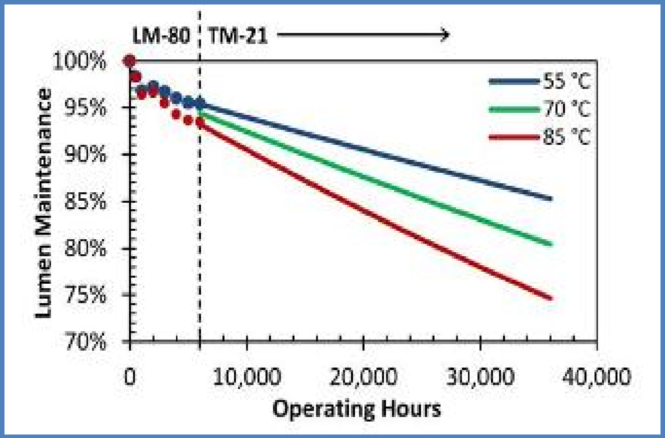
# LED System Reliability

# Introduction

- LED luminaires promise long service life
- Claimed life data
  - Presently, standards require reporting luminaire life based on LED lumen depreciation (LM-80, TM-21).

www.dansdata.com/caselight2.htm

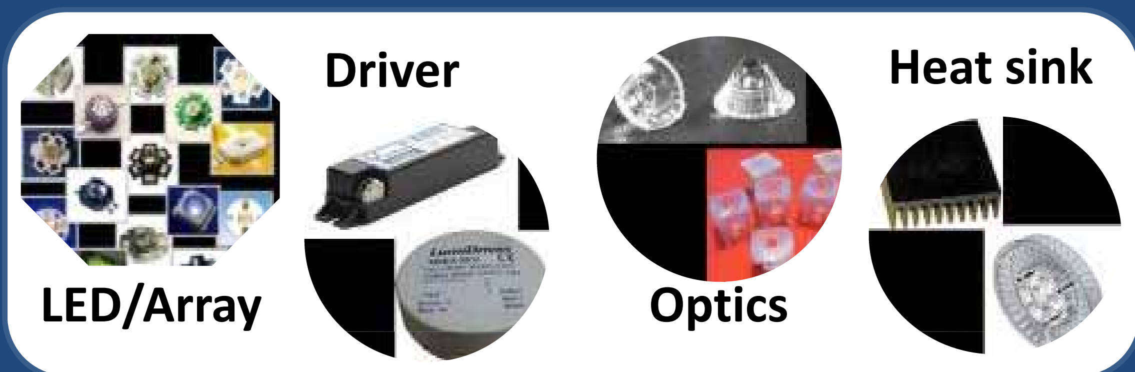


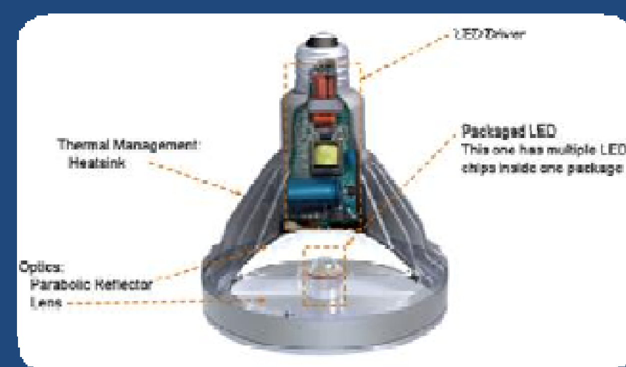

lighting.com/stand-by-your-luminaire/tm-21-extrapolation-from-lm-80-data/

# Introduction

- An LED luminaire has many components
  - LEDs/Array circuit, driver, optics, heat sink components, interface materials, etc.
  - System reliability depends on the weakest component

- Luminaire (or system) life based only on the LED is not appropriate



# Introduction

- Presently, there is no industry standard for testing or estimating the life of LED luminaires or systems.
  - Several organizations are presently working to address this issue.
- The objective of the LRC's study is to develop an accelerated test method that can predict the failure of LED systems under realistic operating conditions.
  - Catastrophic failure (beyond lumen maintenance)

# Introduction

- Lighting Applications
  - Real-life luminaire use pattern:
    - Office:  Lights on 6am to 6pm
      - (12 hrs on, 12 hrs off)
    - Home: Lights on 6am to 10am / 6pm to 10pm
      - (4 hrs on, 4 hrs off)

https://community.lighting.philips.com/

http://www.ledsource.com/products/residential

- The test method should predict luminaire lifetime based on factors such as:
  - application temperature, on-off cycling, and others if applicable

# Study Outline

- Literature survey
- Hypotheses
- Experimental setup and procedure
- Preliminary results

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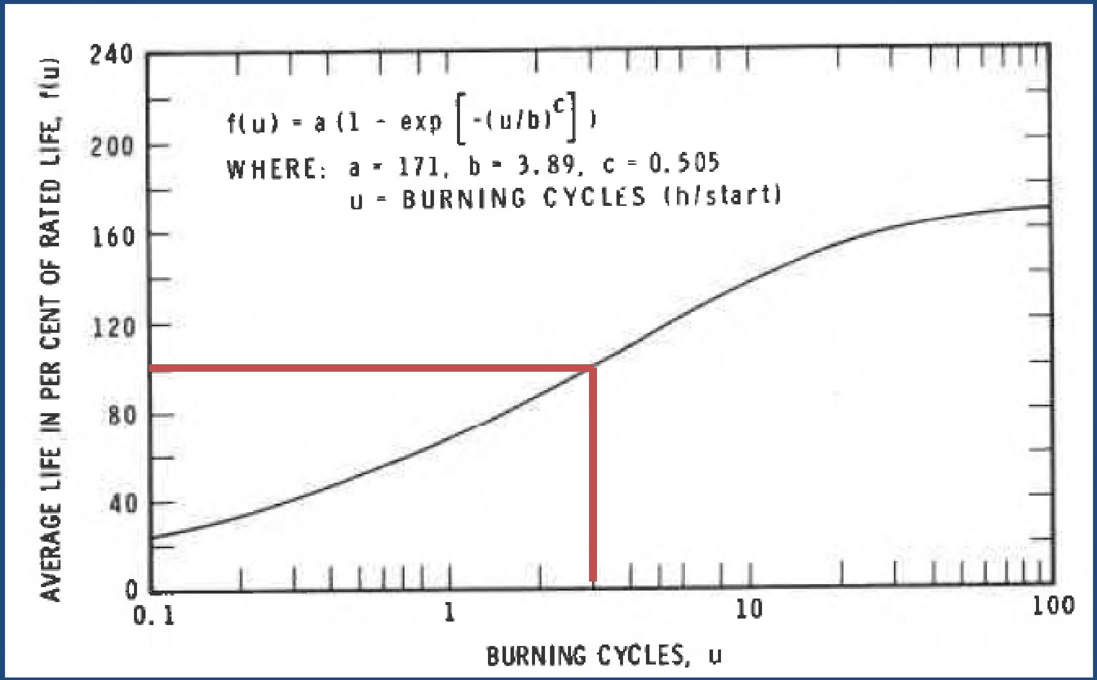
# Literature Survey

- Linear fluorescent lamp life testing standard:
  - 3 hours **ON**; 20 Minutes **OFF**
  - Past studies have shown the effect of burning cycles on average lamp life for linear fluorescent lamps




F.J. Vorlander and E. H. Raddin, "The effect of operating cycles on fluorescent lamp performance," ***Illuminating Eng.,*** pp. 21-27, Jan. 1950.

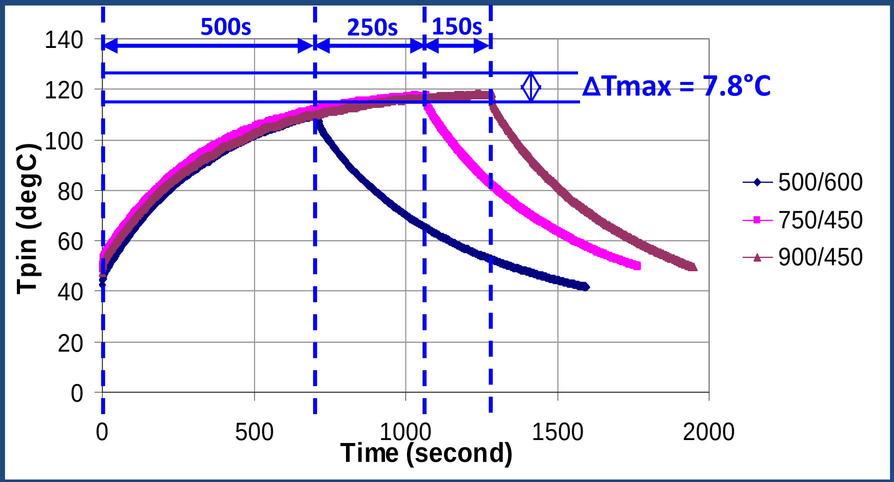
# Literature Survey

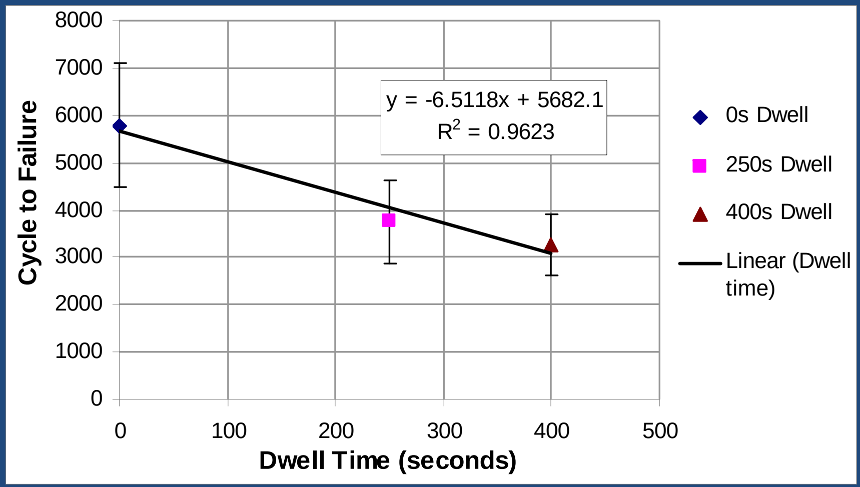
- High-power LED Array
  - Dominant failure mechanism due to power cycling is solder interconnect failure
    - Delta T – strong correlation to cycles to failure
    - Max Tj – no correlation to cycles to failure
      - Below device breakdown temperature
    - Temperature increase ramp rate – very weak correlation to cycles to failure
      - With increasing ramp rate the cycles to failure increases

Yinan Wu, LRC M.S. Thesis, 2010, "Failure analysis of LED array due to rapid power cycling"

# Literature Survey

- High-power LED Array
  - Effect of dwell time at $T_{max}$
  - 3 dwell time groups
    - 0, 250 s, and 400 s
  - Dwell time at $T_{max}$ – strong correlation to cycles to failure
    - Longer dwell time resulted in lower cycles to failure



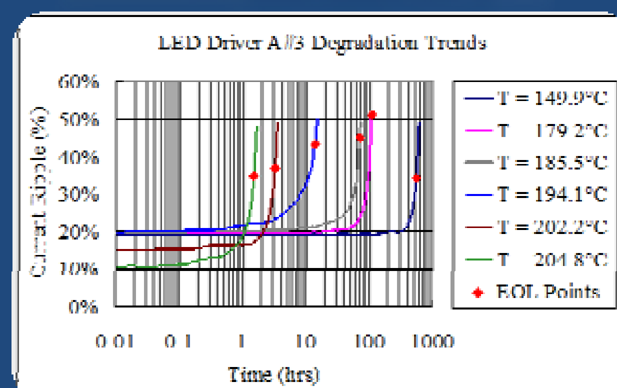




Yi -wei Liu et al. 2011, ASSIST

# Literature Survey

- High-power LED driver life
  - Electrolytic capacitors have the highest probability of failure
  - Heat affects electrolytic capacitors
    - ESR increases and capacitance decreases
      - LED driver output current ripple increase was used to predict life

- LED driver lifetime decreases exponentially with temperature




Han, L., and N. Narendran. 2011. An accelerated test method for predicting the useful life of an LED driver. *IEEE Transactions on Power Electronics* 26(8): 2249–2257.

# Literature Survey Summary

- LED array life affected by:
  - $\Delta T$
  - Temperature increase ramp rate
  - Dwell time at $T_{max}$
- LED driver life affected by
  - Capacitor temperature

# Experiment Setup and Procedure

- LED integral lamps were selected for this study
- Test conditions
  - Realistic: 4hrs ON/4hrs OFF; and 12 hrs ON/ 6 hrs OFF
  - Accelerated: ΔT, T max, T increase ramp rate, and Dwell time at T max
- Study Objectives:
  - Correlation of accelerated test results to realistic test condition results (ON/OFF cycle and $T_{max}$)
  - Determine failure points

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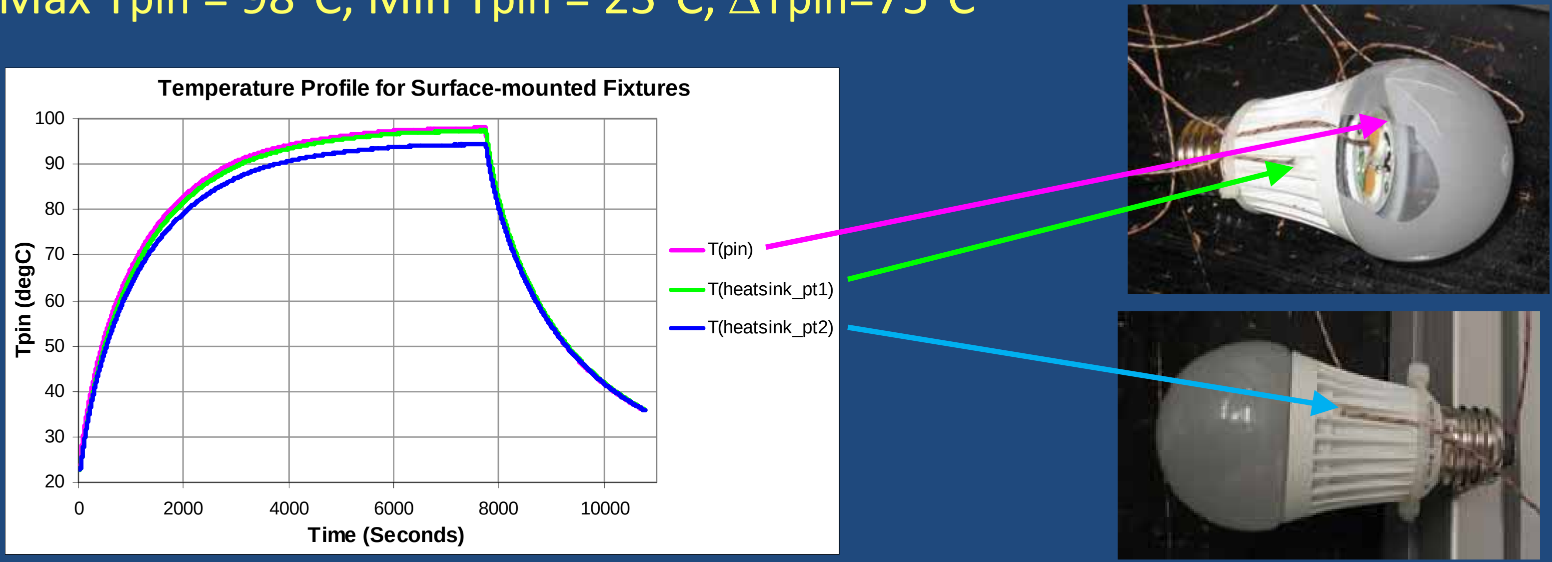
# Pilot Study

- Objectives
  - To identify the Tpin of the LEDs when used inside a surface-mounted luminaire
    - 3 LED integral A-19 lamps
  - To identify a thermocouple attachment point
- Pilot study results:
  - Max Tpin = 98°C, Min Tpin = 23°C, ΔTpin=75°C

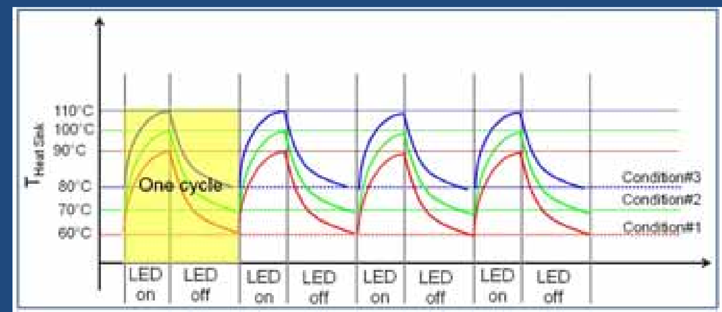


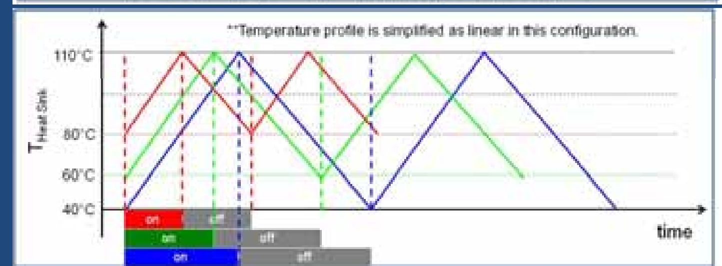
# Hypotheses

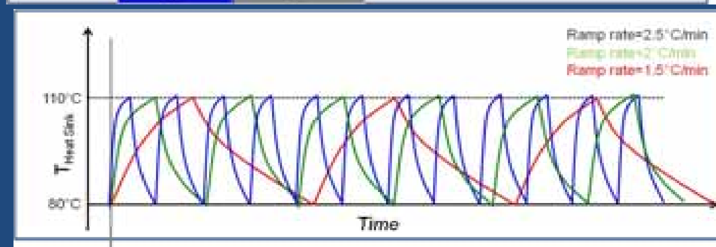
1. At the same Max. $T_{pin}$ and ramp rate, if $\Delta$(T) increases, then the number of cycles to failure decreases.
2. At the same $\Delta$(T) and ramp rate, if Max. $T_{pin}$ increases, then the number of cycles to failure decreases.
3. At the same $\Delta$(T) and Max. $T_{pin}$, if the temperature ramp rate increases, then the number of cycles to failure decreases.
4. At the same $\Delta$(T), Max. $T_{pin}$ and ramp rate, if the dwell time increases, then the number of cycles to failure decreases initially to a point and then increases.

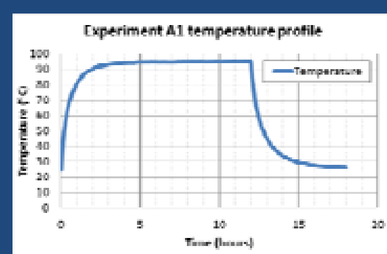
# Tests in Progress

- Accelerated tests
  - Determine the relationship between time to failure and
    - T max, ΔT, Ramp rate, Dwell time
- Realistic conditions
    - 12 hrs on, 6 hrs off
    - 4 hrs on, 4 hrs off



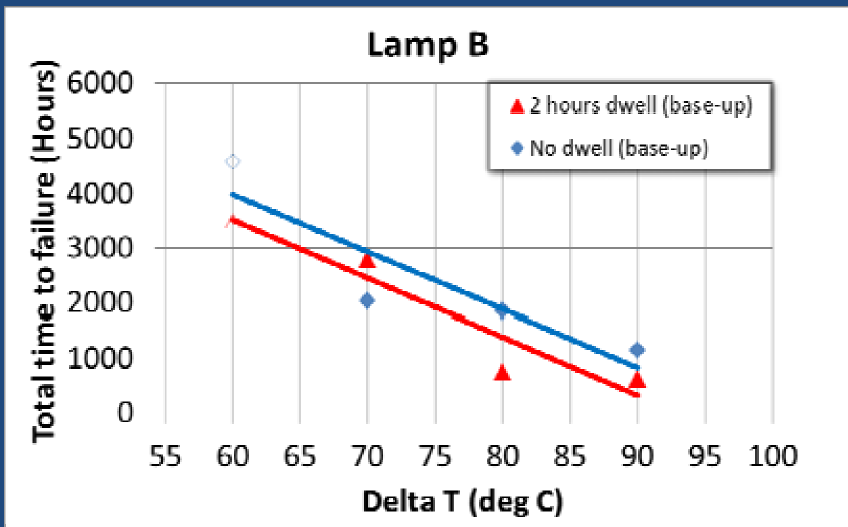



# Results

- Preliminary results for product B

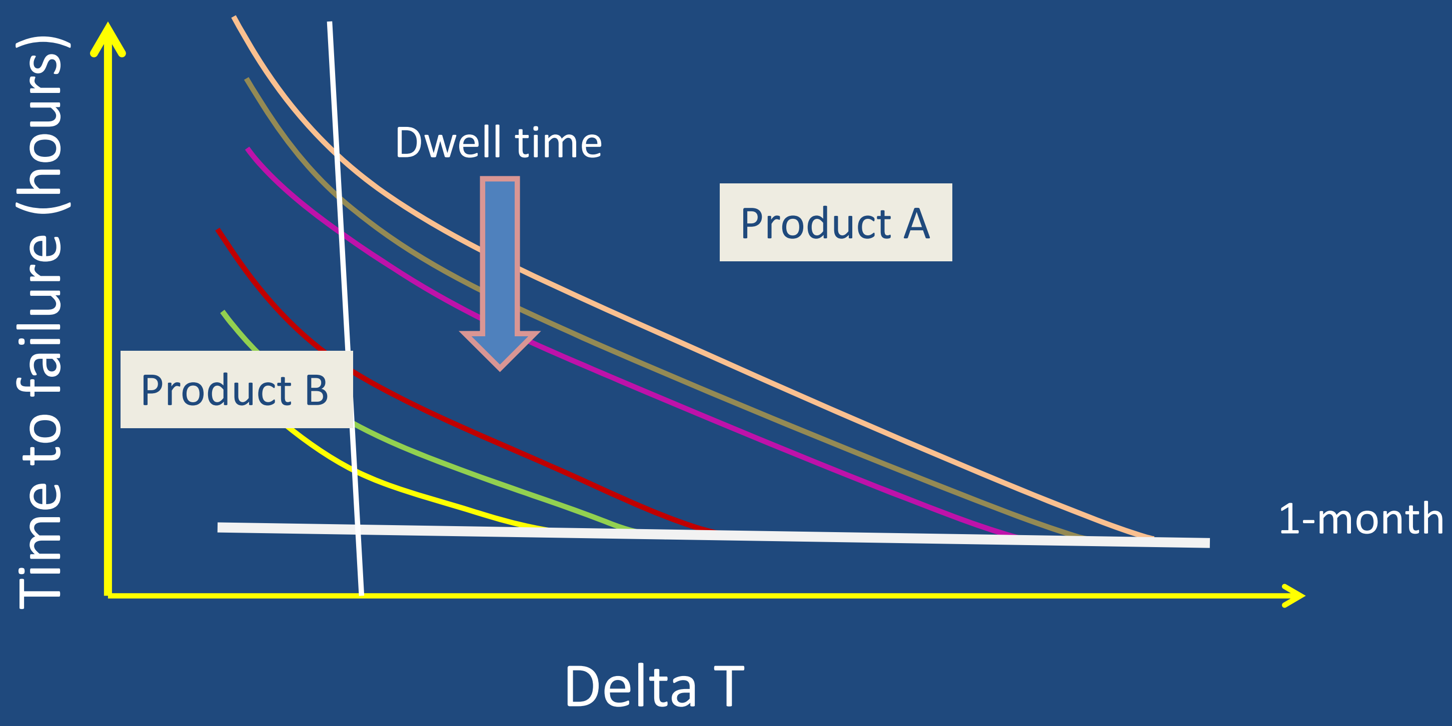



| Lamp B | Delta T (deg C ) | Sample size | Failures | Still operating |
|---|---|---|---|---|
| 2 Hrs dwell time | 60 | 5 | 2 | 3 |
| 2 Hrs dwell time | 70 | 5 | 3 | 2 |
| 2 Hrs dwell time | 80 | 5 | 5 | 0 |
| 2 Hrs dwell time | 90 | 5 | 3 | 2 |
| | | | | |
| No dwell time | 60 | 5 | 3 | 2 |
| No dwell time | 70 | 5 | 5 | 0 |
| No dwell time | 80 | 4 | 3 | 1 |
| No dwell time | 90 | 5 | 5 | 0 |

– An equation can be developed to project system failure time based on ΔT and Dwell time
  - ΔT: depends on fixture operating temperature and ambient
  - Dwell time: depends on on/off time
– Faster test time (~ 1 month) may be feasible
  – Needs more testing (different products)

# Results

- Expected results:
  - Different products would have different delta T / dwell time relationship



# Thank You