9th SSL Annex
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An accelerated test method for estimating LED system life

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Background

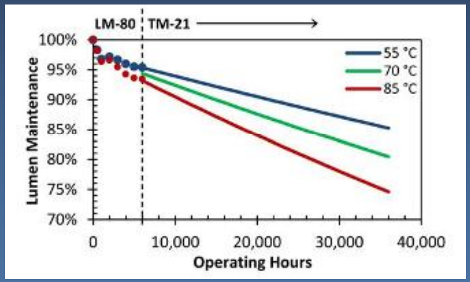
- Why LED system life?
  - How often to change the light bulb
  - Life cycle cost analysis
- Users buying a lighting system expects it to perform and last the same in all applications

Applications

www.destinationlighting.com/

Background

- LED system life
  - Presently, LED lighting product life is rated based on LED lumen maintenance (LM80/TM21)



- A lighting system has many components
  - Failure of any component can cause system failure

- Therefore, whole system has be tested to obtain reasonable life estimate

Background

- IESNA LM84-14 standard:
  - First attempt towards developing a system life test method
  - Test method is based on continuous operation.
- In applications the lighting systems are turned on and off
  - Typical use pattern:
    - A - Office: 12 hrs on, 12 hrs off
    - B - Home: 4 hrs on, 4 hrs off

A

B

- community.lighting.philips.com/
- www.ledsource.com/products/residential

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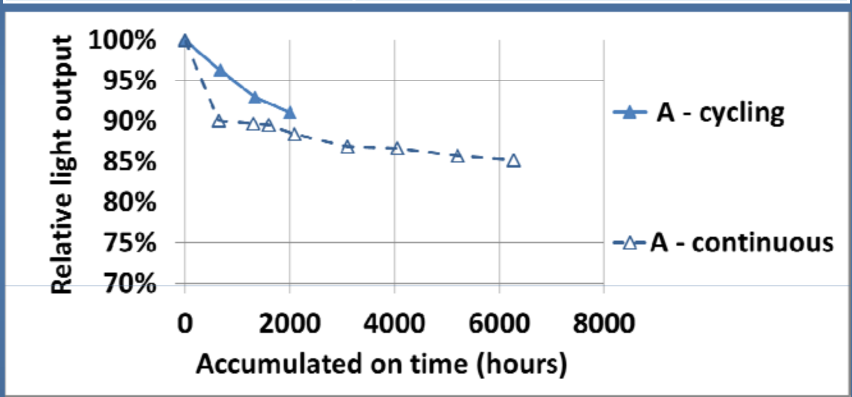
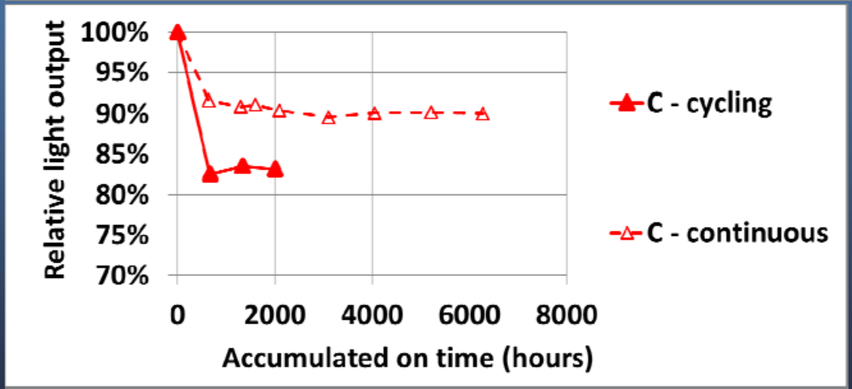
Background

- Power cycling can cause component/system failure
  - Dynamic stress
  - LRC study (2013 – 2014)
    - COB LEDs
  - Testing conditions:
    - 700 mA; Tj = 150°C; Continuous vs. cycling (4 hours on, 2 hours off)
  - Results:
    - Catastrophic failures were only discovered in cycling test

Product No.	Catastrophic failure (cycling test)
A	4 out of 5
C	4 out of 5





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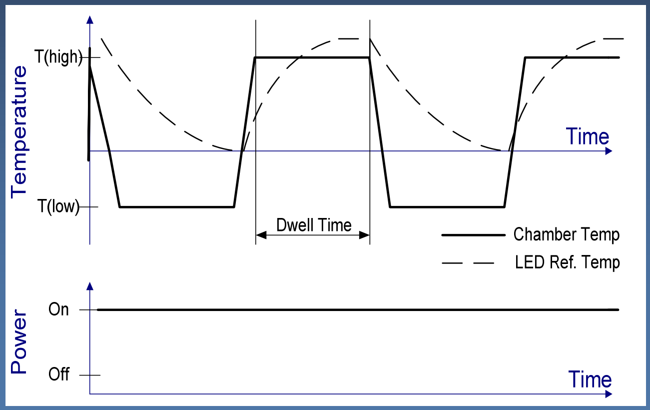
Background

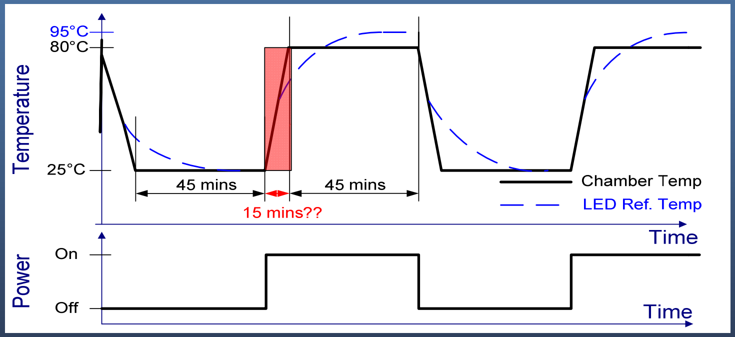
- The electronic industry has several rapid cycle test methods for failure testing
  - Example:
    - IEC 60068-2-14
    - Strife
- Some manufacturers have adopted similar methods for LED reliability testing
  - Test for 1000 cycles
  - Usually a pass/fail test (helps to identify early failures)

IEC 60068-2-14 Method



IEC 60068-2-14 : Test the ability to withstand rapid changes of ambient temperature."

Strife method

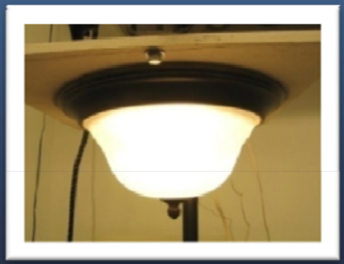


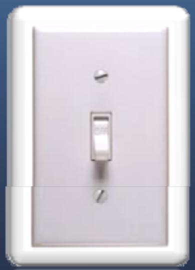
STRIFE method is the most destructive among test method.

Study Objective

- None of the test procedures presently available are designed to project system life based on the environment temperature and the use pattern (on-off)

- Objective - To develop an accelerated test method that can predict failure of LED system based on factors such as
  - Environment temperature (Tpin)
  - On-off cycling.





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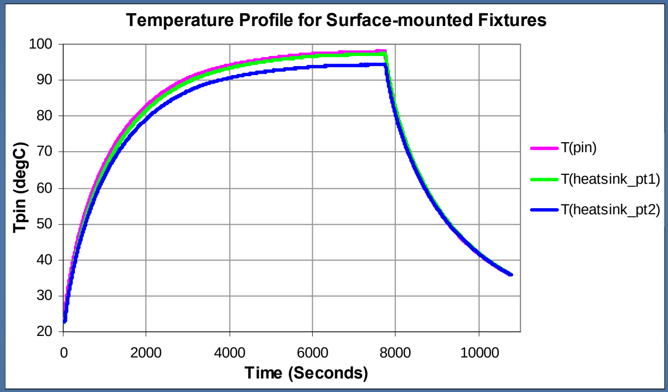
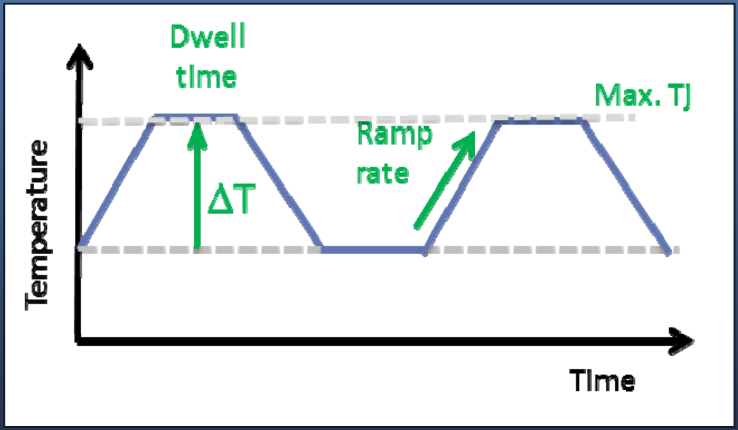
Initial studies

- To determine Tpin of the LED lamp when placed inside a luminaire
  - 40W replacement lamps
    - Max T pin = 98°C; Delta T = 75°C
  - 60W replacement lamps
    - Max T pin = 118°C; Delta T = 95°C
    - Tj ~ 20 C higher than Tpin



- LRC preliminary studies identified the following acceleration parameters:
  - ΔT, Max. Tj, Ramp rate, Dwell time



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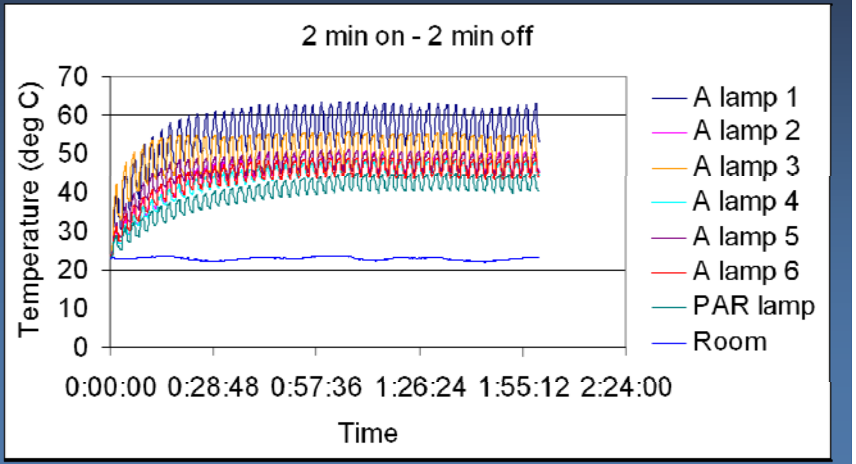
Failure Testing

- Some standards have very fast cycling of LED products to test for failures.
  - Very small delta T
  - May not cause damage



- Generally there are two types of failures:
  - Parametric
    - Lumen depreciation or color shift
  - Catastrophic
    - Ceases to produce light

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STUDY 1

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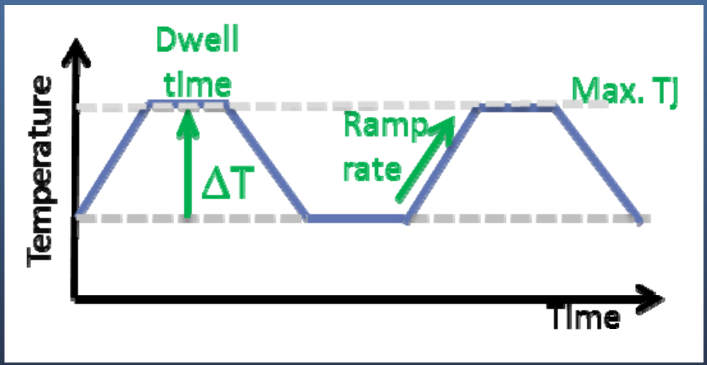
Study 1

- **Objective:** To understand failure modes and the their relationship to test parameters:
  - Delta T (70, 95 C);
  - Dwell time = 1 to 9 hrs

- Over 14,000 hours of test time

- **Results:**
  - Cycling without dwell time did not show any degradation or failure
  - Delta 70, no failure
    - catastrophic or lumen depreciation
  - Delta 95, no catastrophic failure but lumen depreciation

System tested
G25 LED lamp
(40W incandescent replacement)



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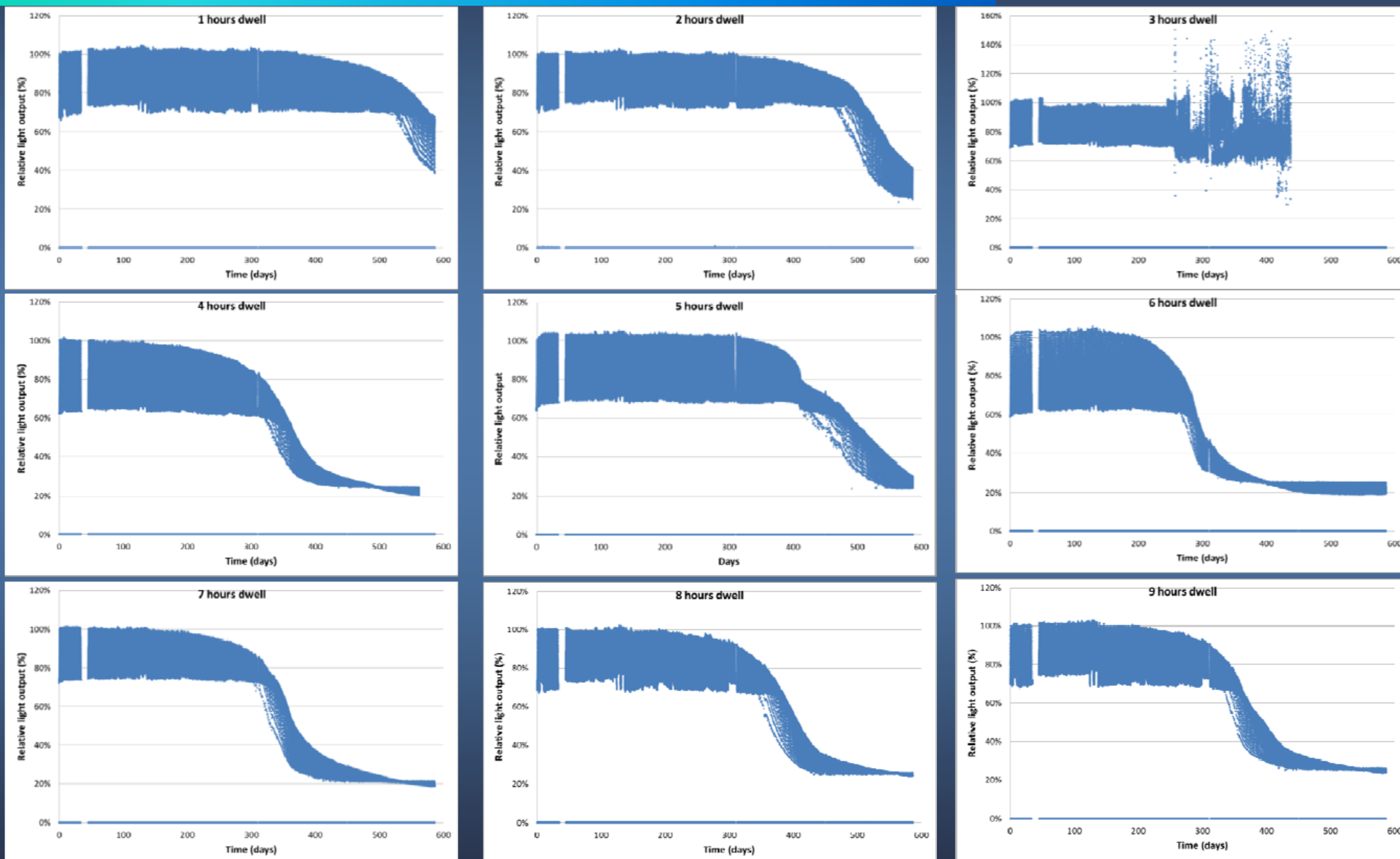
Results: Delta 95°C study

Light output pattern



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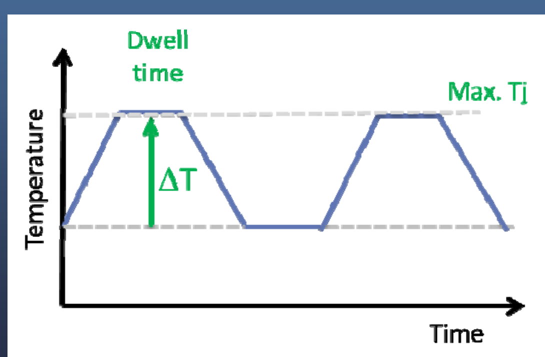
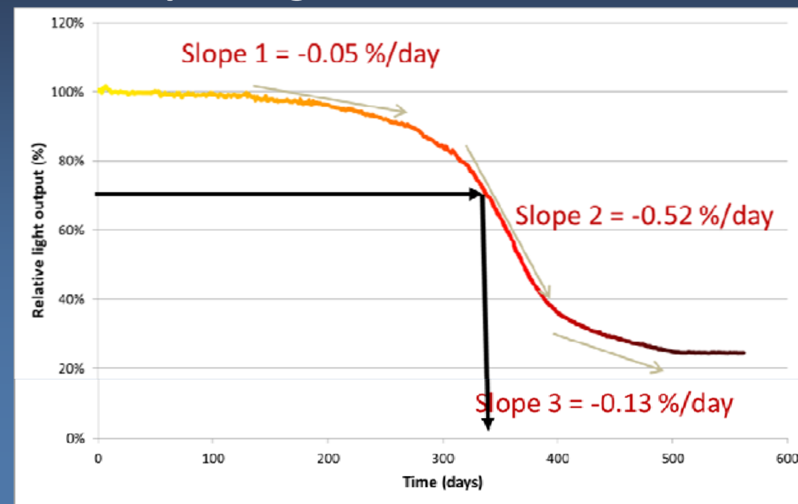
Results: Delta 95°C study

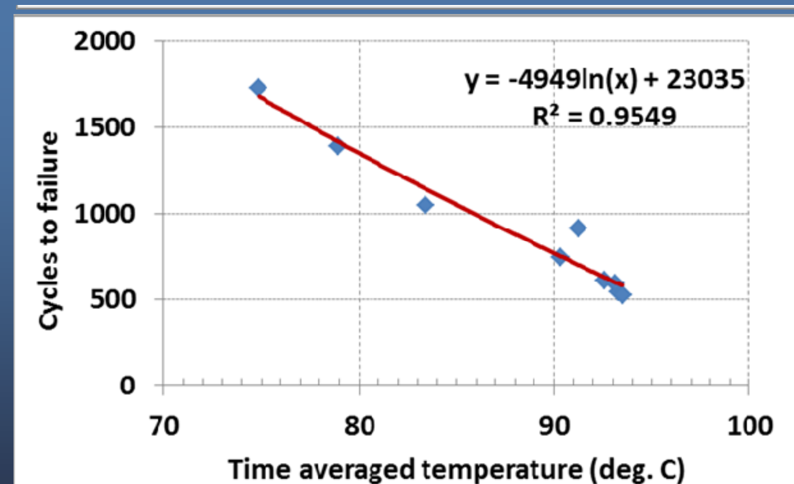
- No catastrophic failures but lumen deprecation was observed
- Failure assumption:
  - 70% light level
- Cycles to failure
  - Correlated well with
    - time averaged temperature



Multiple degradation mechanisms



*4 hours dwell sample



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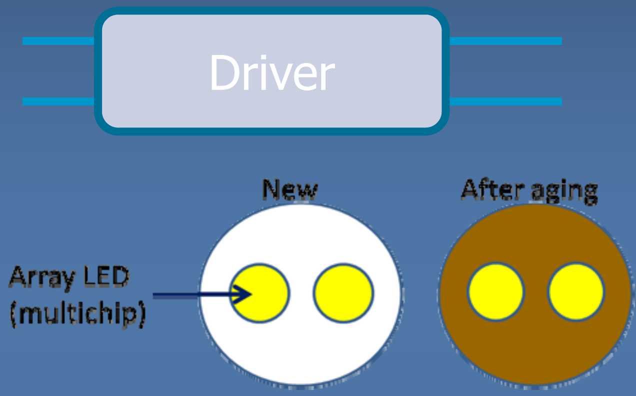
Analysis

- Lumen depreciation was due to electrical and optical degradations
  - 40% light loss due to electrical
  - 13% light los due to optical



	New sample	D95 Aged sample	D95 aged sample with original current
Current (mA)	193	117	193
Light output	100%	47%	87%

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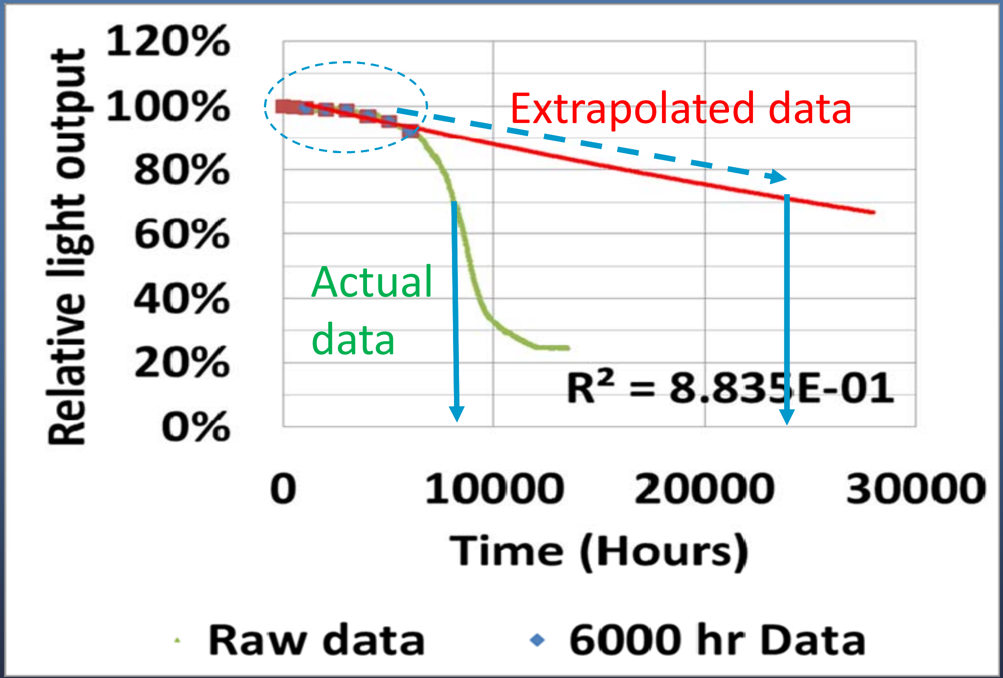
Data Extrapolation

- Extrapolating the 6000 hr data can lead to erroneous results
  - Projected life = 25,000 hrs
  - Actual life = 8,000 hrs



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Study 1 Summary

- For the selected product (40W incandescent G25 replacement)
  - Cycling without dwell time did not show any degradation or failure
  - Cycling with dwell time showed no catastrophic failure, but showed lumen depreciation due to multiple failure modes
    - Electrical / Optical (Electrical degradation much greater than optical)
  - Cycles to failure correlated well with time-averaged T
  - Need to be careful when extrapolating system data
    - multiple degradation mechanisms

STUDY 2

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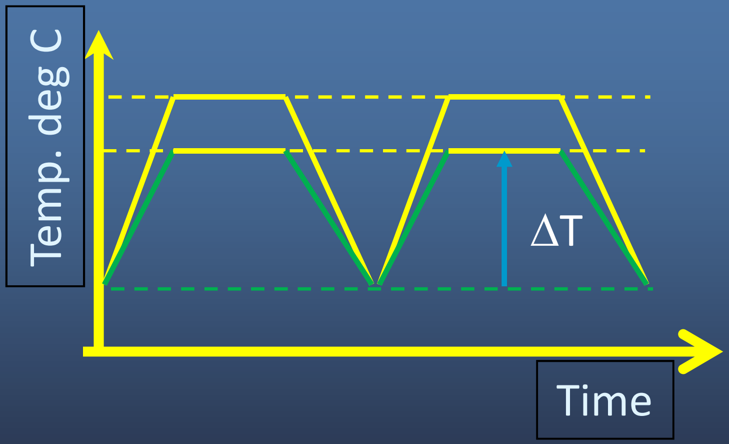
Study 2

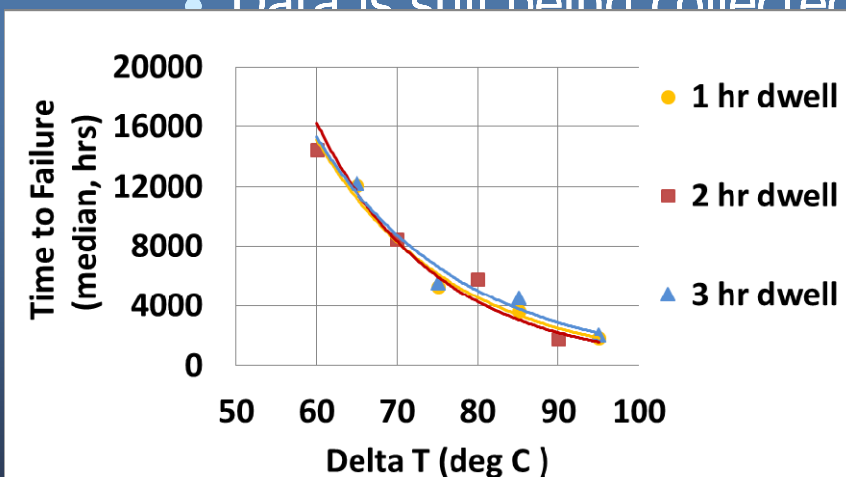
- Objective: To understand the effect of different delta temperate and dwell times on failure time
  - Lamp used: A 60W equivalent LED lamp

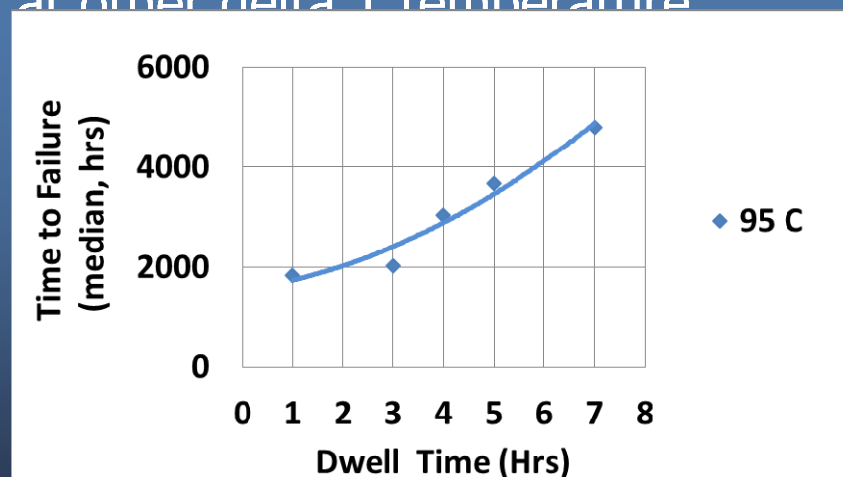
ΔT	60°C	70°C	80°C	90°C



Study 2 Results

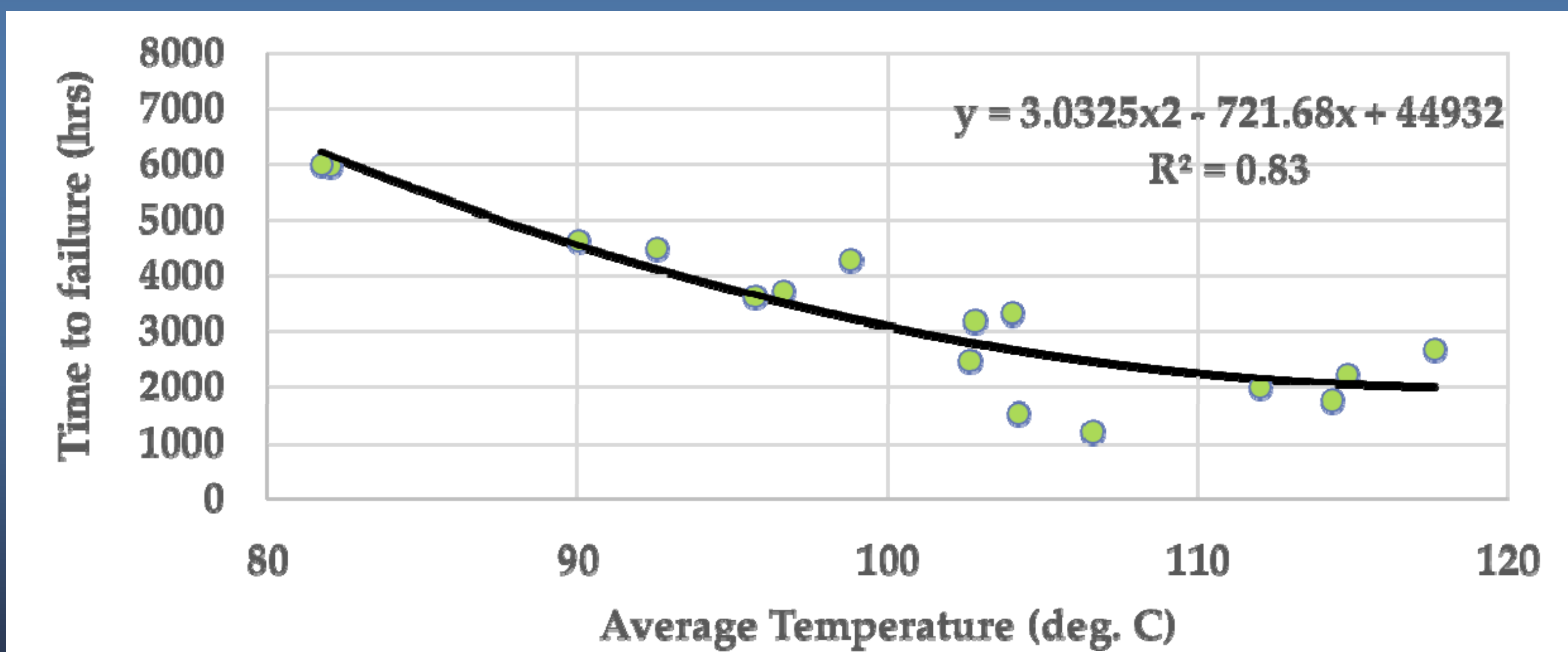
- For the system tested
  - Delta temperature increase results in shorter TTF
    - Catastrophic failure
  - Dwell time increase
    - Results in longer time to failure at delta T 95 C
    - Data is still being collected at other delta T temperature





Results

- For the system tested, time to failure h  d correlation with time averaged temper
  - Dominant failure mode: Solder joint failure



Study 2 - Summary

- Failure acceleration to predict system life
  - Higher Delta T, shorter time to failure
  - Dwell time also influences time to failure
- For the system tested, time to failure has a good correlation with time averaged temperature

Final Remarks

- Failures can be parametric (lumen depreciation) or catastrophic (complete failure)
- Life testing of LED systems must include on-off cycling
  - Very fast cycling may not show failure
    - Not a suitable test for stressing system
- Over accelerated life testing may result in additional failure modes
- In an LED system lumen depreciation can be due to several factors (Electrical and optical)
  - Simple function extrapolation for systems may lead to erroneous results
- Failure acceleration using delta T and dwell time is showing promise in predicting the failure of LED systems under different operating conditions
  - Time average temperature correlates well with time to failure
  - However, more products need to be tested to validate test procedure

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