ENERGY STAR Lighting Webinar: CPUC LED Lab Test Study Update

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LED LAB TEST STUDY UPDATE

Presentation Overview

- Research objectives
- Experimental design
- Sample design
- Interim results
- Current take-aways and a look ahead

LED LAB TEST STUDY

Research Objectives

- **Predecessor study:** CFL lab test study funded under 10-12 EM&V
  - Focused on relationship between switching cycles and CFL lamp life
  - CPUC set aside $500K to conduct analogous study focusing on LEDs
- **National program context:** Energy Star, Lighting Facts, CALiPER
  - All three use standardized lab testing for compliance, verification, and/or market tracking: IES LM-79 (initial photometric performance), LM-80 & LM-84 (lumen maintenance), TM-21 (lumen maintenance projection)
  - Most of these tests are conducted in pre-specified, constant, laboratory conditions (e.g. 25ºC ± 5ºC)
  - Rated life based on lumen depreciation, not catastrophic failure
- **California program context: Voluntary California Quality Spec**
  - Largely Energy Star, but with higher standards for CRI, warranty, dimmability, power factor, and noise
  - D.12-05-015 required IOUs' LED offerings in upstream programs to be compliant with CA Quality Spec (which they have been since Jan 2014)

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Research Objectives

- **Knowledge gaps related to LED performance and testing:**
  - Solicited input on needs and research priorities from IOUs and other LED industry stakeholders
    - Strong consensus on need for stress testing in order to identify conditions that cause early/catastrophic failure (e.g. temperature, humidity, switching patterns, voltage, vibration, etc.)
    - Elevated temperature and thermal cycling (due to switching) identified as most prevalent stress condition in CA homes and most tractable to evaluate in laboratory setting
- **Research objectives defined for this study:**
  - To assess the effect of temperature and switching patterns (thermal cycling) on the performance of a representative sample of LED replacement lamps in “real world” thermal conditions
  - To assess differences in performance (under the test conditions above) between CA Quality Spec-compliant LED replacement lamps and their non-Spec competitors

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Experimental Design

- **Overall experiment** based on operation conditions and measurements defined in IES LM-84 and LM-79, except:
  - Lamps operated in ***actual luminaires*** in order to approximate operating temperatures experienced in the field
    - Enclosed ceiling fixture
    - Recessed downlight
    - Bare socket
  - Lamps subjected to switching cycles that maximize the number of ***thermal cycles*** experienced by test lamps
- **Three types of testing** comprise the entire testing regime:
  - Thermal testing: lamp operating temps, near-ambient temps
  - Photometric testing: power input, lumen output, pf, THD, CRI, CCT
  - Maintenance testing: lumen maintenance, catastrophic failures

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Experimental Design – Test Fixtures

- **Recessed downlight:**
  - Model = Halo H7UICAT
  - Attic-side covered with 3” of fiberglass insulation
  - All reflectors, all A-lamps
- **Enclosed ceiling fixture:**
  - Model = Westinghouse 6660700
  - 6” diameter, 7.5” height
  - All A-lamps, all candelabra-base torpedo lamps
- **Bare sockets:**
  - Base-up and base-down configurations
  - All lamp types

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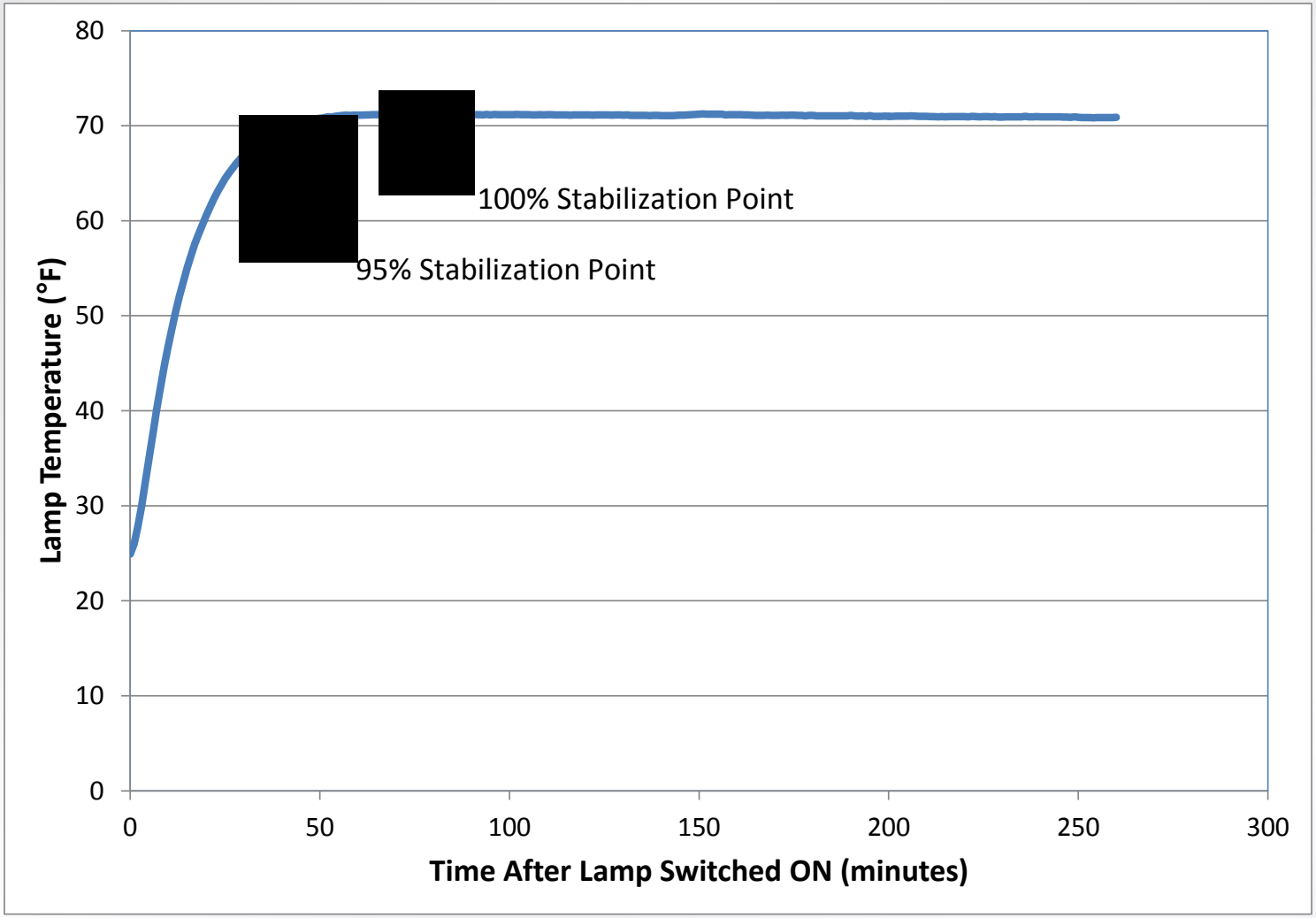
Experimental Design – Thermal Testing



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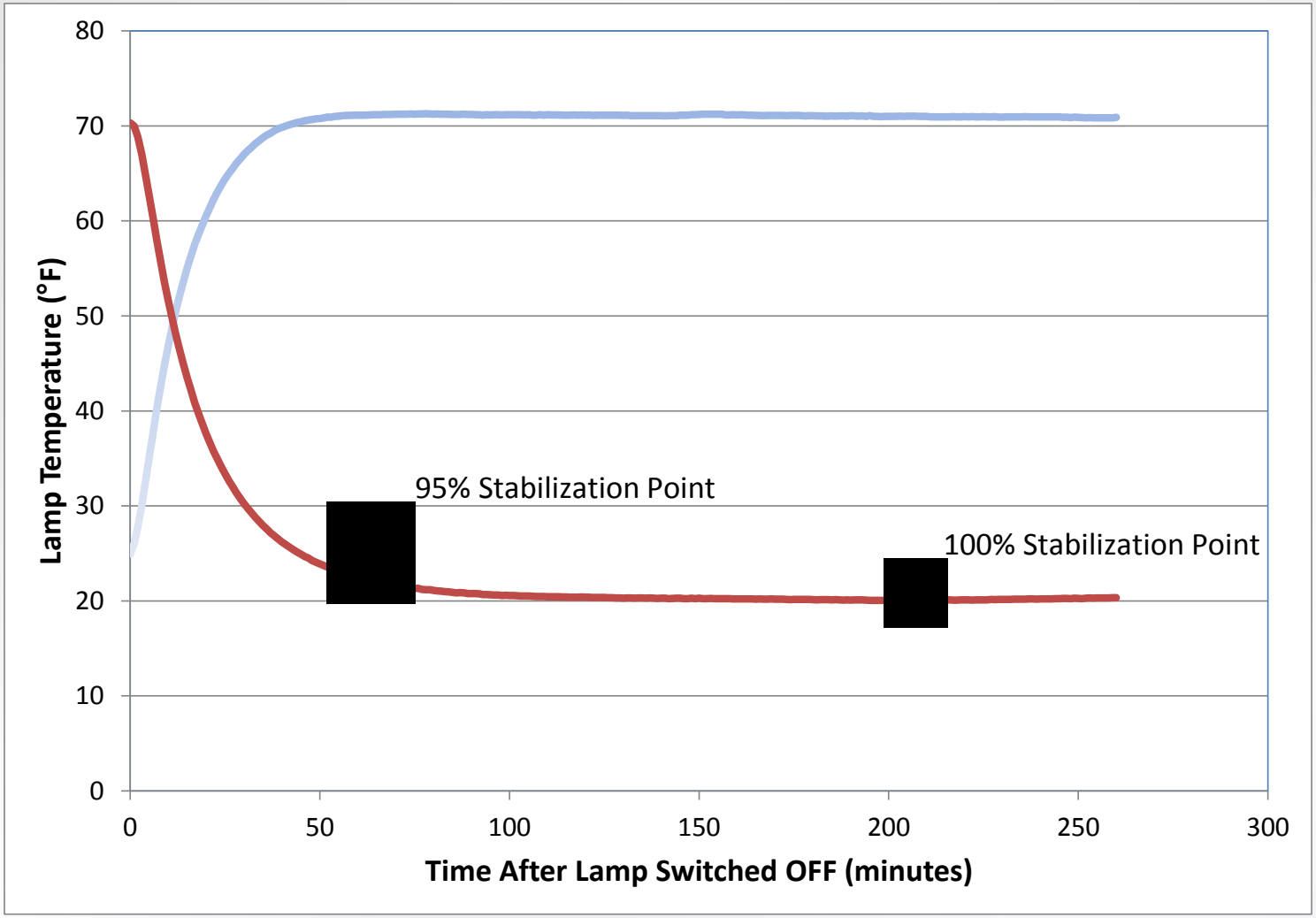
Experimental Design – Thermal Testing



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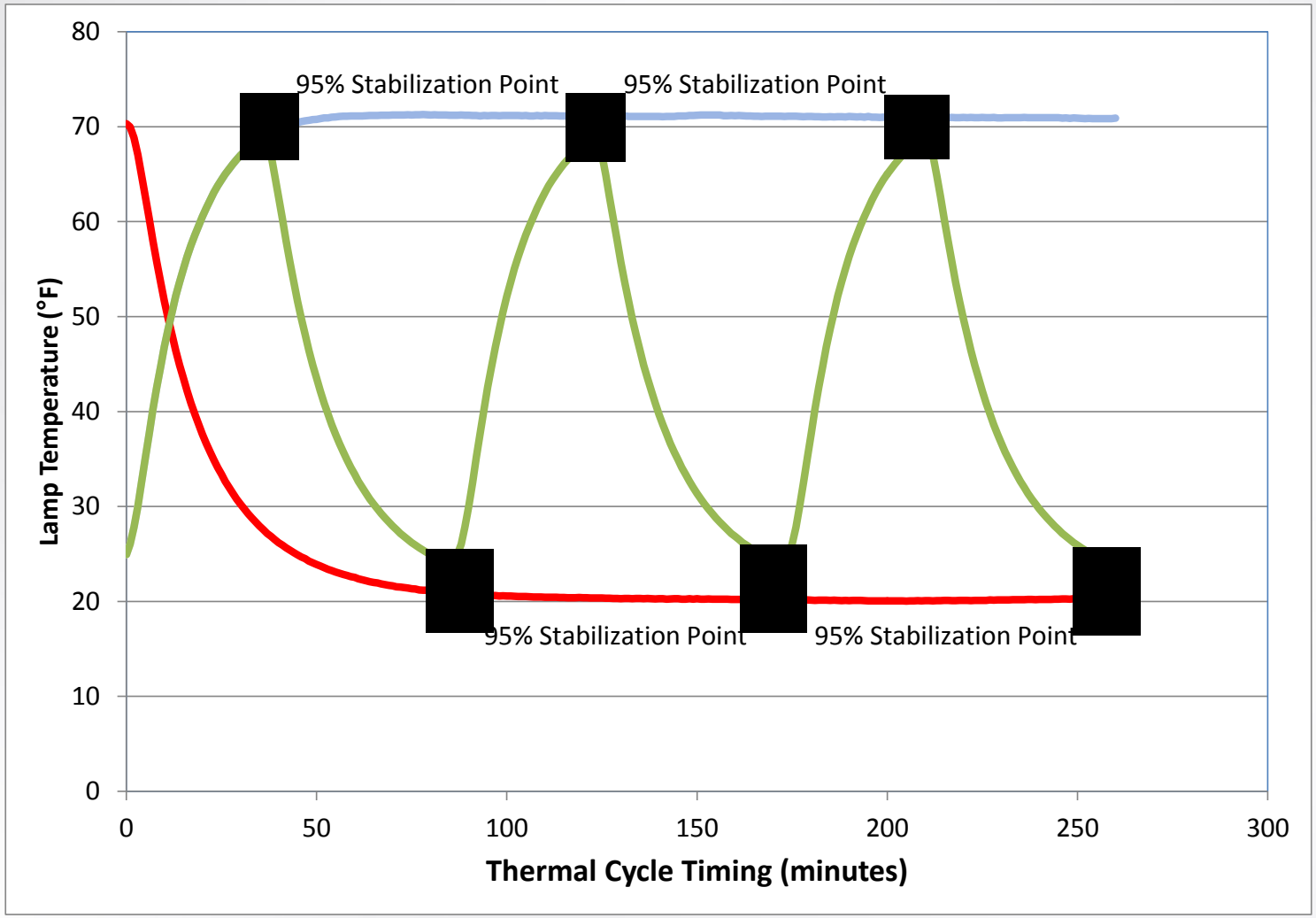
Experimental Design – Thermal Testing



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Experimental Design – Thermal Testing

Control Zone	On-time (min)	Off-time (min)	On-time per day (hrs)	Thermal Cycles per day	Number of Luminaires per Control Zone				
					Recessed Downlight	Ceiling Fixture	Base-up Socket	Base-down Socket	Total Luminaires
1	56	89	9.3	9.9	25	0	15	0	40
2	72	102	9.9	8.3	21	0	0	3	24
3	89	117	10.4	7.0	24	0	7	0	31
4	75	94	10.7	8.5	24	0	0	12	36
5	76	114	9.6	7.6	26	0	18	0	44
6	89	129	9.8	6.6	26	0	0	14	40
7	105	140	10.3	5.9	26	0	4	0	30
8	48	60	10.7	13.3	0	0	0	48	48
9	58	80	10.1	10.4	0	0	0	34	34
10	73	112	9.5	7.8	0	0	0	28	28
11	144	202	10.0	4.2	24	0	0	0	24

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Experimental Design – Photometric & Maintenance Testing

- **Photometric testing:**
  - Followed IES LM-79 (integrating sphere, bare sockets)
    - Power input, lumen output, pf, THD, SPD, CRI, CCT
  - Two rounds: ***prior to*** and ***following*** maintenance testing
    - Allows assessment of changes in photometric performance over time
- **Maintenance testing:**
  - Followed IES LM-84, with exception that lamps operated inside fixtures and switched on-off to maximize number of full thermal cycles
    - Ambient air temperatures inside test lab facility maintained at 25°C±5°C
  - Photosensors in each test cell used to record light output (1-min intervals) and ID sudden drops in light output (i.e. catastrophic failures)
    - Failures validated by technician to ensure drops not related to photosensor malfunction or other issues not related to lamp performance
  - Maintenance testing initiated in February 2016 and will run through February 2017

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Sample Design

- Best available source of CA LED market share data with detail suitable for sample design was 2014-2015 RLSS
- From RLSS, 18 strata defined by lamp type, base type, and lumen output accounted for **81%** of total CA LED market in late 2014/early 2015

Lamp Type	Reflector Subtype	Base Type	Lumen Bin	Share of CA Market
A-LAMP	N/A	MSB (E26)	201-400 lm.	2.1%
A-LAMP	N/A	MSB (E26)	401-600 lm.	15.1%
A-LAMP	N/A	MSB (E26)	601-800 lm.	13.9%
A-LAMP	N/A	MSB (E26)	801-1,000 lm.	7.2%
A-LAMP	N/A	MSB (E26)	1,001-1,200 lm.	3.5%
A-LAMP	N/A	MSB (E26)	1,401-1,600 lm.	2.8%
GLOBE	N/A	MSB (E26)	201-400 lm.	2.4%
GLOBE	N/A	MSB (E26)	401-600 lm.	4.5%
TORPEDO	N/A	Candelabra (B10)	1-200 lm.	2.7%
TORPEDO	N/A	Candelabra (B10)	201-400 lm.	7.2%
TORPEDO	N/A	MSB (E26)	201-400 lm.	2.0%
REFLECTOR	BR30	MSB (E26)	601-800 lm.	8.5%
REFLECTOR	BR40	MSB (E26)	1,001-1,200 lm.	1.4%
REFLECTOR	PAR20	MSB (E26)	401-600 lm.	1.1%
REFLECTOR	PAR30	MSB (E26)	601-800 lm.	1.7%
REFLECTOR	PAR38	MSB (E26)	801-1,000 lm.	1.4%
REFLECTOR	PAR38	MSB (E26)	1,001-1,200 lm.	1.3%
REFLECTOR	R20	MSB (E26)	401-600 lm.	2.7%

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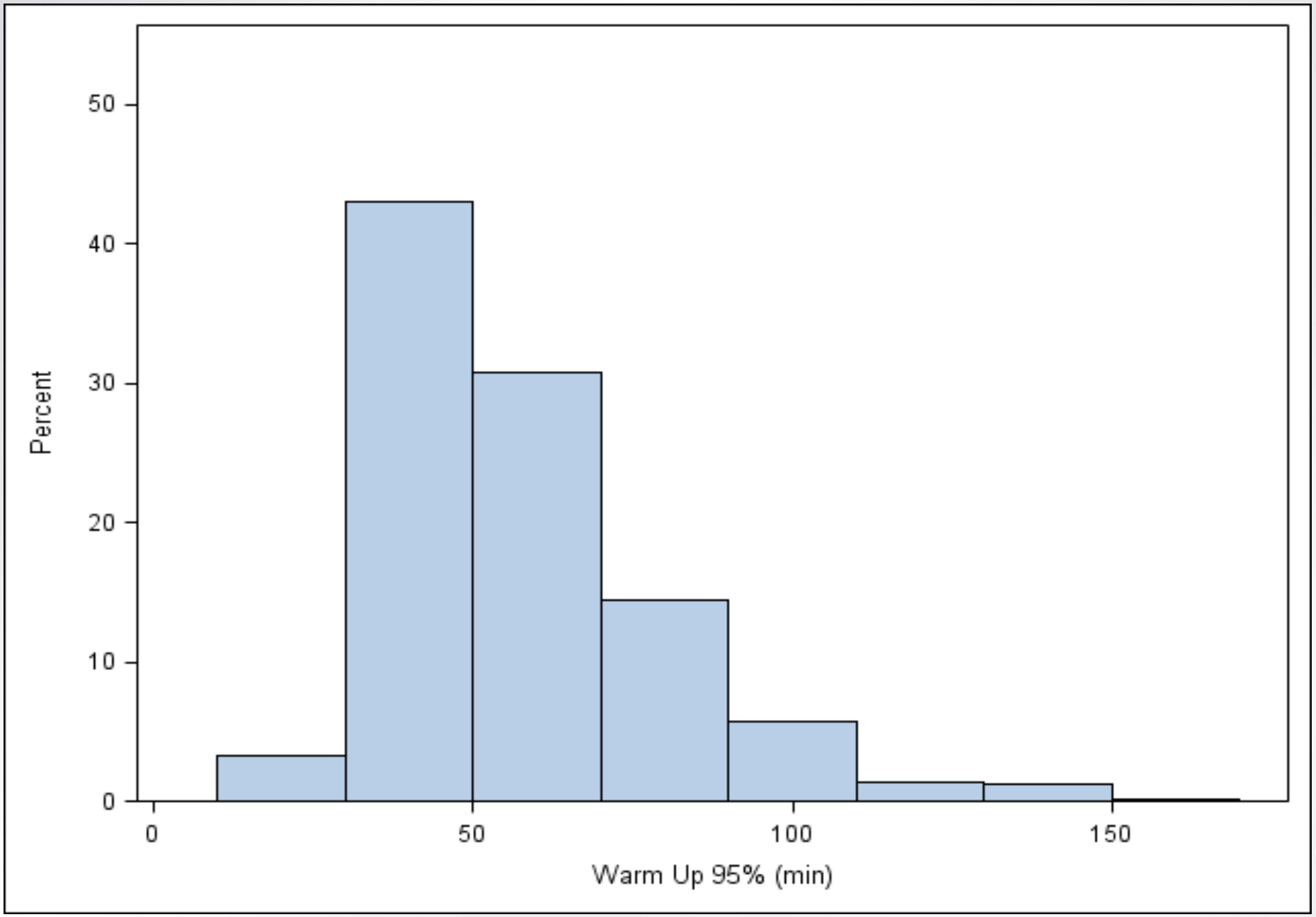
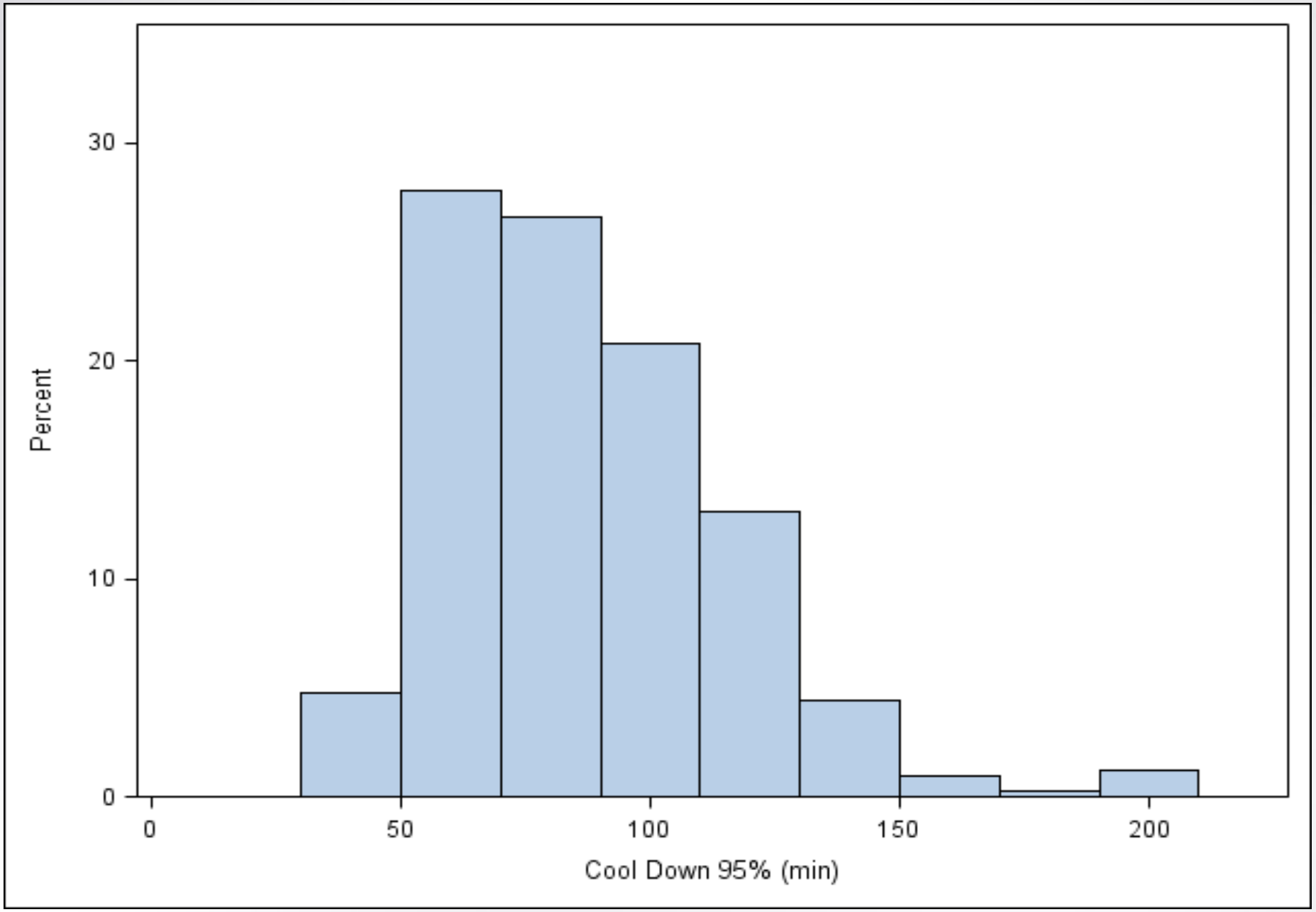
Sample Design and Procurement

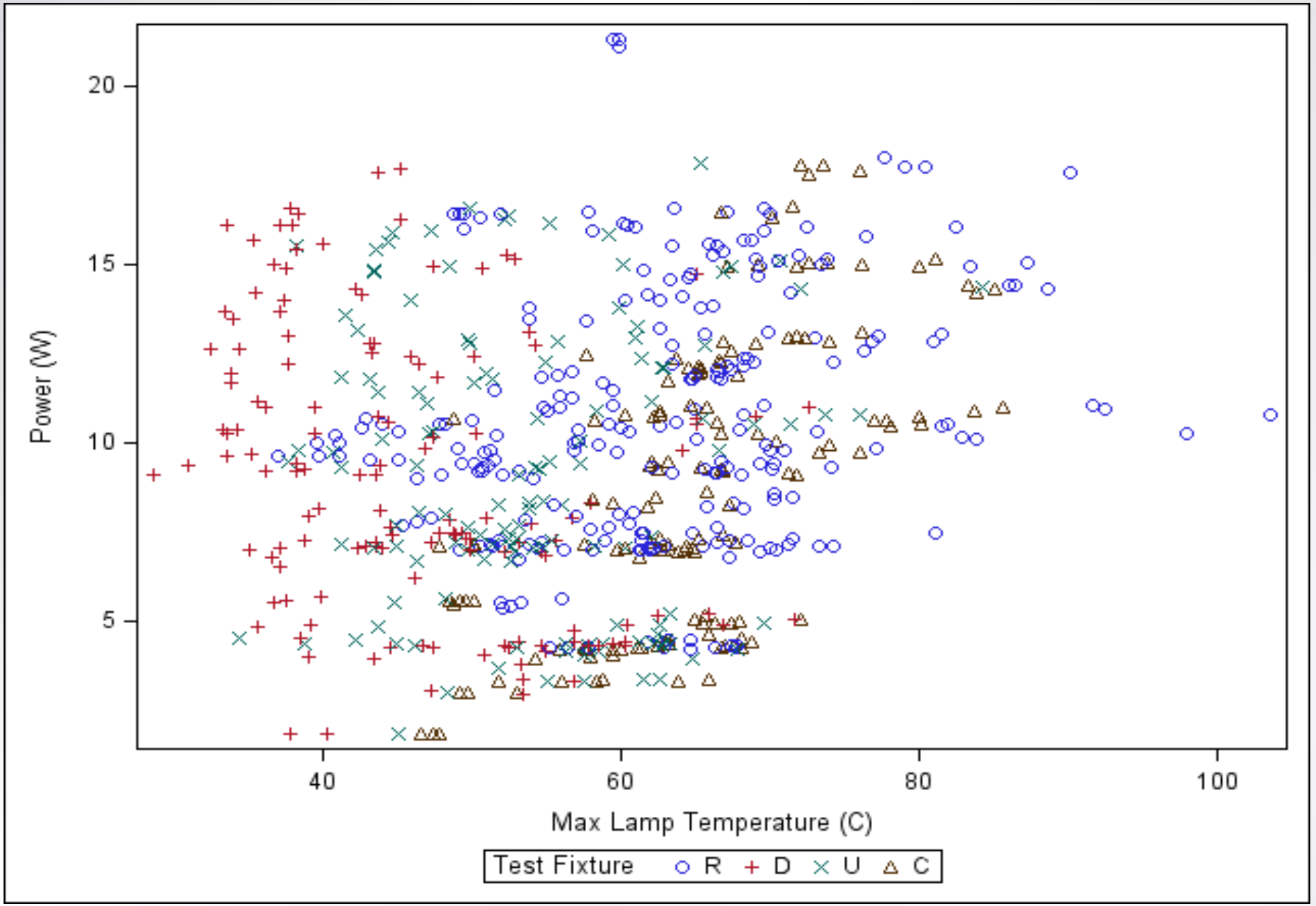
- In order to support research objectives, selected models within each strata such that:
  - ~50% of models were CA Quality Spec-compliant
  - ~25% of models were Energy Star but not CA Quality Spec-compliant
  - ~25% of models were least-expensive, non-Energy Star
- Used “off the shelf” procurement, largely via online retailers with direct shipping to test facility
  - Majority of CA Quality Spec-compliant models not available for online purchase
  - IOU program staff procured those models and shipped to test facility
- Final test sample included:
  - 627 individual lamps (92 models)
    - Account for 53% of total in-scope CA LED market
  - 39 trim kits (13 models)

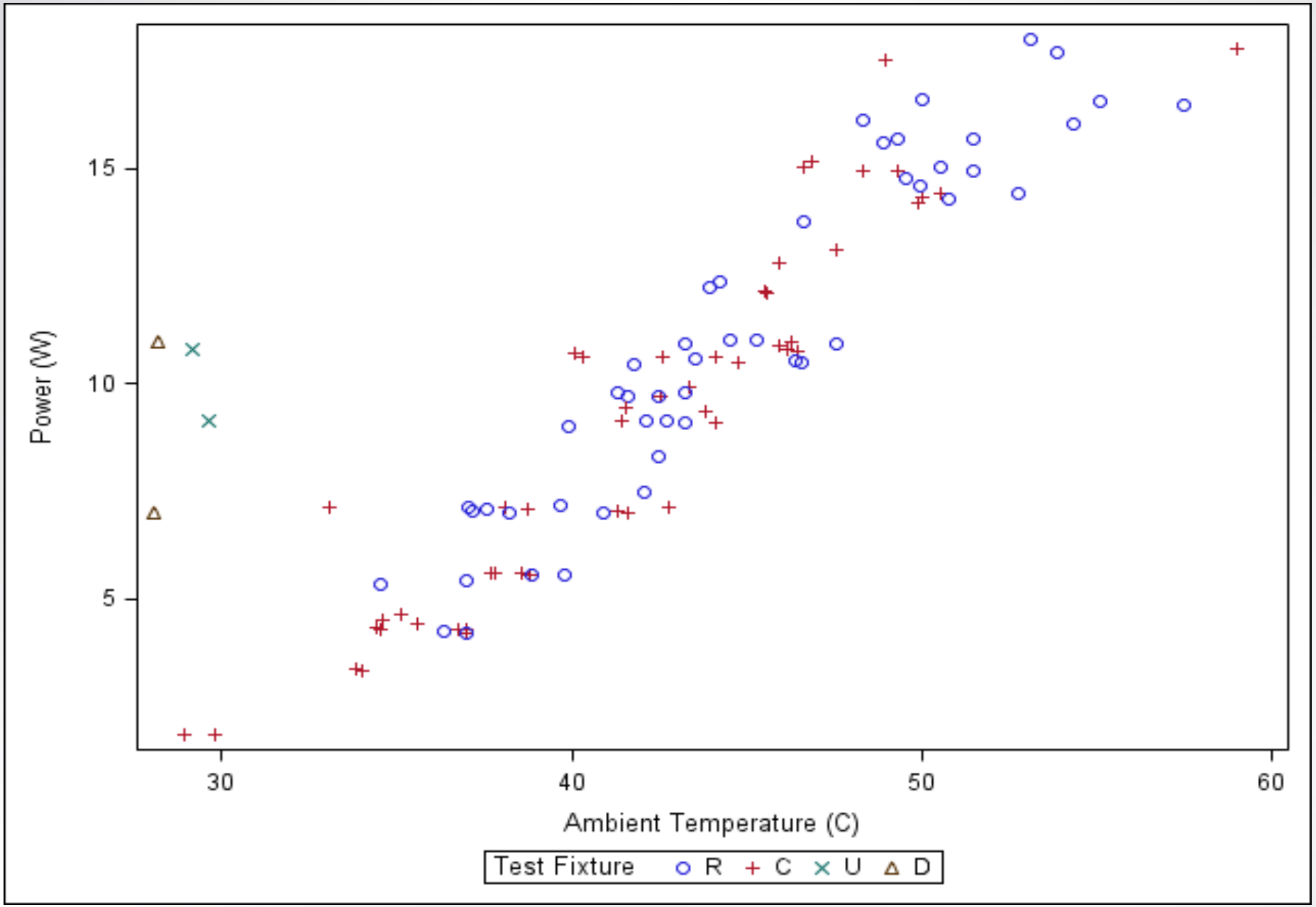
INTERIM RESULTS

Thermal Testing


50
40
30
20
10
0
Percent
0
50
100
150
Warm Up 95% (min)

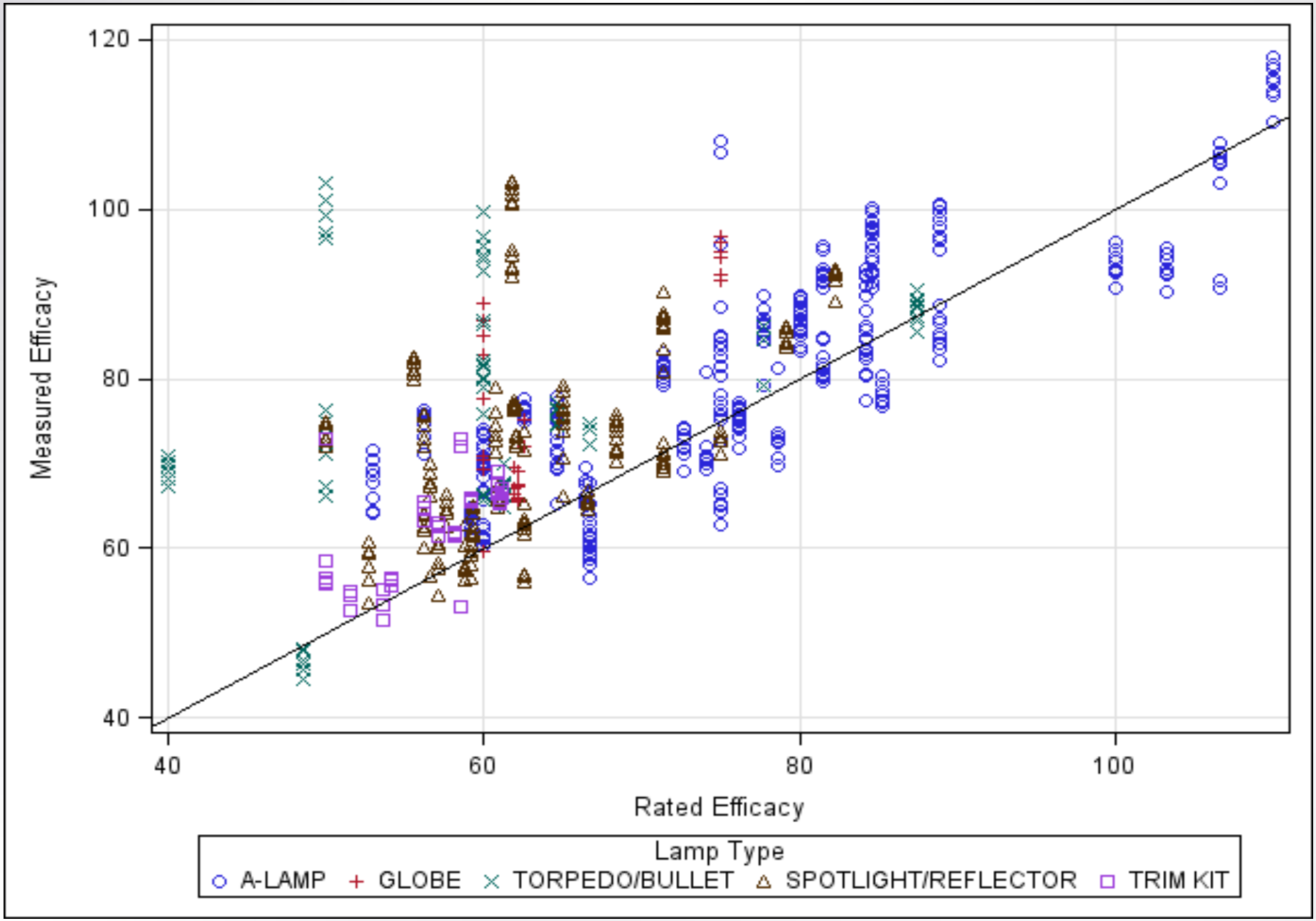

30
20
10
0
Percent
0
50
100
150
200
Cool Down 95% (min)

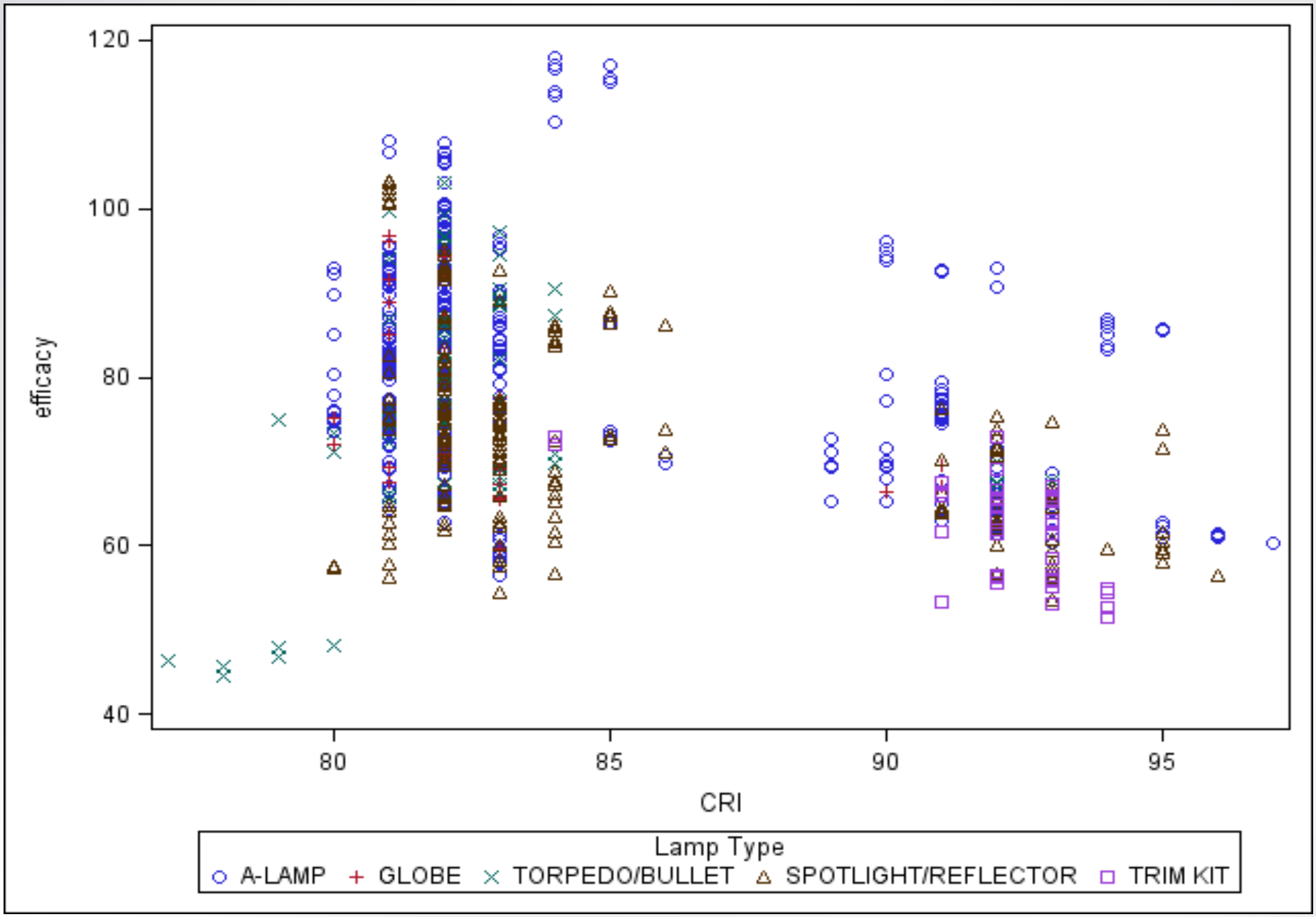

20
15
10
5
Power (W)
40
60
80
100
Max Lamp Temperature (C)
Test Fixture
R
D
U
C

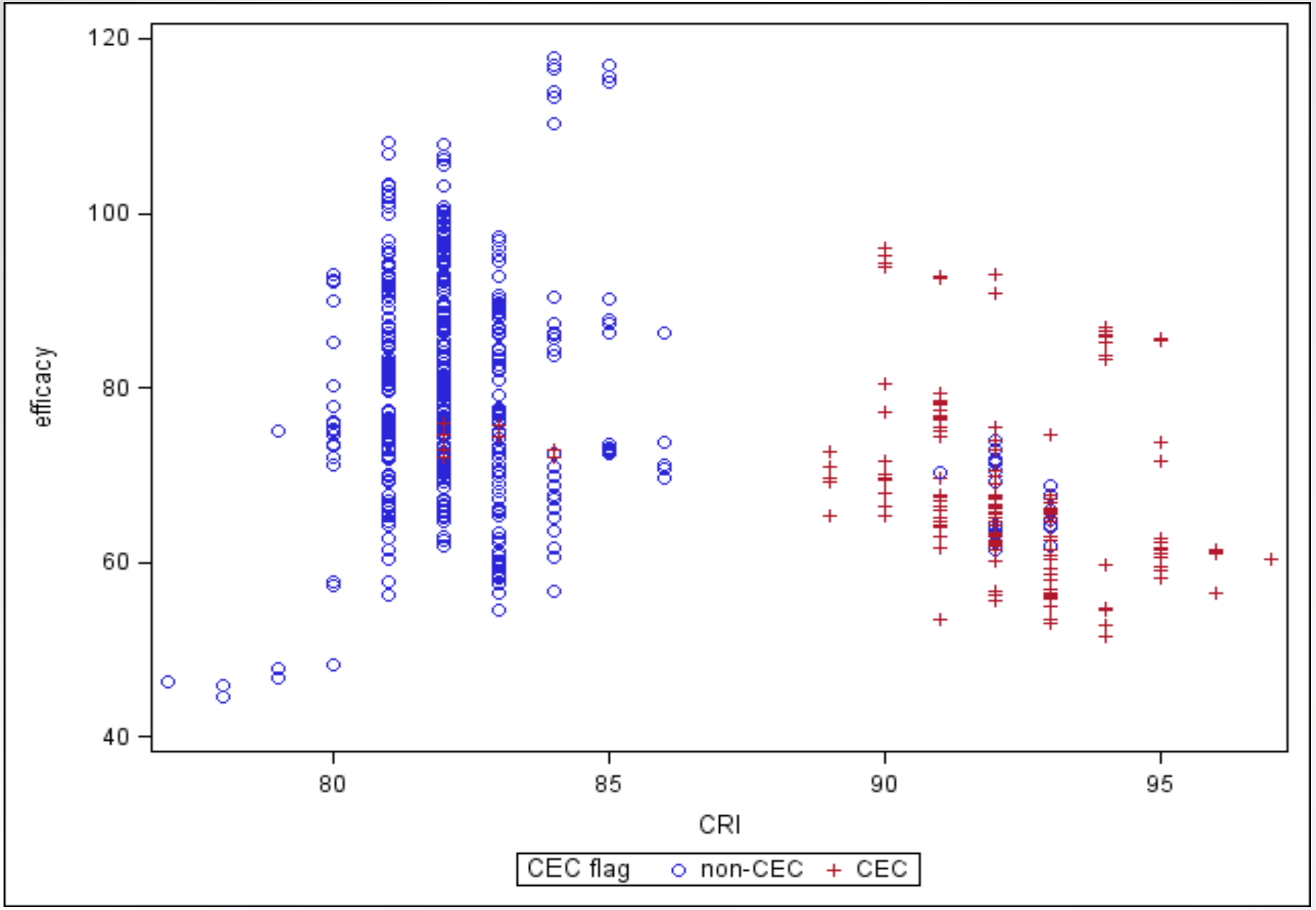

Power (W)
15
10
5
30
40
50
60
Ambient Temperature (C)
Test Fixture
R
C
U
D

INTERIM RESULTS

Initial Photometric Testing

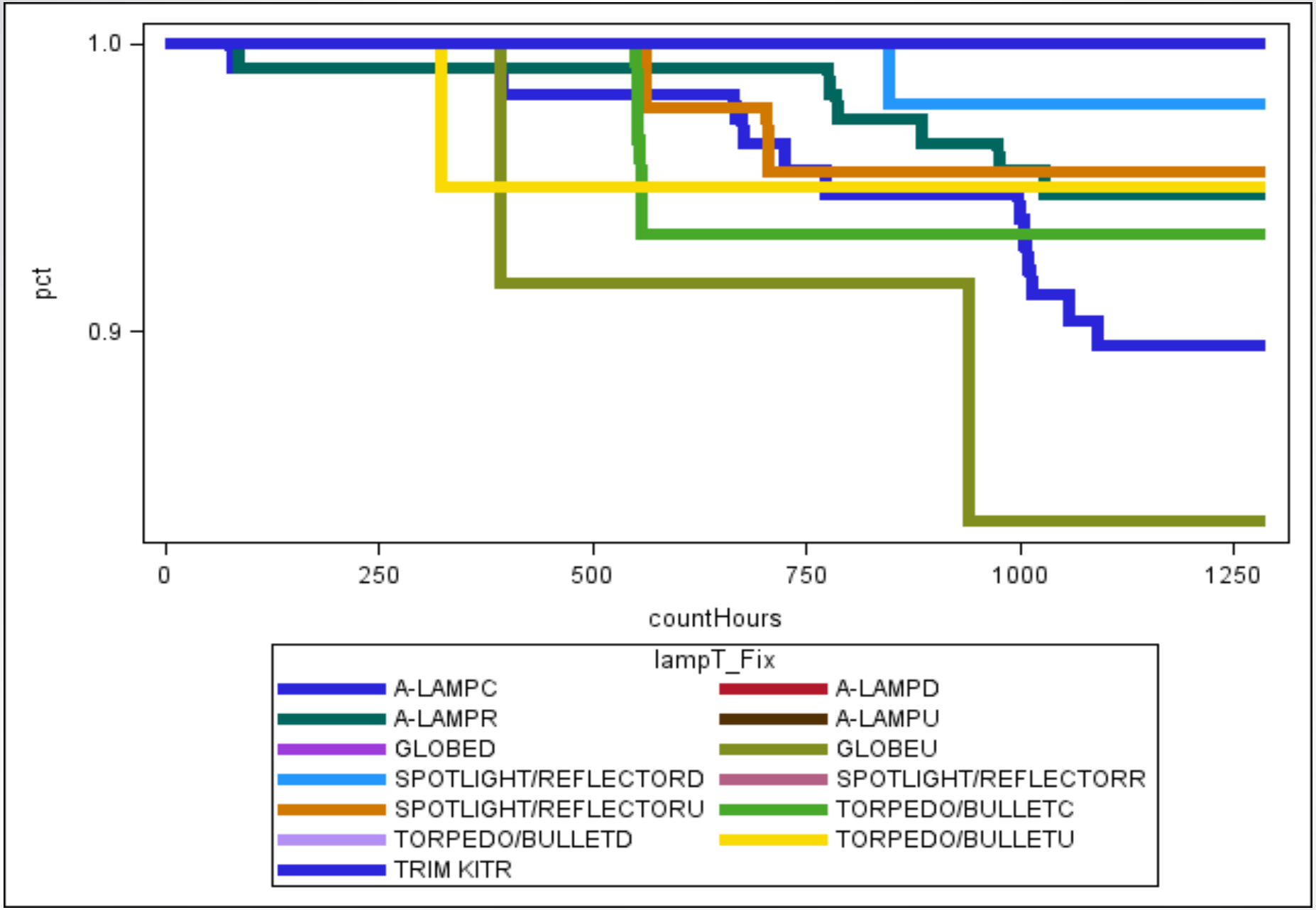

120
100
80
60
40
Measured Efficacy
40
60
80
100
Rated Efficacy
Lamp Type
A-LAMP
GLOBE
TORPEDO/BULLET
SPOTLIGHT/REFLECTOR
TRIM KIT

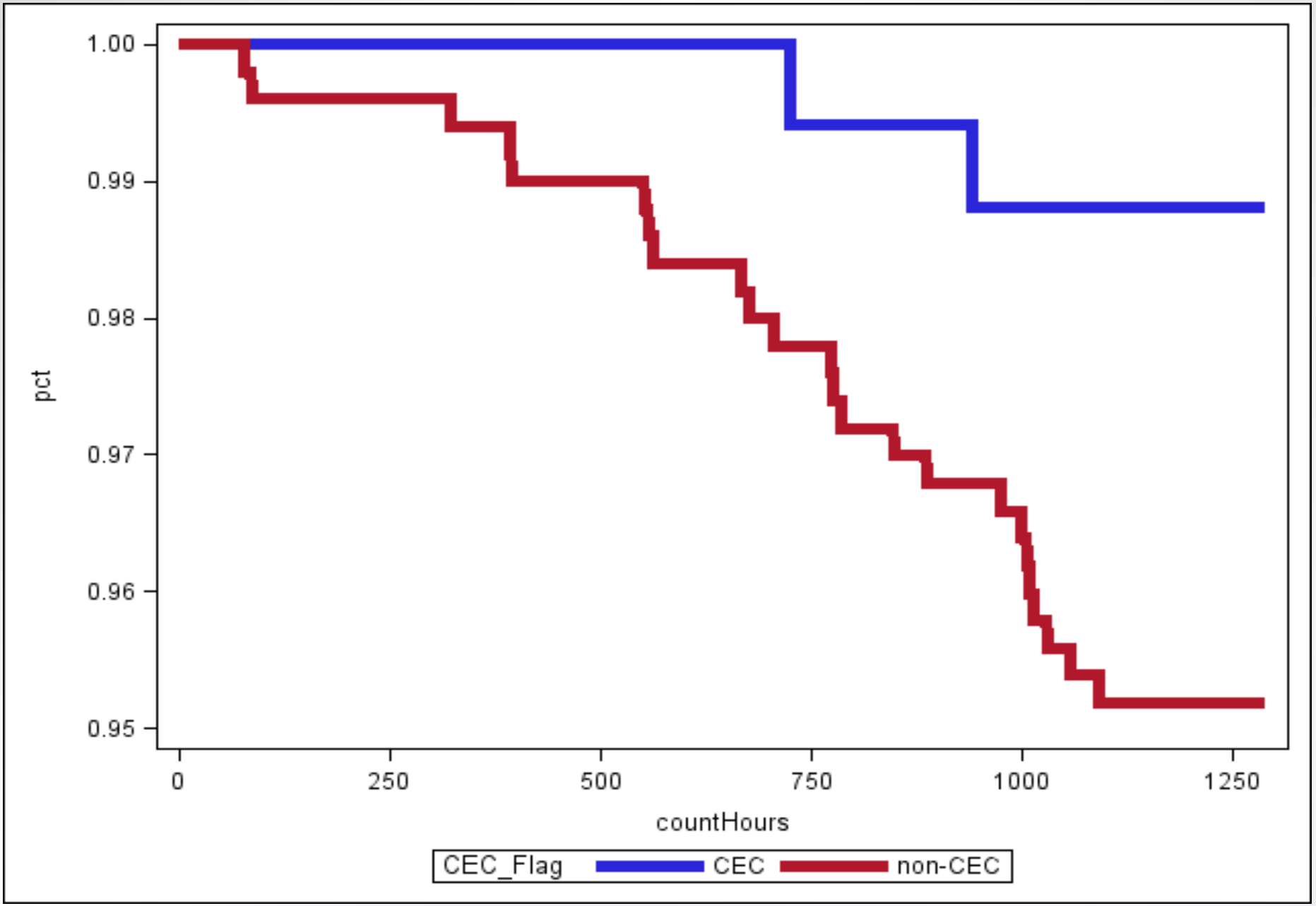

120
100
80
60
40
efficacy
80
85
90
95
CRI
Lamp Type
A-LAMP
GLOBE
TORPEDO/BULLET
SPOTLIGHT/REFLECTOR
TRIM KIT


120
100
80
60
40
efficacy
80
85
90
95
CRI
CEC flag
non-CEC
CEC

INTERIM RESULTS

Maintenance Testing to Date


1.0
0.9
pct
0
250
500
750
1000
1250
countHours
lampT_Fix
A-LAMPC
A-LAMPD
A-LAMPR
A-LAMPU
GLOBED
GLOBEU
SPOTLIGHT/REFLECTORD
SPOTLIGHT/REFLECTORR
SPOTLIGHT/REFLECTORU
TORPEDO/BULLETC
TORPEDO/BULLETD
TORPEDO/BULLETU
TRIM KITR


1.00
0.99
0.98
0.97
0.96
0.95
pct
0
250
500
750
1000
1250
countHours
CEC_Flag
CEC
non-CEC

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Current Take-Aways

- Rated values for photometric performance seem accurate
  - Lumens, power, efficacy, CCT, CRI, etc.
- Evidence of strong CRI vs. efficacy trade off
- Experimental design seems to be working well:
  - “Real world” thermal conditions replicated in controlled, laboratory environment
  - Documented range of lamp and air temperatures lamps experience in these conditions (for most common fixture types)
  - Significant amount of lamp failures with several months of testing remaining
- Much too early to make any definitive conclusions

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Looking Ahead

- Maintenance testing will run at least another 6 months
  - More complete picture of failure trends/patterns
- Second round of photometric testing following maintenance tests
  - Assessment of lumen depreciation
- Complete set of test data may ultimately yield a variety of useful outcomes beyond CPUC's core research objectives including:
  - Screening tests for premature failure
  - Updates to existing temperature testing requirements (e.g. Energy Star)
  - Info for manufacturers on real-world, near-ambient operating temps
- There may be an opportunity to do post-mortem analysis on failed lamps to better understand the failure mechanisms
  - May also lead to new tests and/or product specifications

THANK YOU

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