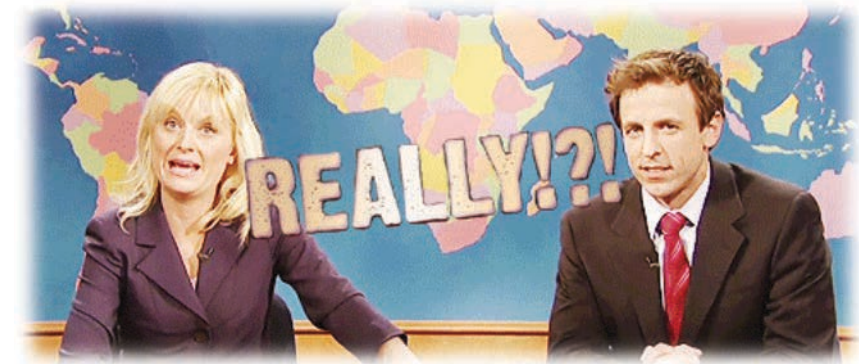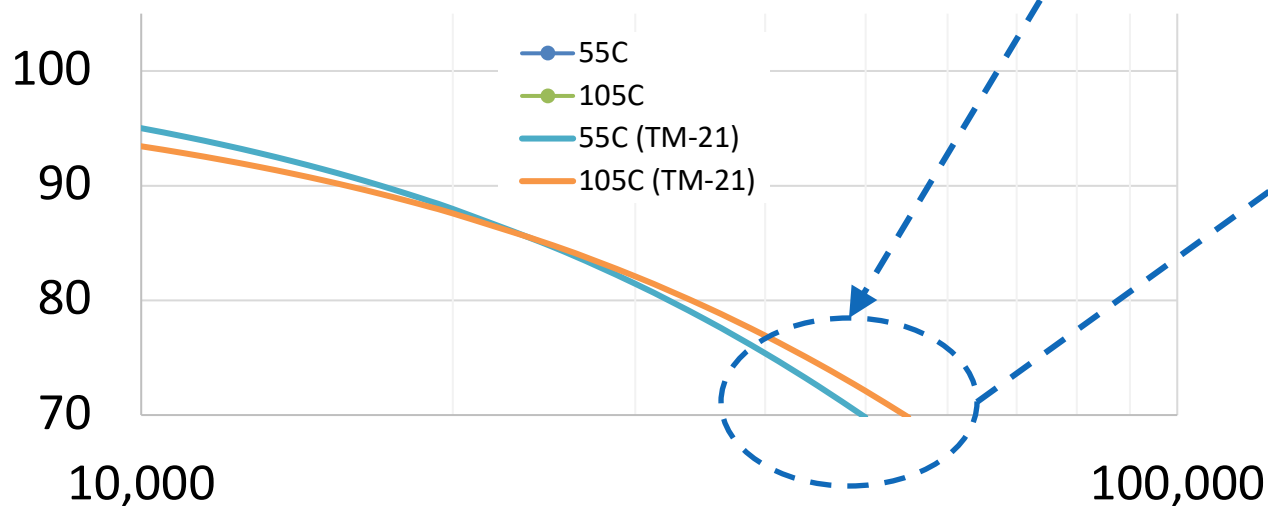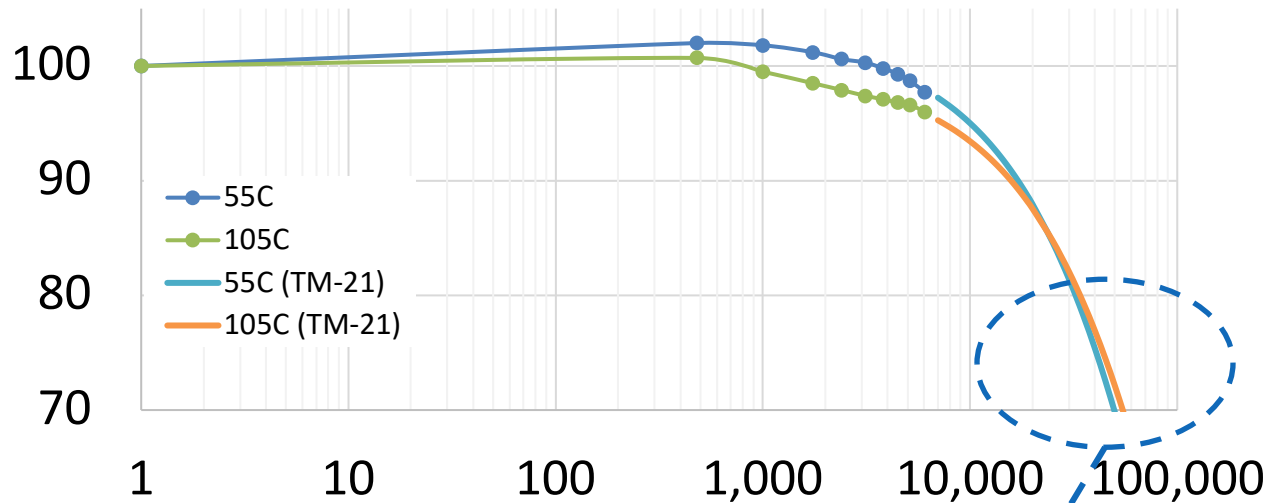L70 = 1 Million hours or 114 years!
L90 = 312,000 hours or 35 years!

TM-21 can be misleading

Measurements have tolerance and "bounce," especially with a limited sample set...

At 55⁰C the LED will last forever!

The true TM-21 Calculation says it will actually get brighter over time!
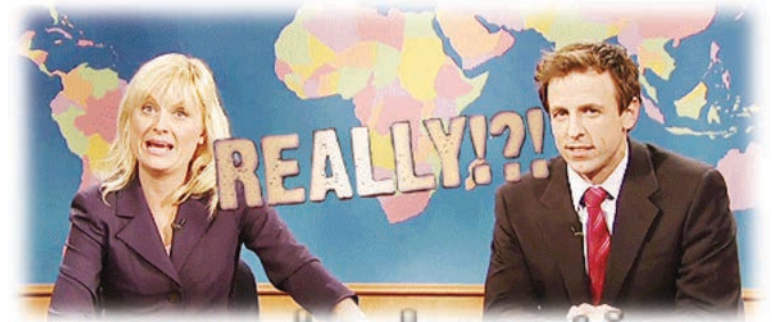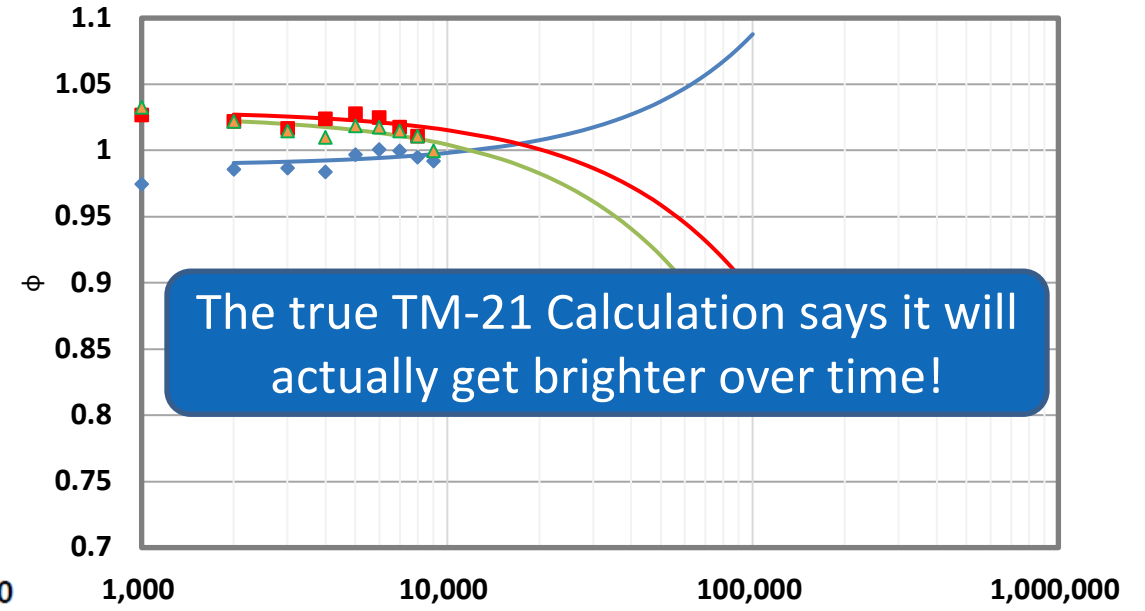
TM-21 can be misleading

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

105^0C has a better TM-21 Calculated value than 85^0C?

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TM-21 can be misleading

Why are these anomalies happening?

eriod to predict * 6 times rule

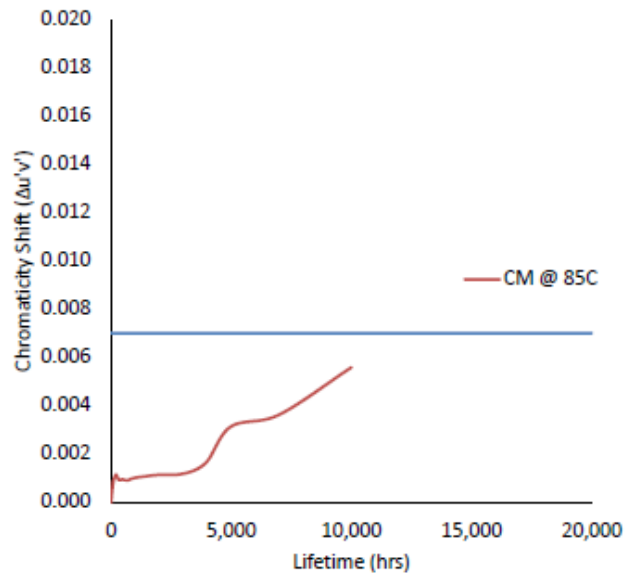nation for actual result (BEST)

1 @100K

@100K

y TM-21 method

Time(Hours)

The reasons for lumen depreciation are the same.
However, *__when__* this breakdown occurs has a dramatic effect on the TM-21 value.
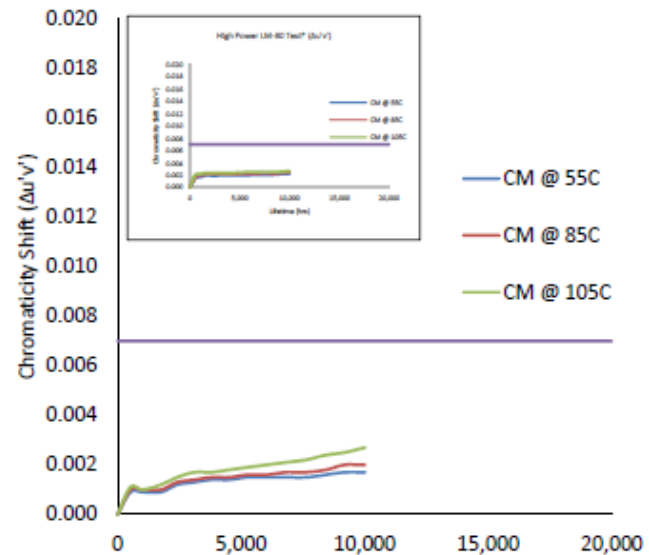
TM-21 can be misleading

What about color shift?
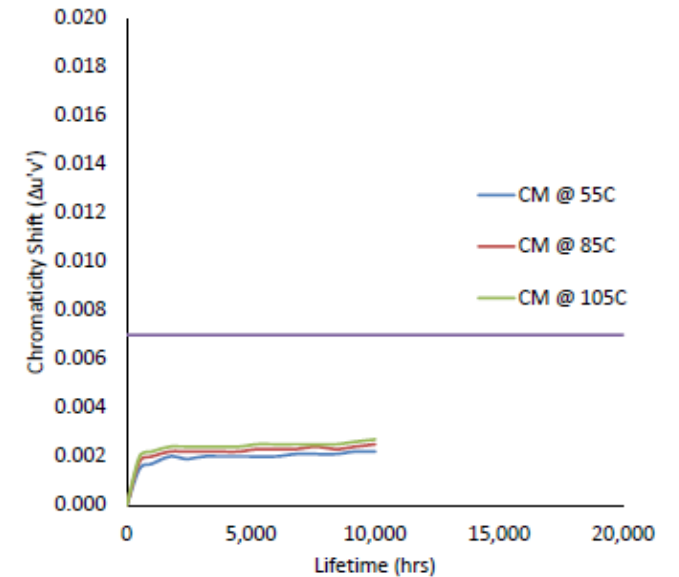

Thermo "Plastic" — Mid Power Lifetime Test* (Δu'v')

Thermoset — Mid Power LM-80 Test* (Δu'v')

Ceramic — High Power LM-80 Test* (Δu'v')

There is not yet a good to predict color shift over the lifetime of an LED.
The Working Group is attempting to develop a method, but it won't be perfect.

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3. LM-80 / TM-21 is being misused

4. New proposals for lifetime prediction beyond LM-80

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How LM-80 / TM-21 is being misused
Excerpts from US DOE SSL 2017 Suggested Research Topics Supplement

3.1.3 Reliability

LEDs are the heart of SSL lighting products. They provide long lifetimes that last well beyond 50,000 hours of operation, much longer than most conventional light sources. The end of life for all lighting technologies is signaled by the loss of light, but this may be less evident for LED luminaires, in which the light output may continuously fade or the color may slowly shift, to the point where these events constitute practical failure.

"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."

would create a much more accurate lifetime claim from LED luminaire manufacturers.

"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…"

While an LED does have it's depreciation, we all know it is not the weakest link. So why pretend otherwise?

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
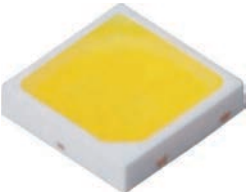
LED
Package and die degradation, etc.

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...

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How LM-80 / TM-21 is 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, this mindset will continue!

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Test	Reference Standard	Test Condition	Purpose (to evaluate)
High Temperature Operating Life (HTOL)	JESD22-A108	T_S=max, I_F=max or Corresponding max rated current (1,000hours)	Accelerated test for LED life time
Wet High Temperature Operating Life (WHTOL)	JESD22-A101C	T_A=60C, RH=90%, I_F=max (1,000hours) or T_A=85C, RH=85%, I_F=max (1,000hours)	Accelerated test for LED life time
Temperature Cycling (TMCL)	JEITA ED-4701 100 105 Or JESD22-A108	-40C to 100C (1,000cycles) or -40C to 125C (500cycles)	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	260C (-0 / +5C), 10second Precondition : according to MSL rating (2 times)	Robustness of LED materials against heat.
Electrostatic Discharge	JEITA ED-4701 300 304	HBM 2kV (3 pulses)	Robustness against ESD
Sulfuration Test	-	T_A=40C, RH=75% : H2S 2ppm, NO2 4ppm (240hrs) or T_A=40C, RH=80% : H2S>10ppm (96hours)	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 (i.e. TM-21)

Summary

- 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 it has flaws.

- Since TM-21 is based only off a calculation of a limited sample set:
    - It can, and does, frequently go against logic .
    - It <u>is not</u> realistic to use as a comparison beyond a minimum value, i.e. L70 60k hours.

- Additional testing beyond LM-80 must be required and implemented (i.e. LM-87 one page prior).

- The LED is just a piece of the puzzle and it <u>IS NOT</u> 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.

We must better educate the market and be realistic with claims
so to best manage lifetime expectations.

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