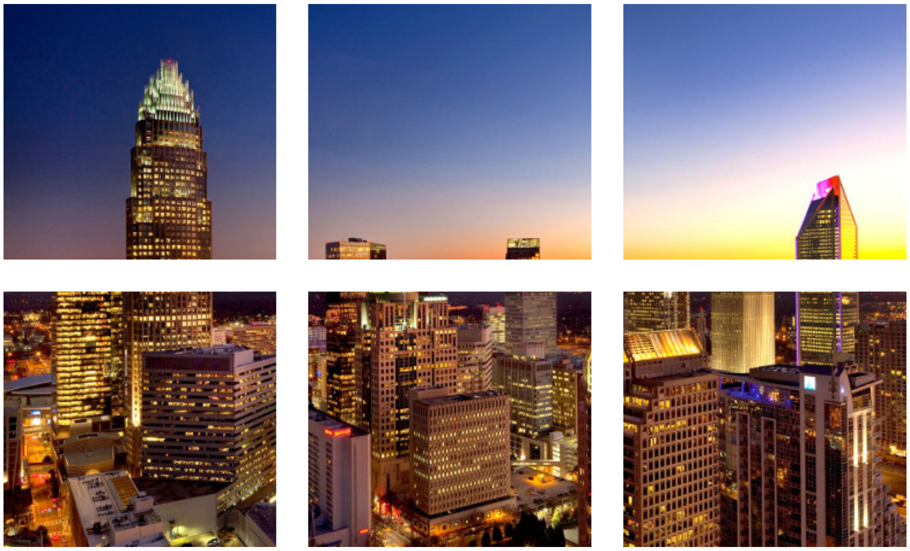

# 2013-2014 Work Order ED_I_Ltg_1:

## LED Lab Test Study Final Report


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# DEFINITIONS

Catastrophic lamp failure – The point at which a lamp ceases to produce any light output.

Cool-down time – The length of time required for lamp temperatures to decrease from their operational steady-state temperature to room ambient temperature after being switched off.

Cycle – One on-period followed by one off-period.

Cycling – The process of repeatedly turning a lamp on and off.

Failure curve – A graph that displays the failure rates as a function of operating hours (also referred to as survival curve).

Failure rate – The percentage of lamps that have failed.

Failure time – The run-time of a lamp at the point of lamp failure.

Final light output – The luminous flux of a lamp at the end of the testing period measured in lumens.

Initial light output – The luminous flux of a lamp before usage or seasoning measured in lumens.

Lamp failure – The point at which a lamp ceases producing any light output or displays flickering, flashing, and other behavior that does not provide steady useful light.[1]

Light output – See luminous flux.

Lumen depreciation – The decrease in the luminous flux of a lamp at a given time expressed as a percentage of that lamp's initial light output, e.g., a lamp with a lumen maintenance value of 70% will have experienced a lumen depreciation of 30%.

Luminous efficacy – The luminous flux of a source divided by the source's power, measured in lumens per watt.

Lumen maintenance – The luminous flux of a lamp at a given time expressed as a percentage of that lamp's initial light output, e.g., if a lamp with an initial light output of 1,000 lumens generates only 700 lumens after 4,000 hours of operation, it will have lumen maintenance of 70% at 4,000 hours.

Lumen output – See luminous flux.

Luminous flux – The total amount of visible light generated by a light source, measured in lumens (lm); also known as light output or lumen output).

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[1] This definition of lamp failure does not include excessive lumen depreciation (e.g., if a lamp is still providing any measurable light, it was not considered to have failed).

95% thermal stability – The point when a lamp has experienced 95% of the necessary temperature increase after switching on or decrease after switching off to reach thermal stability.

Rated life – The expected lamp life as specified by the manufacturer.

Run-time – The total amount of time a lamp has been operated for, i.e., the sum of all the lamp's on-periods.

Thermal cycling – Cycling using switching cycles long enough to allow lamps to achieve full or near thermal stability both at the end of the on-period and the off-period.

Thermal stability – The point when a lamp reaches its maximum temperature during an on-period or its minimum temperature during an off-period.

Survival rate – The percentage of lamps that are still operational.

Switching cycle – A protocol in which lamps are repeatedly turned on for a defined period of time and then turned off for a defined period of time.

Switching frequency – The specific on-times and off-times that are utilized by a switching cycle.

Warm-up time – The length of time required for lamp temperatures to increase from room ambient temperature to their operational steady-state temperature after being switched on.

# 1 EXECUTIVE SUMMARY

## 1.1 INTRODUCTION

This report documents the results of a large-scale laboratory test of the performance of light-emitting diode (LED) lamps. Itron conducted this study as part of the California Public Utilities Commission (CPUC) Energy Division (ED) Evaluation Measurement & Verification *Work Order ED_I_LTG_1: LED Lab Test Study*.

The primary objective of this study was to assess the effect of two common, temperature-related stress conditions on LED performance and longevity. This objective reflects a critical first step in meeting the CPUC's and its stakeholders' longer-term objective to assess the full suite of "real world" conditions that impact LED reliability and performance. From this perspective, the study was also designed to provide the data necessary to develop adjustments to the effective useful life (EUL)[2] assumptions for LED lamps included in California's investor-owned utilities' energy efficiency portfolios.

## 1.2 BACKGROUND

LED lamps have seen explosive market growth in recent years and now are the primary lighting technology promoted in utility program portfolios across the country, including California. The high efficacy[3] and longer life combine to promise attractive lifecycle cost savings of LED lamps over less efficient alternatives. However, significant uncertainties exist with respect to actual, average LED lamp life in real-world applications. These uncertainties stem primarily from the fact that current standardized tests focus on gradual decreases in light output as the primary measure of LED lamp life and do not directly account for early catastrophic failures due to heat, humidity, vibration, voltage fluctuations, and other real-world stress conditions. Consequently, both regulators and utility program administrators are increasingly wary of repeating the customer experience problems that occurred with the early generations of compact fluorescent lamps (CFLs) – particularly with respect to LED reliability.

In addition to this market context, there is also important programmatic context specific to California in the form of the *Voluntary California Quality LED Specification* (CA Quality Spec). The California Energy Commission (CEC) adopted this specification in late 2012 to establish performance standards to help identify and promote high quality LED lamps and avoid the customer-perception issues that impacted

[2] Effective useful life is the average number of years a given piece of equipment is likely to remain in service.

[3] Efficacy describes the energy efficiency of light sources in terms of the amount of light output (measured in lumens) per unit of input power (measured in watts).

CFLs.[4] In turn, the CPUC issued a decision (D.12-05-015) as part of the larger energy efficiency proceeding (R.09-11-014) that required the LED products offered through the investor-owned utilities' (IOUs) programs to be compliant with the CA Quality Spec starting in January 2014. Despite the intent of the CA Quality Spec, however, the CEC and the CPUC both acknowledged a host of on-going uncertainties with respect to assessing LED reliability in the field and customer perceptions of CA Quality Spec-compliant products.

## 1.3 OBJECTIVES

As part of the 2013-2014 EM&V Roadmap for Lighting, the CPUC specified the following over-arching research questions that were to be addressed by the LED Lab Study:

- How does switching LED lamps on/off impact the life and performance of the LED lamps?
- Are the manufacturers' specifications of LED rated life[5] accurate?
- Are the IOUs' LED workpaper assumptions properly stated?

We then attempted to refine these high-level research questions into a more specific set of research objectives around which we could develop a coherent experimental design, sample design, and analysis plan. With significant participation from relevant California and national stakeholders, we developed a research plan designed to assess the impacts of the stress conditions most prevalent in residential homes and, simultaneously, the most tractable to evaluate in a laboratory setting. These stress conditions were high operating temperature and on-off switching patterns that cause lamps to repeatedly fully heat up and then fully cool down (often referred to as "thermal cycling"). Importantly, these two stress conditions could be investigated in a laboratory setting using a limited number of experiments, which allowed the test to be administered to a large, representative sample of lamps. Given this assessment, the specific research objectives for this study were:

- To assess the effect of temperature and switching patterns on efficacy, color quality, effective useful life, etc.; and
- To assess differences in performance between California Quality Spec-compliant LED lamps with the non-compliant competitors.

[4] The CA Quality Spec builds directly off the current ENERGY STAR product specifications, except for higher standards for Color Rendering Index (CRI), warranty, dimmability, power factor, and noise. The CA Quality Spec does not include any additional certification or reliability testing beyond that required for ENERGY STAR.

[5] Rated life is a manufacturer's estimate of the number of years (or hours) that an LED lamp will remain in service.

## 1.4 APPROACH

The overall experimental design developed for this study focused on evaluating the impact of the ambient temperature conditions typically found in homes on LED lamp life. To do this, we followed the industry-standard testing procedures defined in the Illuminating Engineering Society's (IES) LM-84 with two key exceptions: 1) rather than testing lamps in bare sockets, lamps were tested in a variety of actual luminaires (i.e., light fixtures); 2) rather than operating lamps continuously, lamps were repeatedly switched on and off such that lamps could repeatedly fully heat up and then fully cool down.[6]

For our experiment, test lamps were operated in three common residential luminaire types: recessed downlights, ceiling fixtures, and bare sockets. These three luminaire types account for nearly two-thirds of the installed residential lighting fixtures in California according to the 2012 California Lighting and Appliance Saturation Survey (DNV GL, 2014). For each lamp model-luminaire combination, we tested three samples of the same model.

The overall experiment was composed of the following three main testing elements:

- **Thermal testing**. Each test unit was placed in its assigned luminaire type and was operated for a warm-up period of at least 12 hours and then and cool-down period of at least 12 hours. The temperature of a characteristic spot on the test lamp was measured and recorded at 1-minute intervals. These data were needed in order calculate the switching cycles to be used for the longer maintenance test.

- **Photometric testing**.[7] Following the thermal tests, test lamps were removed from the luminaires and placed a light measurement device (known as an integrating sphere) and tested according to IES LM-79.[8] All photometric tests were repeated on all surviving test units at the end of the experiment to assess changes in lumen output, color temperature, and other performance metrics.

- **Maintenance testing**. Following the initial photometric tests, all test units were placed in test luminaires and "maintenance testing" was initiated where lamps were switched on and off according to the lamp-temperature profiles established from the thermal testing. The maintenance testing was initiated in February 2016 and ran through April 2017.

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6 IES LM-84 is the current industry testing standard for producing rated values of lumen maintenance over time for LED lamps. It is important to note that rated life values are currently based exclusively on estimates of lumen depreciation, i.e. the average time required for the lumen output of an LED lamp to decrease to 70 percent of its initial output.

7 "Photometrics" is a general term used to describe the various units used to measure and describe light. The specific photometric and electrical measurements included in IES LM-79 are: power input, lumen output, power factor, total harmonic distortion, color rendering index (CRI), and correlated color temperature (CCT).

8 IES LM-79 is the current industry testing standard for measuring and verifying the rated photometric and electrical performance of LED lamps.

In order to support the research objectives, we developed a sample of specific LED lamp models that was designed to be representative of the market in California at that point in time. Using the latest market data available from the California Retail Shelf Survey,[9] we identified 92 models with the highest market shares in California that also allowed comparative analysis of CA Quality Spec, ENERGY STAR®, and non-ENERGY STAR cohorts of products. At the request of the IOUs, our sample also included 13 models of recessed downlight retrofit kits (sometimes called trim kits). It should be noted, however, that the trim kit models included in our testing were limited to those being offered in the IOUs' programs at the time and were not necessarily representative of the larger trim kit market in California.

Following the conclusion of the maintenance testing and second round of photometric testing, most of the failed test lamps were sent to a second laboratory for post-mortem forensic analysis. The objective of the post-mortem analysis was to determine the exact point of failure, wherever possible, for each lamp that failed during maintenance testing and how those failure points were or were not related to elevated operating temperature and/or switching patterns.

## 1.5 KEY RESULTS

The key empirical results from each element of our overall testing experiment are summarized below.

- **Initial photometric testing**:
  - Measured values of lighting performance were largely consistent with rated values.
  - Where deviations from rated values occurred, these deviations were mostly in the preferable direction from an energy efficiency point of view, i.e., lower power, higher output, higher efficacy, etc.
  - On average, the measured efficacy of CA Quality Spec lamps was 20% lower compared to that of non-CA Quality Spec lamps (62 vs. 77 lumens/W).
- **Maintenance testing**:
  - 24% of the units tested (160 out of 666) either failed catastrophically or exhibited "pre-failure" behavior within a maximum of 4,500 hours of total on-time.[10]
  - Failure rates were highest among A-lamps (38%),[11] while failure rates for globe, torpedo, and reflector lamps were comparatively lower (between 9% and 12%).

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[9] DNV GL (2015), "2015 California Retail Lighting Shelf Survey." Prepared for the CPUC.

[10] Examples of "pre-failure" conditions are severe flickering and dramatically reduced light output (i.e. <70% rated lumen output). From a consumer perspective, we believe it is reasonable to treat such pre-failure lamps as equivalent to lamps that have catastrophically failed, since it is likely that consumers would replace such lamps as soon as pre-failure behavior manifests itself.

[11] A-lamps are the most common type of screw-based general service lamp, known for their pear-like shape.

- None of the trim kits tested failed catastrophically or exhibited "pre-failure" behavior.
- Two-thirds of all failures came from 12 specific models that performed particularly poorly.

- **Final photometric testing**:
  - Only 8 of the test lamps (1.5%) that survived maintenance testing experienced decreases in light output of 30% or more.
  - Only 12 of the test lamps (2.2%) that survived maintenance testing experienced changes in color temperature that might be considered noticeable/objectionable.
- **Post-mortem forensic analysis**:
  - The most common points of failure were related to contact failures from poor or degraded solder connections that were consistent with high heat operation and repeated expansion and contraction due to operating temperature changes from switching.

Overall, the results produced by this study provide strong evidence that two stress conditions commonly found in residential homes – elevated operating temperature and on-off switching – are indeed significant stress conditions that can lead to early catastrophic failures in LED lamps. Our results also show that a significant portion of observed failures were concentrated in a few specific lamp models. A post-mortem forensic analysis of these failed lamps indicated that the most common points of failure were related to contact failures from poor or degraded solder connections that were consistent with high heat and repeated thermal expansion and contraction due to switching. Taken together, these findings suggest that the current industry testing standards for LED lamps either do not adequately address two common field conditions (i.e., operating temperature and switching patterns) and/or that certain models have latent manufacturing defects that are exposed as a result of our experimental design. The corollary to this is that we believe the results from this study indicate a distinct opportunity to augment or supplement current standardized performance tests with short-run reliability tests focused on temperature-related early failure modes that could help detect the type of poor-performing models identified in this study.

## 1.6 RECOMMENDATIONS

With these key findings in mind, we offer the following recommendations designed to build upon the key findings and address the key uncertainties from this study.

**Temporal analysis of failure data.** We believe that it is critical to explore the extent to which it may be possible to use failure rates observed over relatively short time scales (e.g., 1,000-2,000 hours) to reasonably project failure rates over longer time scales. Specifically, the objective of such an analysis would be to determine how much total on-time and/or switching is required to be able to reasonably project the failure rates that we observed through 4,500 hours of total on-time.

**Leverage the upcoming In-Home Lighting Inventory and Metering Study to address major assumptions and primary data gaps**. The key uncertainties in this study are all related to a lack of specific types of primary data. We believe that it would be possible to address these primary data gaps by expanding the scope of the upcoming In-Home Lighting Inventory and Metering Study to include:

- Detailed descriptive data on the installed stock of residential lighting fixtures and luminaires;
- Measurement of LED lamp operating temperatures in the field; and
- Detailed data on switching patterns by fixture type and room type.

**Develop formal adjustments to the reported EULs for LED lamps in IOU programs**. Despite the key uncertainties in this study, we believe that the data generated by our testing experiment and the data currently available from the 2012 California Lighting and Appliance Saturation Survey (CLASS) would enable a reasonable survival analysis to be conducted immediately.[12] Indeed, SCE staff conducted a survival analysis for CFLs using the results of the previous CFL Lab Test Study and the logger data from the 2008 CLASS. We recommend that the CPUC conduct a survival analysis for LED lamps based on the same approach. If and when primary data from the upcoming In-Home Lighting Inventory and Metering Study become available, this survival analysis can be updated. However, given the highly dynamic nature of the LED market and LED programs in California, we do not recommend delaying a formal survival analysis.

## 1.7 CONTACT INFORMATION

The ED Project Manager for this study was Mr. Jeorge Tagnipes. Itron served as the Prime Contractor managing this study, led by Mr. Mike Ting. Erik Page (Erik Page & Associates) was the lead investigator as a subcontractor to Itron. The contact information for Mr. Tagnipes, Mr. Ting, and Mr. Page is provided below.

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[12] Survival analysis refers to a kind of statistical analysis where the variable being modeled is the time until the occurrence of an event of interest (e.g. product failure).

# 2 INTRODUCTION

In this section, we provide a brief overview of the background and context for this study, which directly informed the research objectives and approach. Additional details are available in the Research Plan.[13]

## 2.1 BACKGROUND

During the 2010-2012 EM&V cycle, the CPUC and Southern California Edison (SCE) funded a large-scale laboratory test of Compact Fluorescent Light (CFL) lamps in order to address uncertainties in estimates of CFL rated life (and therefore lifecycle energy savings and cost-effectiveness). Specifically, the CFL lab test study focused on quantifying the relationship between switching cycles and CFL lamp life.

As part of the 2013-2014 EM&V Roadmap for Lighting, the CPUC set aside $500,000 to conduct an analogous study focusing on Light Emitting Diode (LED) lamps to address the same set of core questions, specifically:[14]

- How does switching LED lamps on/off impact the life and performance of the LED lamps?
- Are the manufacturers' specifications for LED effective useful life accurate?
- Are the IOUs' LED workpaper assumptions properly stated?

In addition to this, the CPUC also expressed the following high-level objectives that this LED lab test study should be designed to address:

- Generate results that can help inform updates to ex ante estimates of effective useful life (EUL) and energy savings impacts for LED replacement lamps
- Generate results that can help inform the design and evaluation of IOU upstream lighting programs for LED replacement lamps
- Generate results in the near-to-midterm (6-12 months) in order to inform 2016 program offerings and maintain pace with a rapidly evolving LED market

The dynamic nature of the LED lamp market must be taken into account when designing a large-scale lab test in order to avoid or minimize the prospect of testing products that are no longer available by the time

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13 Available at: http://www.energydataweb.com/cpucFiles/pdaDocs/1275/LED_Lab_Test_Study_Public_Final_Research_Plan_WithAppendices.pdf

14 http://www.cpuc.ca.gov/NR/rdonlyres/7350FF48-9AFC-449E-8AD2-19E520E2A7F5/0/20132014_EMV_EvaluationPlan_v4.pdf

the study is completed. The LED lamp market has been evolving and expanding rapidly over the last decade. Shipments of omnidirectional LED lamps grew by a factor of 50 from 2008 to 2012, and shipments of directional LED lamps grew by a factor of nearly 100 over the same period.[15] At the same time, the luminous efficacy of LED replacement lamps (lumens per watt) has steadily increased (from an average of 40 lm/W in 2008 to 65 lm/W in 2012), and average prices have steadily decreased (from $250/klm in 2008 to $40/klm in 2012). These trends are expected to continue going forward, with average prices expected to drop by another 50% over the next two years and average lamp performance expected to exceed 200 lm/W by 2020.[16] Further complicating this issue is the fact that the rated useful life of LED replacement lamps is significantly longer than analogous CFL lamps – typically 25,000 hours or longer – which adds to the tension between the time needed to design and execute a large-scale lab test and the dynamic nature of the LED market.

In December 2012, the California Energy Commission (CEC) adopted the *Voluntary California Quality LED Specification* (CA Quality Spec) that established performance standards to help identify and promote high quality LED lamps.[17] The impetus behind the development and adoption of the CA Quality Spec was born directly from California's collective experience with compact fluorescent lamps (CFLs), where public perceptions of CFLs were severely tainted by early customer experiences with poor product quality, e.g., light color, flicker, noise, lack of dimmability, and early failure.[18]

Industry-standard tests promulgated by the Illuminating Engineering Society (IES) focus on measurements of photometric performance (LM-79-08) and lumen maintenance over time (LM-80-08 and LM-84-14). LM-79 provides a wide range of photometric performance data (e.g., lumen output, luminous efficacy, color temperature, color rendering index, etc.) on a snapshot basis. LM-80 focuses on producing standardized measurements of lumen maintenance of LED packages, arrays, and modules over time, which can then be used to estimate and verify total useful life using a projection formula developed and published by IES in 2011 (TM-21-11). The recently adopted LM-84 is similar to LM-80 but includes LED lamps and luminaires in its scope, recognizing that components in these systems other than the LED light sources may also impact lumen maintenance. IES has also recently released TM-28-14 which provides methods for projecting lumen maintenance for LED lamps and luminaires based on LM-84 test results.

The IES procedures and methods are critical for defining uniform test conditions so that results from different laboratories and of different light sources can be fairly compared. But "real-world" operating conditions can vary significantly from IES defined test conditions and these variations can have significant

15 http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/led-adoption-report_2013.pdf

16 http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_trend-analysis_2013.pdf

17 http://www.energy.ca.gov/2012publications/CEC-400-2012-016/CEC-400-2012-016-SF.pdf

18 The CA Quality Spec builds directly off the current ENERGY STAR product specifications, except for higher standards for Color Rendering Index (CRI), warranty, dimmability, power factor, and noise. The CA Quality Spec does not require any additional certification or reliability testing beyond that required for ENERGY STAR.

impacts on LED lamp performance. It is also important to note that total useful life estimates that are derived from LM-80 and TM-21 as well as LM-84 and TM-28 strictly reflect estimated lumen maintenance levels over time and do not reflect any standardized testing or estimates of catastrophic failure rates.

## 2.2 STUDY OBJECTIVES

Given the market, regulatory, and programmatic contexts summarized above, we then attempted to refine the high-level objectives set forth by the CPUC in the 2013-2014 EM&V Roadmap for Lighting into a more specific set of research objectives around which we could develop a coherent experimental design, sample design, and analysis plan.

At the highest order, the research objectives must be achievable within the total budget and time constraints defined for this study. Specifically, this translates into a total scope of effort that cannot exceed the available budget and generates results that could inform 2016 program offerings.

Secondly, we have a clear obligation to focus the research objectives on assessing the performance of CA Quality Spec-compliant products against their non-compliant competitors in order to align our efforts with the regulatory and program environment in California.

Third, there was a strong consensus across the IOUs, the CEC, and other LED industry stakeholders around the need for stress testing LED lamps in conditions beyond those reflected in current industry-standard tests in order to identify conditions that cause early/catastrophic failure. The specific stress conditions identified by stakeholders and in the research literature as potentially important were temperature, humidity, switching patterns, voltage, vibration, and interactions with controls (particularly dimmers).

Given this consensus, we then assessed the scope of stress testing that could be feasibly executed within the budget and time constraints of this study. This assessment indicated that the authorized budget could support either a stress test focused on one variable (e.g., temperature) across a large, representative sample of lamps or a broader set of experiments across a much smaller sample of lamps. The tradeoff we face, therefore, is between generating a narrow, focused set of results based on representative samples and generating a wider range of results based on small, anecdotal samples.

When viewed through the lens of the larger body of LED research, conducting a large-sample test of narrowly-defined stress conditions would complement small-sample, more extreme/multi-dimensional stress testing recently done/being done by the USDOE's Commercially Available LED Product Evaluation and Reporting (CALiPER) program, the Lighting Research Center at Rensselaer Polytechnic Institute, and the California Lighting Technology Center, and others. When viewed through the lens of IOU programs in California, conducting a large-sample test of narrowly-defined stress conditions would allow the IOUs and the CPUC to use the results of the tests to make regulatory and program design decisions with more certainty over the immediate term than a small-sample test of more widely-defined stress conditions where follow-on tests (and funding) would likely be required to establish statistical validity.

We also attempted to assess which stress condition (among those identified by stakeholders) is most prevalent in residential homes in California and also most tractable to evaluate in a laboratory setting. Of the six specific stress conditions identified by stakeholders, we agree with stakeholders that high operating temperature and thermal cycling (due to specific switching patterns) are the two most prevalent stress conditions in California homes and the most tractable to evaluate in a laboratory setting using a limited number of experiments, which would allow the test to administered to a large, representative sample of lamps.

Given the assessments summarized above, the specific research objectives defined for this study were therefore:

- To assess the effect of temperature and switching patterns (thermal cycling) on the performance (efficacy, color quality, useful life, etc.) of a representative sample of LED replacement lamps; and
- To assess differences in performance (under the test conditions above) between CA Quality Spec-compliant LED replacement lamps and their cheapest, non-Spec competitors.

## 2.3 ROADMAP TO REST OF REPORT

This final report is intended to provide the CPUC and its stakeholders with documentation of the testing procedures, test sample, and data collection methods used in the study, along with a comprehensive presentation of the laboratory testing results. We also present results from a post-mortem forensic analysis of test lamps that experienced catastrophic failure during our stress testing regime.

The remainder of this report is organized as follows:

- Section 3 provides an overview of the experimental design and provides details about the specific testing procedures and data collection methods used in the study.
- Section 4 provides an overview of the sample design used to determine the specific models tested in the study, the procurement process used to acquire those models, and the steps taken to prepare units for testing.
- Section 5 presents the key results from the laboratory testing, along a summary of the results from the post-mortem analysis.
- Section 6 provides a discussion of the key findings from the study and identifies areas for follow-on research.

# 3 EXPERIMENTAL DESIGN & SETUP

In this section, we provide an overview of the experimental design developed for this study and provide details related to the specific laboratory testing and data collection procedures that were implemented.[19] The laboratory tests were implemented by Independent Testing Laboratories, Inc.

## 3.1 EXPERIMENTAL DESIGN OVERVIEW

In field application, LED lamps can be expected to experience variations in operating conditions that differ from conditions defined by the IES test procedures utilized to develop "rated values" of LED lamp life and performance. While these variations between laboratory conditions and field condition may impact LED lamp life and performance, these relationships are largely undocumented. Significant knowledge gaps remain concerning how much operating conditions typically vary between laboratory conditions and field conditions, which operating conditions are most likely to see variation and in turn impact lamp life and performance, and how much variability exists between specific LED lamp models in terms of resiliency to changes in operating conditions.

***Note on CPUC-funded vs. IOU-funded testing scope:*** The study team developed the experimental design and sample design presented here with a sole focus on screw-based LED lamps, per the priorities communicated by Energy Division staff. However, while the study team was contracting with the testing facility, the IOU program tracking data from Q1 2015 indicated that LED recessed downlight retrofit kits ("trim kits") were beginning to account for a larger share of IOU portfolio claims than anticipated. The electric IOUs (PG&E, SCE, and SDG&E) expressed a strong interest in including a sample of LED trim kits in the testing regime already developed for screw-based LED lamps and provided separate funding to cover the associated increase in testing and analysis scope. In this sense, it should be understood that the experimental design and test procedures were not modified for the addition of trim kits to the test sample. Similarly, the sample of trim kits that were tested are only reflective of the products currently offered through IOU upstream programs and are not intended to be representative of the larger LED trim kit market in California.

Based on stakeholder feedback and research into the parameters most likely to impact LED lamp life, our experiment focused on evaluating the impact of the thermal conditions typically found in residential applications. Specifically, we looked at the impact of high heat and thermal cycling on LED lamps according to the operation conditions defined in IES LM-84, except as specified in the section below. LED lamps were operated at elevated temperatures and with near-full thermal cycling (due to switching patterns) for extended periods of time.

In order to achieve elevated temperatures typical of residential applications, test lamps were operated in three common residential luminaire

[19] Additional background and rationale behind the experimental design is provided in the Final Research Plan: http://www.energydataweb.com/cpucFiles/pdaDocs/1275/LED_Lab_Test_Study_Public_Final_Research_Plan_WithAppendices.pdf

types: recessed downlights, ceiling fixtures, and bare sockets (see Figure 3-1). These three luminaire types account for nearly two-thirds of the installed residential lighting fixtures in California according to the 2012 California Lighting and Appliance Saturation Survey (DNV GL, 2014). Because of their design and expected normal application, some LED lamp types were only tested one or two luminaires. For example, reflector LED lamps were tested in recessed downlights and bare sockets but not in enclosed fixtures because their field application in enclosed fixtures is considered unlikely.[20] For each lamp model-luminaire combination, we tested three samples of the same model.

**FIGURE 3-1: EXAMPLES OF RECESSED DOWNLIGHTS (LEFT), ENCLOSED CEILING FIXTURES (MIDDLE), AND BARE SOCKETS (RIGHT)**

The overall experiment was composed of the three main elements: thermal testing, photometric testing, and maintenance testing. Each of these testing elements is described in more detail in Section 3.2, 3.3, and 3.4, respectively. Before that, however, we present more detail and documentation related to the luminaires used in the overall testing regime.

### 3.1.1 Recessed Downlight

This application accounts for the vast majority of reflector lamp applications, as well as 10% of A-lamp LED applications in California Homes.[21] This application represents the some of the most extreme temperature conditions and also has significant operating hours. With the exception of the 4” retrofit kits, all lamps and retrofit kits tested in recessed downlights were operated in in Halo H7UICAT recessed downlights.[22] The 4” retrofit kits were operated in Halo EI400ATSP recessed downlights. Downlights were

[20] It should be noted that some LED lamps are explicitly labeled by their manufacturers as not being compatible with enclosed fixtures. However, we chose not to use this compatibility information as a criterion for determining the lamp model-luminaire combinations to test. This choice is related primarily to the likelihood that such compatibility information is not always followed by consumers. As such, we wanted to explicitly evaluate the performance of these LED lamps in “incompatible” luminaires.

[21] See http://www.calmac.org/publications/WO13_CA_Res_Ltg_Mkt_Status_Report_-_FINALES.pdf

[22] These are the luminaires used in ENERGY STAR’s Elevated Temperature Life Test: Option A.

covered with 3” of fiberglass insulation in a lamp maintenance facility where ambient temperatures were controlled at 25°C ± 5°C. No accessories (e.g., reflectors, trims, etc.) other than the test lamps themselves were installed in the downlight housings. For each A-lamp, reflector lamp, and downlight retrofit kit model included in the test, three units of each model were tested in recessed downlights. In total, 246 lamps/retrofit kits representing 82 models were tested in recessed downlights.

### 3.1.2 Enclosed Ceiling Fixture

Along with wall-mount luminaires, this application is the most popular for A-lamp replacement lamps. Ceiling fixtures were selected for use in this test rather than wall fixtures because the temperatures were expected to be higher. The enclosed ceiling fixtures used in this test had a diameter of 6” and a height of 7.5” (Westinghouse model #6660700). The fixtures were installed in a lamp maintenance facility where ambient temperatures were controlled at 25°C ± 5°C. For each A-lamp and medium screw base torpedo/bullet model included in the test, three units of each model lamps were tested in enclosed ceiling fixtures. In total, 144 lamps representing 48 models were tested in enclosed ceiling fixtures.

### 3.1.3 Bare Socket

The last “luminaire type” is not a luminaire at all but rather a bare socket. This application was selected because it can serve as a good proxy for table and floor lamps as well as non-enclosed ceiling and wall mounted luminaires. This application would also represent the lowest temperature application that LED lamps might be expected to operate in. Roughly half of the bare sockets in the test were oriented base down (i.e., matching the orientation of floor lamps and table lamps), and half were oriented base up. The bare sockets were installed in a lamp maintenance facility where ambient temperatures were controlled at 25°C ± 5°C. For each A-lamp, reflector lamp, globe, and torpedo/bullet model included in the test, three units of each model were tested in bare sockets. In total, 276 lamps representing 92 models were tested in enclosed ceiling fixtures.

## 3.2 THERMAL TESTING

In order to assess the impact of thermal cycling, it was first necessary to determine the time required for test lamps to achieve thermal equilibrium after they were turned on or off through an initial set of thermal testing. These data were needed in order calculate the switching cycles to be used for the longer maintenance test. In selecting switching cycles, our goal was to select warm-up and cool-down times that were long enough to allow lamps to at least reach 95% of their steady-state operating temperature while also trying to maximize the total number of thermal cycles and total on-time per day.

Each test sample was placed in its assigned luminaire type and switched on for a period of at least 12 hours and then switched off for a period of at least 12 hours. The temperature of a characteristic spot on the surface of the test subjects was measured and recorded continuously at 1-minute intervals. The location of the thermal measurement spot varied slightly from between lamp models based on their shapes and sizes. However, the usual measurement point was at the midpoint of the section of the lamp that housed the lamp driver and associated electronics. The axial location of the temperature measurement spot was selected randomly (i.e., we did not attempt to identify and select the hottest side of the lamp). Figure 3-2 shows photographs of the thermal testing of recessed downlights and enclosed ceiling fixtures.

**FIGURE 3-2: THERMAL TESTING IN RECESSED DOWNLIGHTS (LEFT) AND ENCLOSED CEILING FIXTURES (RIGHT)**

In approximately 15% of thermal tests, a second temperature measurement of the air ambient temperature near the test subject was also recorded. Figure 3-3 shows a photograph of a near-ambient air measurement in bare sockets (base up and base down). The vast majority of near ambient measurements were conducted in recessed downlights and enclosed ceiling fixtures, and lamps were selected based on the results of their measured temperature profiles in order to capture a wide and representative range of operating temperatures. Several models were tested in all luminaire types (including bare sockets).

**FIGURE 3-3: NEAR-AMBIENT TEMPERATURE MEASUREMENT IN BARE SOCKETS**

Figure 3-4 shows a curve of the warm-up and stabilization of one of the lamps included in the test as characterized during the thermal test. This lamp experienced temperature change of 46°C at the measurement spot on its surface, rising from room temperature of 25°C to a maximum temperature of 71°C after 80 minutes. This lamp experienced 95% of this temperature increase (to 69°C) after 37 minutes. This test indicates that this lamp could be put on a switching cycle with a warm-up time of 37 minutes or longer. This allows the lamp to achieve a near-full warm up while doubling the number of thermal cycles we could subject the lamp to compared to an approach requiring 100% thermal stability.

**FIGURE 3-4: EXAMPLE OF LED LAMP THERMAL STABILIZATION CURVE DURING WARM-UP**

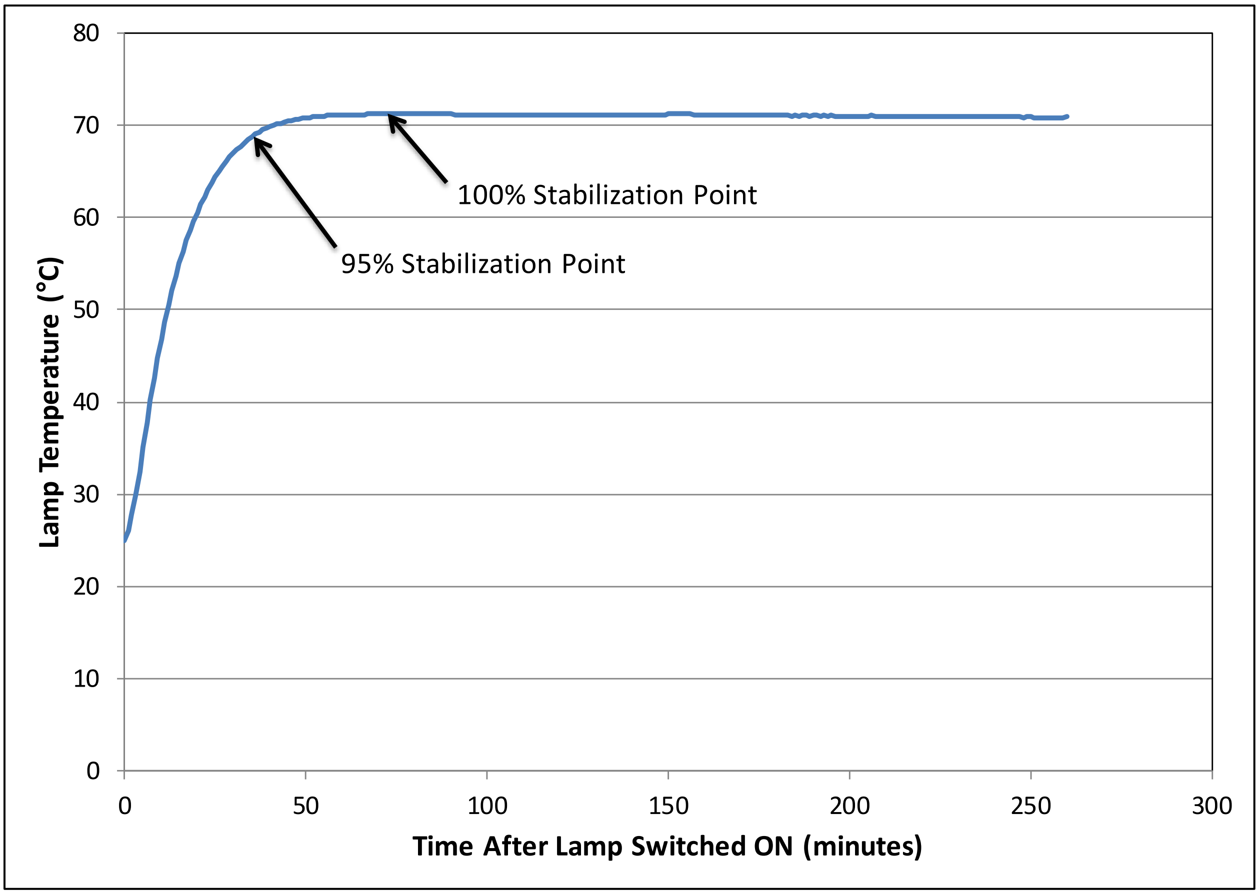
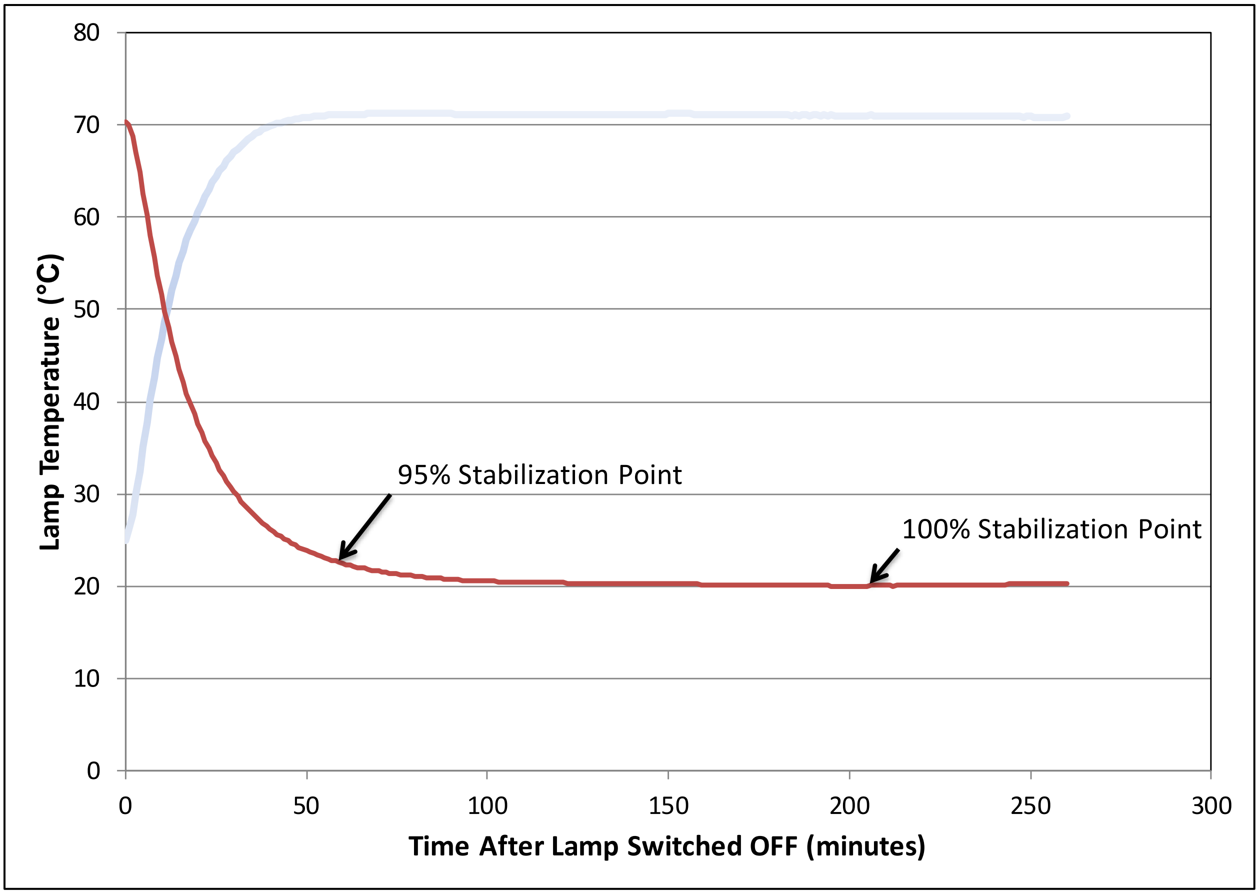


Figure 3-5 shows the cool-down for this same LED lamp after the lamp is turned off. The lamp experienced temperature change of 51°C at the measurement spot on its surface, dropping from a maximum temperature of 71°C to a room temperature of 20°C after 205 minutes.[23] However, the lamp experienced 95% of this total temperature decrease (to 23°C) after 60 minutes.

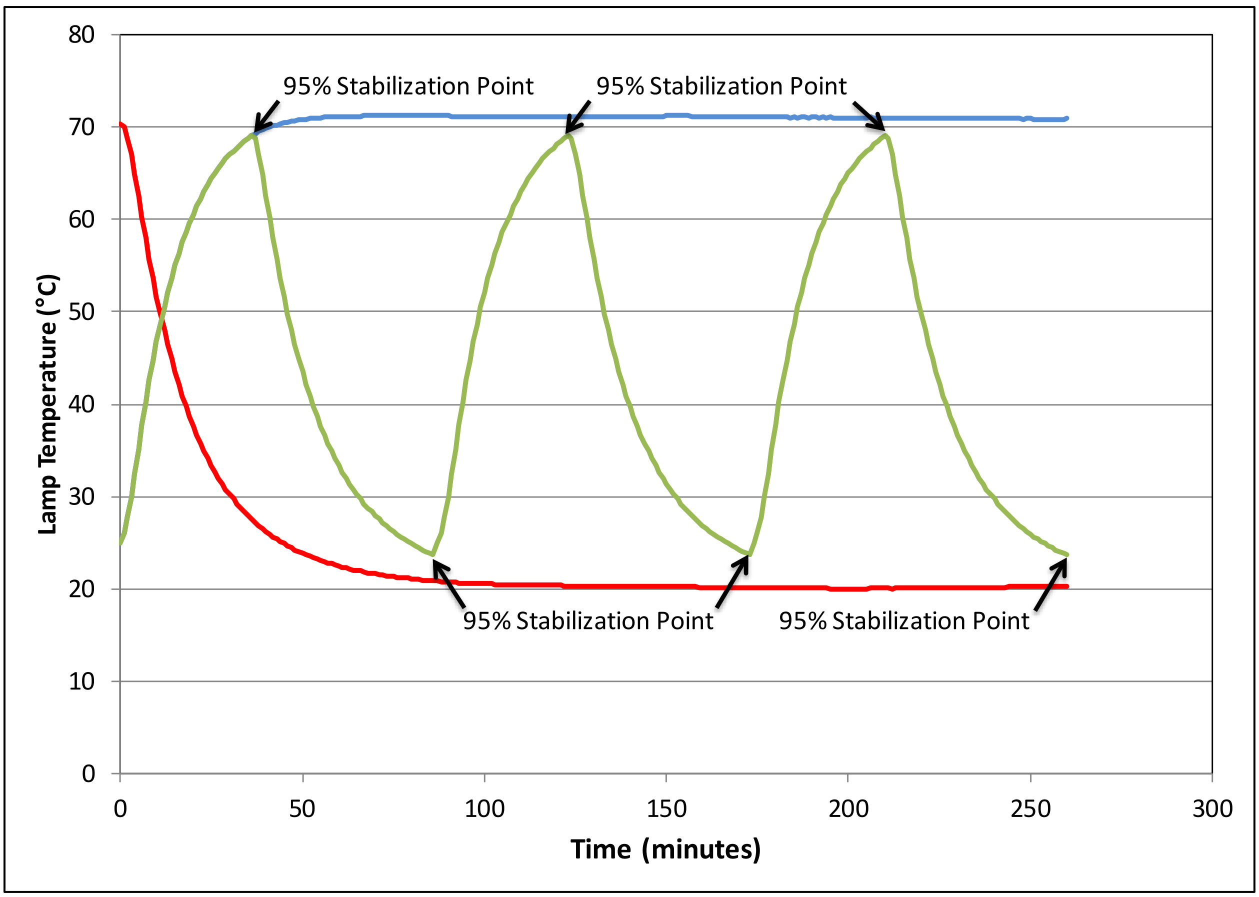
**FIGURE 3-5: EXAMPLE OF LED LAMP THERMAL STABILIZATION CURVE DURING COOL-DOWN**




[23] The room temperature was maintained at 25°C +/- 5°C. In this example, the warm-up period was during the daytime hours when ambient temperatures in the test facility were at 25°C while the cool-down period was during nighttime hours when the ambient temperatures in the test facility dropped to 20°C.

Figure 3-6 adds a green line on to the warm-up and cool-down plots from Figure 3-4 and Figure 3-5 to illustrate what a switching cycle for this lamp may look like in our experimental design. The lamp would be turned on for 37 minutes until it reached 95% of its steady-state operating temperature and then turned off for 60 minutes to allow it to cool down to near room temperature. In this example, a “complete” warm-up and cool-down cycle would take 98 minutes, allowing this lamp to be thermally cycled 14.7 times a day. Using this approach, we identified the switching cycles that would produce full or near-full thermal cycles for each test lamp. To be clear, the switching cycles established via the thermal testing were designed to maximize the number of thermal cycles that each test lamp could be subjected to over a fixed period of time so that we could assess thermal cycling as a stress condition that leads to catastrophic failure of LED lamps.

**FIGURE 3-6: EXAMPLE OF THERMAL SWITCHING CYCLE FOR AN LED LAMP**



In summary, data collected from the thermal test included the following:

- Profiles of the temperature of a characteristic location on each lamp and retrofit kit during warm-up and cool-down when operated in assigned luminaires. Warm-up and cool-down periods were at least 12 hours long with temperature measurements taken at 1-minute intervals
- Profiles of the air temperature inside the test luminaires for 103 of the test lamps (also at 1-minute intervals over 12-hour warm-up and cool-down periods)
- Calculations of the time required for lamps to reach 95% of their steady-state operating temperature after being switched on (warm-up time) and the time required for lamp temperatures to decrease from their steady-state operating temperature to room ambient temperature after being switched off (cool-down time)

The complete set of thermal test results for each test lamp is provided in Appendix A.

## 3.3 PHOTOMETRIC TESTING

Following the thermal tests, we conducted an initial round of photometric testing on each test lamp. These photometric tests were conducted on bare lamps (i.e., without luminaires) in an integrating sphere according to IES LM-79. The specific photometric and electrical measurements included: power input, lumen output, power factor, total harmonic distortion (THD), color rendering index (CRI), correlated color temperature and (CCT) for each test unit. All photometric tests were repeated on all surviving test units at the end of the experiment to assess changes in lumen output, color temperature, and other performance metrics.

## 3.4 MAINTENANCE TESTING

Following the initial photometric tests, all test units were placed in test luminaires and “maintenance testing” was initiated where lamps were switched on and off according to the thermal cycle timing established from the thermal testing. This varies from the test conditions described in IES LM-84 where lamps are continuously operated at 25°C ± 5°C in open air in bare sockets. Otherwise, all other conditions were identical with those in IES LM-84. The maintenance testing was initiated in February 2016 and ran through April 2017.

Recessed downlights were placed 12” on center from each other, had a least 12” of unobstructed area beneath them, and were covered in 3” of fiberglass insulation to simulate typical ceiling installations (see Figure 3-7). Enclosed ceiling fixtures were installed with a minimum spacing of 24” on center and 18” vertically. Bare sockets lamps were tested in 12"x12"x12" cavities. Half of bare socket lamps were tested in a “base-up” orientation while the other half were tested “base-down.” An automated control and data acquisition system was used to turn test units on and off, as well as to record failure times. Each test unit had a photosensor associated with it and failure times were recorded when these photo-sensors registered a sudden drop in light output without the lamp having been switched off. The failures were confirmed physically with a technician going to the failure location and ensuring the lamp had in fact failed (e.g., that it was not a problem with the photosensor, or that the lamp had not become unscrewed).

The control system used to turn test units on and off had 22 control zones. Each control zone could be programmed with a specific on-time and off-time and all test units on that control zone would then be turned on and off according to these settings. The test units with similar warm-up and cool down characteristics (as measured by the thermal test) were grouped together and placed in the same control zone. In this way, the on-time and off-time of each switching cycle could be defined to be as short as possible. Again, this approach maximized the number of thermal cycles each test unit was subjected to while allowing all test units to reach at least 95% thermal stability. Since the thermal cycle timing for each group was defined so that the test units with the longest warm-up and cool down times were able to reach 95% thermal stability, most lamps were operated for longer periods than were necessary to achieve 95% stability. As shown previously in Figure 3-6, test units on each control zone were repeatedly subjected to warm-up periods and then cool down periods long enough to at least achieve 95% thermal stability. Table 3-1 provides the on-time and off-times of each of the 22 switching cycles, the amount of on-time and number of thermal cycles per day lamps and retrofit kits on these cycles experienced, and the quantities of each luminaire type in each control zone.

**FIGURE 3-7: MAINTENANCE TEST RACKS**

### TABLE 3-1: TIMING AND LUMINAIRE DISTRIBUTION FOR EACH CYCLE ZONE

| Control Zone | On-time (min) | Off-time (min) | On-time per day (hrs) | Number of Luminaires per Control Zone | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Thermal Cycles per day | 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 |
| 12 | 62 | 94 | 9.5 | 9.2 | 0 | 0 | 15 | 0 | 15 |
| 13 | 65 | 87 | 10.3 | 9.5 | 0 | 0 | 34 | 0 | 34 |
| 14 | 51 | 67 | 10.4 | 12.2 | 0 | 0 | 39 | 0 | 39 |
| 15 | 41 | 107 | 6.6 | 9.7 | 24 | 0 | 0 | 0 | 24 |
| 16 | 49 | 81 | 9.0 | 11.1 | 26 | 0 | 0 | 5 | 31 |
| 17 | 38 | 57 | 9.6 | 15.2 | 0 | 18 | 0 | 0 | 18 |
| 18 | 43 | 61 | 9.9 | 13.8 | 0 | 21 | 0 | 0 | 21 |
| 19 | 45 | 67 | 9.6 | 12.9 | 0 | 27 | 0 | 0 | 27 |
| 20 | 54 | 67 | 10.7 | 11.9 | 0 | 24 | 0 | 0 | 24 |
| 21 | 59 | 91 | 9.4 | 9.6 | 0 | 27 | 0 | 0 | 27 |
| 22 | 78 | 109 | 10.0 | 7.7 | 0 | 27 | 0 | 0 | 27 |
| | | | | **Total** | **246** | **144** | **132** | **144** | **666** |

# 4 SAMPLE DESIGN & PREPARATION

In this section, we present an overview of the final sample design used for the LED lab test study, describe the approach used to procure the test samples, and summarize the steps taken to prepare the test samples for the photometric, thermal, and maintenance testing regimes.

## 4.1 SAMPLE DESIGN

As described in more detail in the Research Plan, we assessed the completeness, product detail, and vintage of the three readily available sources of comprehensive LED market share data to determine their respective usefulness as a basis for sample design:

1) The IOUs' standard program tracking (SPT) data (for both the 2010-2012 and 2013-2014 program cycles),
2) The 2014-2015 retail lighting shelf survey (RLSS)[24] data collected by DNV GL as part of the Upstream Residential Lighting Impact Evaluation (WO28), and
3) National shipment data published by the USDOE. Of these three data sources shown, the source with the model-specific detail required to support sample design development for this study was the RLSS data.

Strictly speaking, these data represent the relative availability of different LED lamp products in California, rather than their relative sales volumes. However, in the absence of up-to-date, comprehensive point-of-sales (POS) data for LED lamps, the RLSS data represent the best proxy for relative sales volumes available for purposes of developing a sample design for this LED lab test effort.

Using the 2014-2015 RLSS data, we began defining sample strata as unique combinations of lamp type (i.e., A-lamp, globe, PAR30, PAR38, etc.), base type (medium screw base, GU, etc.), and lumen output. Using these strata definitions, we then examined the relative market shares of each stratum in order to identify the specific strata that account for the majority of LEDs lamps current available in retail stores. These strata are shown in Table 4-1below and accounted for 81% of the total retail availability in California in the winter of 2014 and beginning of 2015.

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[24] https://webtools.dnvgl.com/projects62/crlss/Home.aspx

**TABLE 4-1: SAMPLE STRATA AND THEIR RELATIVE MARKET SHARES IN LATE 2014/EARLY 2015**

| Lamp Type | Reflector Subtype | Base Type | Lumen Bin | Share of CA Market | Share within Lamp Type |
|---|---|---|---|---|---|
| A-LAMP | N/A | MSB (E26) | 201-400 lm. | 2.1% | 4.3% |
| A-LAMP | N/A | MSB (E26) | 401-600 lm. | 15.1% | 31.2% |
| A-LAMP | N/A | MSB (E26) | 601-800 lm. | 13.9% | 28.7% |
| A-LAMP | N/A | MSB (E26) | 801-1,000 lm. | 7.2% | 14.9% |
| A-LAMP | N/A | MSB (E26) | 1,001-1,200 lm. | 3.5% | 7.2% |
| A-LAMP | N/A | MSB (E26) | 1,401-1,600 lm. | 2.8% | 5.7% |
| GLOBE | N/A | MSB (E26) | 201-400 lm. | 2.4% | 31.7% |
| GLOBE | N/A | MSB (E26) | 401-600 lm. | 4.5% | 59.7% |
| TORPEDO | N/A | Candelabra (B10) | 1-200 lm. | 2.7% | 26.9% |
| TORPEDO | N/A | Candelabra (B10) | 201-400 lm. | 7.2% | 71.3% |
| TORPEDO | N/A | MSB (E26) | 201-400 lm. | 2.0% | 51.4% |
| REFLECTOR | BR30 | MSB (E26) | 601-800 lm. | 8.5% | 94.0% |
| REFLECTOR | BR40 | MSB (E26) | 1,001-1,200 lm. | 1.4% | 68.1% |
| REFLECTOR | PAR20 | MSB (E26) | 401-600 lm. | 1.1% | 94.7% |
| REFLECTOR | PAR30 | MSB (E26) | 601-800 lm. | 1.7% | 66.7% |
| REFLECTOR | PAR38 | MSB (E26) | 801-1,000 lm. | 1.4% | 38.8% |
| REFLECTOR | PAR38 | MSB (E26) | 1,001-1,200 lm. | 1.3% | 36.9% |
| REFLECTOR | R20 | MSB (E26) | 401-600 lm. | 2.7% | 99.8% |

In order to support the research objectives summarized in Section 2.2, we developed a sample design of specific lamp models within each sample stratum such that roughly 50% of the models are compliant with the CA Quality Spec and ENERGY STAR-certified, 25% are ENERGY STAR-certified but not compliant with the CA Quality Spec, and 25% are the least expensive, non-ENERGY STAR products available. Within these general three categories, we used the approach summarized below to select the specific lamp models to be procured and tested:

- CA Quality Spec-compliant:
  - These products were identified using IOU-approved product lists.
  - If the IOUs currently do not offer products in a given sample stratum, then CA Quality Spec-compliant products were identified using Lighting Facts listed on the product's packaging.
  - Where market share data is available, the highest market-share models were identified using the RLSS.
- ENERGY STAR-certified, but not CA Quality Spec-compliant:
  - These products were identified using Lighting Facts

- The highest market-share models were identified using the RLSS

- Least expensive, non-ENERGY STAR-certified:
  - These products were identified using the ENERGY STAR field in the RLSS and verified using the ENERGY STAR-qualified product lists
  - The least expensive, highest market-share models were identified using the RLSS

This process was followed to develop a model-level sample design that was representative of the current California market for screw-based LED lamps and allows comparative analysis between cohorts of CA Quality Spec-compliant, ENERGY STAR-certified but not CA Quality Spec-compliant, and non-ENERGY STAR–certified LED products. Following the development of this model-level sample design, the next step was to begin procuring multiple units of each model identified in the sample design to use in the testing regime described in Section 3.

## 4.2 SAMPLE PROCUREMENT

We procured all of the LED test lamps for this study "off the shelf" (i.e., via retailers), as opposed to via direct procurement from manufacturers. Several stakeholders, notably NRDC and SCE, noted the importance of using "off the shelf" procurement for this effort to eliminate the possibility of bias stemming from manufacturers providing test units directly (as is the case with current testing procedures for ENERGY STAR certification and the USDOE's LED Lighting Facts program).

The predecessor CFL lab test study also used an "off the shelf" procurement approach that used field staff to physically purchase test lamps at a sample of retail stores that was representative of the distribution of CFL sales across geographies and retail channels in California. Given the relative price premium for LED lamps (compared to CFLs), we wanted to explore opportunities to reduce procurement costs for this effort by leveraging direct online procurement (with shipping direct to testing facility to also save time) wherever possible.[25]

The first step in our procurement process was to verify online availability of all lamp models identified in our sample design. Nearly all of the models included in our initial sample design were indeed immediately available for purchase from online retailers, with a small number of exceptions. Specifically, five models targeted in our sample design had been discontinued by the manufacturers since the time of the 2015 RLSS. For three of these models, we were able to use manufacturer product catalogs to identify

[25] Note that the direct online procurement approach assumes that such "retail channel effects" are statistically insignificant. In consultation with the CPUC, we decided to test this hypothesis using the CFL test data to determine if retail channel had any statistically significant impact on CFL lamp performance. The results of this analysis indicated that retail channel did not have a statistically significant impact on CFL lamp performance. The details of this analysis are presented in Appendix A of the Research Plan.

"successor" models that featured the same product characteristics, i.e., lamp type, base type, lumen output, CRI, color temperature, dimmability, and ENERGY STAR/non-ENERGY STAR certification. For the other two discontinued models, we were not able to clearly identify "successor" models, so those models were dropped from our sample design.

Once this verification process was complete, Itron procurement staff then began purchasing in-sample models with shipping directly to the test lab. During this procurement process, three specific in-sample models were temporarily out of stock. In these cases, in order to avoid calendar delays, Itron procurement staff purchased "backup" models that had been previously identified during the sample design process. Procurement began in mid-September 2015 and concluded in mid-November 2015.

Finally, it should be noted that the majority of the CA Quality Spec-compliant models were not available for online purchase, due to their availability being limited to California. For these models, IOU program staff procured the test models on behalf of the study team directly at brick-and-mortar retailers that participate in the IOUs' respective upstream lighting programs and shipped those units directly to the testing facility.

## 4.3 FINAL TEST SAMPLE

Table 4-2 below summarizes the final sample of LED lamps procured by Itron and the IOUs, and how those lamps were installed for testing by fixture type. The table also includes the estimated market shares of the specific models procured in each stratum based on the 2015 RLSS data. In total, the final test sample included 627 individual lamps covering 92 lamp models and 39 individual trim kits covering 13 trim kit models. The estimated market share of final sample of LED lamps is 44% of the total LED lamp market in California and 53% of the in-scope lamp market.[26,27] Note that the market share estimates in Table 4-2 are necessarily an underestimate of actual market shares, since the vast majority of the CA Quality Spec-compliant lamp models were not available in retail stores at the time of the 2015 RLSS.

[26] In-scope refers to the strata identified in Table 3-1, which do not include strata with small (i.e. <5%) market shares. These strata include MR16, MR11, PAR16, PAR20, BR20, and R40.

[27] The RLSS does not include data on downlight retrofit kits, so we are unable to estimate the market shares of the downlight retrofit kit models included in our test sample. However, as mentioned previously, the retrofit kit test sample was not designed to be representative of the California market.

## TABLE 4-2: SUMMARY OF FINAL TEST SAMPLE OF LED LAMPS AND DOWNLIGHT RETROFIT TRIM KITS

| Lamp Type | Reflector Subtype | Base Type | Lumen Bin | Models | Units Tested in: | | | Market Shares: | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Bare Sockets | Recessed Downlights | Enclosed Ceiling Fixtures | Total CA | Final Sample | Intra-Strata |
| A-LAMP | N/A | MSB (E26) | 201-400 lm. | 4 | 12 | 12 | 12 | 2.6% | 1.3% | 51% |
| A-LAMP | N/A | MSB (E26) | 401-600 lm. | 10 | 30 | 30 | 30 | 18.5% | 7.4% | 40% |
| A-LAMP | N/A | MSB (E26) | 601-800 lm. | 10 | 30 | 30 | 30 | 17.0% | 8.1% | 47% |
| A-LAMP | N/A | MSB (E26) | 801-1,000 lm. | 5 | 15 | 15 | 15 | 8.9% | 1.2% | 13% |
| A-LAMP | N/A | MSB (E26) | 1,001-1,200 lm. | 5 | 15 | 15 | 15 | 4.3% | 2.8% | 64% |
| A-LAMP | N/A | MSB (E26) | 1,401-1,600 lm. | 4 | 12 | 12 | 12 | 3.4% | 2.3% | 67% |
| GLOBE | N/A | MSB (E26) | 201-400 lm. | 4 | 12 | 0 | 0 | 3.0% | 1.6% | 55% |
| GLOBE | N/A | MSB (E26) | 401-600 lm. | 5 | 15 | 0 | 0 | 5.6% | 5.3% | 95% |
| TORPEDO | N/A | Candelabra (B10) | 1-200 lm. | 4 | 12 | 0 | 12 | 3.3% | 1.4% | 42% |
| TORPEDO | N/A | Candelabra (B10) | 201-400 lm. | 6 | 18 | 0 | 18 | 8.8% | 5.9% | 66% |
| TORPEDO | N/A | MSB (E26) | 201-400 lm. | 4 | 12 | 0 | 0 | 2.4% | 1.5% | 64% |
| REFLECTOR | BR30 | MSB (E26) | 601-800 lm. | 8 | 24 | 24 | 0 | 10.4% | 6.8% | 65% |
| REFLECTOR | BR40 | MSB (E26) | 1,001-1,200 lm. | 3 | 9 | 9 | 0 | 1.7% | 1.0% | 58% |
| REFLECTOR | PAR20 | MSB (E26) | 401-600 lm. | 4 | 12 | 12 | 0 | 1.3% | 0.8% | 57% |
| REFLECTOR | PAR30 | MSB (E26) | 601-800 lm. | 4 | 12 | 12 | 0 | 2.1% | 1.6% | 75% |
| REFLECTOR | PAR38 | MSB (E26) | 801-1,000 lm. | 4 | 12 | 12 | 0 | 1.7% | 1.5% | 88% |
| REFLECTOR | PAR38 | MSB (E26) | 1,001-1,200 lm. | 4 | 12 | 12 | 0 | 1.6% | 1.0% | 62% |
| REFLECTOR | R20 | MSB (E26) | 401-600 lm. | 4 | 12 | 12 | 0 | 3.3% | 2.6% | 80% |
| **TOTAL TEST LAMP SAMPLE** | | | | **105** | **276** | **246** | **144** | **100%** | **53.9%** | N/A |
| TRIM KITS | 4" | N/A | N/A | 6 | 0 | 18 | 0 | N/A | N/A | N/A |
| TRIM KITS | 6" | N/A | N/A | 7 | 0 | 21 | 0 | N/A | N/A | N/A |

## 4.4 TEST SAMPLE PREPARATION

Upon receipt of the test sample, staff at the testing facility prepared the test lamps and trim kits for the testing regime described in Section 3. This sample preparation process followed three specific steps:

- First, the model numbers of each test sample received were verified against the model numbers in the shipping invoice and the final sample design. The rated performance of each test sample (as shown on product labels) was also recorded, i.e., rated lumens, wattage, CRI, color temperature, and dimmability.
- Second, each test sample was labeled with a unique bar code on the lamp/trim kit itself. These bar codes allowed each test sample to be accurately tracked in terms of status and location and correctly associated with individual data streams from the photometric, thermal, and maintenance tests.
- Lastly, each sample was tested to verify basic functionality, i.e., whether the sample turned on when connected to a live socket. This step was necessary in order to screen for non-functional units. In one case, testing facility staff verified that a non-functional test sample was indeed shipped and received. In this case, staff removed that sample from the testing regime and prepared a backup sample of the same model.[28]

Once all test samples were received, labeled, and basic functionality verified, they were then subjected to initial photometric testing as well as thermal testing. The long-term maintenance testing was initiated following the conclusion of the thermal testing (which was used to determine the control zone groups and timing parameters to which individual lamps/fixtures would be assigned).

[28] Itron and IOU staff intentionally procured one extra test sample of each model included in the final sample design as a backup in case of breakage during shipping, breakage during sample preparation, or receipt of non-functioning units.

# 5 RESULTS

This section presents the summarized results from the thermal, photometric, and maintenance testing. Also included here are the findings from a post-mortem forensic analysis on the lamps that experienced catastrophic failure during maintenance testing. The complete set of empirical results from the thermal, photometric, and maintenance tests are provided in Appendix A.

It is important to note that results for trim kits have been included here even though these products were a late add-on to a test design that was originally designed specifically for lamps. While we believe the results from trim kits are valid, there are notable differences in the designs of these products (e.g., more thermal mass), the applications in which they were tested (e.g., only in recessed downlights), and sampling (e.g., small sample of only 39 products representing 13 models; samples all procured via utility partner channels) that the reader should bear in mind when considering these results alongside those of other lamp types.

The thermal testing results presented here provide a high-level overview of the results of the thermal test. While these tests were primarily undertaken in order to establish the appropriate switching cycle timing for the maintenance test, the thermal test results themselves may have additional value. The discussion of the photometric results generally focuses on comparing the initial measured values of the test lamps to their rates values (e.g., measured CRI vs. rated CRI) as well as comparing changes in measured values between the initial testing period and the final testing period. The maintenance testing results focus exclusively on the failure rates observed over the 15-month testing period.[29]

## 5.1 THERMAL TESTING

As described in Section 3.2, the lamp surface temperature of each test lamp was monitored during the initial stages of this experiment, as well as the near-ambient air temperatures for a sub-set of the test lamps. These tests were primarily conducted in order to allow us to optimize switching cycle timing for the maintenance test, but the thermal testing itself also generated rich datasets, the highlights of which are briefly discussed below.

[29] Note that the testing facility experienced some unexpected events during the course of maintenance testing. Appendix B provides documentation of these events and how these events were addressed in order to maintain the integrity of the test and its results.

Figure 5-1 shows a histogram of the time required for test lamps to reach the 95% thermal stability point during warm-up (i.e., time required for lamps to reach 95% of their steady-state operating temperature after being switched on). This figure shows that most lamps reached 95% thermal stability within 60 minutes of operation while a small minority of lamps (primarily trim kits which have significantly more thermal mass) required over 100 minutes to reach 95% thermal stability.

**FIGURE 5-1: HISTOGRAM OF WARM-UP TIMES FOR TEST LAMPS**

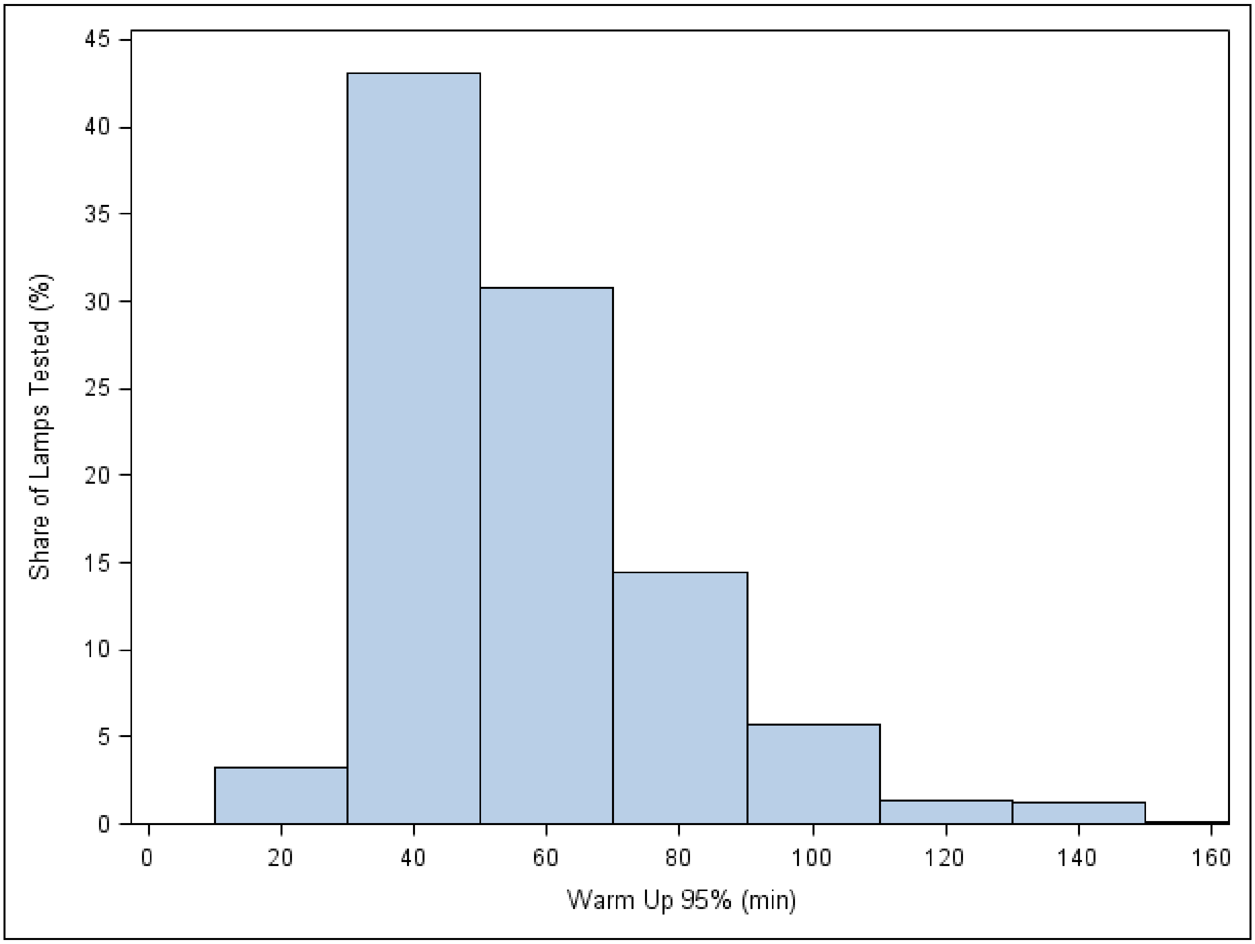


Figure 5-2 shows a similar histogram for the cool-down times. The length and distribution of cool-down times were found to be slightly longer than warm-up times, with the majority of lamps reaching 95% thermal stability within 80 minutes.

**FIGURE 5-2: HISTOGRAM OF COOL DOWN TIMES FOR TEST LAMPS**

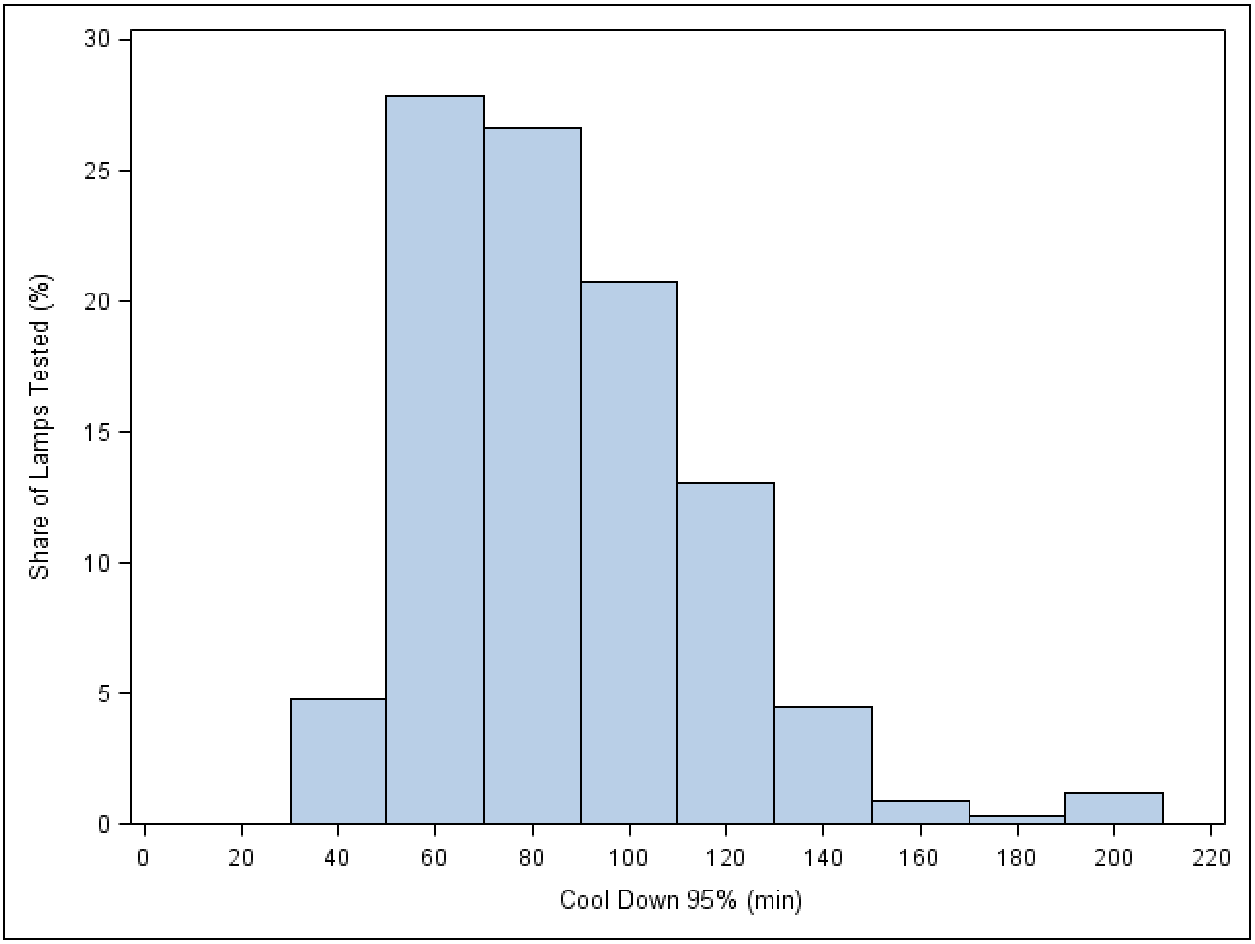
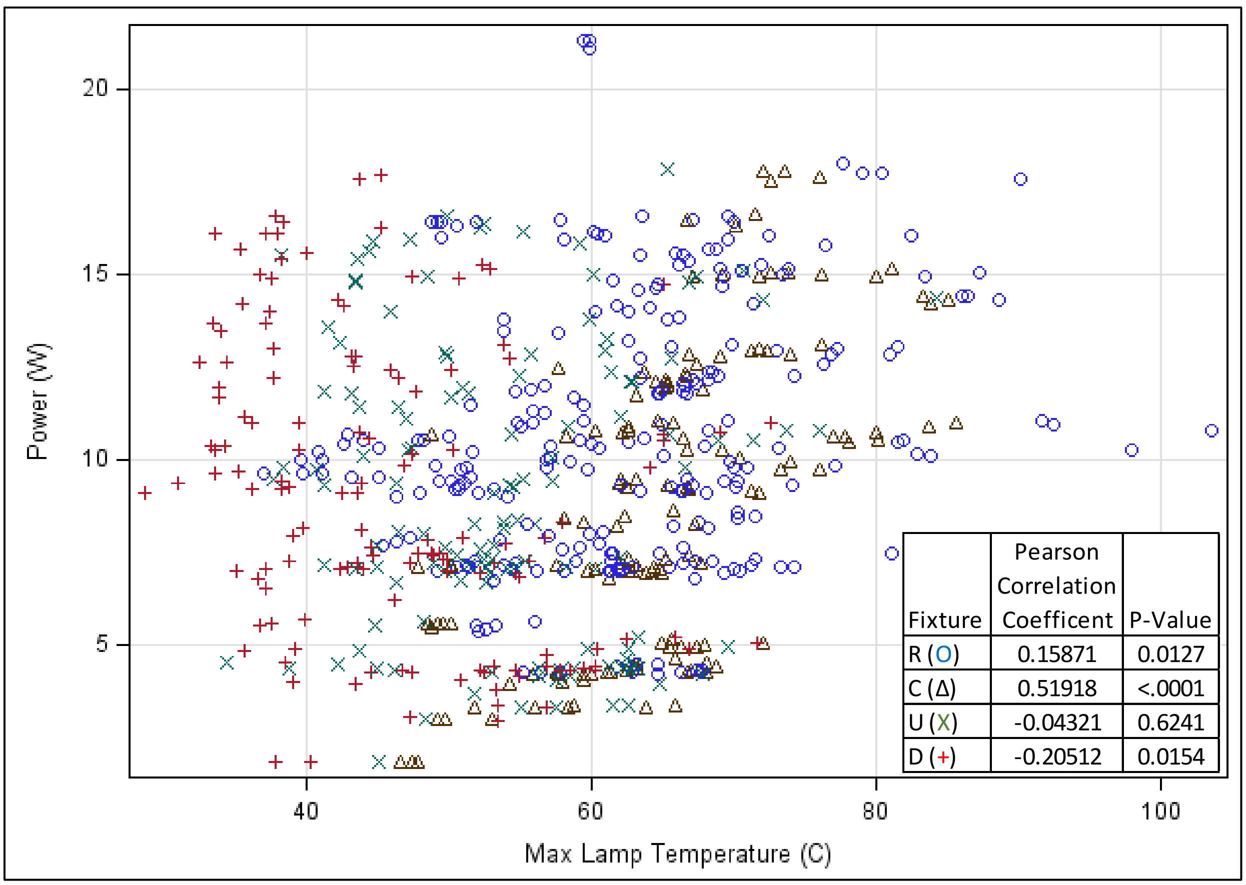


Figure 5-3 shows the maximum lamp temperature recorded by lamp wattage and fixture type (R = Recessed Downlight, C = Ceiling Fixture, U = Base-Up Bare Socket, D = Base-Down Bare Socket), as well as the overall correlation coefficients between lamp wattage and maximum lamp temperature by fixture type. As expected, the highest lamp temperatures were found on higher wattage lamps in constrained-air fixtures, i.e., enclosed ceiling fixtures and recessed downlights.[30] Perhaps more importantly, however, Figure 5-3 shows that maximum lamp temperatures for lamps in constrained-air fixtures exhibited a stronger correlation with wattage compared to lamps in bare sockets.

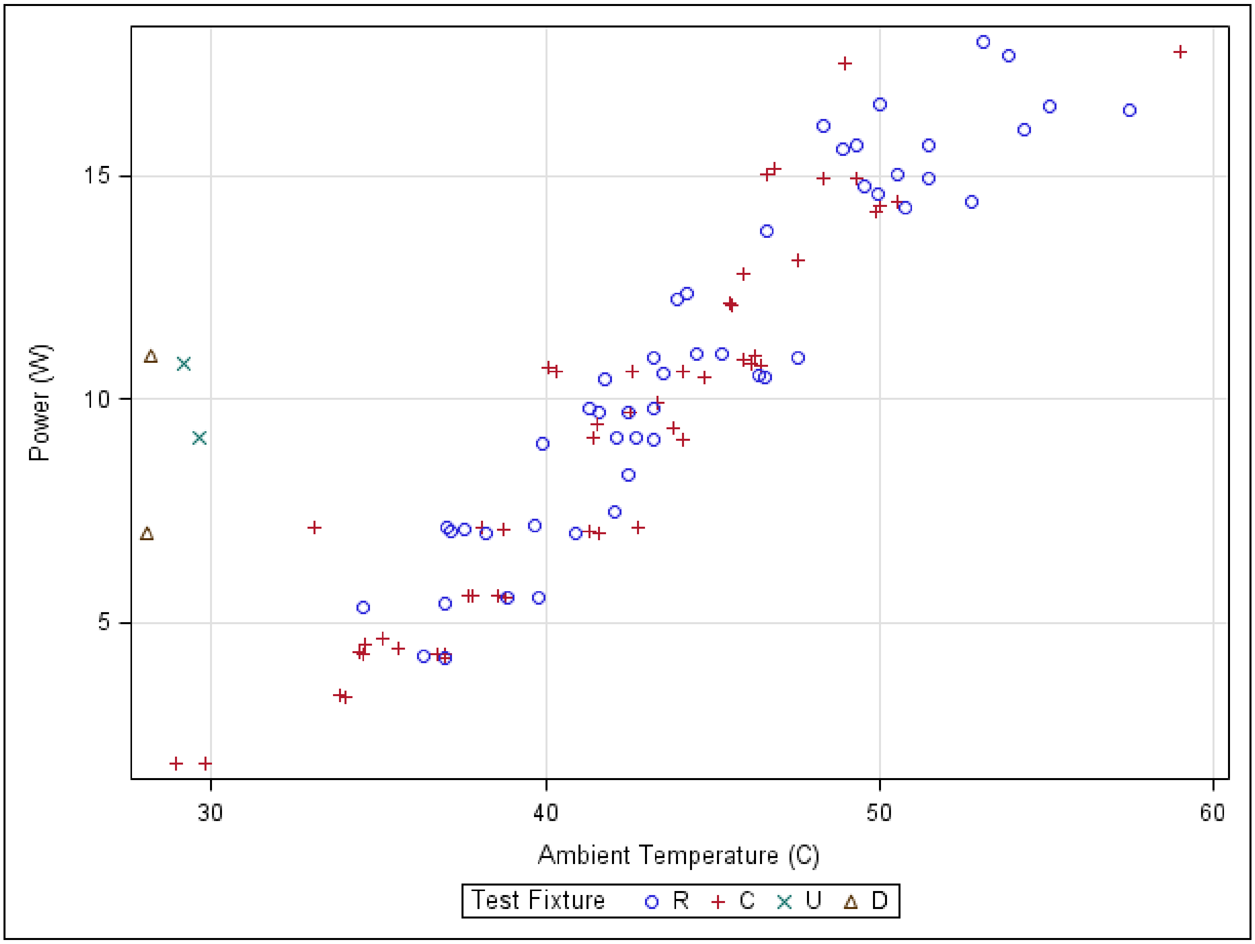
#### FIGURE 5-3: MAXIMUM LAMP TEMPERATURE VS LAMP INPUT POWER AND FIXTURE TYPE




[30] We measured lamp temperature at a single point on each lamp. While the process for placing the thermocouples was consistent, differences in lamp designs as well as some random effects (e.g. placement of thermocouple near particularly hot components) likely contribute the variability of these results.

Figure 5-4 shows the near-ambient maximum air temperature measured by lamp wattage and fixture type. This figure shows that while air temperature inside each luminaire trends very strongly with lamp wattage, it does not vary significantly by fixture type.[31] It should be noted that the near-ambient air temperatures shown below are in the same range as the ambient air temperatures specified in ENERGY STAR's current elevated temperature test (55°C for directional lamps over 20W, 45°C for most other lamp types). These new near-ambient air temperature data may be useful to help further refine such screening tests by accounting for the strong ambient temperature/lamp wattage relationship shown below so that lamps are tested in ambient temperatures closer to what would be expected in the field.

**FIGURE 5-4: NEAR AMBIENT AIR TEMPERATURE VS LAMP INPUT POWER AND FIXTURE TYPE**




[31] Note that the thermal tests includes only a few near-air measurements for bare socket fixtures, mainly to confirm that air temperatures near lamps in these open air applications are minimal as compared to constrained-air applications.

## 5.2 INITIAL PHOTOMETRIC TESTING

Figure 5-5 shows the measured initial light output versus the rated light output for each lamp included in the test. Data points above the diagonal line indicate lamps that were found to produce more lumens than their rated values while those below the line produced less than their rated value. In this and subsequent graphs, results by particular lamp categories are indicated but different data point symbols.

**FIGURE 5-5: RATED LIGHT OUTPUT (LUMENS) VS. MEASURED LIGHT OUTPUT (LUMENS)**

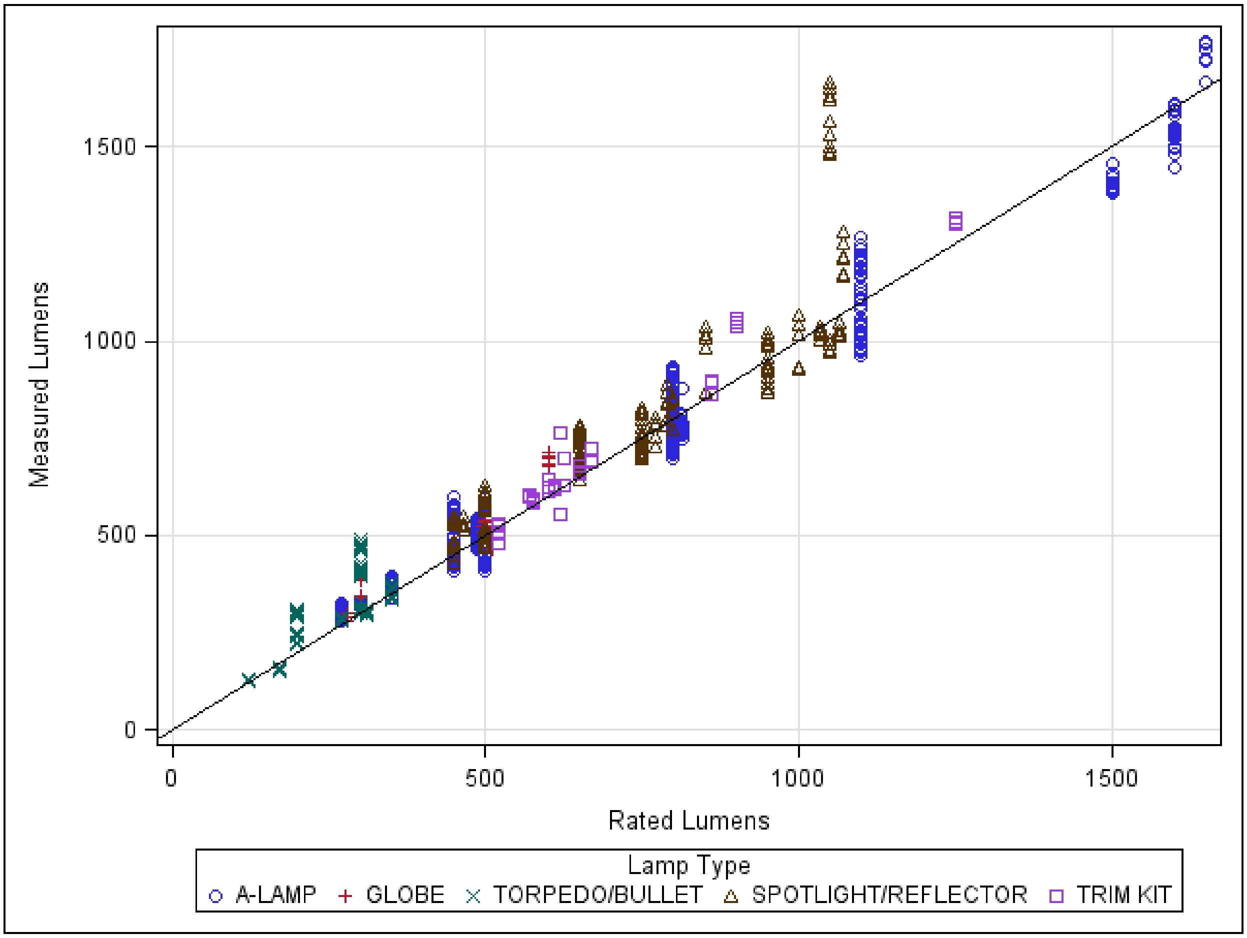


Figure 5-6 shows the measured initial input power verses the rated power for each lamp included in the test. Data points above the diagonal line indicate lamps that were found to draw than their rated values while those below the line draw less than their rated value.

**FIGURE 5-6: RATED POWER (W) VS. MEASURED POWER (W)**

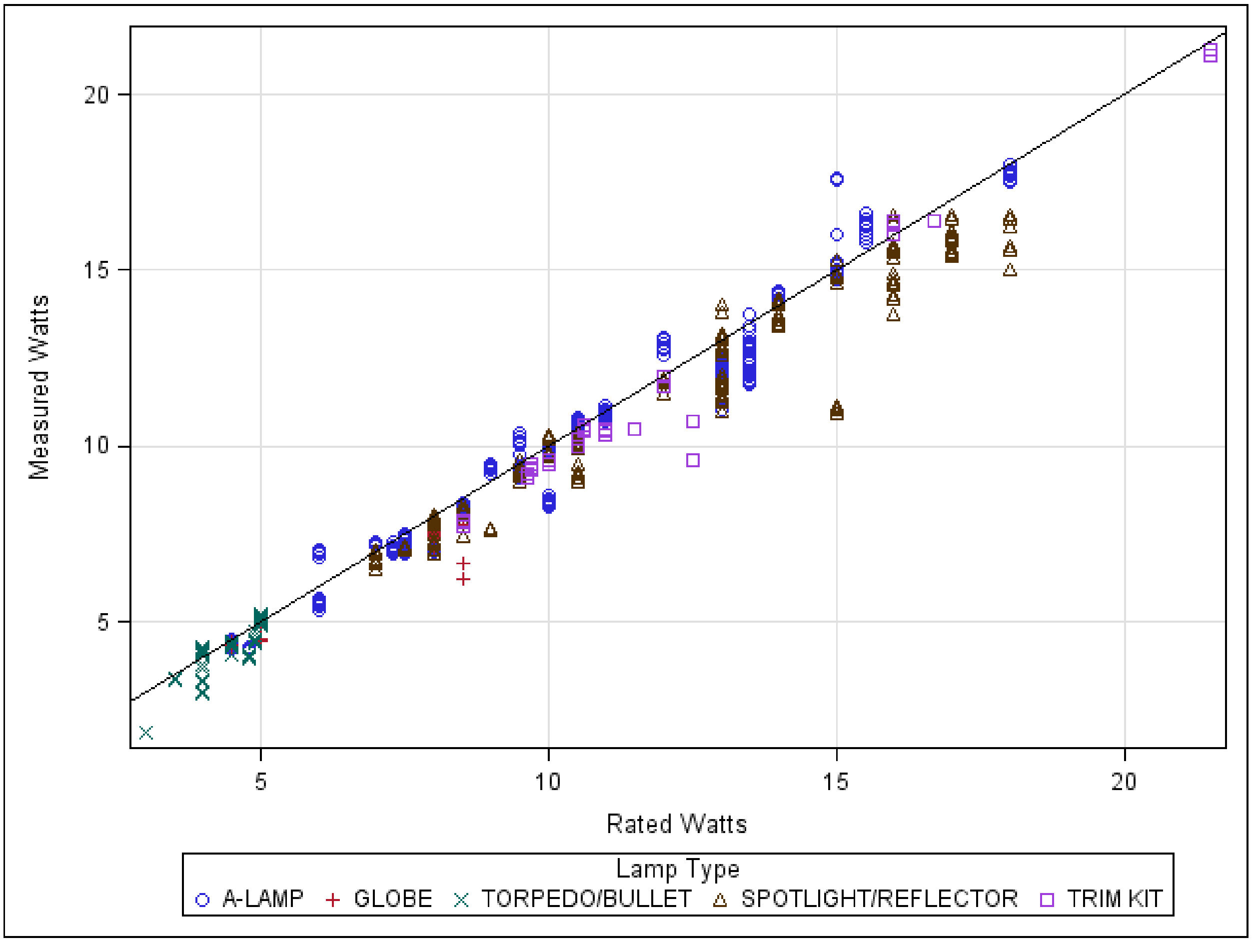


Figure 5-7 looks at initial measured versus rated luminous efficacy, which is essentially a combination of the results shown in Figure 5-5 and Figure 5-6. These three graphs show lamps in the test generally under reported light output (lumens) while over reporting power input (watts), resulting in an under reporting of efficacy (lm/W). This would seem to indicate for the majority of LED lamps, rated efficacy values can be expected to provide accurate or conservative values of actual performance.

#### FIGURE 5-7: RATED EFFICACY (LM/W) VS. MEASURED EFFICACY (LM/W)

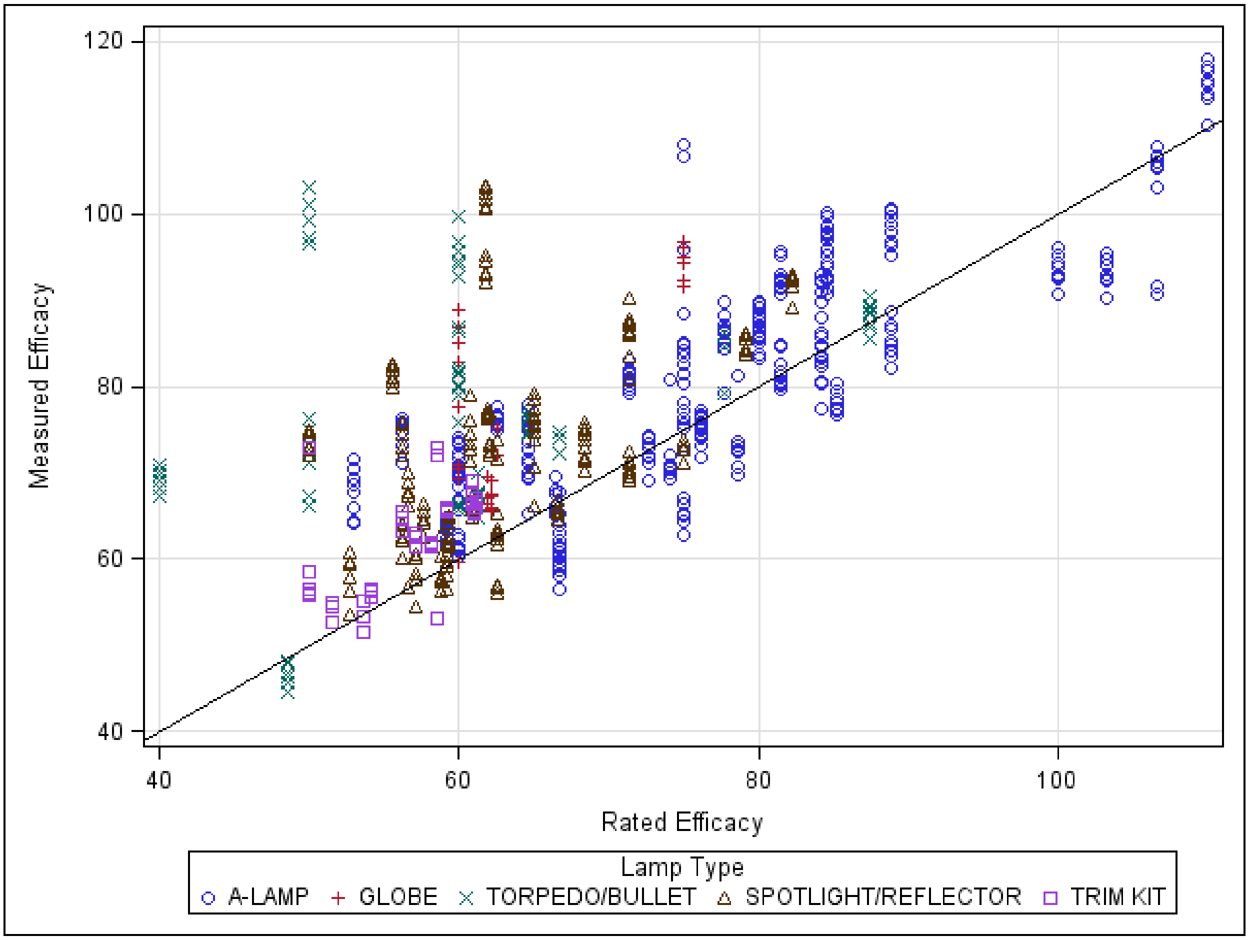


Figure 5-8 presents the initial measured efficacy versus initial measured light output. This graph shows how lamps with higher light output tend to trend with higher efficacy.

**FIGURE 5-8: MEASURED LIGHT OUTPUT (LUMENS) VS. MEASURED EFFICACY (LM/W)**

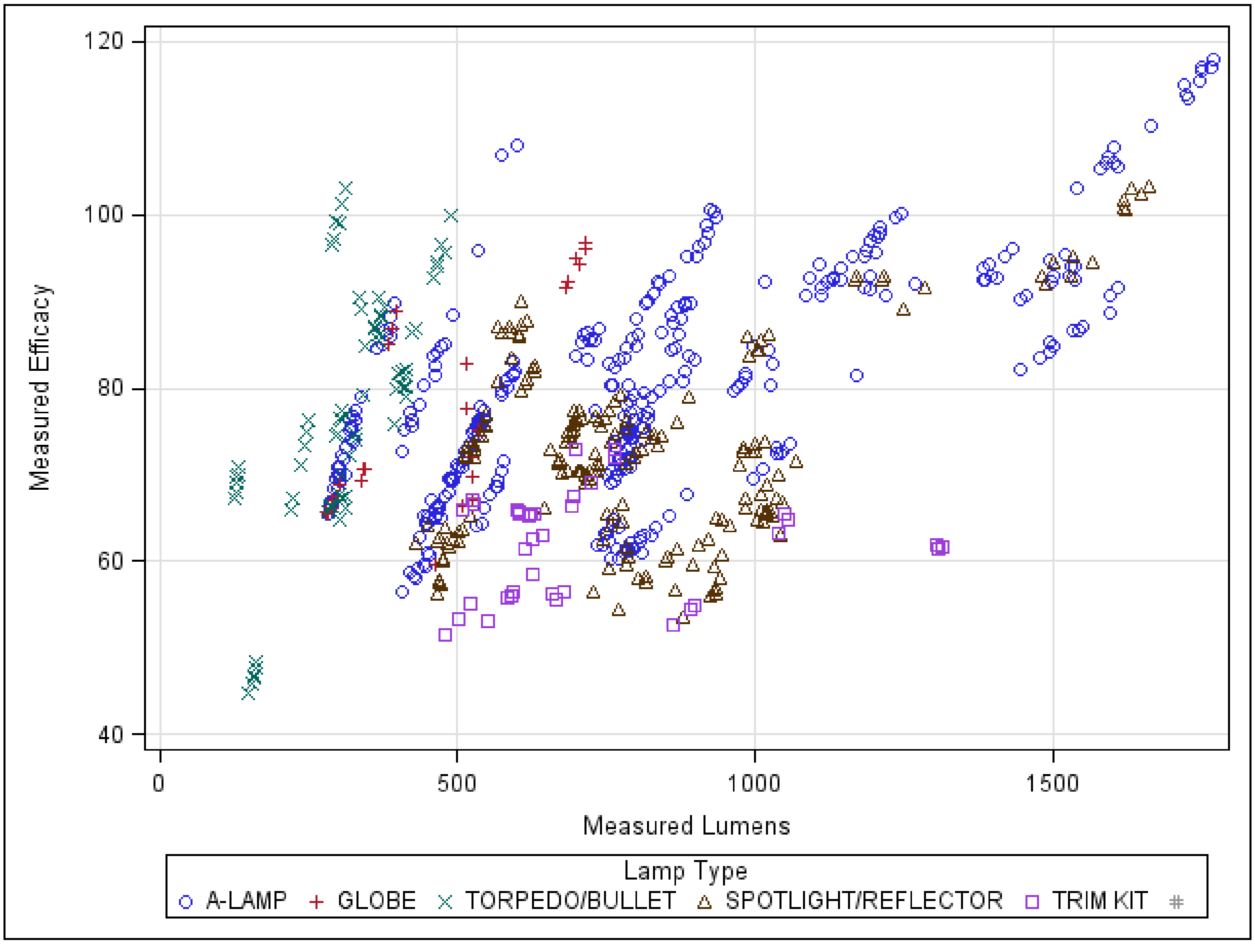


Figure 5-9 shows the initial measured color temperature versus the rated color temperature for each lamp included in the test while Figure 5-10 shows the initial measured color rendering versus the rated color rendering. Again, data points above the diagonal line indicate that lamps that were found to have higher measured values than their rated values while those below the line were lower than their rated values.

**FIGURE 5-9: RATED COLOR TEMPERATURE (CCT) VS. MEASURED COLOR TEMPERATURE (CCT)**

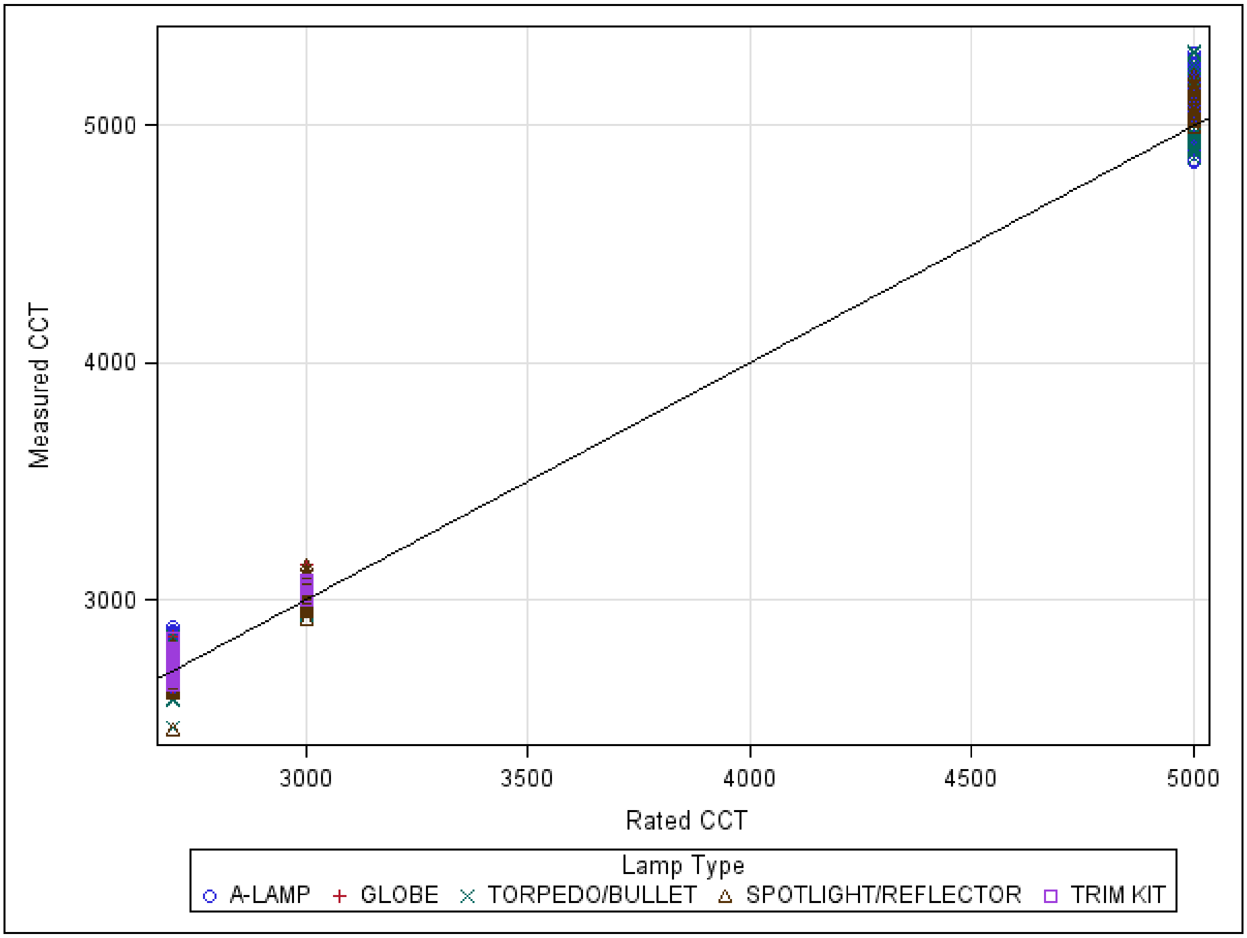


FIGURE 5-10: RATED COLOR RENDERING (CRI) VS. MEASURED COLOR RENDERING (CRI)

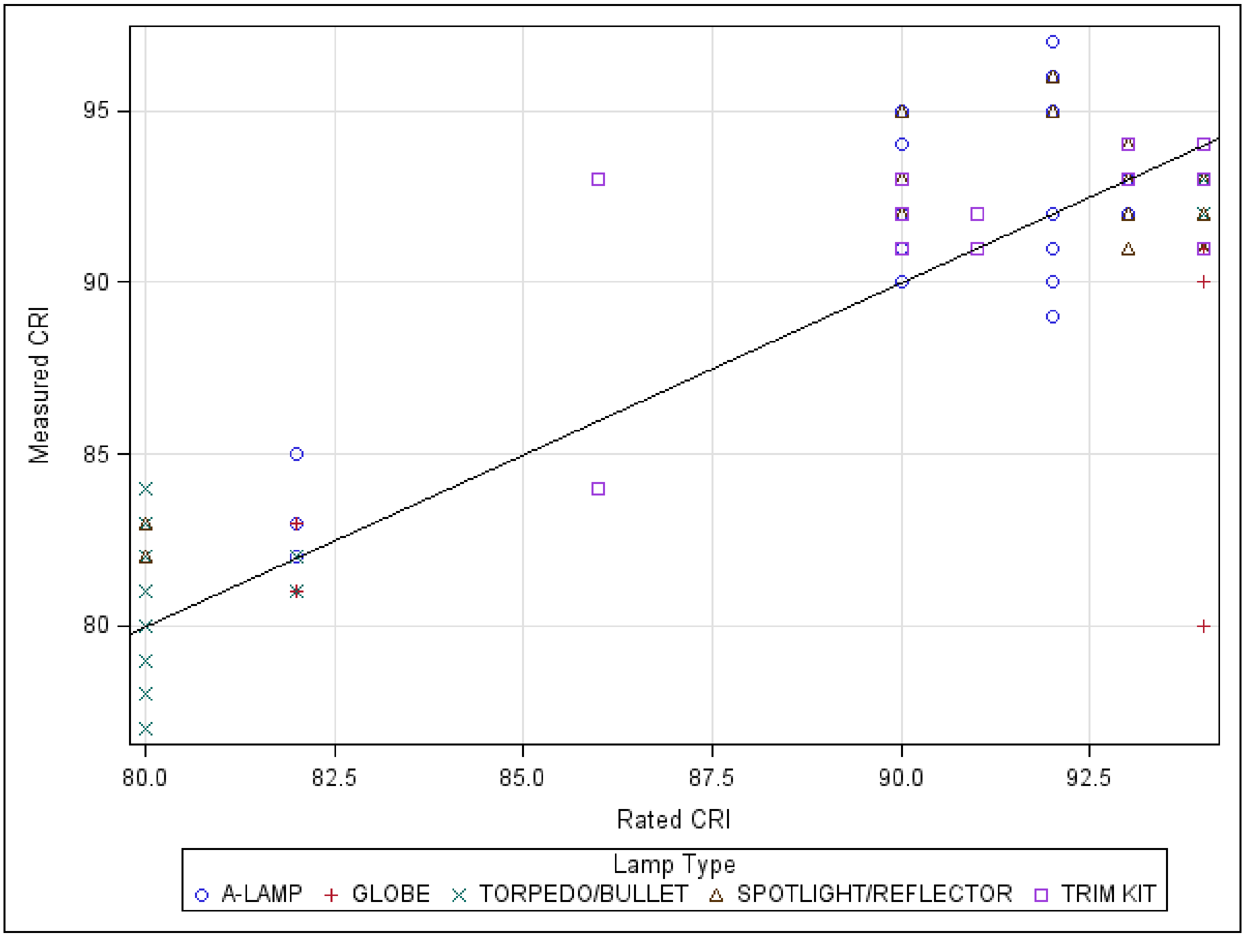


Figure 5-11 shows initial measured color rendering versus initial measured efficacy. While this graph seems to show that while some lamps were able to maintain both a high efficacy and a high CRI, efficacy generally suffers at CRI is increased.

**FIGURE 5-11: MEASURED COLOR RENDERING INDEX (CRI) VS. MEASURED EFFICACY (LM/W) BY LAMP TYPE**

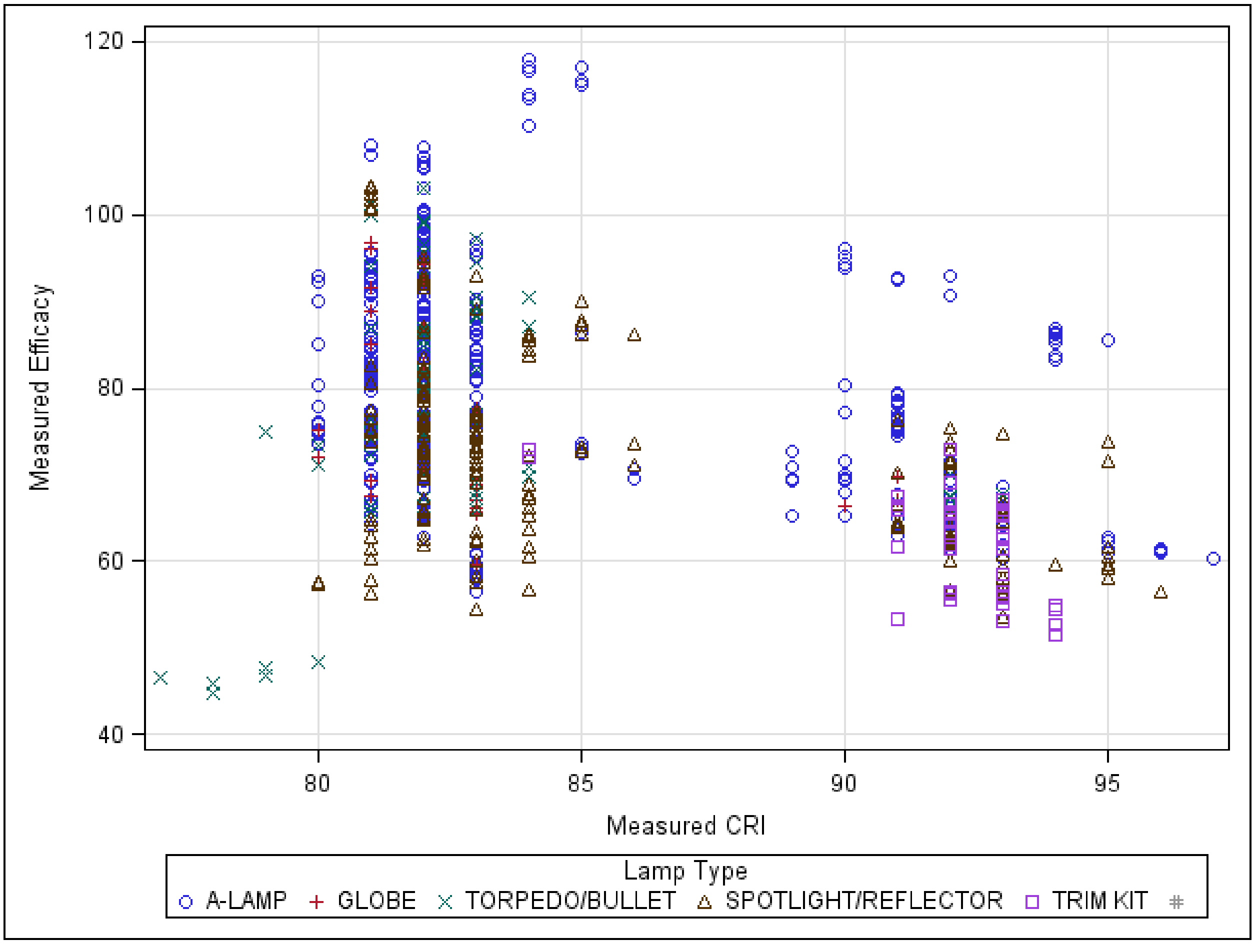
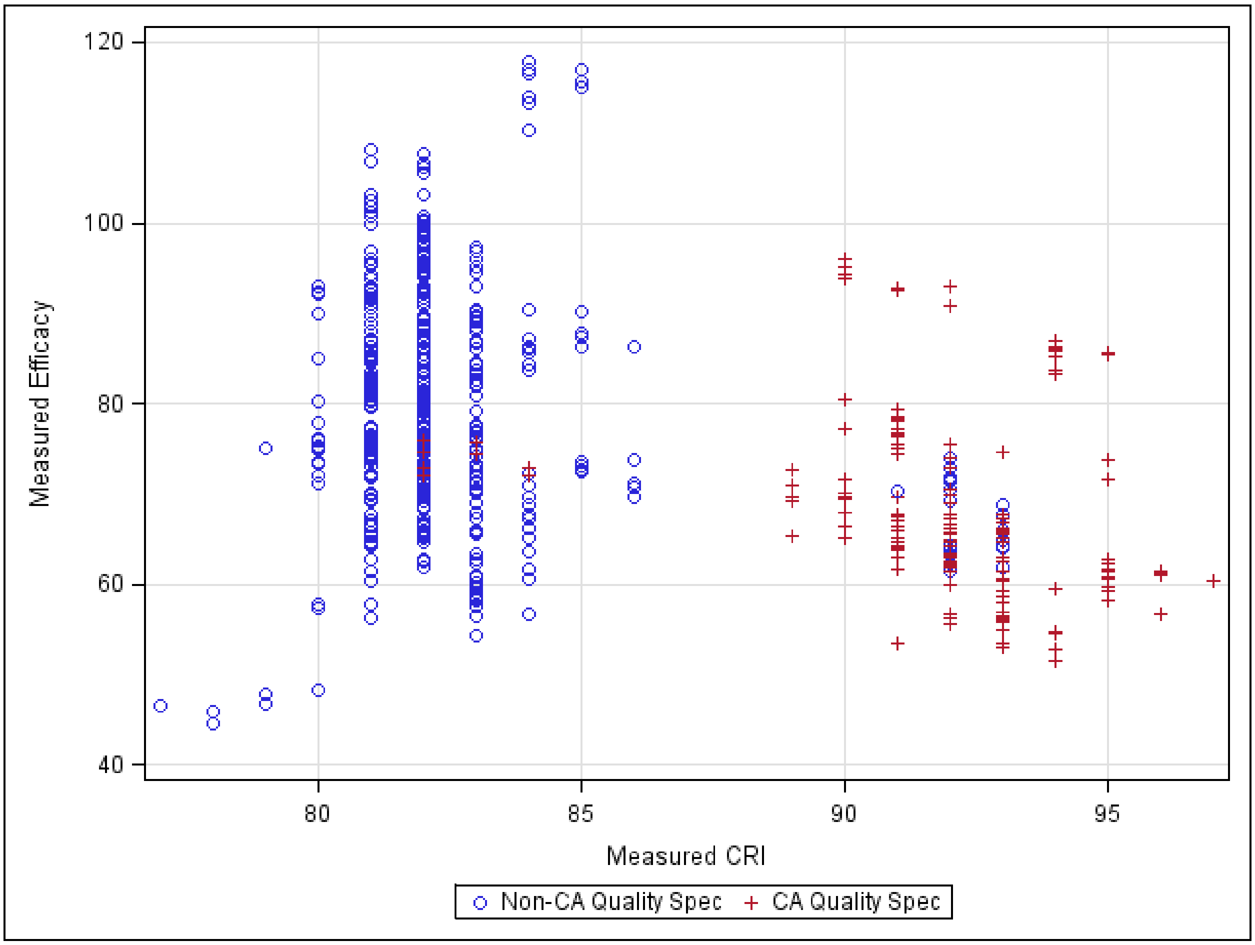


Figure 5-12 presents the same data as Figure 5-11 but now identified by CA Quality spec compliance rather than by lamp type. This figure shows that the two distinct clusters correlate almost completely with a lower-efficacy, higher-CRI CA Quality Spec group (average efficacy = 62.1 lm/W, average CRI = 92.0) and a higher-efficacy, lower CRI non- CA Quality Spec group (77.6 lm/W, 84.4 CRI). There are some notable occurrences of lamps that are listed as compliant with the CA Quality Spec, but were found to have CRI measurements below the 90 CRI CA Quality Spec requirements.

**FIGURE 5-12: MEASURED COLOR RENDERING INDEX (CRI) VS. MEASURED EFFICACY (LM/W) BY CA QUALITY SPEC COMPLIANCE**

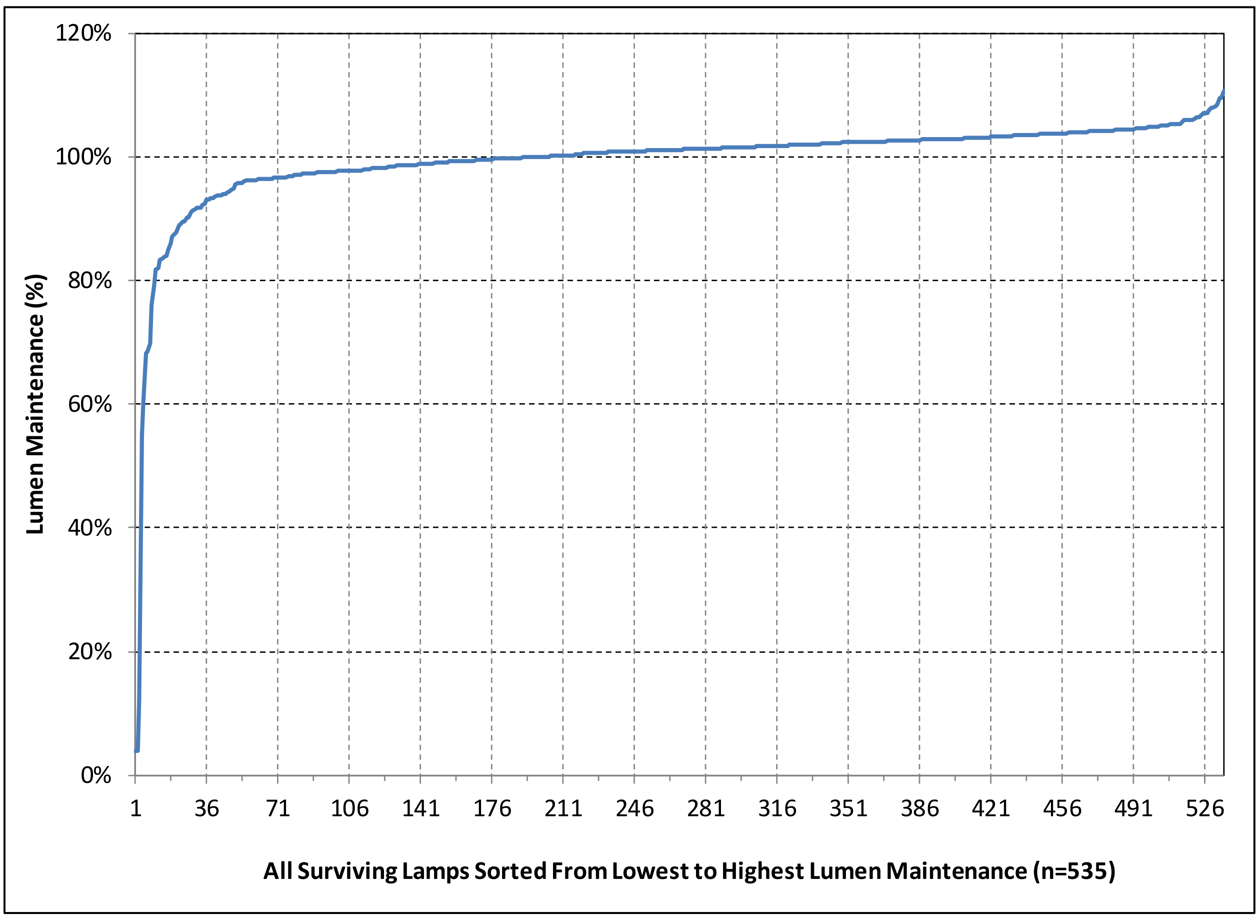



## 5.3 FINAL PHOTOMETRIC TESTING

Following the conclusion of the maintenance testing, a second round of photometric testing was conducting on all surviving test lamps. These results were used primarily to examine changes in two key performance metrics – lumen maintenance and color shift.

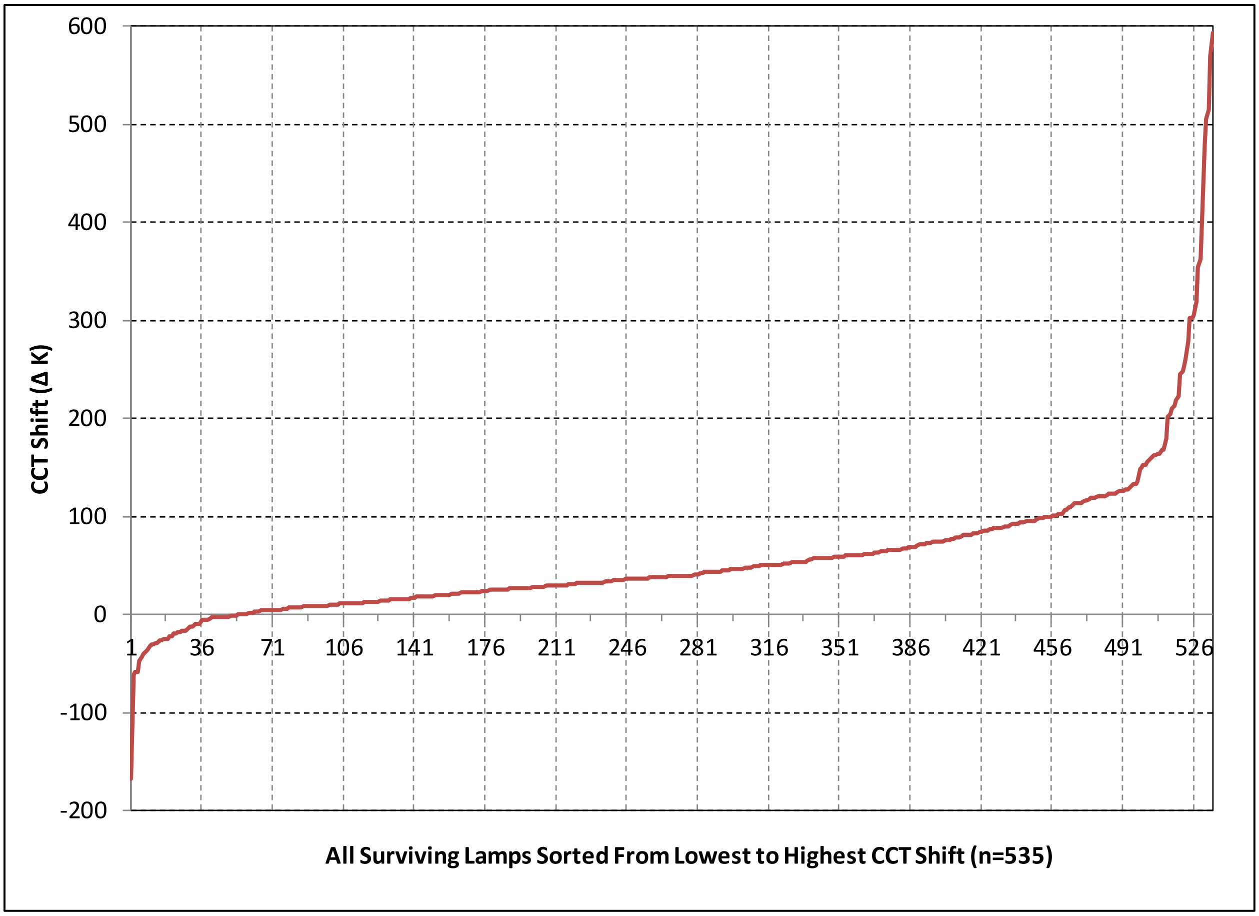
Figure 5-13 presents the lumen maintenance values (i.e., the measured lumen output at the end of the maintenance test compared to the initial measured values) for the 535 lamps that survived maintenance testing (sorted by lowest to highest). LED lamps and luminaires are often considered to have "failed" once their lumen output drops below 70% of rated or initial output. As the figure shows, only 8 of the test lamps (1.5%) that survived to the final photometric test crossed this threshold of decreased lumen maintenance. Indeed, Figure 5-13 shows that – generally speaking – lumen depreciation was not found to be a significant issue. In fact, most lamps (63%) experienced an increase in light output between initial photometric testing and final photometric testing. It is well documented, including in IES LM-79 itself, that some LED sources will see an increase in light output during the first 1,000 hours of operation. But the fact that a wide majority of LED lamps in our test saw such an increase over the course of the maintenance testing is notable.

**FIGURE 5-13: LUMEN MAINTENANCE RATES FOR ALL TEST UNITS**



LEDs can also be considered to have failed if their light color has changed so significantly over time that they are no longer considered acceptable for the applications in which they have been placed. These color changes can be noticeable and objectionable if they are extreme and/or if light sources in the same field of view experience different changes in color. Figure 5-14 summarizes the change in correlated color temperature (CCT) values for the 535 lamps that survived maintenance testing (sorted from largest decrease to largest increase).[32] As the figure shows, significantly more lamps (477 vs. 58) experienced an increase in CCT (a shift toward blue or green) compared to a decrease in CCT (a shift toward red). Generally speaking, however, most surviving lamps did not see a significant change in CCT, with 85% of lamps seeing a CCT shift of 100 K or less. Only 12 lamps (2.2%) experienced CCT shifts that might be considered noticeable/objectionable (i.e., >300 K).

### FIGURE 5-14: COLOR SHIFT OBSERVED FOR ALL TEST UNITS




[32] While it would be technically more accurate to evaluate color shift in term of changes in u'v' values, we discuss color shift in terms of CCT both for simplicity and because CCT is a more common consumer-facing metric.

## 5.4 MAINTENANCE TESTING

A significant portion of the lamps tested experienced catastrophic failure during our maintenance testing. Table 5-1 provides a summary of the overall catastrophic failure rates observed during the maintenance testing.

**TABLE 5-1: SUMMARY OF CATASTROPHIC FAILURE RATES OBSERVED BY LAMP-FIXTURE COMBINATION**

| Lamp Type | Lamp Specification | Total Lamps Tested | Total Catastrophic Failure Rate (%) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Fixture Type | | | | Total |
| | | | Ceiling | Recessed | Bare, Down | Bare, Up | |
| A-lamp | CEC and EStar | 72 | 0% | 25% | 8% | 0% | 18% |
| | EStar-only | 144 | 56% | 44% | 35% | 55% | 48% |
| | Not Estar | 126 | 31% | 31% | 14% | 14% | 25% |
| | All | 342 | 40% | 35% | 22% | 27% | 33% |
| Globe | CEC and EStar | 3 | - | - | 0% | 50% | 33% |
| | EStar-only | 18 | - | - | 0% | 0% | 0% |
| | Not Estar | 6 | - | - | 0% | 0% | 0% |
| | All | 27 | - | - | 0% | 8% | 4% |
| Torpedo | CEC and EStar | 6 | 0% | - | 0% | 0% | 0% |
| | EStar-only | 21 | 0% | - | 0% | 0% | 0% |
| | Not Estar | 45 | 22% | - | 0% | 0% | 9% |
| | All | 72 | 13% | - | 0% | 0% | 6% |
| Reflector | CEC and EStar | 48 | - | 8% | 0% | 0% | 4% |
| | EStar-only | 78 | - | 8% | 0% | 0% | 4% |
| | Not Estar | 60 | - | 20% | 0% | 0% | 10% |
| | All | 186 | - | 12% | 0% | 0% | 6% |
| Trim Kit | CEC and EStar | 39 | - | 0% | - | - | 0% |
| | EStar-only | 0 | - | - | - | - | - |
| | Not Estar | 0 | - | - | - | - | - |
| | All | 39 | - | 0% | - | - | 0% |
| Total | CEC and EStar | 168 | 22% | 9% | 4% | 4% | 10% |
| | EStar-only | 261 | 47% | 28% | 15% | 21% | 28% |
| | Not Estar | 237 | 28% | 26% | 5% | 6% | 18% |
| | All | 666 | 35% | 21% | 9% | 12% | 20% |

As the table shows, 130 out of 666 lamps tested experienced catastrophic failures – representing a 20% overall catastrophic failure rate across all lamps tested. By lamp type, catastrophic failure rates were highest among A-lamps (33%), with those tested in enclosed ceiling fixtures and recessed downlights experiencing the highest catastrophic failure rates observed across all lamp-fixture combinations tested (40% and 35%, respectively). The overall failure rates for globe, torpedo, and reflector lamps were all comparatively lower – between 6% and 4%. Notably, none of the downlight retrofit trim kits tested experienced catastrophic failure.

Comparing the catastrophic failure results across "lamp specification", Table 5-1 also shows that lamps that are compliant with the CA Quality Spec (labeled "CEC") experienced 10% catastrophic failures (17 out of 168 units tested). ENERGY STAR-certified but not CA Quality Spec-compliant (labeled "EStar-only") lamps along with non-ENERGY STAR-certified lamps experienced relatively higher catastrophic failure rates (28% and 18%, respectively).

A small minority of the models included in our testing (11 out of 105 models) were explicitly labeled by their manufacturers as not being compatible with enclosed fixtures. However, as noted earlier in Section 3.2, we chose to test those lamps in enclosed ceiling fixtures due to the likelihood that such compatibility information is not always followed by consumers. Of those 11 models, four models had test units experience catastrophic failure in enclosed ceiling lamps. However, it should also be noted that those same models had the exact same number of test units experience catastrophic failure in other fixture types (8 units across four models).

In addition to catastrophic failures where test lamps stopped working completely, lab technicians also observed and systematically recorded lamps that experienced "pre-failure" conditions, such as severe flickering and dramatically reduced light output (i.e., <70% rated lumen output). In some cases, lamps that exhibited pre-failure conditions eventually experienced catastrophic failure. In other cases, such lamps continued to function through the duration of the maintenance tests. From a consumer perspective, we believe it is reasonable to treat such pre-failure lamps as equivalent to lamps that have catastrophically failed, since it is likely that consumers would replace such lamps as soon as pre-failure behavior manifests itself. To this end, Table 5-2 below provides a summary of lamps that exhibited pre-failure characteristics. As the table shows, 4% of all lamps tested exhibited pre-failure behavior but not catastrophic failure during the maintenance tests.

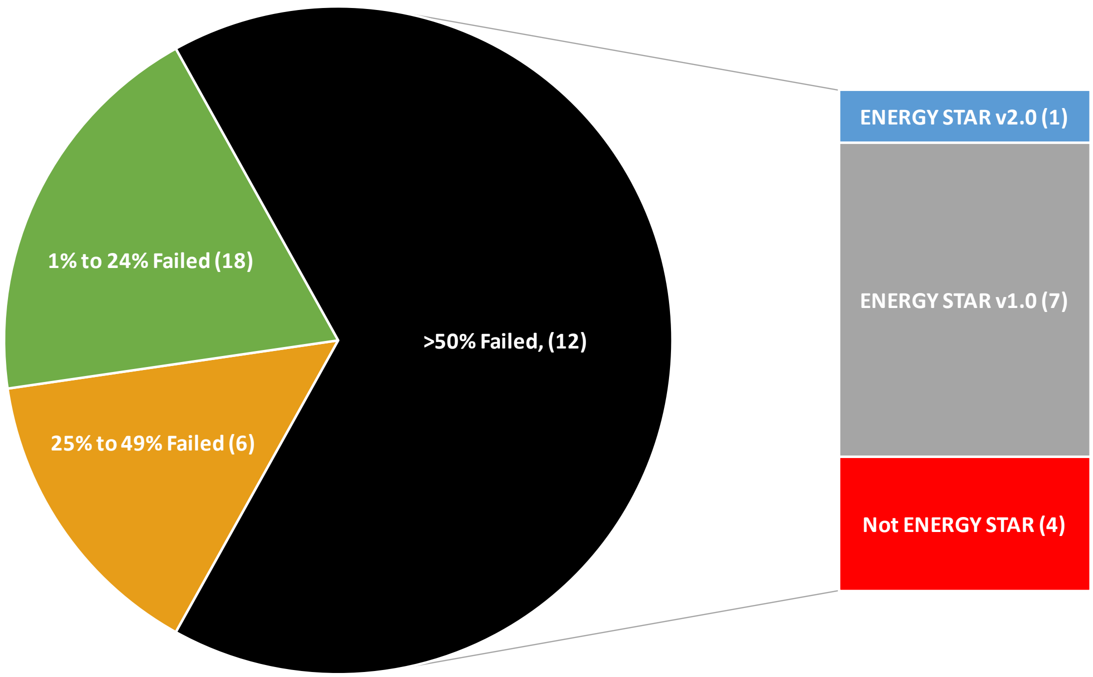
TABLE 5-2: SUMMARY OF PRE-FAILURE BEHAVIOR RATES OBSERVED BY ALL LAMP-FIXTURE COMBINATIONS

| Lamp Type | Lamp Specification | Total Lamps Tested | Total Pre-Failure Behavior Rate (%) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Fixture Type | | | | Total |
| | | | Ceiling | Recessed | Bare, Down | Bare, Up | |
| A-lamp | CEC and EStar | 72 | 0% | 8% | 0% | 0% | 3% |
| | EStar-only | 144 | 2% | 6% | 4% | 9% | 5% |
| | Not Estar | 126 | 5% | 7% | 10% | 0% | 6% |
| | All | 342 | 3% | 7% | 5% | 4% | 5% |
| Globe | CEC and EStar | 3 | - | - | 0% | 0% | 0% |
| | EStar-only | 18 | - | - | 0% | 13% | 6% |
| | Not Estar | 6 | - | - | 0% | 0% | 0% |
| | All | 27 | - | - | 0% | 8% | 4% |
| Torpedo | CEC and EStar | 6 | 0% | - | 0% | 0% | 0% |
| | EStar-only | 21 | 0% | - | 0% | 0% | 0% |
| | Not Estar | 45 | 11% | - | 7% | 8% | 9% |
| | All | 72 | 7% | - | 5% | 5% | 6% |
| Reflector | CEC and EStar | 48 | - | 0% | 0% | 0% | 0% |
| | EStar-only | 78 | - | 3% | 12% | 0% | 4% |
| | Not Estar | 60 | - | 0% | 0% | 17% | 3% |
| | All | 186 | - | 1% | 4% | 4% | 3% |
| Trim Kit | CEC and EStar | 39 | - | 0% | - | - | 0% |
| | EStar-only | 0 | - | - | - | - | - |
| | Not Estar | 0 | - | - | - | - | - |
| | All | 39 | - | 0% | - | - | 0% |
| Total | CEC and EStar | 168 | 0% | 2% | 0% | 0% | 1% |
| | EStar-only | 261 | 2% | 5% | 5% | 5% | 4% |
| | Not Estar | 237 | 7% | 4% | 5% | 6% | 5% |
| | All | 666 | 3% | 4% | 4% | 5% | 4% |

Taken together, Table 5-1 and Table 5-2 indicate that the bulk of the observed lamp "failures" (i.e., catastrophic failures and pre-failure behavior) were concentrated among A-lamps that are ENERGY STAR-certified but not CA Quality Spec-compliant, and non-ENERGY STAR-certified lamps. However, it is important to understand that these failures were not evenly distributed across all ENERGY STAR and non-ENERGY STAR lamp models that had test units fail. Indeed, quite the opposite is true. Figure 5-15 shows how more than two-thirds of all failures (86 out of 130) came from 12 specific models that performed particularly poorly, with 50% or more of the units from those models that were tested experiencing either catastrophic failure or pre-failure behavior (shown in black), while 15% of all failures came from 6 models where 25-49% of test units failed (shown in orange), and 19% of all failures came from 18 models where

1-24% of test units failed (shown in green). Among poorest performing models (shown in black), one was ENERGY STAR-certified under the latest version of the ENERGY STAR product specification (v2.0), seven were ENERGY STAR-certified under the first version of (v1.0), and four were not ENERGY STAR-certified.

**FIGURE 5-15: DISTRIBUTION OF LAMP MODELS RELATIVE TO THE NUMBER OF FAILED TEST UNITS PER MODEL**



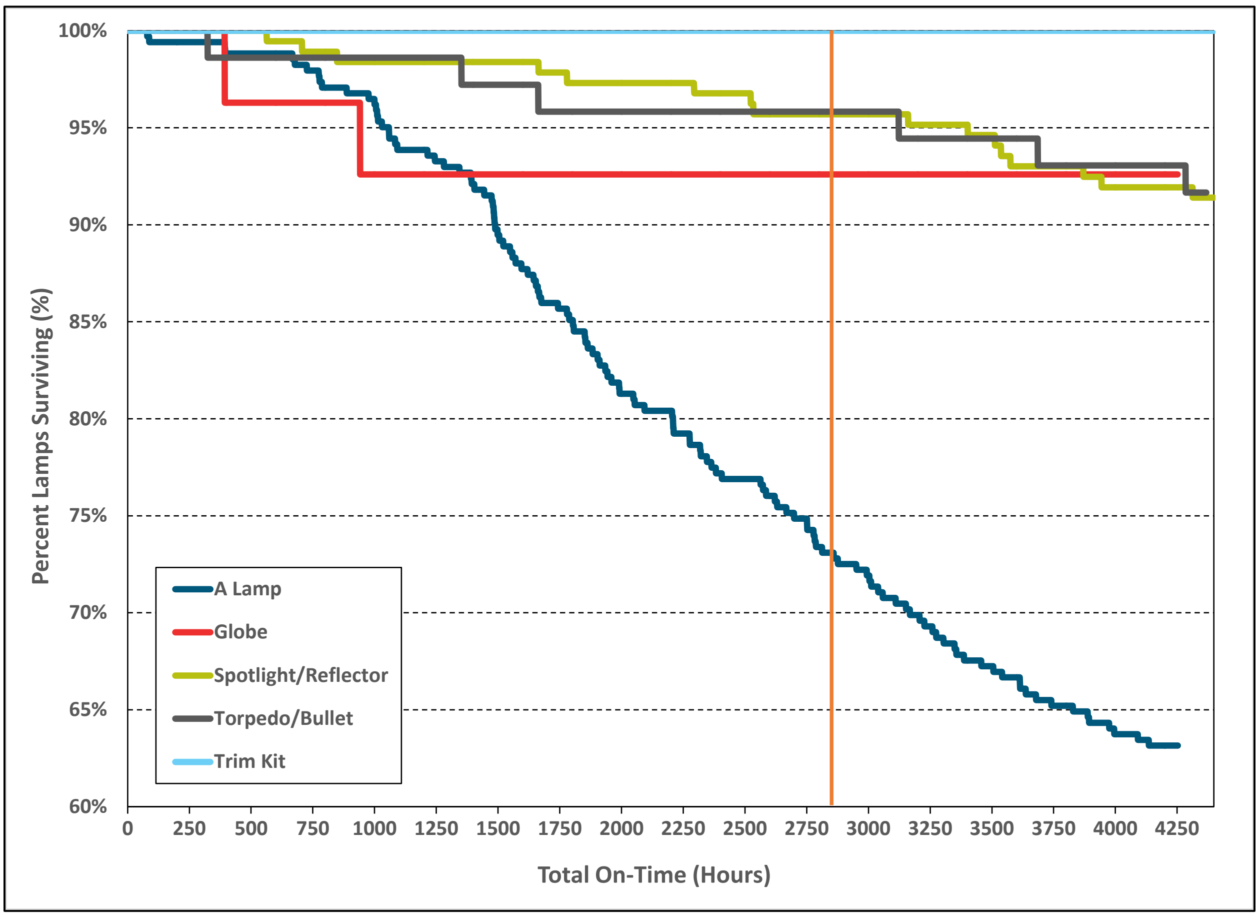

Apart from the magnitude of the overall failure rates observed in our testing and their concentration in A-lamps, the highly "clustered" nature of the observed failures is clearly also a key finding of this study. Indeed, the concentration of failures within a minority of specific models is a critical factor to take into account when interpreting our overall results.

In addition to the overall failure rates, it is also important to look at the associated temporal dynamics. In the lighting research literature, this is commonly accomplished in the form of "survival curves" which plot cumulative failures (in terms of percent of lamps surviving) over time. Below, we present three survival curves that summarize the observed failure rates over time – first by lamp type (Figure 5-16), then by fixture type (Figure 5-17), and finally by lamp type-fixture type combinations (Figure 5-18).

The primary objective of plotting results as survival curves is to identify, where possible, temporal patterns in failure rates. In this respect, it is important for readers to recall that due to the nature of our experimental design, lamps or fixtures of a common type were not necessarily on the same control circuit and therefore did not necessarily experience the same amount of total on-time during the maintenance test (since the switching cycles were determined by thermal cycle length, not lamp or fixture type). As such, our survival curves include a vertical orange line at hour 2,818 to indicate the minimum total on-time experienced by all lamps in the test. In this sense, the temporal trends across lamp and fixture type aggregations are strictly comparable *to the left of the orange line*. In contrast, the temporal trends to the right of the orange line are not strictly comparable across lamp and fixture type aggregations, and readers should use caution when interpreting any temporal patterns that may be implied.[33]

Figure 5-16 presents the survival curves by lamp type. The figure shows that A-lamp failures accelerated between 500 and 1,500 hours of on-time and then continued at a fairly steady rate. Reflector lamps and torpedo lamps experienced fairly steady rates of failure throughout the maintenance test, and globe lamps experienced no failures after the first 940 hours of on-time. Trim kits experienced no failures at all.

**FIGURE 5-16: SURVIVAL CURVES BY LAMP TYPE**




[33] The comparability issue stems from aggregating data across lamps on different switching cycles. This results in a data series that reflect the longest total on-time experienced by any lamp of a given type and masks lamps that had shorter total on-times due to differences in the lengths of their respective switching cycles. This same phenomenon arises when aggregating across fixture type and lamp-fixture combinations.

Figure 5-17 presents the survival curves by fixture type. This figure shows that lamp failures within enclosed ceiling fixtures and recessed downlights accelerated between 500 and 1,500 hours of on-time and then continued in a more linear fashion. Lamps in base-up bare sockets experienced fairly steady failure rates. Interestingly, lamps in base-down bare sockets experienced the bulk of their total failures between 1,400 hours and 2,000 hours of on-time.

## FIGURE 5-17: SURVIVAL CURVES BY FIXTURE TYPE

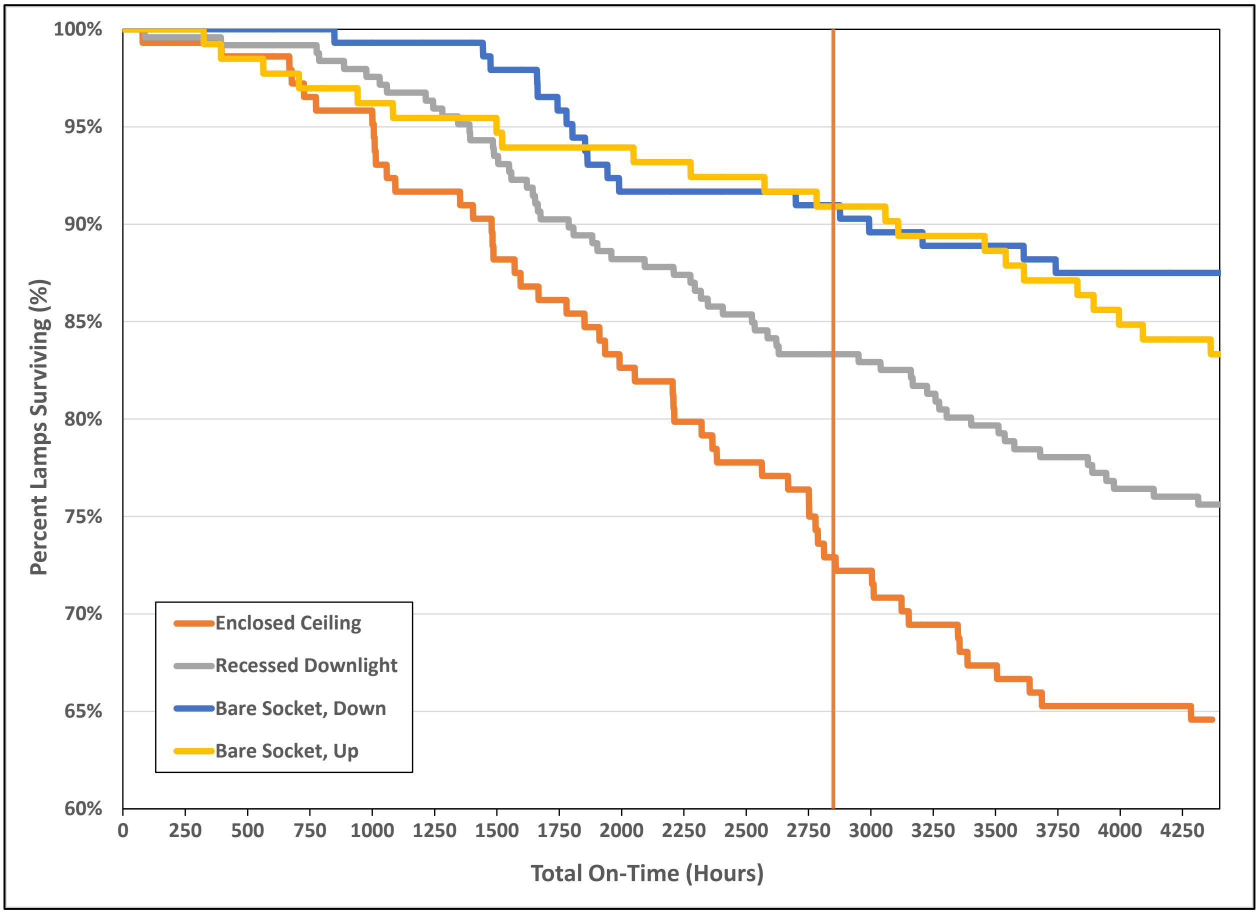
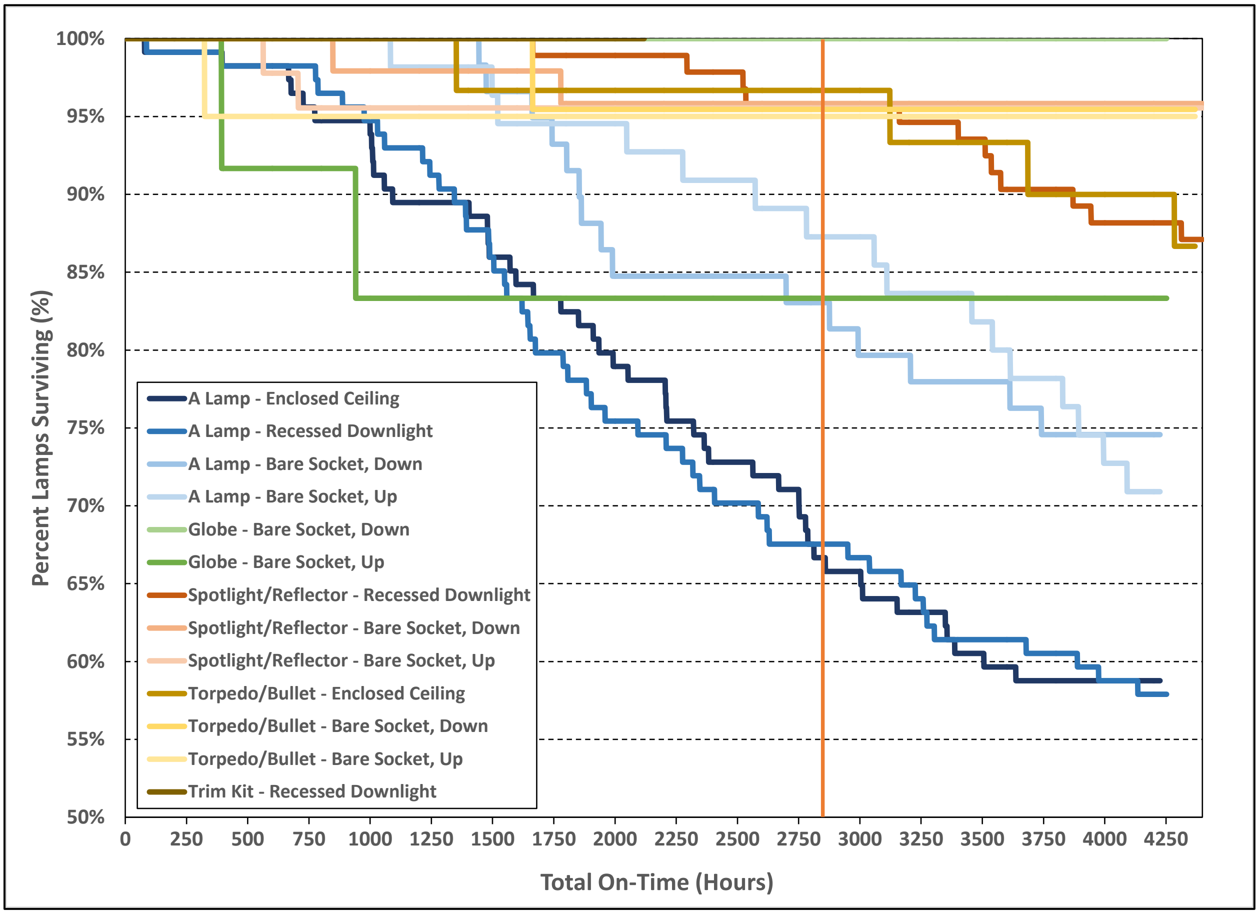


Figure 5-18 presents the survival curves by lamp type-fixture type combination. This figure separates some of the specific lamp/fixture combinations that exhibit distinct temporal dynamics. For example, the figure shows that while the failure rate for A-lamps in enclosed ceiling fixtures and recessed downlights accelerates between 500 and 1,500 hours of on-time, the failure rate for A-lamps in bare sockets accelerates only after 1,500 hours of on-time and appears to stabilize around 2,000 hours.

**FIGURE 5-18: SURVIVAL CURVES BY LAMP TYPE-FIXTURE TYPE COMBINATIONS**




## 5.5 REGRESSION ANALYSIS OF FAILURE RATES

Given the wide range of LED lamps, lamp-fixture combinations, and switching cycles that were included in this study, we also sought to isolate the impact of individual variables (e.g., wattage, lamp temperature, thermal cycle length, and lamp-fixture combinations) on observed failure rates. To do this, we conducted a regression analysis using the data generated by the experiment. The methods and findings from this regression analysis are presented below.

Because lamp failure is a binary variable (i.e., either failed or not failed), we concentrated on developing a logit model specification for our regression analysis. In logit models, the dependent variable is expressed as an "odds ratio" or the probability that the event (i.e., lamp failure) will occur as a function of a given set of independent variables. In this respect, we developed regression models that attempted to explain the probability of lamp failure as a function of independent variables such as wattage, lamp temperature, etc.

We tested over 20 different logit model specifications using various combinations of initial photometric characteristics, thermal characteristics, switching cycle length, and dummy variables representing lamp type, fixture type, lamp-fixture combinations, and CA Quality Spec compliance as independent, explanatory variables. Overall, our initial logit models achieved what could be described as "poor to moderate" levels of model fit, with the highest maximum rescaled R-squared values converging around 0.63.[34] In order to test whether the clustering of failures within specific models was impacting the explanatory power of our models, we also re-estimated models after removing the results for certain cohorts, including all models with 100% failures, all A-lamps, etc. While these "no outliers" models resulted in better levels of model fit, the sign and significance of some independent variables changed in counter-intuitive ways, suggesting that the "outlier" observations included some critical information that should not be disregarded. The complete set of results for the best-performing model specifications are presented in Appendix C.

Overall, the moderate levels of model fit that we were able to achieve indicates that even our best performing regression results are not likely robust enough to be considered conclusive for predictive purposes (i.e., using the estimated coefficients for predictive analysis). However, it is important to note that the modeling exercise did yield some consistent findings, namely:

- The estimated coefficients for warm-up time, max lamp temperature, on-hours per day, and CA Quality Spec compliance were consistently statistically significant with intuitively correct signs across all model specifications that included those variables
- Power, power factor, CRI, lumen output, efficacy, thermal cycles per day, luminaire type, lamp type, and labeled fixture compatibility were not significant explanatory variables[35]

[34] For logistic regressions, R-squared values can never achieve a maximum value of 1. In this sense, such R-squared values from logistic regressions can artificially appear low. A maximum re-scaled R-squared provides a metric of overall model fit that is more closely analogous to R-squared values from linear models. Mathematically, the maximum rescaled R-squared is a ratio of the R-squared over the maximum achievable R-squared for that discrete model.

[35] Although some dummy variables representing various lamp-fixture combinations has statistically significant coefficients, the magnitude of those coefficients across the various lamp-fixture combinations were not significantly different from each other.

For the former set of "stable" variables (i.e., max lamp temperature, on-hours per day, and CA Quality Spec compliance), Table 5-3 provides a summary of the estimated coefficients for those variables, their p-values, and a translation of the estimated coefficients into the change in likelihood of failure due to a unit change in that variable. The table provides the range of each value across our seven best-performing logit models. We provide ranges rather than point estimates in order to illustrate the degree to which our results varied across model specifications, while providing readers with an indication of the relative magnitude of impact of each variable on the odds ratio or likelihood of failure.

**TABLE 5-3: SUMMARY OF ESTIMATED COEFFICIENTS FOR "STABLE" VARIABLES ACROSS BEST-FITTING MODELS**

| Parameter (units) | Estimated Coefficients | P-Values | Marginal Change in Likelihood of Failure per Unit Change in Parameter |
|---|---|---|---|
| 95% Warm-Up Time (minutes) | -0.0517 to -0.0322 | 0.0002 to 0.0253 | -5.04% to -3.17% |
| Maximum Lamp Temperature (°C) | 0.03 to 0.0603 | 0.0003 to 0.0832 | 3.05% to 6.22% |
| Number of On-Hours per Day (hrs/day) | 0.5157 to 0.7878 | 0.0003 to 0.002 | 67.48% to 119.86% |
| CA Quality Spec Compliant (binary) | -2.9289 to -1.0324 | <.0001 to 0.0098 | -94.65% to -64.38% |

Note that values in the right-hand column of Table 5-3 should be interpreted as the change in likelihood of failure that results from a one-unit change in the parameter value. For example, the estimated coefficient for warm-up time should be interpreted as "for every one-minute increase in warm-up time, the likelihood of failure decreases by 3.2% to 5.0%." For the CA Quality Spec compliance variable, the estimated coefficient should be interpreted as "for lamps compliant with the CA Quality Spec, the likelihood of failure decreases by 64% to 95% compared to lamps not compliant with the CA Quality Spec." This particular result should be interpreted carefully, since – as we noted earlier in this section – we found that CRI and power factor (in isolation) were not significant explanatory variables. In other words, the coefficient for the CA Quality Spec compliance variable should be interpreted as the combined effect of all its differentiating features (CRI, power factor, warranty, dimmability, and noise) and not driven or attributable to any one specific feature.

## 5.6 POST-MORTEM FORENSIC ANALYSIS OF FAILED LAMPS

Following the conclusion of the maintenance testing, most of the failed test lamps were sent to a second laboratory for post-mortem forensic analysis in order to determine the exact point of failure, wherever possible, and how those failure points were or were not related to elevated operating temperature and/or thermal cycling.[36] The complete stand-alone report from this post-mortem analysis is provided in Appendix D. For the sake of brevity, the main methods and key findings are summarized below.

### 5.6.1 LED Drivers and LED Modules

Before presenting the methods of findings of the forensic analysis, it may be helpful to review the basics of LED lamp construction and functionality. Most LED lighting devices use a driver to convert mains electricity to the proper voltage and current necessary to capitalize on the efficiency of LEDs. These drivers are typically constant current providers, meaning that the driver will vary the voltage across its load (i.e., the LEDs) to maintain a constant electric current. A constant voltage and current supply is essential to these devices because it maintains regulated light output and ensures device reliability. These drivers rely on an integrated circuit (IC) controller to operate a transistor.[37] The transistor is responsible for regulating the device, and it achieves this by switching on and off at high frequency.

An LED module is an assembly of LED packages (i.e., individual or clusters of LED chips), on a printed circuit board and additional thermal, mechanical, and electrical interfaces to connect to the load side of an LED driver. Interruption of the electrical or thermal connections provided by the LED module could result in abrupt failure of the device. Additionally, loss of contact between the module and individual LEDs or LED packages (e.g., in the way of solder failure) would also be detrimental to the operation of the LED lamp.

### 5.6.2 Methods

A three-step analysis process was used to identify the point of failure for each failed LED lamp. These three steps involved: 1) initial inspection and disassembly; 2) interior inspection; and, 3) electrical continuity testing of key components. Although this method has been very successful at identifying LED device failure location in the past, the failed lamps examined herein had a much lower component failure rate than expected. Therefore, additional analysis beyond the main three-step process was performed to identify the location of the failure. This additional analysis included some thermal, electrical, and surface composition testing. Because many failures were localized to the LED module, scanning electron microscopy (SEM) was also used to determine the surface texture and composition of LED solder joints and the LED contacts and pads (when applicable).

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[36] The post-mortem analysis was conducted on a total of 105 failed lamps, which represents 80% of all failures observed during the maintenance test. While we had intended to have post-mortem analysis conducted on all lamps that failed during maintenance testing, project calendar constraints restricted the post-mortem analysis to all lamps that had failed by mid-May 2017 (i.e. 105). However, two of the 22 control circuits continued operation through the end of May 2017 to make up for lost testing time following a power outage at the test facility (as detailed in Appendix B). The impact of this is that none of the lamps on those control circuits that failed in late May 2017 were included in the post-mortem analysis.

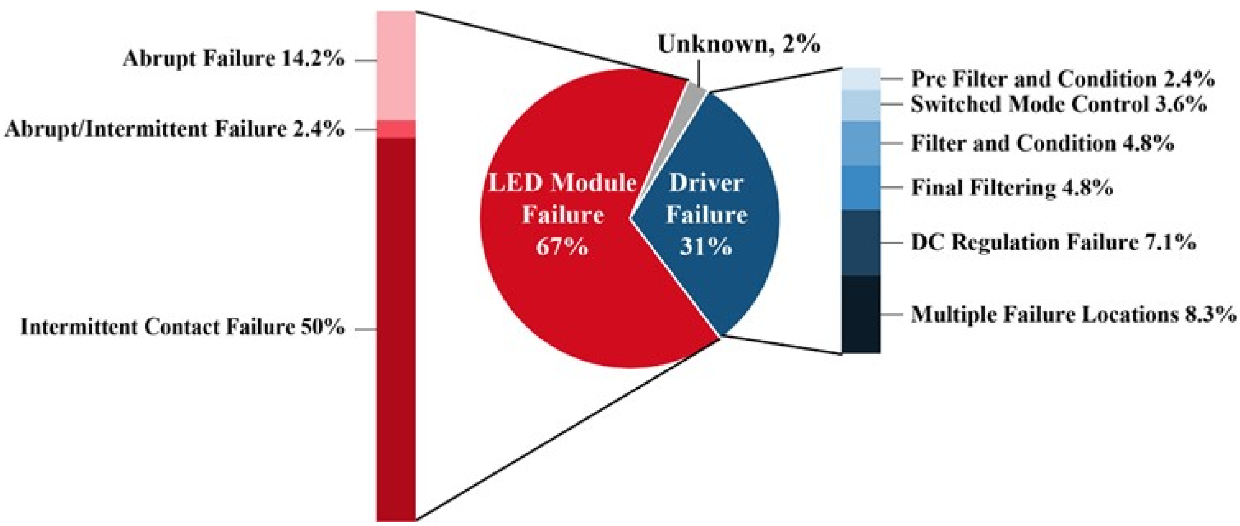
[37] Many, but not all, IC controllers used in LED drivers include a temperature sensor that reduces current when temperatures exceed certain limits (generally around 115°C).

### 5.6.3 Results

The location of test lamp failure was investigated for 26 LED lamp models, which consisted of a total of 84 failed test lamps. In addition to the 84 failed devices, another 15 devices that were prone to fail intermittently or otherwise exhibit pre-failure behavior were also analyzed. Often, these devices operated without incident for minutes or hours, and then shut off.

Figure 5-19 summarizes the failure locations that were identified for all failed test examined in the post-mortem forensic analysis. Failure location is sorted into the following three main categories: 1) LED module failures, 2) driver failures, and 3) unknown failures. As the figure shows, LED module failure was the most prevalent failure location for the test lamps in this study (67%). Failures that occurred on the LED module could be further classified by whether the failure was abrupt or because of an intermittent contact issue. For two of the devices that experienced LED module failure, the failure location was not classified as abrupt or intermittent. The failure location for these devices was classified as an abrupt/intermittent failure to account for the uncertainty in whether the device was damaged during disassembly.

**FIGURE 5-19: FAILURE LOCATION BY CATEGORY FOR TEST LED LAMPS**

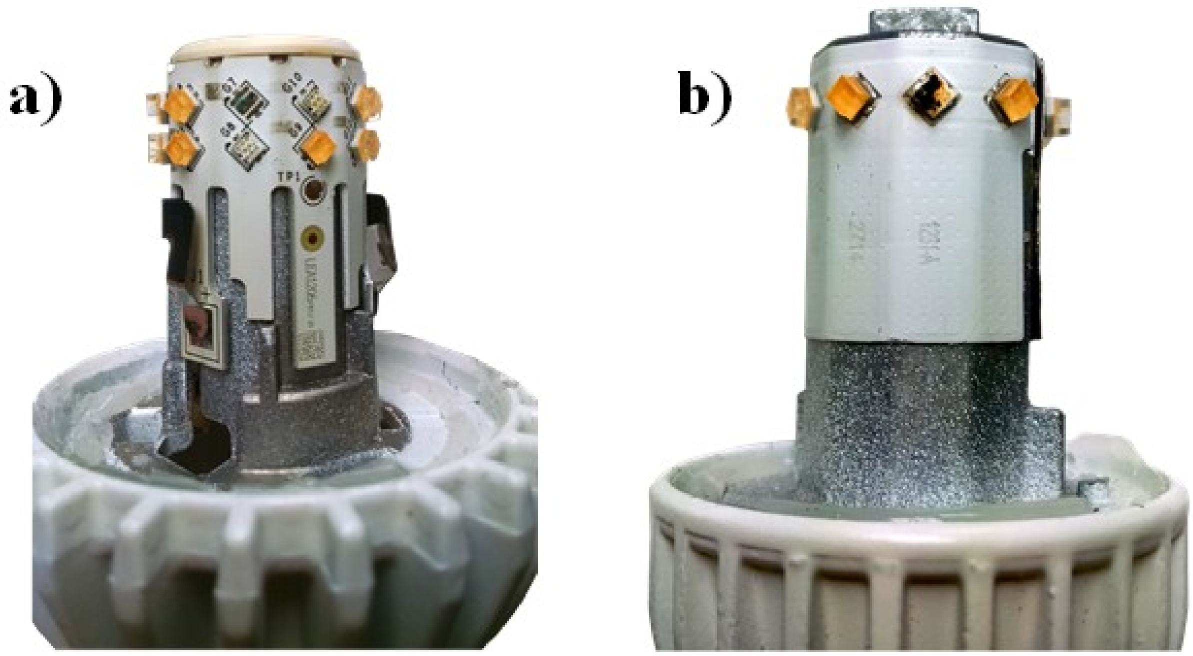



Failures that occurred on the LED driver were classified into six categories that correspond to the main circuit types in LED drivers and their associated components (i.e., inductors, capacitors, resistors, diodes, etc.). These categories are: 1) pre-filter and condition, 2) switched-mode control, 3) filter and condition, 4) final filtering, 5) DC regulation failure, and 5) multiple failure locations. These six categories, except for DC regulation failure, pinpoint an exact location on the driver where failure location occurred. Finally, the location of failure for two devices could not be determined through our tests; therefore, the assignment of failure location for these devices was classified as unknown. In the subsections below, we provide more detail of the forensic results within LED module failures and LED driver failures.

## LED Module Failures

Signs of complete LED package solder failure (i.e., a loose LED in the globe) were noted, if possible, before disassembly. In two cases, it was difficult to determine whether the LED solder failed before disassembly.[38] Other LED packages on these failed devices had such brittle solder that simply touching them, or the shock of removing the globe, caused complete solder failure. Brittle solder joints were prevalent in specific model numbers and, in some cases, particular LEDs within that model number. This problem suggests that there was a manufacturing or design issue. Drivers with a boost topology were most likely to have LED modules that experienced complete LED solder failure (Figure 5-20a).[39] In two cases, an abrupt failure occurred even when all LED packages still appeared to be attached to the module (Figure 5-20b). In these cases, the encapsulant had become dislodged, leaving behind a black carbon residue. Subsequent LED failure resulted.

**FIGURE 5-20: EXAMPLES OF (A) LED SOLDER FAILURE AND (B) LED FAILURE**

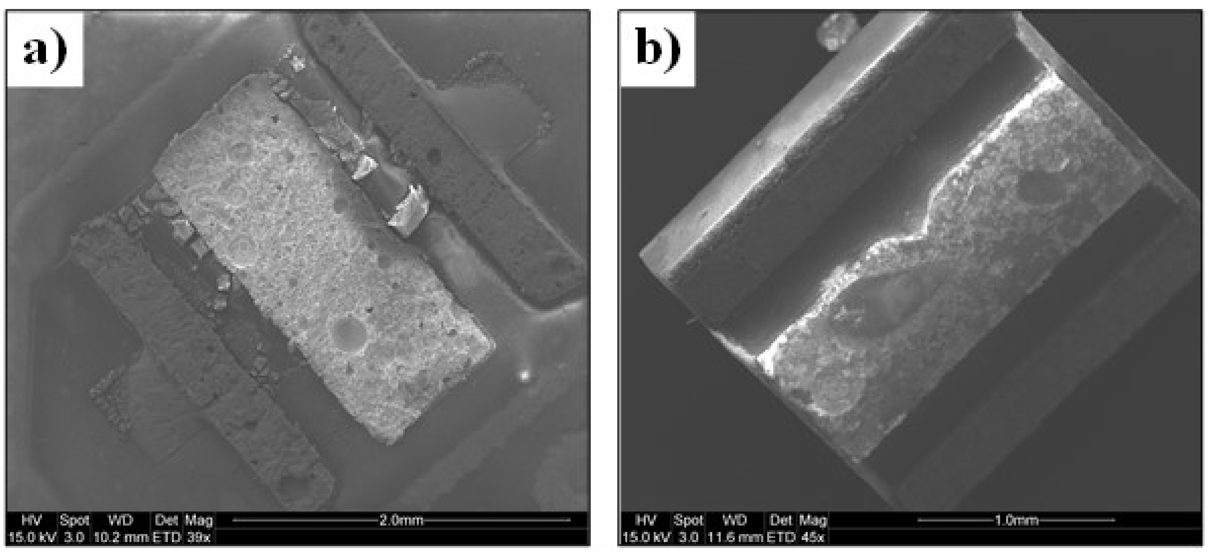



[38] For these two devices, we assumed that failure occurred on the LED module, but we did not classify the failure as abrupt or intermittent.

[39] Driver topology refers to the strategies used by manufacturers to achieve and maintain the voltage and current required to operate LED modules under optimal conditions. The common driver topologies are boost, buck, buck-boost, and flyback.

The remaining LED module failures were determined through electrical tests. These tests showed that failure was not introduced at any point within the driver and must be within the LED module. Although the electrical test did not reveal an exact failure location on the LED module, there is strong evidence to support that solder embrittlement and contact oxidation led to lower device performance (Figure 5-21). We believe that these failures were at least partially the result of high, localized heat near the LED packages that resulted in the formation of intermetallics (i.e. alloys) in the solder and soldered surface metals. Such intermetallics are known to be brittle and can introduce micro-cracks into the solder joints. In particular, many of these lamps used gold pads as solder surfaces, and it is well known that gold dissolves in many solders to form brittle intermetallics. The dissolution of gold into solder often occurs as early as the manufacturing process (i.e. when the solder is solidifying) and progresses as the device is operated at high temperatures for prolonged periods of time. The latter of these occurrences is more responsible for solder embrittlement.

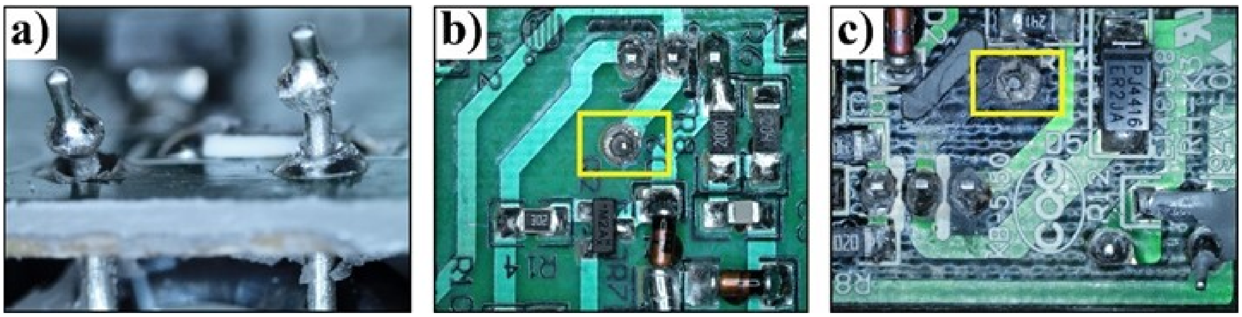
**FIGURE 5-21: SEM IMAGES OF (A) AN LED CONTACT PAD SHOWING EMBRITTLEMENT, INHOMOGENEOUS CONTACT SURFACE, AND ALLOY WHISKERING; AND (B) AN LED WITH AN INHOMOGENEOUS CONTACT SURFACE**




## LED Driver Failures

Typical continuity failures (that lead to abrupt failures) included through-hole solder failure and localized signs of heat stress near the transformer and metal-oxide semiconductor field-effect transistor (MOSFET) components (Figure 5-22). Other through-hole solder failure (e.g., capacitors, inductors, power lines), as well as open fuses, broken diode bridges, or any combination thereof, were also found. Through-hole failures were often manifested as visible cracks in the solder joint, often cylindrical in nature (see Figure 5-22). In some instances of through-hole failure, the solder joint fractured completely, and the lead separated from the joint (see Figure 5-22a). The continuity failures were likely the result of repeated thermal expansion induced by switching cycles in the switched-mode control and final filtering stages, as evidenced by the large number of transformer to MOSFET and inductor to MOSFET solder failures and localized signs of heat stress on the driver at these locations (Figure 5-22c).

**FIGURE 5-22: EXAMPLES OF MAJOR CONTINUITY FAILURES FOR LED DRIVERS: (A) CAPACITOR SOLDER FAILURE, (B) TRANSFORMER SOLDER FAILURE, AND (C) MULTIPLE SOLDER AND COMPONENT FAILURE (TRANSFORMER AND CAPACITOR SOLDER FAILURES WITH LOCALIZED HEAT STRESS ARE SHOWN)**




While most of the LED driver failures were because of discontinuity and component failures (see Figure 5-19), approximately one-fourth of the failed drivers were DC regulation failures. This failure mode was detected and assigned when the output voltage of the test driver (connected to the control LED module load) was much lower than the voltage necessary to operate the control LED module (as determined by the control driver). Notably, the tested electrical components on these drivers passed initial continuity and electrical tests. However, there could have been an undetected component failure that rendered the driver incapable of regulating direct current at the proper level when power was supplied. It is hypothesized that localized heat around the transformer and inductor, respectively, and MOSFET damaged the control IC. Most IC controllers among the tested lamps contain a temperature sensor that reduces current when the temperature is too high. Further investigation was not pursued regarding whether the IC controller itself failed or whether some other component failure caused the DC regulation failure.

### 5.6.4 Summary of Findings

In this post-mortem forensic analysis of LED lamps that failed during maintenance testing, an examination of the failed test devices revealed a clear correlation between model number and failure location and between driver topology and failure location. It was also found that the percentage of driver component failures (approximately 24%) was less than expected and that most failures (67%) occurred on the LED module. These results were surprising because we anticipated that more test lamps would experience driver component failure than LED module failure. Upon examination of devices that failed intermittently, we found that more devices experienced driver component failures (66%) than LED module failures (20%). However, failure location did not change for intermittent devices produced by the same manufacturer and with the same driver topology. Therefore, for LED lamps, we postulate that the rate for LED module failure is higher than the rate for driver component solder or functionality failure under the conditions used in the maintenance test, as described in Section 3.4.

An examination of the failed lamps also revealed that the driver and LED modules often failed because of a solder or contact issue; we have identified high-stress locations where manufacturers can improve the solder technique. In particular, drivers were susceptible to through-hole component solder failure—transformer and MOSFET solder joints were often damaged because of localized heating around these components. Additionally, solder technique could be improved between the LED packages and the LED modules. By improving solder technique in these high-stress areas, it is likely that manufacturers could improve LED lamp lifetime substantially and capitalize on the robustness of individual LEDs. Such actions would benefit LED-device manufacturers and their customers and would also provide benefits to lighting industry stakeholders in California including taxpayers, municipalities, and utilities.

# 6 SUMMARY AND DISCUSSION

The key empirical results from each element of our overall testing experiment, along with the key findings from our related analyses of the results are summarized below.

- **Initial photometric testing**:
  - Measured values of lighting performance were largely consistent with rated values.
  - Where deviations from rated values occurred, these deviations were mostly in the preferable direction from an energy efficiency point of view, i.e., lower power, higher lumen output, higher efficacy, etc.
  - On average, the measured efficacy of CA Quality Spec lamps was 20% lower compared to that of non-CA Quality Spec lamps (62 vs. 77 lumens/W).
- **Maintenance testing**:
  - 24% of the units tested (160 out of 666) either failed catastrophically or exhibited "pre-failure" behavior within a maximum of 4,500 hours of total on-time.
  - Failure rates were highest among A-lamps (38%), while failure rates for globe, torpedo, and reflector lamps were comparatively lower (between 9% and 12%).
  - None of the trim kits tested failed catastrophically or exhibited "pre-failure" behavior.
  - Two-thirds of all failures came from 12 specific models that performed particularly poorly.
- **Final photometric testing**:
  - Only 8 of the test lamps (1.5%) that survived maintenance testing experienced decreases in light output of 30% or more.
  - Only 12 of the test lamps (2.2%) that survived maintenance testing experienced changes in color temperature that might be considered noticeable/objectionable.
- **Regression analysis**:
  - Logit regression modeling of the probability of failure as a function of initial photometric characteristics, thermal characteristics, switching cycle length, and various dummy variables could only explain up to 65% of the variation in the observed probability of failure.
  - The logit models yielded consistent findings related to the explanatory power of certain independent variables, namely:
    - Warm-up time, max lamp temperature, on-hours per day, and CA Quality Spec compliance were consistently statistically significant explanatory variables with intuitively correct signs.

- Power, power factor, CRI, lumen output, efficacy, thermal cycles per day, luminaire type, lamp type, and labeled fixture compatibility were not significant explanatory variables.

- **Post-mortem forensic analysis**:
  - The most common points of failure were related to contact failures from poor or degraded solder connections that were consistent with high heat operation and repeated expansion and contraction due to operating temperature changes from switching.

## 6.1 DISCUSSION

Overall, the results produced by this study provide strong evidence that two stress conditions commonly found in residential homes – thermal cycling from repeated switching and elevated operating temperature due to restricted airflow and relative lamp position within the luminaire – are indeed significant stress conditions that can lead to early catastrophic failures in LED lamps. The temperature-related stress testing used in our study resulted in an overall failure rate of 24% over a maximum of 4,500 hours of total on-time across a large, representative sample of LED lamps available in California procured in late 2015.

While the test lamps in our study were operated at temperatures explicitly designed to approximate field conditions (through testing in typical residential fixtures), the switching cycles used in our stress testing were not explicitly designed to reflect common or typical switching patterns in the field. Rather, the switching patterns used in our study were designed to maximize the number of complete thermal cycles that test lamps could be subjected to within a fixed amount of calendar time. In this sense, the overall failures rates observed in this study should not be interpreted as those that would be reasonably expected from typical residential applications in the field. It should be noted, however, that the thermal cycles used for our stress testing were not exceedingly long. Over half of the lamps tested were determined to have thermal cycles of one hour or less of continuous on-time and over 90% of the lamps tested exhibited thermal cycles of 90 minutes or less of continuous on-time. In this sense, the switching patterns used to produce "full" thermal cycles in our study were short enough that one can easily imagine a significant portion of actual switching patterns in residential homes producing such "full" thermal cycles. To be clear, it was not the objective of this study to simulate the typical switching patterns in California homes or their impact on LED lamp life – largely because the primary data needed to conduct such a simulation is currently not available – and our results should not be interpreted as such. Nonetheless, the magnitude of the overall observed failure rates (24%) and the fact that nearly all of the thermal cycles used for our stress testing required less than 90 minutes of continuous on-time strongly suggest that this failure mode should be explicitly considered in the ex-ante EUL assumptions for LED lamps. From an energy efficiency program planning and evaluation perspective, even minor adjustments to the ex-ante EUL assumptions (based on rated values) may have an important impact on lifecycle savings and cost-effectiveness estimates. While developing such EUL adjustments was beyond the scope of this study, the results represent an important empirical foundation for more formal EUL adjustments.

Our results also show that a significant portion of observed failures were concentrated in a few specific lamp models, the majority of which were ENERGY STAR-certified products. A post-mortem forensic analysis of these failed lamps indicated that the most common points of failure were related to contact failures from poor or degraded solder connections – both on the LED driver and, surprisingly, on the LED modules themselves – that were consistent with high heat and repeated thermal expansion and contraction. Taken together, these findings suggest that the certification tests currently employed by ENERGY STAR either do not adequately address two common field conditions (i.e. operating temperature and switching patterns) and/or that certain models have latent manufacturing defects that are exposed as a result of our experimental design. The corollary to this is that we believe the results from this study indicate a distinct opportunity to augment or supplement current standardized performance tests with short-run reliability tests focused on temperature-related early failure modes that could help detect the type of poor-performing models identified in this study. This short-run reliability test could potentially resemble a scaled-down version of this study and could be administered under ENERGY STAR or funded by California IOUs every 2-3 years.

## 6.2 KEY FINDINGS RELATIVE TO PRIMARY RESEARCH QUESTIONS

Below, we reframe the key findings and discussion presented above relative to the primary research questions originally set forth for this study in the 2013-2014 EM&V Roadmap for Lighting.

***How does switching LED lamps on/off impact the life and performance of the LED lamps?***

As discussed above, the results produced by this study provide strong evidence that two stress conditions commonly found in residential homes – thermal cycling from repeated on/off switching and elevated operating temperature due to restricted airflow and relative lamp position within the luminaire – are indeed significant stress conditions that can lead to early catastrophic failures in LED lamps. A post-mortem forensic analysis of failed lamps indicated that the most common points of failure were related to contact failures from poor or degraded solder connections consistent with exposure to high heat and repeated thermal expansion and contraction (due to on/off switching patterns).

***Are the manufacturers' specifications of LED rated life accurate?***

Given the significant number of test lamps that experienced catastrophic failures or pre-failure behavior within 4,500 hours of total runtime and the fact that the operating temperatures and switching cycles used in our experiment were well within the operating temperatures and switching patterns one would expect in typical residential homes, we believe that the empirical data resulting from this study strongly suggest that, on average, manufacturers' current estimates of LED rated life are likely to be overstated.

However, we currently lack the primary data necessary to reasonably extrapolate our lab-based results to the population of LEDs installed in California homes and therefore cannot reasonably estimate the extent to which current LED rated life estimates are overstated (see recommendations below).

***Are the IOUs' LED workpaper assumptions properly stated?***

The key performance and reliability metrics that were examined in this study that are also used in the IOUs' LED workpapers are efficacy and EUL. For both of those metrics, the IOUs rely on manufacturers' rated values, but in slightly different ways.

For efficacy, the IOUs apply a product's (or product categories') rated efficacy to an ED-approved "delta watts" equation to determine the per-unit ex ante energy and peak demand savings. The photometric tests conducted for this study indicated that measured efficacy was largely consistent with rated efficacy. Where deviations from rated values occurred, these deviations were mostly in the preferable direction from an energy efficiency point of view, i.e., lower power input, higher lumen output, and higher efficacy. For efficacy, therefore, the IOUs' current workpaper assumptions for LEDs appear to be properly stated.

For EUL, the assumptions used in the IOUs' current set of LED workpapers (for the lamp types included in this study) are based on EUL values recommended by Energy Division and the Database for Energy Efficiency Resources (DEER) consultant team. These recommended values are based on the prevailing rated life estimates from manufacturers (by lamp type and wattage) in terms of total on-hours and then translated to years by dividing rated life by the DEER-recommended estimates of average annual hours of use by building type. Since the basis of current EUL values are still tied directly to manufacturers' rated life estimates, we believe that the empirical data resulting from this study strongly suggest that the DEER-recommended EUL values for LEDs are overstated and recommend conducting a survival analysis using our results in combination with data from the 2012 California Lighting and Appliance Survey (CLASS) to develop formal adjustments to the current ex ante EUL values for LED lamps. This recommendation is discussed in more detail below.

## 6.3 RECOMMENDATIONS FOR FUTURE WORK

With these key findings in mind, we outline our recommendations for future work below. These recommendations are designed to build upon the key findings and address the key uncertainties from this study.

## Temporal Analysis of Failure Data

A detailed statistical analysis of the temporal data generated by this study was determined to be beyond the scope of this study, but potentially would be highly useful for developing a short-run reliability test.[40] Specifically, the objective of such a temporal analysis would be to determine how much thermal cycling and/or total on-time is required to be able to reasonably project the failure rates that we observed through 4,500 hours of total on-time. We believe that it is critical to explore the extent to which it may be possible to use failure rates observed over relatively short time scales (e.g. 1,500 thermal cycles of 1 hour on/1 hour off, which would require 125 days of testing) to reasonably project failure rates over longer time scales.

Because this type of temporal analysis has direct implications for the potential development of short-run reliability tests, we strongly encourage the CPUC to coordinate any such analysis with ENERGY STAR and its stakeholders, in addition to California stakeholders.

## Develop Primary Data on Installed Stock of Residential Fixtures and Luminaires

While the sample of LED lamps tested in our study was large and designed to be representative of the market in California, the specific fixtures that the test lamps were operated in were not representative. In this sense, a key uncertainty in this study is the degree to which the specific characteristics of the fixtures and luminaires used for our testing differ from those most commonly found in California homes. To be clear, the most recent CLASS includes data on lighting technology by fixture type and room type. Indeed, we used the population estimates from CLASS when selecting the fixture types to use in this study. However, the CLASS data do not include the type of fixture characteristics that would be needed to properly specify "representative" fixtures and luminaires for the purposes of temperature-related, standardized stress testing – particularly for air-constrained fixtures and luminaires that contributed to high operating temperatures. Such characteristics would include the diameter of the luminaire, luminaire material, and the relative lamp position within the luminaire.

We believe that expanding data collection scope of the upcoming In-Home Lighting Inventory and Metering Study (IHLIMS) to include this type of fixture characteristics data would have only a marginal impact on the relative cost of the overall IHLIMS effort, and we encourage the CPUC to consider such a scope expansion for the upcoming IHLIMS.

40 The regression analysis presented in Section 4.5 was focused on isolating the relative contribution of individual thermal, photometric, and lamp/luminaire characteristics on the probability of early failure over the entire maintenance test.

## Verify Operating Temperatures of Lamps in the Field

Similar to recommendation above, the operating temperatures measured in this study were based on test lamps in four specific luminaire models which are not necessarily representative of the most common fixtures and luminaires installed in California homes. In this respect, it is important to verify that the laboratory-based measurements of operating temperature reasonably approximate those that lamps experience in the field and develop a broader set of primary data on lamp operating temperatures across a wider array of lamp/fixture/luminaire combinations.

As with the fixture characteristics data discussed above, we believe that expanding IHLIMS's data collection scope to include spot measurements of lamp operating temperatures would have only a marginal impact on the relative cost of the overall IHLIMS effort, and we encourage the CPUC to consider such a scope expansion for the upcoming IHLIMS.

## Develop Primary Data on Switching Patterns by Fixture Type

As discussed earlier in this section, the switching cycles used in our stress testing were not explicitly designed to reflect common or typical switching patterns in the field, and the lack of primary data needed to estimate average switching cycles in homes prevents us from directly assessing the "representativeness" of the switching cycles we used. In theory, the lighting loggers used in the most recent CLASS studies should have produced the data streams needed to estimate average switching cycle length (by fixture type and room type). Unfortunately, the lighting loggers used in previous CLASS studies (as well as many previous on-site studies of lighting in California and elsewhere) proved to be overly sensitive to flicker and other transient phenomena that affect the accurate measurement of on-off events. While it has been possible to develop data cleaning algorithms and approaches to correct for flicker and other measurement issues for the purposes of estimating total hours of use (HOU) per day, it does not appear tractable or cost-effective to attempt a similar data cleaning exercise for the purposes of accurately measuring lengths and distribution of actual switching cycles from the same data set.

Fortunately, a new generation of lighting loggers is now available that appears to be capable of discerning flicker and other transient phenomena from true on-off switching. Indeed, it is our understanding that the CPUC is already contemplating using advanced loggers for the upcoming IHLIMS in order to avoid the data cleaning and interpretations issues that have plagued past efforts. From this perspective, we strongly encourage the CPUC to also consider accurate measurement of switching cycle length as a key performance criterion when selecting and procuring loggers for the upcoming IHLIMS and expanding the scope of the IHLIMS to include estimation of average switching cycle length by fixture type and room type.

## Develop Formal Adjustments to Ex Ante EULs for LED lamps in IOU programs

Finally, we believe that the results of this study represent an important empirical foundation for more formal adjustments to the current ex ante EUL values for LED lamps. While there are a handful of key uncertainties in our study that could be addressed through expanded primary data collection (most likely as part of the upcoming IHLIMS), we also believe that the data generated in this study and the data currently available from the 2012 CLASS would enable a reasonable survival analysis to be conducted immediately. Indeed, SCE staff conducted a survival analysis for CFLs using the results of the previous CFL Lab Test Study and the logger data from the 2008 CLASS.[41] We recommend that the CPUC conduct a survival analysis for LED lamps based on the same approach. If and when primary data from the upcoming IHLIMS become available, this survival analysis can be updated. However, given the highly dynamic nature of the LED market and LED programs in California, we do not recommend delaying a formal survival analysis.

[41] See http://www.calmac.org/publications/CFL_Lab_Study.pdf.

# 7 APPENDICES

# APPENDIX A DETAILED RESULTS

Appendix A contains the complete set of detailed test results and is organized as follows:

- A1 – Test Sample Product Characteristics: These tables provide the main performance characteristics of each lamp and trim kit model procured for testing as labeled on product packaging and the verified compliance with the CA Quality Spec and/or ENERGY STAR product specifications.

- A2 – Thermal Testing Results and Switching Zone Assignment & Timing: These tables provide the thermal testing results, resulting switching control zone assignments, and switching cycle characteristics for each test unit.

- A3 – Initial and Final Photometric Testing Results: These tables provide the detailed photometric testing results for each test lamps prior to the beginning of the maintenance test, as well as a second set of identical photometric results for each test lamps that was still operating normally at the end of the maintenance test.

- A4 – Early Failure Timing and Calculated Values: These tables provide the total on-time (or "burn time") experienced by each test unit, the time at which test units experienced catastrophic early failure, and the time at which test units began exhibiting pre-failure behavior. These tables also include select calculated values that describe key changes in photometric performance (i.e. efficacy, lumen maintenance, and color shift) for each test lamp that was still operating normally at the end of the maintenance test.

| Sampling Criteria | | | | | | Values as Found on Product Labels | | | | | | | | | Verified Compliance | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model # | Bulb Style | Reflector Subtype | Base Type | Lumen Bin | Make # | Watts | Lumens | CRI | Color Temp | Rated Life | Energy Star | Dimmable | Exterior Rated | Fixture Compatability | CA Quality Spec | Energy Star QPL v2.0 | Energy Star QPL v1.4 | Energy Star QPL v1.1 |
| 1 | A-LAMP | N/A | MEDIUM SCREW BASE | 201-400 lm. | 1 | 4.5 | 270 | NOT LISTED | 2700 | 15000 | NO | YES | NO | CEILING FANS | NO | NO | NO | NO |
| 2 | A-LAMP | N/A | MEDIUM SCREW BASE | 201-400 lm. | 1 | 4.5 | 270 | NOT LISTED | 2700 | 15000 | NO | YES | NO | CEILING FANS | NO | NO | NO | NO |
| 3 | A-LAMP | N/A | MEDIUM SCREW BASE | 201-400 lm. | 2 | 4.8 | 300 | NOT LISTED | 3000 | 25000 | NO | YES | NO | NOT ENCLOSED | NO | NO | NO | NO |
| 4 | A-LAMP | N/A | MEDIUM SCREW BASE | 201-400 lm. | 1 | 4.5 | 350 | NOT LISTED | 5000 | 15000 | NO | YES | NO | CEILING FANS | NO | NO | NO | NO |
| 5 | A-LAMP | N/A | MEDIUM SCREW BASE | 401-600 lm. | 2 | 7.5 | 485 | NOT LISTED | 3000 | 25000 | YES | YES | NO | | NO | NO | NO | YES |
| 6 | A-LAMP | N/A | MEDIUM SCREW BASE | 401-600 lm. | 2 | 7.5 | 500 | NOT LISTED | 3000 | 25000 | YES | YES | NO | OK ENCLOSED | NO | NO | YES | NO |
| 8 | A-LAMP | N/A | MEDIUM SCREW BASE | 401-600 lm. | 1 | 7 | 500 | NOT LISTED | 5000 | 25000 | NO | YES | NO | ? | NO | NO | NO | NO |
| 9 | A-LAMP | N/A | MEDIUM SCREW BASE | 401-600 lm. | 10 | 8 | 450 | NOT LISTED | 2700 | 25000 | NO | YES | NO | NOT ENCLOSED | NO | NO | NO | NO |
| 12 | A-LAMP | N/A | MEDIUM SCREW BASE | 401-600 lm. | 5 | 6 | 450 | NOT LISTED | 2700 | 25000 | YES | YES | NO | ? | NO | YES | YES | NO |
| 13 | A-LAMP | N/A | MEDIUM SCREW BASE | 401-600 lm. | 5 | 8.5 | 450 | 93 | 2700 | 25000 | NO | YES | NO | ? | NO | NO | NO | YES |
| 14 | A-LAMP | N/A | MEDIUM SCREW BASE | 401-600 lm. | 2 | 7.5 | 485 | 92 | 2700 | 25000 | Yes | Yes | NO | OK ENCLOSED | YES | NO | NO | YES |
| 15 | A-LAMP | N/A | MEDIUM SCREW BASE | 401-600 lm. | 2 | 7.3 | 485 | 92 | 2700 | 25000 | Yes | Yes | NO | ? | YES | NO | NO | YES |
| 16 | A-LAMP | N/A | MEDIUM SCREW BASE | 401-600 lm. | 5 | 6 | 450 | NOT LISTED | 5000 | 25000 | YES | YES | NO | ? | NO | NO | YES | YES |
| 17 | A-LAMP | N/A | MEDIUM SCREW BASE | 401-600 lm. | 6 | 6 | 450 | NOT LISTED | 2700 | 20000 | NO | NO | NO | ? | NO | NO | NO | NO |
| 18 | A-LAMP | N/A | MEDIUM SCREW BASE | 601-800 lm. | 11 | 10 | 800 | 82 | 2700 | 25000 | YES | NO | NO | NOT ENCLOSED | NO | NO | YES | YES |
| 19 | A-LAMP | N/A | MEDIUM SCREW BASE | 601-800 lm. | 1 | 10.5 | 800 | NOT LISTED | 2700 | 15000 | NO | YES | NO | NOT ENCLOSED | NO | NO | NO | NO |
| 20 | A-LAMP | N/A | MEDIUM SCREW BASE | 601-800 lm. | 5 | 13.5 | 800 | 93 | 2700 | 25000 | NO | YES | NO | ? | NO | NO | NO | NO |
| 22 | A-LAMP | N/A | MEDIUM SCREW BASE | 601-800 lm. | 5 | 9.5 | 800 | NOT LISTED | 2700 | 25000 | YES | YES | NO | ? | NO | YES | YES | YES |
| 23 | A-LAMP | N/A | MEDIUM SCREW BASE | 601-800 lm. | 5 | 9.5 | 800 | NOT LISTED | 2700 | 25000 | YES | YES | NO | ? | NO | YES | YES | YES |
| 24 | A-LAMP | N/A | MEDIUM SCREW BASE | 601-800 lm. | 8 | 12 | 800 | NOT LISTED | 2700 | 25000 | YES | YES | NO | OK ENCLOSED | YES | NO | NO | YES |
| 27 | A-LAMP | N/A | MEDIUM SCREW BASE | 601-800 lm. | 9 | 10 | 800 | 90 | 3000 | 25000 | Yes | Yes | NO | ? | YES | NO | NO | YES |
| 29 | A-LAMP | N/A | MEDIUM SCREW BASE | 601-800 lm. | 10 | 10.5 | 800 | NOT LISTED | 2700 | 25000 | NO | YES | NO | NOT ENCLOSED | YES | NO | NO | YES |
| 30 | A-LAMP | N/A | MEDIUM SCREW BASE | 601-800 lm. | 5 | 9 | 800 | NOT LISTED | 5000 | 25000 | YES | YES | NO | ? | NO | NO | NO | YES |
| 31 | A-LAMP | N/A | MEDIUM SCREW BASE | 601-800 lm. | 1 | 11 | 800 | NOT LISTED | 2700 | 25000 | YES | YES | NO | NOT ENCLOSED | NO | NO | NO | YES |
| 33 | A-LAMP | N/A | MEDIUM SCREW BASE | 801-1,000 lm. | 1 | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | NO | GENERAL PURPOSE | NO | NO | NO | NO |
| 36 | A-LAMP | N/A | MEDIUM SCREW BASE | 801-1,000 lm. | 7 | 15 | 1650 | NOT LISTED | 5000 | 25000 | NO | NO | YES | NOT ENCLOSED | NO | NO | NO | NO |
| 37 | A-LAMP | N/A | MEDIUM SCREW BASE | 801-1,000 lm. | 2 | 13.5 | 810 | 92 | 2700 | 25000 | YES | YES | NO | NOT RECESSED | YES | NO | NO | YES |
| 38 | A-LAMP | N/A | MEDIUM SCREW BASE | 801-1,000 lm. | 2 | 9.5 | 810 | 92 | 2700 | 25000 | Yes | Yes | NO | OK ENCLOSED | YES | NO | NO | YES |
| 39 | A-LAMP | N/A | MEDIUM SCREW BASE | 801-1,000 lm. | 5 | 11 | 815 | NOT LISTED | 2700 | 25000 | YES | YES | NO | ? | NO | NO | NO | YES |
| 40 | A-LAMP | N/A | MEDIUM SCREW BASE | 1,001-1,200 lm. | 2 | 13 | 1100 | NOT LISTED | 3000 | 25000 | NO | YES | NO | NOT RECESSED | NO | NO | NO | YES |
| 41 | A-LAMP | N/A | MEDIUM SCREW BASE | 1,001-1,200 lm. | 7 | 13 | 1100 | NOT LISTED | 2700 | 25000 | NO | NO | YES | ? | NO | NO | NO | NO |
| 43 | A-LAMP | N/A | MEDIUM SCREW BASE | 1,001-1,200 lm. | 1 | 14 | 1100 | NOT LISTED | 2700 | 25000 | NO | YES | NO | OPEN FIXTURES | NO | NO | NO | NO |
| 44 | A-LAMP | N/A | MEDIUM SCREW BASE | 1,001-1,200 lm. | 5 | 13.5 | 1100 | NOT LISTED | 2700 | 25000 | YES | YES | NO | ? | NO | NO | NO | YES |
| 45 | A-LAMP | N/A | MEDIUM SCREW BASE | 1,001-1,200 lm. | 5 | 13.5 | 1100 | NOT LISTED | 5000 | 25000 | YES | YES | NO | ? | NO | NO | NO | YES |
| 46 | A-LAMP | N/A | MEDIUM SCREW BASE | 1,401-1,600 lm. | 7 | 15 | 1600 | NOT LISTED | 2700 | 25000 | NO | YES | YES | OK ENCLOSED | NO | NO | NO | NO |
| 47 | A-LAMP | N/A | MEDIUM SCREW BASE | 1,401-1,600 lm. | 2 | 15.5 | 1600 | NOT LISTED | 2700 | 25000 | YES | YES | ? | ? | NO | NO | NO | YES |
| 48 | A-LAMP | N/A | MEDIUM SCREW BASE | 1,401-1,600 lm. | 5 | 18 | 1600 | NOT LISTED | 2700 | 25000 | YES | YES | NO | ? | NO | NO | NO | YES |
| 49 | A-LAMP | N/A | MEDIUM SCREW BASE | 1,401-1,600 lm. | 2 | 15 | 1500 | 90 | 27000 | 25000 | NO | YES | NO | NOT ENCLOSED | YES | NO | NO | YES |
| 50 | GLOBE | N/A | MEDIUM SCREW BASE | 201-400 lm. | 7 | 5 | 300 | NOT LISTED | 2700 | 25000 | NO | YES | YES | OK ENCLOSED | NO | NO | YES | YES |
| 51 | GLOBE | N/A | MEDIUM SCREW BASE | 201-400 lm. | 7 | 5 | 300 | NOT LISTED | 2700 | 25000 | NO | NO | YES | ENCLOSED | NO | NO | YES | YES |
| 52 | GLOBE | N/A | MEDIUM SCREW BASE | 201-400 lm. | 1 | 4.5 | 280 | 82 | 2700 | 15000 | YES | YES | NO | DECORATIVE | NO | NO | YES | NO |
| 53 | GLOBE | N/A | MEDIUM SCREW BASE | 201-400 lm. | 1 | 4.5 | 280 | 82 | 2700 | 15000 | NO | YES | NO | DECORATIVE | NO | NO | YES | NO |
| 54 | GLOBE | N/A | MEDIUM SCREW BASE | 401-600 lm. | 7 | 8 | 600 | NOT LISTED | 2700 | 25000 | NO | NO | YES | OK ENCLOSED | NO | NO | NO | NO |
| 56 | GLOBE | N/A | MEDIUM SCREW BASE | 401-600 lm. | 2 | 8 | 500 | 94 | 3000 | 25000 | YES | YES | NO | ? | NO | NO | NO | YES |
| 57 | GLOBE | N/A | MEDIUM SCREW BASE | 401-600 lm. | 2 | 8 | 495 | 94 | 2700 | 25000 | YES | YES | NO | ? | YES | NO | NO | YES |
| 58 | GLOBE | N/A | MEDIUM SCREW BASE | 401-600 lm. | 7 | 8 | 600 | NOT LISTED | 2700 | 25000 | YES | NO | YES | OK ENCLOSED | NO | NO | NO | NO |
| 59 | GLOBE | N/A | MEDIUM SCREW BASE | 401-600 lm. | 2 | 8.5 | 510 | NOT LISTED | 3000 | 25000 | YES | YES | NO | BATH & VANITY | NO | YES | YES | YES |

| Sampling Criteria | | | | | | Values as Found on Product Labels | | | | | | | | | Verified Compliance | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model # | Bulb Style | Reflector Subtype | Base Type | Lumen Bin | Make # | Watts | Lumens | CRI | Color Temp | Rated Life | Energy Star | Dimmable | Exterior Rated | Fixture Compatability | CA Quality Spec | Energy Star QPL v2.0 | Energy Star QPL v1.4 | Energy Star QPL v1.1 |
| 60 | TORPEDO/BULLET | N/A | CANDELABRA BASE | 1-200 lm. | 7 | 3 | 120 | NOT LISTED | 2700 | 25000 | NO | NO | YES | OK ENCLOSED | NO | NO | NO | NO |
| 61 | TORPEDO/BULLET | N/A | CANDELABRA BASE | 1-200 lm. | 1 | 3.5 | 170 | 80 | 2700 | 15000 | NO | YES | NO | OK ENCLOSED | NO | NO | YES | YES |
| 62 | TORPEDO/BULLET | N/A | CANDELABRA BASE | 1-200 lm. | 1 | 4 | 200 | NOT LISTED | 5000 | 25000 | NO | YES | YES | OK ENCLOSED | NO | NO | NO | NO |
| 63 | TORPEDO/BULLET | N/A | CANDELABRA BASE | 1-200 lm. | 7 | 4 | 200 | NOT LISTED | 2700 | 25000 | NO | YES | YES | OK ENCLOSED | NO | NO | NO | NO |
| 64 | TORPEDO/BULLET | N/A | CANDELABRA BASE | 201-400 lm. | 1 | 4 | 350 | 80 | 5000 | 15000 | YES | YES | NO | CHANDELIERS & SCONCES | NO | NO | NO | NO |
| 66 | TORPEDO/BULLET | N/A | CANDELABRA BASE | 201-400 lm. | 7 | 5 | 300 | NOT LISTED | 2700 | 25000 | YES | YES | YES | OK ENCLOSED | NO | NO | YES | YES |
| 67 | TORPEDO/BULLET | N/A | CANDELABRA BASE | 201-400 lm. | 7 | 5 | 300 | NOT LISTED | 2700 | 25000 | NO | YES | YES | OK ENCLOSED | NO | NO | NO | NO |
| 68 | TORPEDO/BULLET | N/A | CANDELABRA BASE | 201-400 lm. | 7 | 5 | 300 | NOT LISTED | 5000 | 25000 | NO | NO | YES | OK ENCLOSED | NO | NO | NO | NO |
| 70 | TORPEDO/BULLET | N/A | CANDELABRA BASE | 201-400 lm. | 2 | 4.9 | 300 | 94 | 2700 | 25000 | YES | YES | NO | ? | YES | NO | NO | YES |
| 71 | TORPEDO/BULLET | N/A | CANDELABRA BASE | 201-400 lm. | 2 | 4.8 | 310 | NOT LISTED | 3000 | 25000 | YES | YES | NO | NOT ENCLOSED | NO | NO | YES | YES |
| 72 | TORPEDO/BULLET | N/A | MEDIUM SCREW BASE | 201-400 lm. | 1 | 4 | 350 | NOT LISTED | 5000 | 15000 | YES / NO | YES | NO | CHANDELIERS & SCONCES | NO | NO | NO | NO |
| 73 | TORPEDO/BULLET | N/A | MEDIUM SCREW BASE | 201-400 lm. | 1 | 4.5 | 350 | 80 | 5000 | 15000 | NO | YES | NO | CHANDELIERS & SCONCES | NO | NO | NO | NO |
| 74 | TORPEDO/BULLET | N/A | MEDIUM SCREW BASE | 201-400 lm. | 1 | 4.5 | 270 | 82 | 2700 | 15000 | YES | YES | NO | CHANDELIERS & SCONCES | NO | NO | YES | NO |
| 75 | TORPEDO/BULLET | N/A | MEDIUM SCREW BASE | 201-400 lm. | 1 | 4.5 | 300 | 80 | 2700 | 15000 | YES | YES | NO | CHANDELIERS & SCONCES | NO | NO | NO | NO |
| 76 | SPOTLIGHT/REFLECTOR | BR30 | MEDIUM SCREW BASE | 601-800 lm. | 10 | 9.5 | 650 | NOT LISTED | 2700 | 25000 | NO | YES | NO | ? | NO | NO | NO | NO |
| 77 | SPOTLIGHT/REFLECTOR | BR30 | MEDIUM SCREW BASE | 601-800 lm. | 2 | 10.5 | 650 | NOT LISTED | 2700 | 25000 | YES | YES | NO | TRACK/RECESSED | NO | YES | YES | YES |
| 78 | SPOTLIGHT/REFLECTOR | BR30 | MEDIUM SCREW BASE | 601-800 lm. | 5 | 9.5 | 650 | NOT LISTED | 2700 | 25000 | YES | YES | NO | OK ENCLOSED | NO | NO | YES | YES |
| 79 | SPOTLIGHT/REFLECTOR | BR30 | MEDIUM SCREW BASE | 601-800 lm. | 7 | 10 | 650 | NOT LISTED | 2700 | 25000 | YES | YES | YES | ENCLOSED | NO | NO | YES | NO |
| 80 | SPOTLIGHT/REFLECTOR | BR30 | MEDIUM SCREW BASE | 601-800 lm. | 2 | 10.5 | 750 | NO | 2700 | 25000 | YES | YES | NO | TRACK/RECESSED | NO | NO | NO | YES |
| 81 | SPOTLIGHT/REFLECTOR | BR30 | MEDIUM SCREW BASE | 601-800 lm. | 8 | 10 | 650 | NOT LISTED | 2700 | 25000 | YES | YES | NO | ? | YES | NO | NO | YES |
| 82 | SPOTLIGHT/REFLECTOR | BR30 | MEDIUM SCREW BASE | 601-800 lm. | 2 | 13 | 750 | 93 | 2700 | 25000 | YES | YES | NO | TRACK/RECESSED | YES | NO | YES | YES |
| 83 | SPOTLIGHT/REFLECTOR | BR30 | MEDIUM SCREW BASE | 601-800 lm. | 2 | 10.5 | 750 | 80 | 2700 | 25000 | YES | YES | NO | ? | NO | NO | NO | YES |
| 86 | SPOTLIGHT/REFLECTOR | BR40 | MEDIUM SCREW BASE | 1,001-1,200 lm. | 1 | 13 | 1070 | NOT LISTED | 5000 | 25000 | NO | YES | NO | TRACK/RECESSED | NO | NO | NO | NO |
| 87 | SPOTLIGHT/REFLECTOR | BR40 | MEDIUM SCREW BASE | 1,001-1,200 lm. | 2 | 16 | 1065 | 94 | 2700 | 25000 | YES | YES | NO | TRACK/RECESSED | YES | YES | YES | YES |
| 89 | SPOTLIGHT/REFLECTOR | BR40 | MEDIUM SCREW BASE | 1,001-1,200 lm. | 9 | 16 | 1000 | 90 | 3000 | 25000 | Yes | Yes | NO | ? | YES | YES | NO | YES |
| 90 | SPOTLIGHT/REFLECTOR | PAR20 | MEDIUM SCREW BASE | 401-600 lm. | 1 | 7 | 500 | NOT LISTED | 2700 | 25000 | YES | YES | NO | ? | NO | NO | NO | NO |
| 91 | SPOTLIGHT/REFLECTOR | PAR20 | MEDIUM SCREW BASE | 401-600 lm. | 6 | 8 | 500 | NOT LISTED | 3000 | 25000 | YES | YES | NO | NOT ENCLOSED | NO | NO | YES | NO |
| 93 | SPOTLIGHT/REFLECTOR | PAR20 | MEDIUM SCREW BASE | 401-600 lm. | 2 | 7.5 | 465 | NOT LISTED | 3000 | 25000 | YES | YES | NO | TRACK | NO | NO | YES | NO |
| 94 | SPOTLIGHT/REFLECTOR | PAR20 | MEDIUM SCREW BASE | 401-600 lm. | 12 | 8.5 | 500 | NOT LISTED | 3000 | 25000 | NO | YES | NO | ? | NO | NO | NO | NO |
| 95 | SPOTLIGHT/REFLECTOR | PAR30 | MEDIUM SCREW BASE | 601-800 lm. | 2 | 13 | 790 | NOT LISTED | 3000 | 25000 | YES | YES | NO | TRACK/RECESSED | NO | NO | YES | NO |
| 96 | SPOTLIGHT/REFLECTOR | PAR30 | MEDIUM SCREW BASE | 601-800 lm. | 2 | 15 | 750 | NOT LISTED | 3000 | 25000 | YES | YES | NO | TRACK/RECESSED | NO | NO | YES | YES |
| 97 | SPOTLIGHT/REFLECTOR | PAR30 | MEDIUM SCREW BASE | 601-800 lm. | 2 | 13 | 770 | 92 | 3000 | 25000 | YES | YES | NO | ? | YES | YES | YES | YES |
| 98 | SPOTLIGHT/REFLECTOR | PAR30 | MEDIUM SCREW BASE | 601-800 lm. | 6 | 14 | 800 | NOT LISTED | 3000 | 25000 | YES | YES | YES | NOT ENCLOSED | NO | NO | YES | YES |
| 99 | SPOTLIGHT/REFLECTOR | PAR38 | MEDIUM SCREW BASE | 801-1,000 lm. | 12 | 15 | 850 | NOT LISTED | 3000 | 18000 | NO | NO | YES | NOT ENCLOSED | NO | NO | NO | NO |
| 100 | SPOTLIGHT/REFLECTOR | PAR38 | MEDIUM SCREW BASE | 801-1,000 lm. | 2 | 16 | 950 | NOT LISTED | 3000 | 25000 | NO | YES | YES | ? | NO | NO | NO | NO |
| 101 | SPOTLIGHT/REFLECTOR | PAR38 | MEDIUM SCREW BASE | 801-1,000 lm. | 1 | 12 | 950 | NOT LISTED | 3000 | 25000 | YES | YES | YES | ? | NO | NO | NO | YES |
| 102 | SPOTLIGHT/REFLECTOR | PAR38 | MEDIUM SCREW BASE | 801-1,000 lm. | 2 | 18 | 950 | 93 | 3000 | 25000 | YES | YES | YES | RECESSED/SECURITY | YES | YES | YES | NO |
| 104 | SPOTLIGHT/REFLECTOR | PAR38 | MEDIUM SCREW BASE | 1,001-1,200 lm. | 7 | 14 | 1050 | NOT LISTED | 3000 | 25000 | NO | NO | YES | ? | NO | NO | NO | NO |
| 105 | SPOTLIGHT/REFLECTOR | PAR38 | MEDIUM SCREW BASE | 1,001-1,200 lm. | 7 | 17 | 1050 | NOT LISTED | 3000 | 25000 | NO | NO | YES | ENCLOSED | NO | NO | YES | YES |
| 106 | SPOTLIGHT/REFLECTOR | PAR38 | MEDIUM SCREW BASE | 1,001-1,200 lm. | 7 | 17 | 1050 | NOT LISTED | 5000 | 25000 | NO | NO | YES | ENCLOSED | NO | NO | NO | NO |
| 107 | SPOTLIGHT/REFLECTOR | PAR38 | MEDIUM SCREW BASE | 1,001-1,200 lm. | 2 | 17 | 1035 | NOT LISTED | 3000 | 25000 | YES | YES | YES | ? | NO | NO | YES | NO |
| 108 | SPOTLIGHT/REFLECTOR | R20 | MEDIUM SCREW BASE | 401-600 lm. | 1 | 7 | 500 | NOT LISTED | 5000 | 25000 | NO | YES | NO | ? | NO | NO | NO | NO |
| 109 | SPOTLIGHT/REFLECTOR | R20 | MEDIUM SCREW BASE | 401-600 lm. | 7 | 9 | 500 | NOT LISTED | 2700 | 25000 | NO | YES | YES | OK ENCLOSED | NO | NO | NO | NO |
| 110 | SPOTLIGHT/REFLECTOR | R20 | MEDIUM SCREW BASE | 401-600 lm. | 2 | 8 | 450 | NOT LISTED | 2700 | 25000 | YES | YES | NO | TRACK/RECESSED | YES | NO | YES | NO |
| 111 | SPOTLIGHT/REFLECTOR | R20 | MEDIUM SCREW BASE | 401-600 lm. | 2 | 8 | 450 | 94 | 2700 | 25000 | YES | YES | NO | TRACK/RECESSED | YES | NO | NO | YES |

| Sampling Criteria | | | | | | Values as Found on Product Labels | | | | | | | | | Verified Compliance | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model # | Bulb Style | Reflector Subtype | Base Type | Lumen Bin | Make # | Watts | Lumens | CRI | Color Temp | Rated Life | Energy Star | Dimmable | Exterior Rated | Fixture Compatability | CA Quality Spec | Energy Star QPL v2.0 | Energy Star QPL v1.4 | Energy Star QPL v1.1 |
| 201 | TRIM KIT | N/A | MEDIUM SCREW BASE | 601-800 lm. | 3 | 10.6 | 620 | 86 | 3000 | | | | | 4 in. | YES | NO | NO | NO |
| 202 | TRIM KIT | N/A | MEDIUM SCREW BASE | 801-1,000 lm. | 3 | 16.7 | 860 | 93 | 3000 | | | | | 6 in. | YES | NO | NO | NO |
| 203 | TRIM KIT | N/A | MEDIUM SCREW BASE | 401-600 lm. | 3 | 10.5 | 600 | 93 | 3000 | | | | | 6 in. | YES | NO | NO | NO |
| 204 | TRIM KIT | N/A | MEDIUM SCREW BASE | 401-600 lm. | 5 | 11.5 | 575 | 90 | 2700 | | | | | 4 in. | YES | NO | NO | NO |
| 205 | TRIM KIT | N/A | MEDIUM SCREW BASE | 601-800 lm. | 5 | 12.5 | 625 | 90 | 2700 | | | | | 6 in. | YES | NO | NO | NO |
| 206 | TRIM KIT | N/A | MEDIUM SCREW BASE | 401-600 lm. | 2 | 9.7 | 520 | 94 | 2700 | | | | | 4 in. | YES | NO | NO | NO |
| 207 | TRIM KIT | N/A | MEDIUM SCREW BASE | 1201-1400 lm. | 2 | 21.5 | 1250 | 91 | 2700 | | | | | 6 in. | YES | NO | NO | NO |
| 208 | TRIM KIT | N/A | MEDIUM SCREW BASE | 601-800 lm. | 9 | 12 | 650 | 90 | 2700 | | | | | 4 in. | YES | NO | NO | NO |
| 209 | TRIM KIT | N/A | MEDIUM SCREW BASE | 801-1,000 lm. | 9 | 16 | 900 | 90 | 2700 | | | | | 6 in. | YES | NO | NO | NO |
| 210 | TRIM KIT | N/A | MEDIUM SCREW BASE | 601-800 lm. | 10 | 10 | 610 | 90 | 2700 | | | | | 6 in. | YES | NO | NO | NO |
| 211 | TRIM KIT | N/A | MEDIUM SCREW BASE | 401-600 lm. | 10 | 8.5 | 520 | 90 | 2700 | | | | | 4 in. | YES | NO | NO | NO |
| 212 | TRIM KIT | N/A | MEDIUM SCREW BASE | 601-800 lm. | 4 | 11 | 670 | 90 | 2700 | | | | | 6 in. | YES | NO | NO | NO |
| 213 | TRIM KIT | N/A | MEDIUM SCREW BASE | 401-600 lm. | 4 | 9.62 | 570 | 90 | 2700 | | | | | 4 in | YES | NO | NO | NO |

| Test Units | | | | Thermal Testing Results | | | Switching Zone Assignment & Timing | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | 95% Warm up | 95% Cool down time | Max Temperatur | Cluster Warm up Time | Cluster Cool Down Time | Cycle Code # | Cycles per day | Cycles per year | On-hours per day | On-hours per year |
| 1 | 1 | A-LAMP | U | 39 | 61 | 67.79 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 2 | 1 | A-LAMP | D | 39 | 64 | 57.78 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 3 | 1 | A-LAMP | U | 51 | 73 | 61.26 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 4 | 1 | A-LAMP | C | 44 | 68 | 63.16 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 5 | 1 | A-LAMP | C | 41 | 66 | 68.78 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 6 | 1 | A-LAMP | C | 46 | 68 | 66.74 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 7 | 1 | A-LAMP | R | 45 | 70 | 67.78 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 8 | 1 | A-LAMP | R | 46 | 69 | 64.59 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 9 | 1 | A-LAMP | R | 46 | 70 | 66.35 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 10 | 2 | A-LAMP | D | 44 | 54 | 59.52 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 11 | 2 | A-LAMP | U | 42 | 67 | 62.69 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 12 | 2 | A-LAMP | D | 39 | 61 | 58.44 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 13 | 2 | A-LAMP | C | 42 | 63 | 68.12 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 14 | 2 | A-LAMP | C | 44 | 67 | 67.55 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 15 | 2 | A-LAMP | C | 44 | 72 | 61.04 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 16 | 2 | A-LAMP | R | 45 | 72 | 67.39 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 17 | 2 | A-LAMP | R | 44 | 69 | 62.9 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 18 | 2 | A-LAMP | R | 43 | 67 | 67.62 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 19 | 3 | A-LAMP | U | 45 | 70 | 56.33 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 20 | 3 | A-LAMP | D | 52 | 70 | 47.44 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 21 | 3 | A-LAMP | U | 45 | 77 | 52.99 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 22 | 3 | A-LAMP | C | 43 | 65 | 59.49 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 23 | 3 | A-LAMP | C | 0 | 0 | 0 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 24 | 3 | A-LAMP | C | 41 | 63 | 57.48 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 25 | 3 | A-LAMP | R | 50 | 71 | 55.18 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 26 | 3 | A-LAMP | R | 55 | 70 | 56.45 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 27 | 3 | A-LAMP | R | 50 | 72 | 57.77 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 28 | 4 | A-LAMP | D | 43 | 63 | 56.81 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 29 | 4 | A-LAMP | U | 47 | 79 | 56.3 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 30 | 4 | A-LAMP | D | 43 | 63 | 0 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 31 | 4 | A-LAMP | C | 48 | 69 | 61.43 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 32 | 4 | A-LAMP | C | 43 | 62 | 67.03 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 33 | 4 | A-LAMP | C | 43 | 66 | 62.4 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 34 | 4 | A-LAMP | R | 43 | 57 | 61.8 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 35 | 4 | A-LAMP | R | 46 | 66 | 64.6 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 36 | 4 | A-LAMP | R | 45 | 63 | 63.18 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 37 | 5 | A-LAMP | U | 41 | 72 | 58.24 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 38 | 5 | A-LAMP | D | 38 | 68 | 42.36 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 39 | 5 | A-LAMP | U | 49 | 74 | 54.05 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 40 | 5 | A-LAMP | C | 43 | 63 | 59.69 | 43 | 61 | 58 | 13.8 | 5053.8 | 9.9 | 3621.9 |
| 41 | 5 | A-LAMP | C | 41 | 61 | 62.61 | 43 | 61 | 58 | 13.8 | 5053.8 | 9.9 | 3621.9 |
| 42 | 5 | A-LAMP | C | 40 | 60 | 64.96 | 43 | 61 | 58 | 13.8 | 5053.8 | 9.9 | 3621.9 |
| 43 | 5 | A-LAMP | R | 45 | 67 | 73.27 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 44 | 5 | A-LAMP | R | 49 | 74 | 61.82 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 45 | 5 | A-LAMP | R | 50 | 72 | 61.93 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 46 | 6 | A-LAMP | D | 48 | 43 | 47.81 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 47 | 6 | A-LAMP | U | 57 | 81 | 62.11 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 48 | 6 | A-LAMP | D | 34 | 42 | 49.86 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 49 | 6 | A-LAMP | C | 45 | 66 | 67.66 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 50 | 6 | A-LAMP | C | 47 | 56 | 65.27 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 51 | 6 | A-LAMP | C | 49 | 59 | 66.87 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 52 | 6 | A-LAMP | R | 62 | 76 | 71.53 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 53 | 6 | A-LAMP | R | 49 | 64 | 71.25 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 54 | 6 | A-LAMP | R | 58 | 67 | 81.11 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 64 | 8 | A-LAMP | D | 42 | 77 | 53.13 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 65 | 8 | A-LAMP | U | 49 | 88 | 55.29 | 62 | 94 | 49 | 9.2 | 3369.2 | 9.5 | 3481.5 |
| 66 | 8 | A-LAMP | D | 36 | 58 | 55.62 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 67 | 8 | A-LAMP | C | 48 | 75 | 62.58 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 68 | 8 | A-LAMP | C | 47 | 76 | 57.57 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 69 | 8 | A-LAMP | C | 48 | 71 | 61.86 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 70 | 8 | A-LAMP | R | 56 | 85 | 61.39 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 71 | 8 | A-LAMP | R | 57 | 91 | 68.48 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 72 | 8 | A-LAMP | R | 54 | 91 | 66.43 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 73 | 9 | A-LAMP | U | 47 | 43 | 41.29 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |

| Test Units | | | | Thermal Testing Results | | | Switching Zone Assignment & Timing | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | 95% Warm up | 95% Cool down time | Max Temperatur | Cluster Warm up Time | Cluster Cool Down Time | Cycle Code # | Cycles per day | Cycles per year | On-hours per day | On-hours per year |
| 74 | 9 | A-LAMP | D | 50 | 116 | 35.14 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 75 | 9 | A-LAMP | U | 43 | 90 | 43.4 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 76 | 9 | A-LAMP | C | 34 | 59 | 47.84 | 38 | 57 | 57 | 15.2 | 5532.6 | 9.6 | 3504.0 |
| 77 | 9 | A-LAMP | C | 35 | 59 | 50.21 | 38 | 57 | 57 | 15.2 | 5532.6 | 9.6 | 3504.0 |
| 78 | 9 | A-LAMP | C | 32 | 50 | 50.21 | 38 | 57 | 57 | 15.2 | 5532.6 | 9.6 | 3504.0 |
| 79 | 9 | A-LAMP | R | 36 | 73 | 50.51 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 80 | 9 | A-LAMP | R | 37 | 71 | 49.14 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 81 | 9 | A-LAMP | R | 36 | 80 | 51.4 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 100 | 12 | A-LAMP | D | 40 | 61 | 37.55 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 101 | 12 | A-LAMP | U | 36 | 67 | 44.75 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 102 | 12 | A-LAMP | D | 39 | 83 | 36.76 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 103 | 12 | A-LAMP | C | 41 | 64 | 48.47 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 104 | 12 | A-LAMP | C | 40 | 61 | 49.62 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 105 | 12 | A-LAMP | C | 41 | 67 | 48.8 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 106 | 12 | A-LAMP | R | 49 | 76 | 53.36 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 107 | 12 | A-LAMP | R | 46 | 86 | 52.56 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 108 | 12 | A-LAMP | R | 47 | 78 | 55.97 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 109 | 13 | A-LAMP | U | 37 | 51 | 53.91 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 110 | 13 | A-LAMP | D | 51 | 71 | 39.69 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 111 | 13 | A-LAMP | U | 39 | 64 | 51.74 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 112 | 13 | A-LAMP | C | 44 | 63 | 59.43 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 113 | 13 | A-LAMP | C | 43 | 62 | 61.73 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 114 | 13 | A-LAMP | C | 45 | 63 | 58.08 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 115 | 13 | A-LAMP | R | 54 | 74 | 65.71 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 116 | 13 | A-LAMP | R | 55 | 75 | 55.43 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 117 | 13 | A-LAMP | R | 49 | 80 | 60.76 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 118 | 14 | A-LAMP | D | 44 | 53 | 42.92 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 119 | 14 | A-LAMP | U | 46 | 62 | 44.94 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 120 | 14 | A-LAMP | D | 34 | 50 | 47.22 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 121 | 14 | A-LAMP | C | 43 | 56 | 64.4 | 43 | 61 | 58 | 13.8 | 5053.8 | 9.9 | 3621.9 |
| 122 | 14 | A-LAMP | C | 43 | 60 | 60.33 | 43 | 61 | 58 | 13.8 | 5053.8 | 9.9 | 3621.9 |
| 123 | 14 | A-LAMP | C | 43 | 57 | 64.27 | 43 | 61 | 58 | 13.8 | 5053.8 | 9.9 | 3621.9 |
| 124 | 14 | A-LAMP | R | 56 | 79 | 74.3 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 125 | 14 | A-LAMP | R | 56 | 84 | 69.93 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 126 | 14 | A-LAMP | R | 60 | 76 | 65.47 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 127 | 15 | A-LAMP | U | 45 | 67 | 49.69 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 128 | 15 | A-LAMP | D | 48 | 85 | 43.52 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 129 | 15 | A-LAMP | U | 0 | 0 | 0 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 130 | 15 | A-LAMP | C | 40 | 62 | 64.79 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 131 | 15 | A-LAMP | C | 42 | 64 | 63.15 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 132 | 15 | A-LAMP | C | 43 | 63 | 63.84 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 133 | 15 | A-LAMP | R | 45 | 66 | 67.28 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 134 | 15 | A-LAMP | R | 49 | 77 | 62.92 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 135 | 15 | A-LAMP | R | 47 | 78 | 62.25 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 136 | 16 | A-LAMP | D | 46 | 105 | 39.83 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 137 | 16 | A-LAMP | U | 42 | 90 | 48.2 | 62 | 94 | 49 | 9.2 | 3369.2 | 9.5 | 3481.5 |
| 138 | 16 | A-LAMP | D | 46 | 105 | 0 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 139 | 16 | A-LAMP | C | 43 | 68 | 49.21 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 140 | 16 | A-LAMP | C | 39 | 66 | 50.12 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 141 | 16 | A-LAMP | C | 40 | 62 | 49.58 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 142 | 16 | A-LAMP | R | 49 | 69 | 51.91 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 143 | 16 | A-LAMP | R | 0 | 0 | 0 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 144 | 16 | A-LAMP | R | 55 | 86 | 52.08 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 145 | 17 | A-LAMP | D | 29 | 49 | 54.6 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 146 | 17 | A-LAMP | U | 50 | 79 | 60.31 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 147 | 17 | A-LAMP | D | 33 | 45 | 54.88 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 148 | 17 | A-LAMP | C | 35 | 53 | 61.24 | 43 | 61 | 58 | 13.8 | 5053.8 | 9.9 | 3621.9 |
| 149 | 17 | A-LAMP | C | 40 | 64 | 62.87 | 43 | 61 | 58 | 13.8 | 5053.8 | 9.9 | 3621.9 |
| 150 | 17 | A-LAMP | C | 36 | 57 | 63.8 | 43 | 61 | 58 | 13.8 | 5053.8 | 9.9 | 3621.9 |
| 151 | 17 | A-LAMP | R | 51 | 78 | 70.37 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 152 | 17 | A-LAMP | R | 53 | 75 | 69.28 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 153 | 17 | A-LAMP | R | 52 | 80 | 67.2 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 154 | 18 | A-LAMP | D | 57 | 68 | 46.89 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 155 | 18 | A-LAMP | U | 51 | 67 | 66.56 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |

| Test Units | | | | Thermal Testing Results | | | Switching Zone Assignment & Timing | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | 95% Warm up | 95% Cool down time | Max Temperatur | Cluster Warm up Time | Cluster Cool Down Time | Cycle Code # | Cycles per day | Cycles per year | On-hours per day | On-hours per year |
| 156 | 18 | A-LAMP | D | 44 | 69 | 64.09 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 157 | 18 | A-LAMP | C | 53 | 85 | 73.95 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 158 | 18 | A-LAMP | C | 55 | 84 | 73.24 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 159 | 18 | A-LAMP | C | 55 | 84 | 76.02 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 160 | 18 | A-LAMP | R | 61 | 99 | 77.09 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 161 | 18 | A-LAMP | R | 62 | 102 | 69.69 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 162 | 18 | A-LAMP | R | 68 | 105 | 70.97 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 163 | 19 | A-LAMP | U | 47 | 79 | 65.49 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 164 | 19 | A-LAMP | D | 43 | 68 | 65.07 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 165 | 19 | A-LAMP | U | 43 | 72 | 68.85 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 166 | 19 | A-LAMP | C | 43 | 76 | 80.07 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 167 | 19 | A-LAMP | C | 44 | 76 | 77.82 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 168 | 19 | A-LAMP | C | 42 | 73 | 79.97 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 169 | 19 | A-LAMP | R | 51 | 90 | 73.17 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 170 | 19 | A-LAMP | R | 51 | 89 | 81.55 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 171 | 19 | A-LAMP | R | 49 | 82 | 81.9 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 172 | 20 | A-LAMP | D | 62 | 71 | 47.64 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 173 | 20 | A-LAMP | U | 32 | 73 | 62.94 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 174 | 20 | A-LAMP | D | 62 | 73 | 43.32 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 175 | 20 | A-LAMP | C | 29 | 84 | 63.16 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 176 | 20 | A-LAMP | C | 30 | 88 | 65.37 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 177 | 20 | A-LAMP | C | 24 | 87 | 67.75 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 178 | 20 | A-LAMP | R | 24 | 100 | 67.45 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 179 | 20 | A-LAMP | R | 29 | 100 | 66.5 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 180 | 20 | A-LAMP | R | 26 | 100 | 64.94 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 190 | 22 | A-LAMP | D | 59 | 59 | 43.54 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 191 | 22 | A-LAMP | U | 37 | 49 | 53.18 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 192 | 22 | A-LAMP | D | 34 | 59 | 42.42 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 193 | 22 | A-LAMP | C | 37 | 58 | 66.89 | 43 | 61 | 58 | 13.8 | 5053.8 | 9.9 | 3621.9 |
| 194 | 22 | A-LAMP | C | 36 | 59 | 71.29 | 43 | 61 | 58 | 13.8 | 5053.8 | 9.9 | 3621.9 |
| 195 | 22 | A-LAMP | C | 38 | 59 | 71.8 | 43 | 61 | 58 | 13.8 | 5053.8 | 9.9 | 3621.9 |
| 196 | 22 | A-LAMP | R | 34 | 78 | 65.62 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 197 | 22 | A-LAMP | R | 37 | 77 | 68.07 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 198 | 22 | A-LAMP | R | 39 | 84 | 66.46 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 199 | 23 | A-LAMP | U | 46 | 81 | 55.19 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 200 | 23 | A-LAMP | D | 49 | 93 | 43.86 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 201 | 23 | A-LAMP | U | 49 | 65 | 57.25 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 202 | 23 | A-LAMP | C | 41 | 59 | 62.44 | 43 | 61 | 58 | 13.8 | 5053.8 | 9.9 | 3621.9 |
| 203 | 23 | A-LAMP | C | 36 | 57 | 66.74 | 43 | 61 | 58 | 13.8 | 5053.8 | 9.9 | 3621.9 |
| 204 | 23 | A-LAMP | C | 43 | 68 | 62.07 | 43 | 61 | 58 | 13.8 | 5053.8 | 9.9 | 3621.9 |
| 205 | 23 | A-LAMP | R | 58 | 76 | 74.14 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 206 | 23 | A-LAMP | R | 44 | 73 | 70.26 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 207 | 23 | A-LAMP | R | 46 | 73 | 67.11 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 208 | 24 | A-LAMP | D | 83 | 80 | 54.29 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 209 | 24 | A-LAMP | U | 67 | 104 | 65.63 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 210 | 24 | A-LAMP | D | 54 | 82 | 53.78 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 211 | 24 | A-LAMP | C | 68 | 111 | 73.95 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 212 | 24 | A-LAMP | C | 74 | 99 | 76.2 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 213 | 24 | A-LAMP | C | 69 | 98 | 71.2 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 214 | 24 | A-LAMP | R | 82 | 120 | 76.23 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 215 | 24 | A-LAMP | R | 73 | 109 | 77.19 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 216 | 24 | A-LAMP | R | 71 | 114 | 81.47 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 235 | 27 | A-LAMP | U | 40 | 63 | 53.85 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 236 | 27 | A-LAMP | D | 42 | 54 | 57.89 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 237 | 27 | A-LAMP | U | 40 | 63 | 54.87 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 238 | 27 | A-LAMP | C | 50 | 67 | 62.38 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 239 | 27 | A-LAMP | C | 43 | 60 | 65.79 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 240 | 27 | A-LAMP | C | 45 | 60 | 67.29 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 241 | 27 | A-LAMP | R | 61 | 83 | 70.33 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 242 | 27 | A-LAMP | R | 72 | 91 | 70.27 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 243 | 27 | A-LAMP | R | 73 | 78 | 71.56 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 253 | 29 | A-LAMP | D | 37 | 51 | 44.46 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 254 | 29 | A-LAMP | U | 45 | 49 | 54.4 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 255 | 29 | A-LAMP | D | 53 | 60 | 43.76 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |

| Test Units | | | | Thermal Testing Results | | | Switching Zone Assignment & Timing | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | 95% Warm up | 95% Cool down time | Max Temperatur | Cluster Warm up Time | Cluster Cool Down Time | Cycle Code # | Cycles per day | Cycles per year | On-hours per day | On-hours per year |
| 256 | 29 | A-LAMP | C | 15 | 58 | 48.74 | 38 | 57 | 57 | 15.2 | 5532.6 | 9.6 | 3504.0 |
| 257 | 29 | A-LAMP | C | 31 | 58 | 58.18 | 38 | 57 | 57 | 15.2 | 5532.6 | 9.6 | 3504.0 |
| 258 | 29 | A-LAMP | C | 32 | 56 | 60.26 | 38 | 57 | 57 | 15.2 | 5532.6 | 9.6 | 3504.0 |
| 259 | 29 | A-LAMP | R | 34 | 78 | 62.54 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 260 | 29 | A-LAMP | R | 32 | 77 | 63.64 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 261 | 29 | A-LAMP | R | 34 | 82 | 59.21 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 262 | 30 | A-LAMP | D | 49 | 112 | 38.18 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 263 | 30 | A-LAMP | U | 45 | 70 | 54.32 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 264 | 30 | A-LAMP | D | 63 | 106 | 38.28 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 265 | 30 | A-LAMP | C | 39 | 63 | 65.4 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 266 | 30 | A-LAMP | C | 41 | 62 | 61.98 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 267 | 30 | A-LAMP | C | 42 | 66 | 63.11 | 45 | 67 | 59 | 12.9 | 4692.9 | 9.6 | 3519.6 |
| 268 | 30 | A-LAMP | R | 38 | 78 | 69.3 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 269 | 30 | A-LAMP | R | 44 | 75 | 62.01 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 270 | 30 | A-LAMP | R | 45 | 73 | 66.71 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 271 | 31 | A-LAMP | D | 45 | 66 | 65.08 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 272 | 31 | A-LAMP | U | 57 | 97 | 75.99 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 273 | 31 | A-LAMP | D | 42 | 70 | 72.58 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 274 | 31 | A-LAMP | C | 57 | 84 | 83.7 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 275 | 31 | A-LAMP | C | 65 | 94 | 62.62 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 276 | 31 | A-LAMP | C | 61 | 86 | 85.61 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 277 | 31 | A-LAMP | R | 67 | 103 | 92.41 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 278 | 31 | A-LAMP | R | 56 | 99 | 103.54 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 279 | 31 | A-LAMP | R | 63 | 99 | 91.68 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 289 | 33 | A-LAMP | U | 53 | 81 | 73.68 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 290 | 33 | A-LAMP | D | 41 | 55 | 69 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 291 | 33 | A-LAMP | U | 51 | 89 | 71.37 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 292 | 33 | A-LAMP | C | 50 | 85 | 76.93 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 293 | 33 | A-LAMP | C | 51 | 92 | 66.38 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 294 | 33 | A-LAMP | C | 49 | 81 | 78.09 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 295 | 33 | A-LAMP | R | 65 | 96 | 82.92 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 296 | 33 | A-LAMP | R | 66 | 101 | 83.87 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 297 | 33 | A-LAMP | R | 60 | 88 | 97.95 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 316 | 36 | A-LAMP | D | 63 | 93 | 52.9 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 317 | 36 | A-LAMP | U | 66 | 110 | 60.14 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 318 | 36 | A-LAMP | D | 67 | 103 | 52.37 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 319 | 36 | A-LAMP | C | 76 | 111 | 71.78 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 320 | 36 | A-LAMP | C | 64 | 109 | 73.81 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 321 | 36 | A-LAMP | C | 64 | 108 | 72.54 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 322 | 36 | A-LAMP | R | 64 | 122 | 68.99 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 323 | 36 | A-LAMP | R | 70 | 130 | 70.48 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 324 | 36 | A-LAMP | R | 57 | 119 | 73.8 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 325 | 37 | A-LAMP | U | 62 | 83 | 61.08 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 326 | 37 | A-LAMP | D | 55 | 89 | 43.47 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 327 | 37 | A-LAMP | U | 67 | 88 | 55.7 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 328 | 37 | A-LAMP | C | 76 | 105 | 72.3 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 329 | 37 | A-LAMP | C | 82 | 96 | 71.71 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 330 | 37 | A-LAMP | C | 77 | 114 | 69.08 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 331 | 37 | A-LAMP | R | 133 | 125 | 80.93 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 332 | 37 | A-LAMP | R | 126 | 131 | 73.01 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 333 | 37 | A-LAMP | R | 113 | 138 | 76.82 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 334 | 38 | A-LAMP | D | 41 | 55 | 50.35 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 335 | 38 | A-LAMP | U | 49 | 70 | 57.23 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 336 | 38 | A-LAMP | D | 43 | 47 | 47.4 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 337 | 38 | A-LAMP | C | 57 | 66 | 66.76 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 338 | 38 | A-LAMP | C | 52 | 65 | 70.36 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 339 | 38 | A-LAMP | C | 52 | 67 | 69.13 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 340 | 38 | A-LAMP | R | 61 | 81 | 67.95 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 341 | 38 | A-LAMP | R | 63 | 85 | 65.07 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 342 | 38 | A-LAMP | R | 59 | 78 | 69.94 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 343 | 39 | A-LAMP | U | 53 | 80 | 58.32 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 344 | 39 | A-LAMP | D | 45 | 51 | 39.47 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 345 | 39 | A-LAMP | U | 37 | 73 | 62 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 346 | 39 | A-LAMP | C | 31 | 58 | 64.71 | 38 | 57 | 57 | 15.2 | 5532.6 | 9.6 | 3504.0 |

| Test Units | | | | Thermal Testing Results | | | Switching Zone Assignment & Timing | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | 95% Warm up | 95% Cool down time | Max Temperatur | Cluster Warm up Time | Cluster Cool Down Time | Cycle Code # | Cycles per day | Cycles per year | On-hours per day | On-hours per year |
| 347 | 39 | A-LAMP | C | 32 | 49 | 62.15 | 38 | 57 | 57 | 15.2 | 5532.6 | 9.6 | 3504.0 |
| 348 | 39 | A-LAMP | C | 37 | 45 | 62.62 | 38 | 57 | 57 | 15.2 | 5532.6 | 9.6 | 3504.0 |
| 349 | 39 | A-LAMP | R | 34 | 62 | 69.6 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 350 | 39 | A-LAMP | R | 34 | 60 | 68.26 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 351 | 39 | A-LAMP | R | 37 | 72 | 64.92 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 352 | 40 | A-LAMP | D | 47 | 67 | 37.69 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 353 | 40 | A-LAMP | U | 45 | 60 | 51.43 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 354 | 40 | A-LAMP | D | 54 | 69 | 46.39 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 355 | 40 | A-LAMP | C | 58 | 77 | 66.65 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 356 | 40 | A-LAMP | C | 66 | 76 | 65.22 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 357 | 40 | A-LAMP | C | 53 | 77 | 65.79 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 358 | 40 | A-LAMP | R | 60 | 95 | 66.73 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 359 | 40 | A-LAMP | R | 65 | 95 | 68.17 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 360 | 40 | A-LAMP | R | 67 | 90 | 63.41 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 361 | 41 | A-LAMP | U | 58 | 84 | 54.93 | 62 | 94 | 49 | 9.2 | 3369.2 | 9.5 | 3481.5 |
| 362 | 41 | A-LAMP | D | 56 | 87 | 50.1 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 363 | 41 | A-LAMP | U | 61 | 90 | 61.4 | 62 | 94 | 49 | 9.2 | 3369.2 | 9.5 | 3481.5 |
| 364 | 41 | A-LAMP | C | 71 | 104 | 63.69 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 365 | 41 | A-LAMP | C | 81 | 113 | 57.62 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 366 | 41 | A-LAMP | C | 74 | 108 | 66.64 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 367 | 41 | A-LAMP | R | 81 | 130 | 68.55 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 368 | 41 | A-LAMP | R | 73 | 123 | 74.27 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 369 | 41 | A-LAMP | R | 0 | 0 | 0 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 379 | 43 | A-LAMP | U | 48 | 83 | 84.2 | 62 | 94 | 49 | 9.2 | 3369.2 | 9.5 | 3481.5 |
| 380 | 43 | A-LAMP | D | 51 | 88.5 | . | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 381 | 43 | A-LAMP | U | 54 | 94 | 72 | 62 | 94 | 49 | 9.2 | 3369.2 | 9.5 | 3481.5 |
| 382 | 43 | A-LAMP | C | 63 | 101 | 83.27 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 383 | 43 | A-LAMP | C | 57 | 99 | 85.01 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 384 | 43 | A-LAMP | C | 57 | 99 | 83.76 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 385 | 43 | A-LAMP | R | 68 | 113 | 88.6 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 386 | 43 | A-LAMP | R | 68 | 112 | 86.36 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 387 | 43 | A-LAMP | R | 65 | 113 | 85.98 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 388 | 44 | A-LAMP | D | 59 | 73 | 43.19 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 389 | 44 | A-LAMP | U | 35 | 72 | 62.68 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 390 | 44 | A-LAMP | D | 51 | 77 | 45.9 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 391 | 44 | A-LAMP | C | 28 | 87 | 64.46 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 392 | 44 | A-LAMP | C | 28 | 87 | 65.26 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 393 | 44 | A-LAMP | C | 31 | 85 | 65.33 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 394 | 44 | A-LAMP | R | 28 | 100 | 64.59 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 395 | 44 | A-LAMP | R | 26 | 83 | 66.43 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 396 | 44 | A-LAMP | R | 26 | 106 | 67.09 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 397 | 45 | A-LAMP | U | 56 | 77 | 59.81 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 398 | 45 | A-LAMP | D | 55 | 75.5 | . | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 399 | 45 | A-LAMP | U | 54 | 74 | 60.94 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 400 | 45 | A-LAMP | C | 29 | 99 | 65.14 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 401 | 45 | A-LAMP | C | 37 | 87 | 67.37 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 402 | 45 | A-LAMP | C | 34 | 86 | 66.81 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 403 | 45 | A-LAMP | R | 33 | 107 | 69.87 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 404 | 45 | A-LAMP | R | 33 | 107 | 68.2 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 405 | 45 | A-LAMP | R | 29 | 108 | 68.85 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 406 | 46 | A-LAMP | D | 55 | 87 | 47.42 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 407 | 46 | A-LAMP | U | 47 | 121 | 70.67 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 408 | 46 | A-LAMP | D | 62 | 77 | 50.69 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 409 | 46 | A-LAMP | C | 56 | 114 | 69.11 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 410 | 46 | A-LAMP | C | 50 | 106 | 67.08 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 411 | 46 | A-LAMP | C | 41 | 105 | 76.07 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 412 | 46 | A-LAMP | R | 54 | 128 | 71.97 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 413 | 46 | A-LAMP | R | 48 | 120 | 90.09 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 414 | 46 | A-LAMP | R | 48 | 119 | 73.43 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 415 | 47 | A-LAMP | U | 49 | 78 | 55.27 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 416 | 47 | A-LAMP | D | 42 | 76 | 45.22 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 417 | 47 | A-LAMP | U | 50 | 76 | 52.54 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 418 | 47 | A-LAMP | C | 64 | 93 | 66.74 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 419 | 47 | A-LAMP | C | 63 | 90 | 70.12 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |

| Test Units | | | | Thermal Testing Results | | | Switching Zone Assignment & Timing | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | 95% Warm up | 95% Cool down time | Max Temperatur | Cluster Warm up Time | Cluster Cool Down Time | Cycle Code # | Cycles per day | Cycles per year | On-hours per day | On-hours per year |
| 420 | 47 | A-LAMP | C | 59 | 87 | 71.53 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 421 | 47 | A-LAMP | R | 76 | 110 | 76.46 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 422 | 47 | A-LAMP | R | 68 | 95 | 72.51 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 423 | 47 | A-LAMP | R | 73 | 109 | 69.59 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 424 | 48 | A-LAMP | D | 51 | 80 | 43.76 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 425 | 48 | A-LAMP | U | 51 | 75 | 65.36 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 426 | 48 | A-LAMP | D | 57 | 74 | 45.27 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 427 | 48 | A-LAMP | C | 40 | 91 | 73.6 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 428 | 48 | A-LAMP | C | 40 | 89 | 72.58 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 429 | 48 | A-LAMP | C | 43 | 91 | 72 | 59 | 91 | 61 | 9.6 | 3504.0 | 9.4 | 3445.6 |
| 430 | 48 | A-LAMP | R | 42 | 104 | 80.46 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 431 | 48 | A-LAMP | R | 40 | 104 | 77.62 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 432 | 48 | A-LAMP | R | 42 | 102 | 79.02 | 41 | 107 | 52 | 9.7 | 3551.4 | 6.6 | 2426.8 |
| 433 | 49 | A-LAMP | U | 59 | 94 | 67.4 | 62 | 94 | 49 | 9.2 | 3369.2 | 9.5 | 3481.5 |
| 434 | 49 | A-LAMP | D | 56 | 89 | 65.06 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 435 | 49 | A-LAMP | U | 59 | 92 | 66.83 | 62 | 94 | 49 | 9.2 | 3369.2 | 9.5 | 3481.5 |
| 436 | 49 | A-LAMP | C | 67 | 109 | 79.97 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 437 | 49 | A-LAMP | C | 67 | 108 | 81.11 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 438 | 49 | A-LAMP | C | 66 | 109 | 76.14 | 78 | 109 | 62 | 7.7 | 2810.7 | 10.0 | 3653.9 |
| 439 | 49 | A-LAMP | R | 79 | 127 | 87.22 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 440 | 49 | A-LAMP | R | 93 | 134 | 82.49 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 441 | 49 | A-LAMP | R | 81 | 125 | 83.37 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 442 | 50 | GLOBE | D | 41 | 60 | 39.22 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 443 | 50 | GLOBE | U | 39 | 65 | 43.69 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 444 | 50 | GLOBE | D | 30 | 49 | 35.66 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 445 | 51 | GLOBE | U | 51 | 93 | 42.26 | 62 | 94 | 49 | 9.2 | 3369.2 | 9.5 | 3481.5 |
| 446 | 51 | GLOBE | D | 42 | 102 | 38.49 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 447 | 51 | GLOBE | U | 50 | 87 | 34.42 | 62 | 94 | 49 | 9.2 | 3369.2 | 9.5 | 3481.5 |
| 448 | 52 | GLOBE | D | 48 | 61 | 53.2 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 449 | 52 | GLOBE | U | 32 | 68 | 38.78 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 450 | 52 | GLOBE | D | 47 | 54 | 46.78 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 451 | 53 | GLOBE | U | 46 | 62 | 44.93 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 452 | 53 | GLOBE | D | 53 | 65 | 44.59 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 453 | 53 | GLOBE | U | 47 | 69 | 46.2 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 454 | 54 | GLOBE | D | 41 | 49 | 49.38 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 455 | 54 | GLOBE | U | 44 | 64 | 50.51 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 456 | 54 | GLOBE | D | 34 | 53 | 48.81 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 460 | 56 | GLOBE | D | 44 | 85 | 51.33 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 461 | 56 | GLOBE | U | 51 | 92 | 54.6 | 62 | 94 | 49 | 9.2 | 3369.2 | 9.5 | 3481.5 |
| 462 | 56 | GLOBE | D | 47 | 88 | 49.55 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 463 | 57 | GLOBE | U | 44 | 57 | 52.2 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 464 | 57 | GLOBE | D | 45 | 66 | 48.55 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 465 | 57 | GLOBE | U | 39 | 63 | 44.97 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 466 | 58 | GLOBE | D | 26 | 53 | 44.71 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 467 | 58 | GLOBE | U | 46 | 67 | 52.51 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 468 | 58 | GLOBE | D | 48 | 59 | 48.85 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 469 | 59 | GLOBE | U | 50 | 77 | 52.55 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 470 | 59 | GLOBE | D | 42 | 65 | 46.13 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 471 | 59 | GLOBE | D | 39 | 65 | 54 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 472 | 60 | TORPEDO/BULLET | D | 27 | 41 | 37.85 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 473 | 60 | TORPEDO/BULLET | U | 31 | 46 | 45.03 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 474 | 60 | TORPEDO/BULLET | D | 25 | 44 | 40.33 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 475 | 60 | TORPEDO/BULLET | C | 46 | 51 | 47.82 | 38 | 57 | 57 | 15.2 | 5532.6 | 9.6 | 3504.0 |
| 476 | 60 | TORPEDO/BULLET | C | 35 | 45 | 46.54 | 38 | 57 | 57 | 15.2 | 5532.6 | 9.6 | 3504.0 |
| 477 | 60 | TORPEDO/BULLET | C | 34 | 48 | 47.37 | 38 | 57 | 57 | 15.2 | 5532.6 | 9.6 | 3504.0 |
| 478 | 61 | TORPEDO/BULLET | U | 36 | 56 | 62.57 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 479 | 61 | TORPEDO/BULLET | D | 38 | 48 | 53.45 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 480 | 61 | TORPEDO/BULLET | U | 36 | 53 | 61.45 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 481 | 61 | TORPEDO/BULLET | C | 45 | 62 | 63.79 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 482 | 61 | TORPEDO/BULLET | C | 46 | 64 | 58.8 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 483 | 61 | TORPEDO/BULLET | C | 52 | 63 | 65.92 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 484 | 62 | TORPEDO/BULLET | D | 27 | 43 | 47.22 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 485 | 62 | TORPEDO/BULLET | U | 35 | 46 | 48.42 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 486 | 62 | TORPEDO/BULLET | D | 33 | 35 | 53.44 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |

| Test Units | | | | Thermal Testing Results | | | Switching Zone Assignment & Timing | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | 95% Warm up | 95% Cool down time | Max Temperatur | Cluster Warm up Time | Cluster Cool Down Time | Cycle Code # | Cycles per day | Cycles per year | On-hours per day | On-hours per year |
| 487 | 62 | TORPEDO/BULLET | C | 39 | 55 | 49.2 | 38 | 57 | 57 | 15.2 | 5532.6 | 9.6 | 3504.0 |
| 488 | 62 | TORPEDO/BULLET | C | 39 | 52 | 49.8 | 38 | 57 | 57 | 15.2 | 5532.6 | 9.6 | 3504.0 |
| 489 | 62 | TORPEDO/BULLET | C | 37 | 51 | 52.96 | 38 | 57 | 57 | 15.2 | 5532.6 | 9.6 | 3504.0 |
| 490 | 63 | TORPEDO/BULLET | U | 30 | 44 | 57.54 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 491 | 63 | TORPEDO/BULLET | D | 35 | 53 | 56.85 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 492 | 63 | TORPEDO/BULLET | U | 34 | 46 | 55.13 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 493 | 63 | TORPEDO/BULLET | C | 38 | 57 | 56.06 | 43 | 61 | 58 | 13.8 | 5053.8 | 9.9 | 3621.9 |
| 494 | 63 | TORPEDO/BULLET | C | 41 | 56 | 51.77 | 43 | 61 | 58 | 13.8 | 5053.8 | 9.9 | 3621.9 |
| 495 | 63 | TORPEDO/BULLET | C | 36 | 53 | 58.41 | 43 | 61 | 58 | 13.8 | 5053.8 | 9.9 | 3621.9 |
| 496 | 64 | TORPEDO/BULLET | D | 35 | 50 | 54.98 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 497 | 64 | TORPEDO/BULLET | U | 37 | 54 | 58.47 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 498 | 64 | TORPEDO/BULLET | D | 35 | 48 | 50.79 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 499 | 64 | TORPEDO/BULLET | C | 44 | 58 | 59.98 | 43 | 61 | 58 | 13.8 | 5053.8 | 9.9 | 3621.9 |
| 500 | 64 | TORPEDO/BULLET | C | 40 | 57 | 55.94 | 43 | 61 | 58 | 13.8 | 5053.8 | 9.9 | 3621.9 |
| 501 | 64 | TORPEDO/BULLET | C | 45 | 62 | 57.71 | 43 | 61 | 58 | 13.8 | 5053.8 | 9.9 | 3621.9 |
| 508 | 66 | TORPEDO/BULLET | U | 39 | 54 | 63.34 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 509 | 66 | TORPEDO/BULLET | D | 37 | 51 | 65.85 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 510 | 66 | TORPEDO/BULLET | D | 38 | 50 | 62.48 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 511 | 66 | TORPEDO/BULLET | C | 44 | 62 | 64.98 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 512 | 66 | TORPEDO/BULLET | C | 44 | 60 | 65.64 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 513 | 66 | TORPEDO/BULLET | C | 47 | 62 | 72.1 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 514 | 67 | TORPEDO/BULLET | D | 43 | 58 | 66.9 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 515 | 67 | TORPEDO/BULLET | D | 44 | 60 | 71.63 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 516 | 67 | TORPEDO/BULLET | U | 36 | 55 | 69.53 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 517 | 67 | TORPEDO/BULLET | C | 48 | 67 | 67.45 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 518 | 67 | TORPEDO/BULLET | C | 0 | 0 | 0 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 519 | 67 | TORPEDO/BULLET | C | 0 | 0 | 0 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 520 | 68 | TORPEDO/BULLET | U | 34 | 50 | 59.76 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 521 | 68 | TORPEDO/BULLET | U | 38 | 55 | 62.6 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 522 | 68 | TORPEDO/BULLET | D | 34 | 48 | 60.44 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 523 | 68 | TORPEDO/BULLET | C | 46 | 63 | 67.94 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 524 | 68 | TORPEDO/BULLET | C | 48 | 64 | 65.48 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 525 | 68 | TORPEDO/BULLET | C | 46 | 61 | 66.31 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 532 | 70 | TORPEDO/BULLET | U | 27 | 42 | 62.43 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 533 | 70 | TORPEDO/BULLET | U | 29 | 46 | 58.74 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 534 | 70 | TORPEDO/BULLET | D | 30 | 44 | 56.85 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 535 | 70 | TORPEDO/BULLET | C | 36 | 52 | 63.1 | 38 | 57 | 57 | 15.2 | 5532.6 | 9.6 | 3504.0 |
| 536 | 70 | TORPEDO/BULLET | C | 41 | 54 | 68.14 | 38 | 57 | 57 | 15.2 | 5532.6 | 9.6 | 3504.0 |
| 537 | 70 | TORPEDO/BULLET | C | 33 | 49 | 65.89 | 38 | 57 | 57 | 15.2 | 5532.6 | 9.6 | 3504.0 |
| 538 | 71 | TORPEDO/BULLET | D | 44 | 58 | 39.06 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 539 | 71 | TORPEDO/BULLET | U | 46 | 70 | 64.78 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 540 | 71 | TORPEDO/BULLET | D | 41 | 52 | 43.49 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 541 | 71 | TORPEDO/BULLET | C | 53 | 63 | 54.32 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 542 | 71 | TORPEDO/BULLET | C | 46 | 60 | 59.48 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 543 | 71 | TORPEDO/BULLET | C | 50 | 58 | 57.9 | 54 | 67 | 60 | 11.9 | 4343.8 | 10.7 | 3909.4 |
| 544 | 72 | TORPEDO/BULLET | D | 47 | 60 | 53.23 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 545 | 72 | TORPEDO/BULLET | U | 44 | 70 | 51.81 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 546 | 72 | TORPEDO/BULLET | D | 41 | 55 | 52.19 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 547 | 73 | TORPEDO/BULLET | U | 41 | 54 | 57.59 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 548 | 73 | TORPEDO/BULLET | D | 38 | 54 | 52.5 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 549 | 73 | TORPEDO/BULLET | U | 41 | 52 | 57.85 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 550 | 74 | TORPEDO/BULLET | D | 33 | 48 | 60.26 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 551 | 74 | TORPEDO/BULLET | U | 37 | 58 | 62.18 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 552 | 74 | TORPEDO/BULLET | D | 42 | 55 | 54.61 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 553 | 75 | TORPEDO/BULLET | U | 39 | 55 | 63.05 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 554 | 75 | TORPEDO/BULLET | D | 37 | 50 | 60.34 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 555 | 75 | TORPEDO/BULLET | U | 39 | 53 | 63.24 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 556 | 76 | SPOTLIGHT/REFLECTOR | D | 74 | 58 | 33.61 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 557 | 76 | SPOTLIGHT/REFLECTOR | U | 41 | 64 | 46.34 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 558 | 76 | SPOTLIGHT/REFLECTOR | D | 35 | 73 | 30.99 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 559 | 76 | SPOTLIGHT/REFLECTOR | R | 50 | 74 | 49.28 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 560 | 76 | SPOTLIGHT/REFLECTOR | R | 51 | 79 | 54.1 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 561 | 76 | SPOTLIGHT/REFLECTOR | R | 45 | 85 | 51.07 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 562 | 77 | SPOTLIGHT/REFLECTOR | U | 92 | 156 | 37.69 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |

| Test Units | | | | Thermal Testing Results | | | Switching Zone Assignment & Timing | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | 95% Warm up | 95% Cool down time | Max Temperatur | Cluster Warm up Time | Cluster Cool Down Time | Cycle Code # | Cycles per day | Cycles per year | On-hours per day | On-hours per year |
| 563 | 77 | SPOTLIGHT/REFLECTOR | D | 64 | 125 | 28.64 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 564 | 77 | SPOTLIGHT/REFLECTOR | U | 61 | 90 | 41.2 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 565 | 77 | SPOTLIGHT/REFLECTOR | R | 84 | 115 | 50.69 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 566 | 77 | SPOTLIGHT/REFLECTOR | R | 78 | 120 | 48 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 567 | 77 | SPOTLIGHT/REFLECTOR | R | 82 | 116 | 46.38 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 568 | 78 | SPOTLIGHT/REFLECTOR | D | 35 | 66 | 36.13 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 569 | 78 | SPOTLIGHT/REFLECTOR | U | 36 | 46 | 54.52 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 570 | 78 | SPOTLIGHT/REFLECTOR | D | 37 | 54 | 38.75 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 571 | 78 | SPOTLIGHT/REFLECTOR | R | 50 | 87 | 63.37 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 572 | 78 | SPOTLIGHT/REFLECTOR | R | 47 | 81 | 70.17 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 573 | 78 | SPOTLIGHT/REFLECTOR | R | 47 | 74 | 66.29 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 574 | 79 | SPOTLIGHT/REFLECTOR | U | 53 | 89 | 38.44 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 575 | 79 | SPOTLIGHT/REFLECTOR | D | 70 | 83 | 35.22 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 576 | 79 | SPOTLIGHT/REFLECTOR | U | 47 | 82 | 40.7 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 577 | 79 | SPOTLIGHT/REFLECTOR | R | 71 | 93 | 50.81 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 578 | 79 | SPOTLIGHT/REFLECTOR | R | 71 | 102 | 49.09 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 579 | 79 | SPOTLIGHT/REFLECTOR | R | 66 | 104 | 51.21 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 580 | 80 | SPOTLIGHT/REFLECTOR | U | 72 | 108 | 47.4 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 581 | 80 | SPOTLIGHT/REFLECTOR | D | 73 | 108.5 | . | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 582 | 80 | SPOTLIGHT/REFLECTOR | U | 74 | 109 | 47.47 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 583 | 80 | SPOTLIGHT/REFLECTOR | R | 90 | 128 | 58.5 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 584 | 80 | SPOTLIGHT/REFLECTOR | R | 98 | 138 | 60 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 585 | 80 | SPOTLIGHT/REFLECTOR | R | 79 | 118 | 51.63 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 586 | 81 | SPOTLIGHT/REFLECTOR | D | 58 | 78 | 0 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 587 | 81 | SPOTLIGHT/REFLECTOR | U | 59 | 112 | 47.18 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 588 | 81 | SPOTLIGHT/REFLECTOR | D | 58 | 78 | 39.41 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 589 | 81 | SPOTLIGHT/REFLECTOR | R | 85 | 123 | 60.54 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 590 | 81 | SPOTLIGHT/REFLECTOR | R | 73 | 102 | 56.84 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 591 | 81 | SPOTLIGHT/REFLECTOR | R | 92 | 122 | 59.73 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 592 | 82 | SPOTLIGHT/REFLECTOR | U | 78 | 110 | 50.13 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 593 | 82 | SPOTLIGHT/REFLECTOR | D | 72.5 | 110 | . | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 594 | 82 | SPOTLIGHT/REFLECTOR | U | 67 | 110 | 50.93 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 595 | 82 | SPOTLIGHT/REFLECTOR | R | 98 | 113 | 64.8 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 596 | 82 | SPOTLIGHT/REFLECTOR | R | 88 | 118 | 66.56 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 597 | 82 | SPOTLIGHT/REFLECTOR | R | 82 | 115 | 59.41 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 598 | 83 | SPOTLIGHT/REFLECTOR | D | 53 | 95 | 33.31 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 599 | 83 | SPOTLIGHT/REFLECTOR | U | 61 | 82 | 43.98 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 600 | 83 | SPOTLIGHT/REFLECTOR | D | 62 | 90 | 33.57 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 601 | 83 | SPOTLIGHT/REFLECTOR | R | 85 | 124 | 57.15 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 602 | 83 | SPOTLIGHT/REFLECTOR | R | 101 | 148 | 57.08 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 603 | 83 | SPOTLIGHT/REFLECTOR | R | 80 | 113 | 56.92 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 616 | 86 | SPOTLIGHT/REFLECTOR | D | 81 | 97 | 34.46 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 617 | 86 | SPOTLIGHT/REFLECTOR | U | 75 | 127 | 42.41 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 618 | 86 | SPOTLIGHT/REFLECTOR | D | 76 | 92 | 32.5 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 619 | 86 | SPOTLIGHT/REFLECTOR | R | 97 | 131 | 65.66 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 620 | 86 | SPOTLIGHT/REFLECTOR | R | 101 | 126 | 62.67 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 621 | 86 | SPOTLIGHT/REFLECTOR | R | 89 | 128 | 60.28 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 622 | 87 | SPOTLIGHT/REFLECTOR | U | 0 | 0 | 0 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 623 | 87 | SPOTLIGHT/REFLECTOR | D | 95 | 107 | 35.39 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 624 | 87 | SPOTLIGHT/REFLECTOR | U | 91 | 101 | 38.24 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 625 | 87 | SPOTLIGHT/REFLECTOR | R | 146 | 203 | 68.7 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 626 | 87 | SPOTLIGHT/REFLECTOR | R | 142 | 202 | 65.93 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 627 | 87 | SPOTLIGHT/REFLECTOR | R | 143 | 202 | 66.85 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 634 | 89 | SPOTLIGHT/REFLECTOR | D | 84 | 98 | 37.77 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 635 | 89 | SPOTLIGHT/REFLECTOR | U | 91 | 139 | 49.91 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 636 | 89 | SPOTLIGHT/REFLECTOR | D | 78 | 95 | 38.41 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 637 | 89 | SPOTLIGHT/REFLECTOR | R | 121 | 171 | 69.95 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 638 | 89 | SPOTLIGHT/REFLECTOR | R | 75 | 113 | 65.29 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 639 | 89 | SPOTLIGHT/REFLECTOR | R | 76 | 103 | 69.34 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 640 | 90 | SPOTLIGHT/REFLECTOR | D | 57 | 85 | 37.14 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 641 | 90 | SPOTLIGHT/REFLECTOR | U | 58 | 84 | 46.33 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 642 | 90 | SPOTLIGHT/REFLECTOR | D | 72 | 93 | 36.55 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 643 | 90 | SPOTLIGHT/REFLECTOR | R | 77 | 114 | 56.11 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 644 | 90 | SPOTLIGHT/REFLECTOR | R | 74 | 113 | 54.38 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |

| Test Units | | | | Thermal Testing Results | | | Switching Zone Assignment & Timing | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | 95% Warm up | 95% Cool down time | Max Temperatur | Cluster Warm up Time | Cluster Cool Down Time | Cycle Code # | Cycles per day | Cycles per year | On-hours per day | On-hours per year |
| 645 | 90 | SPOTLIGHT/REFLECTOR | R | 73 | 113 | 53.18 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 646 | 91 | SPOTLIGHT/REFLECTOR | U | 52 | 72 | 48.2 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 647 | 91 | SPOTLIGHT/REFLECTOR | D | 43 | 56 | 50.96 | 48 | 60 | 45 | 13.3 | 4866.7 | 10.7 | 3893.3 |
| 648 | 91 | SPOTLIGHT/REFLECTOR | U | 52 | 73 | 46.45 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 649 | 91 | SPOTLIGHT/REFLECTOR | R | 63 | 96 | 59.91 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 650 | 91 | SPOTLIGHT/REFLECTOR | R | 59 | 90 | 56.95 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 651 | 91 | SPOTLIGHT/REFLECTOR | R | 61 | 96 | 53.61 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 658 | 93 | SPOTLIGHT/REFLECTOR | U | 43 | 60 | 52.61 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 659 | 93 | SPOTLIGHT/REFLECTOR | D | 56 | 112 | 37.12 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 660 | 93 | SPOTLIGHT/REFLECTOR | U | 54 | 99 | 48.97 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 661 | 93 | SPOTLIGHT/REFLECTOR | R | 69 | 97 | 51.28 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 662 | 93 | SPOTLIGHT/REFLECTOR | R | 66 | 93 | 53.86 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 663 | 93 | SPOTLIGHT/REFLECTOR | R | 67 | 93 | 52.12 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 664 | 94 | SPOTLIGHT/REFLECTOR | D | 38 | 75 | 43.84 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 665 | 94 | SPOTLIGHT/REFLECTOR | U | 65 | 98 | 55.99 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 666 | 94 | SPOTLIGHT/REFLECTOR | D | 50 | 55 | 56.7 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 667 | 94 | SPOTLIGHT/REFLECTOR | R | 68 | 101 | 64.81 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 668 | 94 | SPOTLIGHT/REFLECTOR | R | 80 | 110 | 67.52 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 669 | 94 | SPOTLIGHT/REFLECTOR | R | 79 | 117 | 68.15 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 670 | 95 | SPOTLIGHT/REFLECTOR | U | 58 | 86 | 43.78 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 671 | 95 | SPOTLIGHT/REFLECTOR | D | 60 | 89 | 36.15 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 672 | 95 | SPOTLIGHT/REFLECTOR | U | 59 | 87 | 46.47 | 56 | 89 | 20 | 9.9 | 3624.8 | 9.3 | 3383.2 |
| 673 | 95 | SPOTLIGHT/REFLECTOR | R | 82 | 117 | 54.82 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 674 | 95 | SPOTLIGHT/REFLECTOR | R | 88 | 118 | 56.65 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 675 | 95 | SPOTLIGHT/REFLECTOR | R | 76 | 117 | 55.89 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 676 | 96 | SPOTLIGHT/REFLECTOR | D | 62 | 89 | 0 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 677 | 96 | SPOTLIGHT/REFLECTOR | U | 62 | 87 | 47.05 | 62 | 94 | 49 | 9.2 | 3369.2 | 9.5 | 3481.5 |
| 678 | 96 | SPOTLIGHT/REFLECTOR | D | 62 | 89 | 35.63 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 679 | 96 | SPOTLIGHT/REFLECTOR | R | 90 | 120 | 59.46 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 680 | 96 | SPOTLIGHT/REFLECTOR | R | 84 | 103 | 55.83 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 681 | 96 | SPOTLIGHT/REFLECTOR | R | 75 | 89 | 55.08 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 682 | 97 | SPOTLIGHT/REFLECTOR | U | 80 | 124 | 49.9 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 683 | 97 | SPOTLIGHT/REFLECTOR | D | 79 | 122.5 | . | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 684 | 97 | SPOTLIGHT/REFLECTOR | U | 78 | 121 | 49.78 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 685 | 97 | SPOTLIGHT/REFLECTOR | R | 103 | 150 | 63.36 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 686 | 97 | SPOTLIGHT/REFLECTOR | R | 103 | 141 | 66.19 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 687 | 97 | SPOTLIGHT/REFLECTOR | R | 94 | 134 | 62.66 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 688 | 98 | SPOTLIGHT/REFLECTOR | D | 42 | 72 | 37.42 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 689 | 98 | SPOTLIGHT/REFLECTOR | U | 51 | 79 | 45.93 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 690 | 98 | SPOTLIGHT/REFLECTOR | D | 38 | 77 | 35.51 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 691 | 98 | SPOTLIGHT/REFLECTOR | R | 79 | 119 | 71.36 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 692 | 98 | SPOTLIGHT/REFLECTOR | R | 71 | 74 | 61.81 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 693 | 98 | SPOTLIGHT/REFLECTOR | R | 67 | 111 | 64.15 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 694 | 99 | SPOTLIGHT/REFLECTOR | U | 67 | 94 | 43.38 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 695 | 99 | SPOTLIGHT/REFLECTOR | D | 62 | 102 | 37.59 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 696 | 99 | SPOTLIGHT/REFLECTOR | U | 73 | 84 | 43.39 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 697 | 99 | SPOTLIGHT/REFLECTOR | R | 101 | 143 | 64.46 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 698 | 99 | SPOTLIGHT/REFLECTOR | R | 98 | 141 | 61.45 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 699 | 99 | SPOTLIGHT/REFLECTOR | R | 96 | 139 | 66.15 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 700 | 100 | SPOTLIGHT/REFLECTOR | D | 79 | 106 | 42.68 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 701 | 100 | SPOTLIGHT/REFLECTOR | U | 68 | 107 | 48.54 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 702 | 100 | SPOTLIGHT/REFLECTOR | D | 70 | 95 | 42.14 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 703 | 100 | SPOTLIGHT/REFLECTOR | R | 104 | 147 | 69.24 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 704 | 100 | SPOTLIGHT/REFLECTOR | R | 106 | 145 | 63.33 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 705 | 100 | SPOTLIGHT/REFLECTOR | R | 109 | 148 | 64.61 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 706 | 101 | SPOTLIGHT/REFLECTOR | U | 57 | 103 | 41.24 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 707 | 101 | SPOTLIGHT/REFLECTOR | D | 68 | 101 | 33.88 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 708 | 101 | SPOTLIGHT/REFLECTOR | U | 52 | 97 | 43.13 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 709 | 101 | SPOTLIGHT/REFLECTOR | R | 78 | 113 | 54.6 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 710 | 101 | SPOTLIGHT/REFLECTOR | R | 79 | 114 | 55.79 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 711 | 101 | SPOTLIGHT/REFLECTOR | R | 78 | 97 | 51.53 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 712 | 102 | SPOTLIGHT/REFLECTOR | D | 66 | 132 | 39.98 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 713 | 102 | SPOTLIGHT/REFLECTOR | U | 76 | 116 | 52.26 | 76 | 114 | 36 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 714 | 102 | SPOTLIGHT/REFLECTOR | D | 67 | 144 | 36.74 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |

| Test Units | | | | Thermal Testing Results | | | Switching Zone Assignment & Timing | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | 95% Warm up | 95% Cool down time | Max Temperatur | Cluster Warm up Time | Cluster Cool Down Time | Cycle Code # | Cycles per day | Cycles per year | On-hours per day | On-hours per year |
| 715 | 102 | SPOTLIGHT/REFLECTOR | R | 118 | 159 | 68.21 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 716 | 102 | SPOTLIGHT/REFLECTOR | R | 120 | 166 | 69.63 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 717 | 102 | SPOTLIGHT/REFLECTOR | R | 136 | 156 | 67.14 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 724 | 104 | SPOTLIGHT/REFLECTOR | D | 67 | 131 | 33.45 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 725 | 104 | SPOTLIGHT/REFLECTOR | U | 67 | 110 | 41.47 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 726 | 104 | SPOTLIGHT/REFLECTOR | D | 61 | 127 | 37.13 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 727 | 104 | SPOTLIGHT/REFLECTOR | R | 88 | 130 | 53.91 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 728 | 104 | SPOTLIGHT/REFLECTOR | R | 98 | 118 | 53.87 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 729 | 104 | SPOTLIGHT/REFLECTOR | R | 92 | 127 | 57.63 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 730 | 105 | SPOTLIGHT/REFLECTOR | U | 80 | 121 | 44.69 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 731 | 105 | SPOTLIGHT/REFLECTOR | D | 90 | 101 | 37.14 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 732 | 105 | SPOTLIGHT/REFLECTOR | U | 67 | 101 | 47.22 | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 733 | 105 | SPOTLIGHT/REFLECTOR | R | 96 | 127 | 57.78 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 734 | 105 | SPOTLIGHT/REFLECTOR | R | 103 | 134 | 60.2 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 735 | 105 | SPOTLIGHT/REFLECTOR | R | 88 | 127 | 63.62 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 736 | 106 | SPOTLIGHT/REFLECTOR | D | 74 | 118 | 37.91 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 737 | 106 | SPOTLIGHT/REFLECTOR | U | 81.5 | 115.5 | . | 89 | 117 | 28 | 7.0 | 2551.5 | 10.4 | 3784.7 |
| 738 | 106 | SPOTLIGHT/REFLECTOR | D | 89 | 113 | 33.58 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 739 | 106 | SPOTLIGHT/REFLECTOR | R | 104 | 144 | 60.98 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 740 | 106 | SPOTLIGHT/REFLECTOR | R | 104 | 142 | 58.05 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 741 | 106 | SPOTLIGHT/REFLECTOR | R | 110 | 147 | 60.48 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 742 | 107 | SPOTLIGHT/REFLECTOR | U | 56 | 87 | 44.38 | 62 | 94 | 49 | 9.2 | 3369.2 | 9.5 | 3481.5 |
| 743 | 107 | SPOTLIGHT/REFLECTOR | D | 60 | 80 | 38.25 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 744 | 107 | SPOTLIGHT/REFLECTOR | U | 58 | 90 | 43.53 | 62 | 94 | 49 | 9.2 | 3369.2 | 9.5 | 3481.5 |
| 745 | 107 | SPOTLIGHT/REFLECTOR | R | 0 | 0 | 0 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 746 | 107 | SPOTLIGHT/REFLECTOR | R | 97 | 139 | 66.38 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 747 | 107 | SPOTLIGHT/REFLECTOR | R | 91 | 110 | 63.41 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 748 | 108 | SPOTLIGHT/REFLECTOR | D | 46 | 85 | 52.26 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 749 | 108 | SPOTLIGHT/REFLECTOR | U | 54 | 93 | 50.77 | 62 | 94 | 49 | 9.2 | 3369.2 | 9.5 | 3481.5 |
| 750 | 108 | SPOTLIGHT/REFLECTOR | D | 48 | 70 | 49.82 | 49 | 81 | 56 | 11.1 | 4043.1 | 9.0 | 3301.8 |
| 751 | 108 | SPOTLIGHT/REFLECTOR | R | 59 | 86 | 58.02 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 752 | 108 | SPOTLIGHT/REFLECTOR | R | 60 | 88 | 61.23 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 753 | 108 | SPOTLIGHT/REFLECTOR | R | 60 | 92 | 61.36 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 754 | 109 | SPOTLIGHT/REFLECTOR | U | 48 | 66 | 49.71 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 755 | 109 | SPOTLIGHT/REFLECTOR | D | 50 | 75 | 44.6 | 58 | 80 | 46 | 10.4 | 3808.7 | 10.1 | 3681.7 |
| 756 | 109 | SPOTLIGHT/REFLECTOR | U | 47 | 62 | 53.19 | 51 | 67 | 51 | 12.2 | 4454.2 | 10.4 | 3786.1 |
| 757 | 109 | SPOTLIGHT/REFLECTOR | R | 61 | 99 | 59.13 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 758 | 109 | SPOTLIGHT/REFLECTOR | R | 64 | 98 | 66.44 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 759 | 109 | SPOTLIGHT/REFLECTOR | R | 65 | 104 | 57.91 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 760 | 110 | SPOTLIGHT/REFLECTOR | D | 55 | 101 | 38.77 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 761 | 110 | SPOTLIGHT/REFLECTOR | U | 60 | 85 | 53.08 | 65 | 87 | 50 | 9.5 | 3457.9 | 10.3 | 3746.1 |
| 762 | 110 | SPOTLIGHT/REFLECTOR | D | 56 | 93 | 43.64 | 73 | 112 | 47 | 7.8 | 2841.1 | 9.5 | 3456.6 |
| 763 | 110 | SPOTLIGHT/REFLECTOR | R | 73 | 107 | 51.77 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 764 | 110 | SPOTLIGHT/REFLECTOR | R | 69 | 99 | 54.67 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 765 | 110 | SPOTLIGHT/REFLECTOR | R | 69 | 101 | 58.95 | 72 | 102 | 24 | 8.3 | 3020.7 | 9.9 | 3624.8 |
| 766 | 111 | SPOTLIGHT/REFLECTOR | D | 55 | 91 | 43.92 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 767 | 111 | SPOTLIGHT/REFLECTOR | U | 74 | 102 | 52.89 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 768 | 111 | SPOTLIGHT/REFLECTOR | D | 56 | 72 | 39.04 | 75 | 94 | 32 | 8.5 | 3110.1 | 10.7 | 3887.6 |
| 769 | 111 | SPOTLIGHT/REFLECTOR | R | 77 | 106 | 60.59 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 770 | 111 | SPOTLIGHT/REFLECTOR | R | 68 | 108 | 61.38 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 771 | 111 | SPOTLIGHT/REFLECTOR | R | 81 | 113 | 61.52 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 1001 | 201 | TRIM KIT | R | 102 | 148 | 48.21 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 1002 | 201 | TRIM KIT | R | 118 | 194 | 50.06 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 1003 | 201 | TRIM KIT | R | 0 | 0 | 0 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 1004 | 202 | TRIM KIT | R | 76 | 98 | 48.79 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 1005 | 202 | TRIM KIT | R | 74 | 93 | 49.23 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 1006 | 202 | TRIM KIT | R | 76 | 88 | 49.5 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 1007 | 203 | TRIM KIT | R | 79 | 110 | 40.87 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 1008 | 203 | TRIM KIT | R | 80 | 103 | 39.66 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 1009 | 203 | TRIM KIT | R | 72 | 115 | 41.12 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 1010 | 204 | TRIM KIT | R | 0 | 0 | 0 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 1011 | 204 | TRIM KIT | R | 131 | 122 | 47.8 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 1012 | 204 | TRIM KIT | R | 0 | 0 | 0 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 1013 | 205 | TRIM KIT | R | 58 | 106 | 39.79 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |

| Test Units | | | | Thermal Testing Results | | | Switching Zone Assignment & Timing | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | 95% Warm up | 95% Cool down time | Max Temperatur | Cluster Warm up Time | Cluster Cool Down Time | Cycle Code # | Cycles per day | Cycles per year | On-hours per day | On-hours per year |
| 1014 | 205 | TRIM KIT | R | 24 | 122 | 37.07 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 1015 | 205 | TRIM KIT | R | 67 | 94 | 42.93 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 1016 | 206 | TRIM KIT | R | 106 | 161 | 51.45 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 1017 | 206 | TRIM KIT | R | 102 | 171 | 50.75 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 1018 | 206 | TRIM KIT | R | 110 | 102 | 50.18 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 1019 | 207 | TRIM KIT | R | 65 | 101 | 59.92 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 1020 | 207 | TRIM KIT | R | 56 | 94 | 59.39 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 1021 | 207 | TRIM KIT | R | 64 | 86 | 59.87 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 1022 | 208 | TRIM KIT | R | 108 | 124 | 58.75 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 1023 | 208 | TRIM KIT | R | 0 | 0 | 0 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 1024 | 208 | TRIM KIT | R | 77 | 200 | 56.7 | 105 | 140 | 44 | 5.9 | 2145.3 | 10.3 | 3754.3 |
| 1025 | 209 | TRIM KIT | R | 68 | 94 | 49.48 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 1026 | 209 | TRIM KIT | R | 71 | 102 | 51.87 | 76 | 114 | 36 | 7.6 | 2766.3 | 9.6 | 3504.0 |
| 1027 | 209 | TRIM KIT | R | 77 | 104 | 50.58 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 1028 | 210 | TRIM KIT | R | 38 | 102 | 41.17 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 1029 | 210 | TRIM KIT | R | 73 | 114 | 45.1 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 1030 | 210 | TRIM KIT | R | 68 | 95 | 43.2 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 1031 | 211 | TRIM KIT | R | 92 | 140 | 45.31 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 1032 | 211 | TRIM KIT | R | 158 | 206 | 46.36 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 1033 | 211 | TRIM KIT | R | 100 | 128 | 47.31 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 1034 | 212 | TRIM KIT | R | 78 | 120 | 44 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 1035 | 212 | TRIM KIT | R | 75 | 120 | 42.67 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 1036 | 212 | TRIM KIT | R | 84 | 122 | 45.15 | 89 | 129 | 40 | 6.6 | 2411.0 | 9.8 | 3576.3 |
| 1037 | 213 | TRIM KIT | R | 140 | 210 | 52 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 1038 | 213 | TRIM KIT | R | 129 | 149 | 53.2 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |
| 1039 | 213 | TRIM KIT | R | 147 | 192 | 50.4 | 144 | 202 | 48 | 4.2 | 1519.1 | 10.0 | 3645.8 |

| Test Units | | | | Initial Photometric Testing Results | | | | | | | | Final Photometric Testing Results | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | Initial Volts | Initial Amps | Initial Power | Initial pf | Initial THD | Initial Lumens | Initial CCT | Initial CRI | Final Volts | Final Amps | Final Power | Final pf | Final THD | Final Lumens | Final CCT | Final CRI |
| 1 | 1 | A-LAMP | U | 120 | 0.0428 | 4.206 | 0.8189 | 46.33 | 303.9 | 2754 | 82 | 120 | 0.043 | 4.1633 | 0.8161 | 46.589 | 295.11 | 2781 | 83 |
| 2 | 1 | A-LAMP | D | 120 | 0.0441 | 4.3316 | 0.8185 | 47.641 | 321.1 | 2835 | 81 | 120 | 0.044 | 4.3419 | 0.8212 | 47.225 | 334.78 | 2821 | 80 |
| 3 | 1 | A-LAMP | U | 120 | 0.0448 | 4.423 | 0.8227 | 48.082 | 326.1 | 2826 | 81 | 120 | 0.045 | 4.4762 | 0.8287 | 47.428 | 345.35 | 2843 | 81 |
| 4 | 1 | A-LAMP | C | 120 | 0.0445 | 4.374 | 0.8191 | 48.44 | 303.4 | 2736 | 81 | 120 | 0.044 | 4.3692 | 0.8216 | 48.296 | 293.01 | 2765 | 81 |
| 5 | 1 | A-LAMP | C | 120 | 0.045 | 4.44 | 0.8204 | 48.454 | 310.8 | 2761 | 81 | 120 | 0.045 | 4.3986 | 0.8184 | 48.301 | 303.12 | 2807 | 82 |
| 6 | 1 | A-LAMP | C | 120 | 0.0435 | 4.277 | 0.8193 | 48.387 | 299.6 | 2760 | 82 | 120 | 0.043 | 4.2733 | 0.8209 | 47.987 | 297.79 | 2809 | 82 |
| 7 | 1 | A-LAMP | R | 120 | 0.0437 | 4.307 | 0.8213 | 47.284 | 308.9 | 2729 | 81 | 120 | 0.043 | 4.2602 | 0.819 | 47.223 | 306.48 | 2775 | 81 |
| 8 | 1 | A-LAMP | R | 120 | 0.0429 | 4.226 | 0.8209 | 46.854 | 299.2 | 2772 | 82 | 120 | 0.043 | 4.2117 | 0.8205 | 46.756 | 297.1 | 2790 | 82 |
| 9 | 1 | A-LAMP | R | 120 | 0.0432 | 4.269 | 0.8235 | 46.989 | 312.7 | 2793 | 82 | 120 | 0.043 | 4.2346 | 0.8238 | 46.909 | 314.75 | 2841 | 82 |
| 10 | 2 | A-LAMP | D | 120 | 0.0448 | 4.366 | 0.8121 | 49.428 | 298.8 | 2730 | 82 | 120 | 0.044 | 4.3272 | 0.8121 | 49.304 | 299.45 | 2710 | 81 |
| 11 | 2 | A-LAMP | U | 120 | 0.044 | 4.291 | 0.8127 | 49.085 | 286.1 | 2731 | 82 | 120 | 0.044 | 4.2534 | 0.8129 | 48.795 | 279.16 | 2764 | 82 |
| 12 | 2 | A-LAMP | D | 120 | 0.0442 | 4.303 | 0.8113 | 48.954 | 300.8 | 2695 | 81 | 120 | 0.041 | 4.6076 | 0.9408 | 27.062 | 205.75 | 2717 | 82 |
| 13 | 2 | A-LAMP | C | 120 | 0.0438 | 4.272 | 0.8128 | 49.184 | 285.9 | 2704 | 82 | 120 | 0.046 | 4.5591 | 0.8346 | 44.984 | 240.16 | 2755 | 82 |
| 14 | 2 | A-LAMP | C | 120 | 0.044 | 4.295 | 0.8134 | 49.141 | 281.5 | 2740 | 82 | 120 | 0.044 | 4.279 | 0.8154 | 48.72 | 292.05 | 2767 | 82 |
| 15 | 2 | A-LAMP | C | 120 | 0.0434 | 4.263 | 0.8185 | 48.211 | 301.9 | 2741 | 82 | 120 | 0.043 | 4.2406 | 0.8194 | 47.941 | 295.95 | 2771 | 82 |
| 16 | 2 | A-LAMP | R | 120 | 0.0443 | 4.323 | 0.8132 | 49.212 | 288.4 | 2708 | 81 | 120 | 0.044 | 4.3047 | 0.8173 | 48.531 | 294.85 | 2793 | 82 |
| 17 | 2 | A-LAMP | R | 120 | 0.0438 | 4.25 | 0.8086 | 48.2 | 296 | 2745 | 82 | 120 | 0.043 | 4.2227 | 0.811 | 48.133 | 306.07 | 2784 | 83 |
| 18 | 2 | A-LAMP | R | 120 | 0.0437 | 4.28 | 0.8162 | 48.188 | 293.1 | 2728 | 82 | 120 | 0.043 | 4.2372 | 0.8183 | 47.571 | 289.76 | 2806 | 83 |
| 19 | 3 | A-LAMP | U | 120 | 0.036 | 4.178 | 0.9671 | 9.994 | 319.4 | 2996 | 82 | 120 | 0.036 | 4.1882 | 0.9678 | 9.9584 | 318.24 | 2979 | 82 |
| 20 | 3 | A-LAMP | D | 120 | 0.0367 | 4.286 | 0.9732 | 10.637 | 327.1 | 3062 | 83 | 120 | 0.037 | 4.2963 | 0.972 | 10.449 | 331.62 | 3021 | 82 |
| 21 | 3 | A-LAMP | U | 120 | 0.0366 | 4.251 | 0.9679 | 10.5 | 329.6 | 2993 | 83 | 120 | 0.037 | 4.2506 | 0.9695 | 10.479 | 339.14 | 3004 | 82 |
| 22 | 3 | A-LAMP | C | 120 | 0.0362 | 4.224 | 0.9724 | 10.347 | 317.2 | 2983 | 83 | 120 | 0.036 | 4.2497 | 0.972 | 10.089 | 322.1 | 3031 | 83 |
| 23 | 3 | A-LAMP | C | 120 | 0.0365 | 4.256 | 0.9717 | 10.578 | 320.9 | 2975 | 82 | 120 | 0.037 | 4.2629 | 0.97 | 10.358 | 321.72 | 3021 | 83 |
| 24 | 3 | A-LAMP | C | 120 | 0.0368 | 4.287 | 0.9708 | 10.546 | 327.6 | 2997 | 82 | 120 | 0.037 | 4.2999 | 0.9703 | 10.423 | 335.84 | 3032 | 82 |
| 25 | 3 | A-LAMP | R | 120 | 0.0364 | 4.236 | 0.9698 | 9.997 | 324.8 | 2986 | 82 | 120 | 0.037 | 4.2506 | 0.9701 | 9.7372 | 329.49 | 3022 | 83 |
| 26 | 3 | A-LAMP | R | 120 | 0.0363 | 4.241 | 0.9736 | 10.388 | 320.3 | 3007 | 82 | 120 | 0.036 | 4.2325 | 0.9704 | 10.131 | 329.66 | 3034 | 83 |
| 27 | 3 | A-LAMP | R | 120 | 0.0366 | 4.258 | 0.9695 | 10.408 | 321.6 | 3007 | 82 | 120 | 0.053 | 4.4845 | 0.7086 | 87.431 | 323.53 | 3040 | 83 |
| 28 | 4 | A-LAMP | D | 120 | 0.0448 | 4.397 | 0.8179 | 47.974 | 394.9 | 4880 | 82 | 120 | 0.044 | 4.3481 | 0.8168 | 48.111 | 364.56 | 4946 | 83 |
| 29 | 4 | A-LAMP | U | 120 | 0.0441 | 4.387 | 0.829 | 47.315 | 373.2 | 4856 | 82 | 120 | 0.044 | 4.3291 | 0.8272 | 47.003 | 370.21 | 5210 | 84 |
| 30 | 4 | A-LAMP | D | 120 | 0.0446 | 4.4 | 0.8221 | 47.495 | 379.6 | 4917 | 82 | 120 | 0.044 | 4.3483 | 0.8186 | 47.951 | 365.24 | 4938 | 81 |
| 31 | 4 | A-LAMP | C | 120 | 0.0435 | 4.279 | 0.8197 | 46.603 | 338.5 | 4852 | 83 | 120 | 0.043 | 4.2651 | 0.8211 | 46.49 | 330.46 | 4911 | 83 |
| 32 | 4 | A-LAMP | C | 120 | 0.0434 | 4.298 | 0.8253 | 45.23 | 363.3 | 4844 | 81 | 120 | 0.043 | 4.272 | 0.8233 | 45.157 | 353 | 4919 | 81 |
| 33 | 4 | A-LAMP | C | 120 | 0.0442 | 4.337 | 0.8177 | 46.77 | 376.2 | 4947 | 83 | 120 | 0.044 | 4.3477 | 0.8232 | 45.96 | 379.64 | 5016 | 83 |
| 34 | 4 | A-LAMP | R | 120 | 0.0446 | 4.407 | 0.8234 | 46.943 | 388.7 | 4903 | 82 | 120 | 0.044 | 4.384 | 0.825 | 46.618 | 372.27 | 5023 | 82 |
| 35 | 4 | A-LAMP | R | 120 | 0.0453 | 4.489 | 0.8258 | 48.926 | 386.5 | 4955 | 83 | 120 | 0.045 | 4.438 | 0.8241 | 48.943 | 392.15 | 5091 | 84 |
| 36 | 4 | A-LAMP | R | 120 | 0.0448 | 4.447 | 0.8272 | 47.479 | 386.5 | 4850 | 83 | 120 | 0.045 | 4.4276 | 0.8285 | 47.156 | 377.73 | 5014 | 84 |
| 37 | 5 | A-LAMP | U | 120 | 0.0669 | 7.085 | 0.8825 | 46.809 | 539.1 | 3031 | 80 | 120 | 0.067 | 7.0735 | 0.8852 | 47.19 | 555.08 | 3089 | 81 |
| 38 | 5 | A-LAMP | D | 120 | 0.0663 | 7.045 | 0.8855 | 47.782 | 532.2 | 3035 | 81 | 120 | 0.066 | 7.0033 | 0.8819 | 48.074 | 550.26 | 3045 | 80 |
| 39 | 5 | A-LAMP | U | 120 | 0.0663 | 7.038 | 0.8846 | 46.699 | 544.4 | 3060 | 81 | 120 | 0.066 | 7.0327 | 0.8854 | 47.138 | 566.97 | 3186 | 82 |
| 40 | 5 | A-LAMP | C | 120 | 0.066 | 7.015 | 0.8857 | 46.907 | 533.1 | 3052 | 81 | 120 | 0.066 | 6.9928 | 0.885 | 47.4 | 534.32 | 3111 | 81 |
| 41 | 5 | A-LAMP | C | 120 | 0.0659 | 7.014 | 0.8869 | 47.245 | 533.8 | 3027 | 81 | 120 | 0.066 | 6.9818 | 0.8847 | 47.576 | 539.1 | 3065 | 81 |
| 42 | 5 | A-LAMP | C | 120 | 0.0654 | 6.924 | 0.8823 | 47.782 | 539.3 | 3024 | 80 | 120 | | | | | | | |
| 43 | 5 | A-LAMP | R | 120 | 0.0661 | 7.086 | 0.8933 | 46.285 | 521.1 | 3022 | 80 | 120 | 0.066 | 7.0455 | 0.8884 | 46.837 | 539.28 | 3067 | 81 |
| 44 | 5 | A-LAMP | R | 120 | 0.0661 | 7.031 | 0.8864 | 47.202 | 529.1 | 3019 | 80 | 120 | 0.066 | 6.9779 | 0.8823 | 47.793 | 534.06 | 3028 | 80 |
| 45 | 5 | A-LAMP | R | 120 | 0.0658 | 7.001 | 0.8867 | 46.908 | 524.9 | 3039 | 80 | 120 | 0.066 | 6.9874 | 0.8855 | 47.223 | 532.21 | 3077 | 80 |
| 46 | 6 | A-LAMP | D | 120 | 0.0693 | 7.45 | 0.8959 | 47.713 | 444.3 | 2973 | 83 | 120 | 0.069 | 7.4044 | 0.8902 | 48.287 | 457.4 | 3010 | 82 |
| 47 | 6 | A-LAMP | U | 120 | 0.0689 | 7.386 | 0.8933 | 48.456 | 429.4 | 2951 | 83 | 120 | 0.069 | 7.3089 | 0.8866 | 49.521 | 448.91 | 3169 | 85 |
| 48 | 6 | A-LAMP | D | 120 | 0.0687 | 7.331 | 0.8893 | 47.967 | 447.9 | 2978 | 83 | 120 | 0.069 | 7.3593 | 0.8903 | 48.315 | 444.95 | 3044 | 83 |
| 49 | 6 | A-LAMP | C | 120 | 0.0678 | 7.22 | 0.8874 | 49.201 | 407.9 | 2968 | 83 | 120 | | | | | | | |
| 50 | 6 | A-LAMP | C | 120 | 0.0683 | 7.329 | 0.8942 | 47.185 | 433.1 | 2958 | 83 | 120 | 0.068 | 7.3211 | 0.8925 | 47.587 | 421.51 | 3041 | 83 |
| 51 | 6 | A-LAMP | C | 120 | 0.0697 | 7.441 | 0.8896 | 48.128 | 451.8 | 2977 | 83 | 120 | | | | | | | |
| 52 | 6 | A-LAMP | R | 120 | 0.0684 | 7.306 | 0.8901 | 48.055 | 425.1 | 2964 | 83 | 120 | 0.069 | 7.3794 | 0.8916 | 48.069 | 417.54 | 3056 | 83 |
| 53 | 6 | A-LAMP | R | 120 | 0.0671 | 7.155 | 0.8886 | 47.422 | 420.1 | 2961 | 83 | 120 | 0.067 | 7.1396 | 0.8905 | 47.989 | 417.05 | 3036 | 83 |
| 54 | 6 | A-LAMP | R | 120 | 0.0697 | 7.49 | 0.8955 | 47.827 | 445.5 | 2978 | 83 | 120 | 0.07 | 7.4545 | 0.8899 | 48.339 | 429.03 | 3095 | 83 |
| 64 | 8 | A-LAMP | D | 120 | 0.0706 | 7.201 | 0.85 | 56.533 | 573.9 | 5239 | 81 | 120 | 0.07 | 7.1709 | 0.8511 | 56.522 | 590.28 | 5261 | 81 |
| 65 | 8 | A-LAMP | U | 120 | 0.071 | 7.251 | 0.8511 | 56.841 | 573.8 | 5289 | 82 | 120 | 0.071 | 7.2075 | 0.8518 | 56.741 | 584.26 | 5511 | 83 |
| 66 | 8 | A-LAMP | D | 120 | 0.0714 | 7.266 | 0.848 | 57.049 | 593.9 | 5198 | 81 | 120 | 0.07 | 7.2003 | 0.8513 | 57.143 | 570.05 | 5247 | 81 |
| 67 | 8 | A-LAMP | C | 120 | 0.0717 | 7.287 | 0.8468 | 57.955 | 597.3 | 5213 | 81 | 120 | 0.071 | 7.2557 | 0.8476 | 57.797 | 591.07 | 5272 | 81 |
| 68 | 8 | A-LAMP | C | 120 | 0.0703 | 7.147 | 0.8472 | 57.928 | 593.5 | 5054 | 81 | 120 | 0.07 | 7.0897 | 0.8462 | 57.865 | 589.01 | 5114 | 81 |
| 69 | 8 | A-LAMP | C | 120 | 0.0703 | 7.192 | 0.8525 | 55.972 | 581.3 | 5179 | 81 | 120 | 0.07 | 7.1417 | 0.8541 | 55.87 | 580.82 | 5225 | 81 |
| 70 | 8 | A-LAMP | R | 120 | 0.0712 | 7.276 | 0.8516 | 56.778 | 583.2 | 5264 | 82 | 120 | 0.071 | 7.2307 | 0.8524 | 56.568 | 576.05 | 5284 | 81 |
| 71 | 8 | A-LAMP | R | 120 | 0.0714 | 7.278 | 0.8494 | 57.158 | 592.8 | 5136 | 82 | 120 | 0.072 | 7.3792 | 0.8521 | 56.547 | 601.81 | 5209 | 83 |
| 72 | 8 | A-LAMP | R | 120 | 0.0712 | 7.228 | 0.846 | 58.48 | 585.2 | 5257 | 83 | 120 | 0.071 | 7.165 | 0.8459 | 58.426 | 592.34 | 5317 | 83 |
| 73 | 9 | A-LAMP | U | 120 | 0.0691 | 7.161 | 0.8636 | 53.654 | 535.3 | 2732 | 80 | 120 | 0.067 | 6.9627 | 0.8619 | 53.769 | 527.12 | 2792 | 81 |
| 74 | 9 | A-LAMP | D | 120 | 0.0675 | 6.989 | 0.8628 | 53.887 | 533.4 | 2756 | 81 | 120 | 0.065 | 6.6628 | 0.8595 | 54.442 | 496.55 | 2828 | 81 |
| 75 | 9 | A-LAMP | U | 120 | 0.0683 | 7.058 | 0.8612 | 54.341 | 535.9 | 2742 | 80 | 120 | 0.068 | 7.0651 | 0.8615 | 54.223 | 526.55 | 2823 | 81 |
| 76 | 9 | A-LAMP | C | 120 | 0.0685 | 7.122 | 0.8664 | 52.315 | 543.1 | 2750 | 81 | 120 | 0.068 | 7.0137 | 0.8658 | 52.511 | 518.27 | 2838 | 81 |
| 77 | 9 | A-LAMP | C | 120 | 0.0687 | 7.11 | 0.8624 | 53.458 | 519.6 | 2764 | 81 | 120 | 0.067 | 6.9915 | 0.864 | 53.606 | 517.74 | 2802 | 81 |
| 78 | 9 | A-LAMP | C | 120 | 0.0685 | 7.134 | 0.8679 | 52.505 | 540.8 | 2752 | 81 | 120 | 0.069 | 7.1576 | 0.8689 | 52.272 | 528.26 | 2842 | 81 |
| 79 | 9 | A-LAMP | R | 120 | 0.0683 | 7.1 | 0.8663 | 52.701 | 537.1 | 2753 | 81 | 120 | 0.068 | 7.1058 | 0.867 | 52.62 | 523.28 | 2822 | 81 |
| 80 | 9 | A-LAMP | R | 120 | 0.068 | 7.022 | 0.8605 | 54.124 | 499.7 | 2803 | 82 | 120 | 0.067 | 6.915 | 0.8605 | 54.224 | 486.07 | 2828 | 82 |
| 81 | 9 | A-LAMP | R | 120 | 0.0682 | 7.076 | 0.8646 | 52.469 | 534.7 | 2767 | 81 | 120 | 0.068 | 7.0652 | 0.8665 | 52.509 | 527.65 | 2824 | 81 |
| 100 | 12 | A-LAMP | D | 120 | 0.0497 | 5.566 | 0.9333 | 19.626 | 471.8 | 2739 | 82 | 120 | 0.049 | 5.54 | 0.942 | 18.179 | 483.16 | 2781 | 82 |
| 101 | 12 | A-LAMP | U | 120 | 0.0481 | 5.501 | 0.953 | 15.797 | 460.3 | 2787 | 82 | 120 | 0.048 | 5.5042 | 0.9498 | 16.242 | 503.91 | 2945 | 84 |

| Test Units | | | | Initial Photometric Testing Results | | | | | | | | Final Photometric Testing Results | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | Initial Volts | Initial Amps | Initial Power | Initial pf | Initial THD | Initial Lumens | Initial CCT | Initial CRI | Final Volts | Final Amps | Final Power | Final pf | Final THD | Final Lumens | Final CCT | Final CRI |
| 102 | 12 | A-LAMP | D | 120 | 0.0488 | 5.525 | 0.9435 | 18.044 | 444.4 | 2762 | 82 | 120 | 0.049 | 5.5449 | 0.941 | 18.512 | 460.23 | 2789 | 82 |
| 103 | 12 | A-LAMP | C | 120 | 0.0492 | 5.572 | 0.9438 | 18.819 | 435 | 2726 | 82 | 120 | 0.049 | 5.5491 | 0.9432 | 18.788 | 446.04 | 2786 | 82 |
| 104 | 12 | A-LAMP | C | 120 | 0.0494 | 5.582 | 0.9416 | 20.088 | 421.7 | 2726 | 82 | 120 | 0.049 | 5.5527 | 0.941 | 19.788 | 417.3 | 2838 | 82 |
| 105 | 12 | A-LAMP | C | 120 | 0.0485 | 5.481 | 0.9418 | 18.557 | 411.7 | 2727 | 82 | 120 | 0.048 | 5.4345 | 0.9457 | 17.203 | 422.35 | 2790 | 82 |
| 106 | 12 | A-LAMP | R | 120 | 0.0491 | 5.545 | 0.9411 | 19.677 | 422.6 | 2718 | 82 | 120 | 0.048 | 5.4832 | 0.943 | 18.601 | 422.11 | 2808 | 82 |
| 107 | 12 | A-LAMP | R | 120 | 0.0479 | 5.436 | 0.9457 | 17.002 | 419.5 | 2724 | 82 | 120 | 0.047 | 5.328 | 0.9476 | 15.529 | 411.36 | 2784 | 82 |
| 108 | 12 | A-LAMP | R | 120 | 0.0503 | 5.616 | 0.9304 | 23.723 | 407.8 | 2773 | 82 | 120 | 0.049 | 5.5242 | 0.9333 | 21.637 | 413.55 | 2853 | 82 |
| 109 | 13 | A-LAMP | U | 120 | 0.0701 | 8.165 | 0.9706 | 10.571 | 553.2 | 2710 | 93 | 120 | | | | | | | |
| 110 | 13 | A-LAMP | D | 120 | 0.0701 | 8.129 | 0.9664 | 10.61 | 573.3 | 2729 | 92 | 120 | | | | | | | |
| 111 | 13 | A-LAMP | U | 120 | 0.0707 | 8.236 | 0.9708 | 10.81 | 566.3 | 2705 | 93 | 120 | | | | | | | |
| 112 | 13 | A-LAMP | C | 120 | 0.0711 | 8.302 | 0.973 | 11.512 | 531.7 | 2721 | 93 | 120 | | | | | | | |
| 113 | 13 | A-LAMP | C | 120 | 0.0705 | 8.181 | 0.967 | 10.856 | 566.5 | 2683 | 92 | 120 | | | | | | | |
| 114 | 13 | A-LAMP | C | 120 | 0.072 | 8.397 | 0.9719 | 12.501 | 540.2 | 2758 | 93 | 120 | | | | | | | |
| 115 | 13 | A-LAMP | R | 120 | 0.0705 | 8.208 | 0.9702 | 11.03 | 563.9 | 2721 | 93 | 120 | | | | | | | |
| 116 | 13 | A-LAMP | R | 120 | 0.0707 | 8.24 | 0.9712 | 11.635 | 544.4 | 2700 | 93 | 120 | | | | | | | |
| 117 | 13 | A-LAMP | R | 120 | 0.0694 | 8.058 | 0.9676 | 11.191 | 576.5 | 2698 | 92 | 120 | | | | | | | |
| 118 | 14 | A-LAMP | D | 120 | 0.0663 | 7.096 | 0.8919 | 46.662 | 493.5 | 2728 | 89 | 120 | 0.067 | 7.1084 | 0.8884 | 46.739 | 511.12 | 2769 | 89 |
| 119 | 14 | A-LAMP | U | 120 | 0.0666 | 7.079 | 0.8858 | 46.713 | 507.4 | 2748 | 90 | 120 | 0.066 | 7.0699 | 0.8867 | 46.892 | 524.4 | 2838 | 90 |
| 120 | 14 | A-LAMP | D | 120 | 0.0669 | 7.181 | 0.8945 | 45.836 | 509.5 | 2717 | 89 | 120 | 0.067 | 7.1706 | 0.8916 | 46.021 | 518.16 | 2726 | 89 |
| 121 | 14 | A-LAMP | C | 120 | 0.0662 | 7.08 | 0.8912 | 45.772 | 502.5 | 2724 | 89 | 120 | 0.066 | 7.0731 | 0.8906 | 45.846 | 505.56 | 2775 | 90 |
| 122 | 14 | A-LAMP | C | 120 | 0.0659 | 7.053 | 0.8919 | 46.198 | 494 | 2760 | 90 | 120 | | | | | | | |
| 123 | 14 | A-LAMP | C | 120 | 0.0655 | 7.012 | 0.8921 | 46.004 | 510.1 | 2719 | 89 | 120 | 0.066 | 7.0093 | 0.8892 | 46.257 | 503.56 | 2778 | 90 |
| 124 | 14 | A-LAMP | R | 120 | 0.0666 | 7.116 | 0.8904 | 46.552 | 493 | 2746 | 89 | 120 | 0.067 | 7.0946 | 0.8875 | 46.766 | 492.58 | 2780 | 89 |
| 125 | 14 | A-LAMP | R | 120 | 0.0661 | 7.06 | 0.8901 | 46.158 | 489.9 | 2750 | 90 | 120 | 0.066 | 7.0674 | 0.8889 | 46.293 | 485.08 | 2771 | 90 |
| 126 | 14 | A-LAMP | R | 120 | 0.0664 | 7.091 | 0.8899 | 45.74 | 462.7 | 2701 | 89 | 120 | | | | | | | |
| 127 | 15 | A-LAMP | U | 120 | 0.0656 | 7.007 | 0.8901 | 45.621 | 464 | 2638 | 92 | 120 | 0.065 | 6.992 | 0.8908 | 45.946 | 487.21 | 2756 | 93 |
| 128 | 15 | A-LAMP | D | 120 | 0.0661 | 7.099 | 0.895 | 45.141 | 461.7 | 2612 | 91 | 120 | 0.066 | 7.0389 | 0.8909 | 45.552 | 471.67 | 2662 | 91 |
| 129 | 15 | A-LAMP | U | 120 | 0.0663 | 7.074 | 0.8891 | 45.883 | 468 | 2630 | 92 | 120 | 0.066 | 7.0656 | 0.8905 | 45.948 | 491.94 | 2732 | 93 |
| 130 | 15 | A-LAMP | C | 120 | 0.0659 | 7.042 | 0.8905 | 46.54 | 489.2 | 2744 | 90 | 120 | 0.066 | 6.9964 | 0.8881 | 46.864 | 477.83 | 2781 | 90 |
| 131 | 15 | A-LAMP | C | 120 | 0.0668 | 7.134 | 0.89 | 46.239 | 484.9 | 2741 | 90 | 120 | 0.067 | 7.1052 | 0.8884 | 46.4 | 483.04 | 2766 | 90 |
| 132 | 15 | A-LAMP | C | 120 | 0.0655 | 6.957 | 0.8851 | 46.706 | 483.9 | 2755 | 90 | 120 | 0.065 | 6.9555 | 0.8873 | 46.839 | 491.7 | 2783 | 90 |
| 133 | 15 | A-LAMP | R | 120 | 0.068 | 7.277 | 0.891 | 45.174 | 472.9 | 2707 | 92 | 120 | | | | | | | |
| 134 | 15 | A-LAMP | R | 120 | 0.0663 | 7.097 | 0.892 | 46.052 | 465.4 | 2661 | 92 | 120 | 0.066 | 7.0563 | 0.886 | 46.802 | 478.56 | 2701 | 92 |
| 135 | 15 | A-LAMP | R | 120 | 0.0663 | 7.061 | 0.8875 | 45.94 | 477.3 | 2660 | 92 | 120 | | | | | | | |
| 136 | 16 | A-LAMP | D | 120 | 0.0512 | 5.677 | 0.924 | 26.691 | 462.8 | 5094 | 81 | 120 | 0.051 | 5.682 | 0.9219 | 27.493 | 486.96 | 5307 | 81 |
| 137 | 16 | A-LAMP | U | 120 | 0.0501 | 5.626 | 0.9358 | 21.079 | 478.5 | 4931 | 80 | 120 | 0.05 | 5.5815 | 0.9373 | 20.509 | 496.9 | 5009 | 80 |
| 138 | 16 | A-LAMP | D | 120 | 0.0489 | 5.55 | 0.9458 | 16.768 | 600.1 | 4878 | 81 | 120 | 0.049 | 5.5604 | 0.946 | 16.9 | 634.06 | 5001 | 82 |
| 139 | 16 | A-LAMP | C | 120 | 0.0496 | 5.586 | 0.9385 | 20.693 | 535.8 | 4935 | 83 | 120 | 0.05 | 5.5801 | 0.937 | 20.634 | 560.2 | 5033 | 83 |
| 140 | 16 | A-LAMP | C | 120 | 0.0492 | 5.582 | 0.9455 | 18.119 | 493.6 | 5038 | 83 | 120 | 0.049 | 5.5724 | 0.9427 | 18.322 | 514.84 | 5186 | 83 |
| 141 | 16 | A-LAMP | C | 120 | 0.0492 | 5.562 | 0.9421 | 18.176 | 491.9 | 4998 | 82 | 120 | 0.049 | 5.5714 | 0.9437 | 18.192 | 526.3 | 5117 | 82 |
| 142 | 16 | A-LAMP | R | 120 | 0.0496 | 5.549 | 0.9323 | 19.357 | 467.3 | 5116 | 82 | 120 | 0.049 | 5.5639 | 0.9406 | 18.88 | 488.66 | 5223 | 83 |
| 143 | 16 | A-LAMP | R | 120 | 0.0494 | 5.586 | 0.9423 | 19.499 | 461.7 | 5132 | 83 | 120 | 0.049 | 5.5068 | 0.9423 | 18.895 | 488.92 | 5223 | 83 |
| 144 | 16 | A-LAMP | R | 120 | 0.047 | 5.357 | 0.9498 | 14.761 | 572.4 | 4909 | 81 | 120 | 0.047 | 5.386 | 0.9479 | 14.909 | 600.47 | 5028 | 81 |
| 145 | 17 | A-LAMP | D | 120 | 0.1092 | 6.94 | 0.5296 | 146.8 | 446.2 | 2758 | 81 | 120 | 0.113 | 7.04 | 0.517 | 151.3 | 465 | 2806 | 82 |
| 146 | 17 | A-LAMP | U | 120 | 0.111 | 7.044 | 0.5288 | 145.03 | 467.9 | 2737 | 81 | 120 | 0.109 | 7.0826 | 0.54 | 139.59 | 495.8 | 2916 | 83 |
| 147 | 17 | A-LAMP | D | 120 | 0.1092 | 6.853 | 0.523 | 148.02 | 447.9 | 2746 | 81 | 120 | 0.107 | 6.9033 | 0.5357 | 141.97 | 461.35 | 2800 | 82 |
| 148 | 17 | A-LAMP | C | 120 | 0.1084 | 6.807 | 0.5233 | 147.65 | 456.2 | 2759 | 81 | 120 | 0.106 | 6.8479 | 0.537 | 141.4 | 455.88 | 2831 | 82 |
| 149 | 17 | A-LAMP | C | 120 | 0.1115 | 6.994 | 0.5227 | 150.09 | 450.1 | 2741 | 81 | 120 | 0.109 | 7.0333 | 0.539 | 140.35 | 457.99 | 2820 | 82 |
| 150 | 17 | A-LAMP | C | 120 | 0.1101 | 6.962 | 0.5269 | 147.24 | 452.8 | 2810 | 82 | 120 | 0.108 | 6.9653 | 0.5359 | 142.43 | 456.02 | 2852 | 82 |
| 151 | 17 | A-LAMP | R | 120 | 0.1102 | 7.008 | 0.5299 | 147.5 | 465.2 | 2769 | 82 | 120 | 0.108 | 6.9861 | 0.5377 | 141.02 | 469.41 | 2838 | 82 |
| 152 | 17 | A-LAMP | R | 120 | 0.1077 | 6.953 | 0.538 | 142.06 | 436.5 | 2795 | 82 | 120 | 0.109 | 7.0366 | 0.5388 | 140.72 | 449.04 | 2842 | 82 |
| 153 | 17 | A-LAMP | R | 120 | 0.1083 | 6.807 | 0.5238 | 148.62 | 444.3 | 2773 | 82 | 120 | 0.108 | 6.9691 | 0.5381 | 142.28 | 450.7 | 2836 | 82 |
| 154 | 18 | A-LAMP | D | 120 | 0.0951 | 9.858 | 0.8638 | 53.25 | 863.3 | 2651 | 82 | 120 | 0.095 | 9.8756 | 0.8627 | 53.499 | 884.86 | 2681 | 82 |
| 155 | 18 | A-LAMP | U | 120 | 0.0943 | 9.774 | 0.8637 | 53.87 | 844.2 | 2654 | 82 | 120 | 0.095 | 9.7674 | 0.8613 | 53.931 | 876.28 | 2682 | 83 |
| 156 | 18 | A-LAMP | D | 120 | 0.0943 | 9.77 | 0.8634 | 53.104 | 843.7 | 2648 | 85 | 120 | 0.094 | 9.7531 | 0.8631 | 53.3 | 866.6 | 2675 | 82 |
| 157 | 18 | A-LAMP | C | 120 | 0.0959 | 9.925 | 0.8624 | 54.636 | 874.2 | 2644 | 83 | 120 | 0.096 | 9.9461 | 0.8594 | 54.848 | 889.13 | 2661 | 83 |
| 158 | 18 | A-LAMP | C | 120 | 0.0938 | 9.737 | 0.865 | 53.067 | 869.3 | 2643 | 82 | 120 | 0.095 | 9.806 | 0.8647 | 53.224 | 871.06 | 2679 | 82 |
| 159 | 18 | A-LAMP | C | 120 | 0.0938 | 9.715 | 0.8631 | 53.529 | 859.5 | 2654 | 82 | 120 | 0.094 | 9.7667 | 0.8622 | 53.587 | 861.48 | 2683 | 82 |
| 160 | 18 | A-LAMP | R | 120 | 0.095 | 9.855 | 0.8645 | 53.701 | 882.1 | 2672 | 82 | 120 | 0.095 | 9.8657 | 0.8625 | 53.942 | 877.36 | 2694 | 83 |
| 161 | 18 | A-LAMP | R | 120 | 0.0958 | 9.938 | 0.8645 | 54.185 | 891.8 | 2678 | 82 | 120 | 0.096 | 9.9384 | 0.8614 | 54.332 | 858.98 | 2705 | 83 |
| 162 | 18 | A-LAMP | R | 120 | 0.0951 | 9.809 | 0.8595 | 54.04 | 880.7 | 2690 | 83 | 120 | 0.095 | 9.8879 | 0.8645 | 53.521 | 880.63 | 2715 | 83 |
| 163 | 19 | A-LAMP | U | 120 | 0.1008 | 10.651 | 0.8805 | 51.197 | 791.5 | 2758 | 81 | 120 | 0.1 | 10.606 | 0.8823 | 50.98 | 779.8 | 2767 | 81 |
| 164 | 19 | A-LAMP | D | 120 | 0.0991 | 10.522 | 0.8848 | 50.08 | 791.7 | 2775 | 81 | 120 | 0.098 | 10.385 | 0.8849 | 50.032 | 772.46 | 2780 | 81 |
| 165 | 19 | A-LAMP | U | 120 | 0.0988 | 10.5 | 0.8856 | 50.054 | 787.9 | 2769 | 81 | 120 | 0.099 | 10.495 | 0.8865 | 49.515 | 798.73 | 2850 | 82 |
| 166 | 19 | A-LAMP | C | 120 | 0.099 | 10.51 | 0.8847 | 50.035 | 768.4 | 2789 | 81 | 120 | | | | | | | |
| 167 | 19 | A-LAMP | C | 120 | 0.0995 | 10.613 | 0.8889 | 59.429 | 818.7 | 2759 | 81 | 120 | | | | | | | |
| 168 | 19 | A-LAMP | C | 120 | 0.1015 | 10.735 | 0.8814 | 51.479 | 769.8 | 2789 | 81 | 120 | 0.099 | 10.473 | 0.8827 | 50.878 | 702.08 | 2800 | 81 |
| 169 | 19 | A-LAMP | R | 120 | 0.0966 | 10.317 | 0.89 | 48.386 | 762.6 | 2790 | 81 | 120 | 0.097 | 10.352 | 0.8933 | 47.727 | 710.71 | 2790 | 81 |
| 170 | 19 | A-LAMP | R | 120 | 0.0987 | 10.486 | 0.8853 | 49.282 | 784.8 | 2778 | 81 | 120 | | | | | | | |
| 171 | 19 | A-LAMP | R | 120 | 0.0991 | 10.519 | 0.8845 | 49.858 | 788.4 | 2774 | 81 | 120 | | | | | | | |
| 172 | 20 | A-LAMP | D | 120 | 0.1002 | 11.82 | 0.983 | 6.69 | 748.8 | 2684 | 92 | 120 | | | | | | | |
| 173 | 20 | A-LAMP | U | 120 | 0.1023 | 12.091 | 0.9849 | 7.503 | 752.8 | 2709 | 92 | 120 | | | | | | | |
| 174 | 20 | A-LAMP | D | 120 | 0.1061 | 12.497 | 0.9815 | 10.372 | 768.2 | 2670 | 92 | 120 | | | | | | | |
| 175 | 20 | A-LAMP | C | 120 | 0.0991 | 11.744 | 0.9876 | 6.008 | 761.8 | 2765 | 93 | 120 | | | | | | | |

| Test Units | | | | Initial Photometric Testing Results | | | | | | | | Final Photometric Testing Results | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | Initial Volts | Initial Amps | Initial Power | Initial pf | Initial THD | Initial Lumens | Initial CCT | Initial CRI | Final Volts | Final Amps | Final Power | Final pf | Final THD | Final Lumens | Final CCT | Final CRI |
| 176 | 20 | A-LAMP | C | 120 | 0.102 | 12.001 | 0.9805 | 7.05 | 742.9 | 2758 | 93 | 120 | | | | | | | |
| 177 | 20 | A-LAMP | C | 120 | 0.1005 | 11.886 | 0.9856 | 6.845 | 750.9 | 2712 | 92 | 120 | | | | | | | |
| 178 | 20 | A-LAMP | R | 120 | 0.103 | 12.066 | 0.9762 | 7.304 | 770.6 | 2673 | 92 | 120 | | | | | | | |
| 179 | 20 | A-LAMP | R | 120 | 0.1001 | 11.824 | 0.9843 | 6.419 | 759.6 | 2694 | 92 | 120 | | | | | | | |
| 180 | 20 | A-LAMP | R | 120 | 0.1006 | 11.891 | 0.985 | 6.64 | 736.1 | 2756 | 93 | 120 | | | | | | | |
| 190 | 22 | A-LAMP | D | 120 | 0.0769 | 9.088 | 0.9848 | 7.397 | 798.9 | 2821 | 81 | 120 | | | | | | | |
| 191 | 22 | A-LAMP | U | 120 | 0.0765 | 9.081 | 0.9892 | 7.122 | 815.7 | 2822 | 81 | 120 | | | | | | | |
| 192 | 22 | A-LAMP | D | 120 | 0.0768 | 9.105 | 0.988 | 7.601 | 838.3 | 2827 | 81 | 120 | 0.077 | 9.1087 | 0.9878 | 7.4001 | 818.68 | 2893 | 81 |
| 193 | 22 | A-LAMP | C | 120 | 0.0773 | 9.205 | 0.9923 | 7.479 | 855.2 | 2830 | 80 | 120 | | | | | | | |
| 194 | 22 | A-LAMP | C | 120 | 0.0771 | 9.131 | 0.9869 | 7.424 | 821.4 | 2828 | 80 | 120 | 0.073 | 8.6115 | 0.987 | 7.326 | 720.04 | 2905 | 81 |
| 195 | 22 | A-LAMP | C | 120 | 0.0765 | 9.076 | 0.9887 | 7.262 | 836.9 | 2820 | 80 | 120 | | | | | | | |
| 196 | 22 | A-LAMP | R | 120 | 0.0779 | 9.251 | 0.9896 | 7.273 | 769.6 | 2886 | 82 | 120 | 0.08 | 9.4591 | 0.9892 | 6.8672 | 670.22 | 3013 | 82 |
| 197 | 22 | A-LAMP | R | 120 | 0.0772 | 9.113 | 0.9837 | 7.419 | 755.1 | 2850 | 81 | 120 | 0.081 | 9.5794 | 0.9894 | 6.8927 | 649.83 | 2971 | 82 |
| 198 | 22 | A-LAMP | R | 120 | 0.0772 | 9.13 | 0.9855 | 7.482 | 830.9 | 2823 | 81 | 120 | 0.08 | 9.4588 | 0.9892 | 6.8057 | 798.36 | 2904 | 81 |
| 199 | 23 | A-LAMP | U | 120 | 0.0796 | 9.454 | 0.9897 | 7.295 | 759.1 | 2834 | 80 | 120 | | | | | | | |
| 200 | 23 | A-LAMP | D | 120 | 0.079 | 9.367 | 0.9881 | 7.033 | 782.1 | 2848 | 81 | 120 | | | | | | | |
| 201 | 23 | A-LAMP | U | 120 | 0.0793 | 9.43 | 0.991 | 7.097 | 800.5 | 2870 | 81 | 120 | | | | | | | |
| 202 | 23 | A-LAMP | C | 120 | 0.0778 | 9.24 | 0.9897 | 7.088 | 793.1 | 2870 | 81 | 120 | | | | | | | |
| 203 | 23 | A-LAMP | C | 120 | 0.0782 | 9.271 | 0.988 | 7.295 | 783.7 | 2843 | 81 | 120 | | | | | | | |
| 204 | 23 | A-LAMP | C | 120 | 0.0798 | 9.454 | 0.9873 | 7.112 | 760.6 | 2847 | 81 | 120 | | | | | | | |
| 205 | 23 | A-LAMP | R | 120 | 0.0785 | 9.284 | 0.9856 | 7.747 | 765.1 | 2846 | 81 | 120 | | | | | | | |
| 206 | 23 | A-LAMP | R | 120 | 0.0795 | 9.434 | 0.9889 | 6.905 | 731.3 | 2851 | 81 | 120 | | | | | | | |
| 207 | 23 | A-LAMP | R | 120 | 0.0789 | 9.328 | 0.9852 | 6.85 | 804.4 | 2834 | 81 | 120 | | | | | | | |
| 208 | 24 | A-LAMP | D | 120 | 0.107 | 12.748 | 0.9928 | 7.585 | 790.9 | 2627 | 92 | 120 | 0.107 | 12.803 | 0.993 | 7.4775 | 798.59 | 2626 | 92 |
| 209 | 24 | A-LAMP | U | 120 | 0.107 | 12.748 | 0.9928 | 6.811 | 783.2 | 2645 | 92 | 120 | 0.107 | 12.697 | 0.9935 | 6.7711 | 798.67 | 2648 | 92 |
| 210 | 24 | A-LAMP | D | 120 | 0.11 | 13.078 | 0.9908 | 8.181 | 824.9 | 2645 | 92 | 120 | 0.11 | 13.079 | 0.9928 | 8.0303 | 808.94 | 2740 | 91 |
| 211 | 24 | A-LAMP | C | 120 | 0.1075 | 12.817 | 0.9936 | 7.163 | 787.7 | 2643 | 92 | 120 | 0.108 | 12.853 | 0.9936 | 7.0234 | 738.25 | 2643 | 92 |
| 212 | 24 | A-LAMP | C | 120 | 0.1102 | 13.109 | 0.9913 | 7.74 | 854.8 | 2618 | 90 | 120 | 0.11 | 13.151 | 0.9932 | 7.5664 | 821.58 | 2656 | 90 |
| 213 | 24 | A-LAMP | C | 120 | 0.108 | 12.922 | 0.997 | 7.552 | 813.5 | 2657 | 91 | 120 | 0.109 | 12.983 | 0.9935 | 7.2667 | 783.96 | 2727 | 90 |
| 214 | 24 | A-LAMP | R | 120 | 0.1055 | 12.586 | 0.9942 | 6.898 | 758.9 | 2647 | 93 | 120 | 0.106 | 12.639 | 0.9935 | 6.5291 | 739.47 | 2630 | 92 |
| 215 | 24 | A-LAMP | R | 120 | 0.1091 | 13.015 | 0.9941 | 8.111 | 833.3 | 2723 | 91 | 120 | 0.11 | 13.089 | 0.9928 | 8.1475 | 816.74 | 2727 | 91 |
| 216 | 24 | A-LAMP | R | 120 | 0.1094 | 13.062 | 0.995 | 7.567 | 884.2 | 2674 | 91 | 120 | 0.109 | 13.049 | 0.9936 | 7.4294 | 864.08 | 2656 | 90 |
| 235 | 27 | A-LAMP | U | 120 | 0.0772 | 8.324 | 0.8985 | 41.34 | 709.3 | 2996 | 94 | 120 | 0.076 | 8.2349 | 0.9037 | 40.594 | 742.82 | 3078 | 95 |
| 236 | 27 | A-LAMP | D | 120 | 0.0769 | 8.333 | 0.903 | 41.248 | 719.5 | 3005 | 94 | 120 | 0.076 | 8.2387 | 0.9028 | 40.884 | 736.49 | 3016 | 94 |
| 237 | 27 | A-LAMP | U | 120 | 0.077 | 8.356 | 0.9043 | 41.142 | 699.7 | 3017 | 94 | 120 | 0.077 | 8.332 | 0.9049 | 40.351 | 730.43 | 3093 | 95 |
| 238 | 27 | A-LAMP | C | 120 | 0.078 | 8.493 | 0.9074 | 39.964 | 738.4 | 2997 | 94 | 120 | 0.077 | 8.3445 | 0.9076 | 39.23 | 727.47 | 3010 | 94 |
| 239 | 27 | A-LAMP | C | 120 | 0.0789 | 8.603 | 0.9086 | 39.627 | 716.9 | 2999 | 94 | 120 | 0.078 | 8.4761 | 0.9104 | 38.893 | 726.27 | 3010 | 94 |
| 240 | 27 | A-LAMP | C | 120 | 0.076 | 8.281 | 0.908 | 39.61 | 713.1 | 2997 | 94 | 120 | 0.074 | 8.1476 | 0.9119 | 38.101 | 706.31 | 3016 | 94 |
| 241 | 27 | A-LAMP | R | 120 | 0.0783 | 8.572 | 0.9123 | 38.62 | 732.6 | 2997 | 95 | 120 | 0.077 | 8.4313 | 0.9141 | 37.521 | 722.71 | 3008 | 95 |
| 242 | 27 | A-LAMP | R | 120 | 0.0777 | 8.429 | 0.904 | 41.118 | 721.9 | 2978 | 95 | 120 | 0.076 | 8.2792 | 0.9049 | 40.321 | 696.63 | 2983 | 95 |
| 243 | 27 | A-LAMP | R | 120 | 0.077 | 8.453 | 0.9148 | 40.436 | 725.8 | 3001 | 94 | 120 | 0.076 | 8.3087 | 0.9085 | 39.379 | 699.31 | 3011 | 94 |
| 253 | 29 | A-LAMP | D | 120 | 0.0976 | 10.578 | 0.9032 | 45.495 | 787.1 | 2684 | 91 | 120 | 0.097 | 10.515 | 0.9029 | 45.484 | 806.31 | 2724 | 91 |
| 254 | 29 | A-LAMP | U | 120 | 0.0983 | 10.664 | 0.904 | 45.343 | 805.9 | 2677 | 91 | 120 | 0.097 | 10.511 | 0.9043 | 45.054 | 816.09 | 2787 | 92 |
| 255 | 29 | A-LAMP | D | 120 | 0.0988 | 10.726 | 0.9047 | 45.351 | 808.7 | 2697 | 91 | 120 | 0.099 | 10.712 | 0.9041 | 45.041 | 799.2 | 2755 | 91 |
| 256 | 29 | A-LAMP | C | 120 | 0.0985 | 10.69 | 0.9044 | 45.175 | 818.7 | 2685 | 91 | 120 | 0.097 | 10.541 | 0.9032 | 45.271 | 801.02 | 2738 | 91 |
| 257 | 29 | A-LAMP | C | 120 | 0.0982 | 10.615 | 0.9008 | 45.513 | 814.1 | 2673 | 91 | 120 | 0.098 | 10.658 | 0.9043 | 45 | 812.4 | 2727 | 91 |
| 258 | 29 | A-LAMP | C | 120 | 0.0996 | 10.802 | 0.9038 | 45.041 | 814.6 | 2677 | 91 | 120 | 0.1 | 10.845 | 0.9058 | 44.583 | 809.74 | 2734 | 91 |
| 259 | 29 | A-LAMP | R | 120 | 0.0968 | 10.449 | 0.8995 | 45.995 | 798.1 | 2690 | 91 | 120 | 0.098 | 10.579 | 0.9031 | 45.387 | 816.43 | 2747 | 91 |
| 260 | 29 | A-LAMP | R | 120 | 0.0974 | 10.554 | 0.903 | 45.229 | 791.7 | 2667 | 91 | 120 | 0.096 | 10.459 | 0.9032 | 45.019 | 804.82 | 2702 | 91 |
| 261 | 29 | A-LAMP | R | 120 | 0.0974 | 10.517 | 0.8998 | 45.542 | 789.6 | 2685 | 91 | 120 | 0.098 | 10.602 | 0.904 | 44.889 | 798.1 | 2729 | 91 |
| 262 | 30 | A-LAMP | D | 120 | 0.079 | 9.401 | 0.9917 | 6.929 | 921.3 | 5170 | 82 | 120 | 0.079 | 9.4226 | 0.9897 | 6.8109 | 906.16 | 5489 | 83 |
| 263 | 30 | A-LAMP | U | 120 | 0.0785 | 9.303 | 0.9876 | 7.32 | 919.4 | 5183 | 82 | 120 | | | | | | | |
| 264 | 30 | A-LAMP | D | 120 | 0.0777 | 9.198 | 0.9865 | 7.417 | 925.9 | 5134 | 82 | 120 | 0.078 | 9.3117 | 0.9886 | 7.0137 | 926.08 | 5388 | 83 |
| 265 | 30 | A-LAMP | C | 120 | 0.0785 | 9.321 | 0.9895 | 7.245 | 886.9 | 5195 | 82 | 120 | | | | | | | |
| 266 | 30 | A-LAMP | C | 120 | 0.0787 | 9.37 | 0.9922 | 7.202 | 934.5 | 5123 | 82 | 120 | | | | | | | |
| 267 | 30 | A-LAMP | C | 120 | 0.0797 | 9.46 | 0.9891 | 6.998 | 900.9 | 5303 | 83 | 120 | | | | | | | |
| 268 | 30 | A-LAMP | R | 120 | 0.0791 | 9.417 | 0.9921 | 7.232 | 906.6 | 5286 | 82 | 120 | | | | | | | |
| 269 | 30 | A-LAMP | R | 120 | 0.0784 | 9.292 | 0.9877 | 7.206 | 932.1 | 5262 | 82 | 120 | | | | | | | |
| 270 | 30 | A-LAMP | R | 120 | 0.0801 | 9.462 | 0.9844 | 6.539 | 915.9 | 5059 | 83 | 120 | | | | | | | |
| 271 | 31 | A-LAMP | D | 120 | 0.099 | 10.684 | 0.8993 | 46.574 | 794.2 | 2751 | 82 | 120 | | | | | | | |
| 272 | 31 | A-LAMP | U | 120 | 0.1 | 10.779 | 0.8983 | 45.981 | 791.4 | 2696 | 82 | 120 | | | | | | | |
| 273 | 31 | A-LAMP | D | 120 | 0.1017 | 10.968 | 0.8987 | 46.351 | 812.5 | 2706 | 81 | 120 | 0.1 | 10.838 | 0.8993 | 45.94 | 794.13 | 2730 | 81 |
| 274 | 31 | A-LAMP | C | 120 | 0.1007 | 10.872 | 0.8997 | 46.363 | 772.5 | 2719 | 82 | 120 | | | | | | | |
| 275 | 31 | A-LAMP | C | 120 | 0.1008 | 10.801 | 0.8929 | 47.824 | 775.2 | 2694 | 81 | 120 | | | | | | | |
| 276 | 31 | A-LAMP | C | 120 | 0.1015 | 10.986 | 0.902 | 45.609 | 791.3 | 2694 | 81 | 120 | | | | | | | |
| 277 | 31 | A-LAMP | R | 120 | 0.1017 | 10.93 | 0.8956 | 47.115 | 756.1 | 2712 | 81 | 120 | | | | | | | |
| 278 | 31 | A-LAMP | R | 120 | 0.1003 | 10.757 | 0.8937 | 47.781 | 785.3 | 2705 | 81 | 120 | | | | | | | |
| 279 | 31 | A-LAMP | R | 120 | 0.1018 | 11.021 | 0.9022 | 44.951 | 793.7 | 2702 | 81 | 120 | | | | | | | |
| 289 | 33 | A-LAMP | U | 120 | 0.1015 | 10.785 | 0.8855 | 50.117 | 898.6 | 5206 | 83 | 120 | | | | | | | |
| 290 | 33 | A-LAMP | D | 120 | 0.1011 | 10.737 | 0.885 | 50.497 | 880.5 | 5219 | 83 | 120 | 0.1 | 10.64 | 0.8849 | 50.326 | 890.97 | 5188 | 83 |
| 291 | 33 | A-LAMP | U | 120 | 0.0993 | 10.545 | 0.8849 | 50.152 | 839.7 | 5242 | 81 | 120 | 0.098 | 10.454 | 0.8848 | 50.172 | 851.51 | 5239 | 81 |
| 292 | 33 | A-LAMP | C | 120 | 0.0994 | 10.614 | 0.8898 | 48.688 | 888.3 | 5240 | 83 | 120 | | | | | | | |
| 293 | 33 | A-LAMP | C | 120 | 0.099 | 10.562 | 0.8891 | 49.475 | 854.4 | 5265 | 83 | 120 | | | | | | | |
| 294 | 33 | A-LAMP | C | 120 | 0.0983 | 10.486 | 0.8889 | 49.158 | 827.8 | 5354 | 82 | 120 | 0.098 | 10.481 | 0.8913 | 48.579 | 804.85 | 5322 | 82 |

| Test Units | | | | Initial Photometric Testing Results | | | | | | | | Final Photometric Testing Results | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | Initial Volts | Initial Amps | Initial Power | Initial pf | Initial THD | Initial Lumens | Initial CCT | Initial CRI | Final Volts | Final Amps | Final Power | Final pf | Final THD | Final Lumens | Final CCT | Final CRI |
| 295 | 33 | A-LAMP | R | 120 | 0.0947 | 10.173 | 0.8952 | 47.101 | 858.5 | 5324 | 83 | 120 | | | | | | | |
| 296 | 33 | A-LAMP | R | 120 | 0.0944 | 10.118 | 0.8932 | 47.487 | 871.2 | 5174 | 83 | 120 | | | | | | | |
| 297 | 33 | A-LAMP | R | 120 | 0.0954 | 10.252 | 0.8955 | 47.548 | 867.1 | 5245 | 83 | 120 | | | | | | | |
| 316 | 36 | A-LAMP | D | 120 | 0.1395 | 15.151 | 0.9051 | 45.151 | 1725.5 | 5115 | 84 | 120 | 0.14 | 15.128 | 0.9026 | 45.181 | 1722.8 | 5130 | 84 |
| 317 | 36 | A-LAMP | U | 120 | 0.1381 | 14.981 | 0.904 | 45.367 | 1722 | 5162 | 85 | 120 | 0.139 | 15.008 | 0.9016 | 45.613 | 1747.3 | 5176 | 84 |
| 318 | 36 | A-LAMP | D | 120 | 0.1405 | 15.231 | 0.9034 | 45.708 | 1727.2 | 5134 | 84 | 120 | 0.141 | 15.188 | 0.9006 | 45.936 | 1741.2 | 5152 | 84 |
| 319 | 36 | A-LAMP | C | 120 | 0.1374 | 14.948 | 0.9066 | 44.338 | 1749.9 | 5146 | 84 | 120 | 0.138 | 15.023 | 0.9057 | 44.508 | 1751.1 | 5126 | 84 |
| 320 | 36 | A-LAMP | C | 120 | 0.1381 | 15.026 | 0.9067 | 44.952 | 1751.6 | 5171 | 84 | 120 | | | | | | | |
| 321 | 36 | A-LAMP | C | 120 | 0.138 | 15.018 | 0.9069 | 44.725 | 1770.4 | 5155 | 84 | 120 | 0.139 | 15.064 | 0.9046 | 44.984 | 1779.3 | 5178 | 84 |
| 322 | 36 | A-LAMP | R | 120 | 0.1396 | 15.121 | 0.9026 | 45.011 | 1747.9 | 5195 | 85 | 120 | | | | | | | |
| 323 | 36 | A-LAMP | R | 120 | 0.1389 | 15.105 | 0.9062 | 44.923 | 1766.9 | 5127 | 85 | 120 | 0.138 | 14.953 | 0.9031 | 45.276 | 1805.7 | 5080 | 84 |
| 324 | 36 | A-LAMP | R | 120 | 0.1395 | 15.121 | 0.9033 | 44.718 | 1667.1 | 5111 | 84 | 120 | 0.14 | 15.235 | 0.9047 | 44.834 | 1707.2 | 5089 | 83 |
| 325 | 37 | A-LAMP | U | 120 | 0.1161 | 13.279 | 0.9531 | 28.49 | 810.1 | 2642 | 96 | 120 | 0.117 | 13.273 | 0.9453 | 29.553 | 840.75 | 2686 | 96 |
| 326 | 37 | A-LAMP | D | 120 | 0.1138 | 12.806 | 0.9378 | 33.389 | 779.7 | 2641 | 95 | 120 | 0.114 | 12.879 | 0.9435 | 29.866 | 805.25 | 2648 | 95 |
| 327 | 37 | A-LAMP | U | 120 | 0.1118 | 12.831 | 0.9564 | 29.994 | 805.7 | 2651 | 95 | 120 | 0.114 | 12.861 | 0.9408 | 31.096 | 858.74 | 2704 | 96 |
| 328 | 37 | A-LAMP | C | 120 | 0.113 | 12.939 | 0.9542 | 29.144 | 806.8 | 2645 | 95 | 120 | 0.115 | 13.039 | 0.9417 | 30.839 | 551.47 | 2808 | 95 |
| 329 | 37 | A-LAMP | C | 120 | 0.1147 | 12.995 | 0.9441 | 30.347 | 797.5 | 2671 | 95 | 120 | 0.116 | 13.143 | 0.9418 | 31.188 | 557.46 | 2785 | 95 |
| 330 | 37 | A-LAMP | C | 120 | 0.113 | 12.778 | 0.9423 | 31.855 | 784.5 | 2660 | 95 | 120 | 0.117 | 12.93 | 0.9231 | 35.109 | 596.2 | 2748 | 95 |
| 331 | 37 | A-LAMP | R | 120 | 0.1131 | 12.818 | 0.9444 | 31.387 | 785.6 | 2651 | 96 | 120 | 0.115 | 12.949 | 0.9353 | 32.881 | 709.15 | 2667 | 95 |
| 332 | 37 | A-LAMP | R | 120 | 0.1147 | 12.945 | 0.9405 | 31.445 | 794.7 | 2662 | 96 | 120 | 0.116 | 13.037 | 0.9395 | 31.482 | 648.94 | 2714 | 95 |
| 333 | 37 | A-LAMP | R | 120 | 0.1121 | 12.807 | 0.9521 | 29.252 | 771.8 | 2650 | 97 | 120 | 0.114 | 12.91 | 0.9447 | 29.772 | 465.62 | 3013 | 97 |
| 334 | 38 | A-LAMP | D | 120 | 0.0938 | 10.24 | 0.9097 | 34.204 | 791.5 | 2747 | 91 | 120 | 0.094 | 10.174 | 0.9031 | 35.243 | 797.4 | 2785 | 91 |
| 335 | 38 | A-LAMP | U | 120 | 0.0928 | 10.047 | 0.9022 | 34.004 | 784.3 | 2732 | 91 | 120 | 0.093 | 10.033 | 0.9018 | 37.088 | 785.8 | 2753 | 91 |
| 336 | 38 | A-LAMP | D | 120 | 0.0944 | 10.145 | 0.8956 | 29.532 | 779.2 | 2754 | 91 | 120 | | | | | | | |
| 337 | 38 | A-LAMP | C | 120 | 0.0945 | 10.247 | 0.9036 | 34.246 | 813.7 | 2742 | 91 | 120 | | | | | | | |
| 338 | 38 | A-LAMP | C | 120 | 0.0931 | 10.056 | 0.9001 | 36.601 | 797.5 | 2740 | 91 | 120 | | | | | | | |
| 339 | 38 | A-LAMP | C | 120 | 0.0938 | 10.237 | 0.9095 | 31.96 | 791.1 | 2752 | 90 | 120 | | | | | | | |
| 340 | 38 | A-LAMP | R | 120 | 0.0991 | 10.347 | 0.8701 | 34.356 | 809.4 | 2752 | 91 | 120 | | | | | | | |
| 341 | 38 | A-LAMP | R | 120 | 0.0938 | 10.086 | 0.8961 | 34.507 | 791.5 | 2725 | 91 | 120 | | | | | | | |
| 342 | 38 | A-LAMP | R | 120 | 0.0914 | 9.775 | 0.8912 | 33.549 | 785.8 | 2773 | 90 | 120 | | | | | | | |
| 343 | 39 | A-LAMP | U | 120 | 0.0912 | 10.872 | 0.9934 | 5.274 | 878.9 | 2752 | 81 | 120 | 0.092 | 10.894 | 0.9917 | 5.1187 | 859.8 | 2784 | 82 |
| 344 | 39 | A-LAMP | D | 120 | 0.0922 | 10.973 | 0.9918 | 3.456 | 767.7 | 2691 | 82 | 120 | 0.091 | 10.863 | 0.9916 | 3.4013 | 741.86 | 2785 | 82 |
| 345 | 39 | A-LAMP | U | 120 | 0.0939 | 11.144 | 0.989 | 3.253 | 788.9 | 2701 | 82 | 120 | | | | | | | |
| 346 | 39 | A-LAMP | C | 120 | 0.0929 | 11.047 | 0.9909 | 3.255 | 765.4 | 2700 | 82 | 120 | 0.093 | 11.134 | 0.9925 | 3.143 | 725.06 | 2802 | 82 |
| 347 | 39 | A-LAMP | C | 120 | 0.0901 | 10.706 | 0.9902 | 3.277 | 750.4 | 2700 | 82 | 120 | 0.089 | 10.539 | 0.9916 | 3.3667 | 703.81 | 2788 | 82 |
| 348 | 39 | A-LAMP | C | 120 | 0.0914 | 10.899 | 0.9937 | 3.521 | 786.1 | 2678 | 82 | 120 | 0.091 | 10.819 | 0.9914 | 3.4447 | 739.57 | 2764 | 82 |
| 349 | 39 | A-LAMP | R | 120 | 0.0924 | 11.023 | 0.9941 | 3.403 | 778.9 | 2710 | 82 | 120 | 0.093 | 11.05 | 0.9919 | 3.3335 | 753.38 | 2774 | 82 |
| 350 | 39 | A-LAMP | R | 120 | 0.0904 | 10.764 | 0.9923 | 3.458 | 758.7 | 2720 | 82 | 120 | 0.091 | 10.803 | 0.9917 | 3.3615 | 741.72 | 2807 | 82 |
| 351 | 39 | A-LAMP | R | 120 | 0.092 | 10.92 | 0.9891 | 3.468 | 772.4 | 2713 | 82 | 120 | 0.092 | 10.935 | 0.9914 | 3.4214 | 747.71 | 2779 | 82 |
| 352 | 40 | A-LAMP | D | 120 | 0.1101 | 12.209 | 0.9241 | 27.127 | 1131.6 | 3047 | 81 | 120 | 0.109 | 12.078 | 0.9213 | 26.392 | 1037.8 | 3168 | 81 |
| 353 | 40 | A-LAMP | U | 120 | 0.106 | 11.77 | 0.9253 | 30.361 | 1091 | 3037 | 81 | 120 | | | | | | | |
| 354 | 40 | A-LAMP | D | 120 | 0.1108 | 12.182 | 0.9162 | 30.025 | 1144.4 | 3023 | 81 | 120 | 0.11 | 12.101 | 0.9147 | 29.64 | 1042.8 | 3123 | 82 |
| 355 | 40 | A-LAMP | C | 120 | 0.1103 | 12.264 | 0.9266 | 26.941 | 1112.2 | 3038 | 81 | 120 | 0.11 | 12.242 | 0.9249 | 25.542 | 1069 | 3103 | 81 |
| 356 | 40 | A-LAMP | C | 120 | 0.1093 | 11.95 | 0.9111 | 28.936 | 1083.8 | 3022 | 81 | 120 | 0.106 | 11.851 | 0.932 | 28.571 | 1090.5 | 3069 | 81 |
| 357 | 40 | A-LAMP | C | 120 | 0.0998 | 11.017 | 0.9199 | 32.863 | 1017.9 | 3006 | 80 | 120 | | | | | | | |
| 358 | 40 | A-LAMP | R | 120 | 0.1082 | 11.761 | 0.9058 | 30.022 | 1108.3 | 3039 | 81 | 120 | 0.107 | 11.653 | 0.908 | 29.367 | 1046.9 | 3097 | 81 |
| 359 | 40 | A-LAMP | R | 120 | 0.1105 | 12.145 | 0.9159 | 29.419 | 1111.4 | 3019 | 81 | 120 | 0.11 | 12.039 | 0.9118 | 30.108 | 1025.6 | 3120 | 82 |
| 360 | 40 | A-LAMP | R | 120 | 0.1111 | 12.213 | 0.9161 | 30.957 | 1130.3 | 3036 | 81 | 120 | 0.11 | 13.079 | 0.9928 | 8.0303 | 1037.2 | 3125 | 81 |
| 361 | 41 | A-LAMP | U | 120 | 0.1146 | 12.281 | 0.893 | 47.021 | 1200 | 2740 | 82 | 120 | 0.115 | 12.309 | 0.8938 | 47.224 | 1231.9 | 2739 | 82 |
| 362 | 41 | A-LAMP | D | 120 | 0.1159 | 12.424 | 0.8933 | 47.567 | 1183.8 | 2741 | 82 | 120 | 0.116 | 12.47 | 0.8926 | 47.588 | 1213 | 2751 | 82 |
| 363 | 41 | A-LAMP | U | 120 | 0.1158 | 12.36 | 0.8895 | 48.936 | 1209.1 | 2734 | 82 | 120 | 0.116 | 12.362 | 0.8903 | 48.263 | 1256.8 | 2728 | 82 |
| 364 | 41 | A-LAMP | C | 120 | 0.1158 | 12.385 | 0.8913 | 48.065 | 1206.6 | 2735 | 82 | 120 | 0.116 | 12.435 | 0.8904 | 48.147 | 1192.1 | 2760 | 82 |
| 365 | 41 | A-LAMP | C | 120 | 0.116 | 12.453 | 0.8946 | 47.651 | 1246.6 | 2751 | 82 | 120 | 0.116 | 12.41 | 0.8918 | 47.76 | 1246 | 2762 | 82 |
| 366 | 41 | A-LAMP | C | 120 | 0.1149 | 12.29 | 0.8914 | 48.053 | 1193.2 | 2756 | 82 | 120 | | | | | | | |
| 367 | 41 | A-LAMP | R | 120 | 0.1154 | 12.386 | 0.8944 | 46.999 | 1235.1 | 2730 | 82 | 120 | 0.116 | 12.424 | 0.894 | 47.212 | 1232 | 2728 | 81 |
| 368 | 41 | A-LAMP | R | 120 | 0.1148 | 12.275 | 0.891 | 47.277 | 1211.3 | 2724 | 82 | 120 | 0.115 | 12.348 | 0.8924 | 47.432 | 1230.3 | 2724 | 81 |
| 369 | 41 | A-LAMP | R | 120 | 0.1146 | 12.375 | 0.8999 | 47.661 | 1186.6 | 2730 | 82 | 120 | | | | | | | |
| 379 | 43 | A-LAMP | U | 120 | 0.1398 | 14.338 | 0.8547 | 58.83 | 1012.7 | 2860 | 86 | 120 | | | | | | | |
| 380 | 43 | A-LAMP | D | 120 | 0.1391 | 14.382 | 0.8616 | 58.261 | 1058.8 | 2795 | 85 | 120 | 0.141 | 14.578 | 0.8633 | 57.775 | 1066.3 | 2816 | 85 |
| 381 | 43 | A-LAMP | U | 120 | 0.1385 | 14.293 | 0.86 | 58.793 | 1035 | 2812 | 85 | 120 | 0.14 | 14.464 | 0.8625 | 57.926 | 1052.9 | 2819 | 85 |
| 382 | 43 | A-LAMP | C | 120 | 0.1394 | 14.395 | 0.8605 | 58.507 | 1171.4 | 2802 | 82 | 120 | | | | | | | |
| 383 | 43 | A-LAMP | C | 120 | 0.1393 | 14.323 | 0.8568 | 59.538 | 997.6 | 2839 | 86 | 120 | | | | | | | |
| 384 | 43 | A-LAMP | C | 120 | 0.1378 | 14.192 | 0.8582 | 58.88 | 1037.4 | 2765 | 85 | 120 | 0.137 | 14.2 | 0.8617 | 58.021 | 993.48 | 2762 | 85 |
| 385 | 43 | A-LAMP | R | 120 | 0.1397 | 14.28 | 0.8518 | 59.177 | 1035.5 | 2783 | 85 | 120 | | | | | | | |
| 386 | 43 | A-LAMP | R | 120 | 0.1402 | 14.409 | 0.8565 | 59.703 | 1043.3 | 2802 | 85 | 120 | 0.14 | 14.458 | 0.8594 | 58.888 | 988.9 | 2786 | 85 |
| 387 | 43 | A-LAMP | R | 120 | 0.1402 | 14.401 | 0.856 | 58.407 | 1046.2 | 2798 | 85 | 120 | | | | | | | |
| 388 | 44 | A-LAMP | D | 120 | 0.1084 | 12.763 | 0.9812 | 10.19 | 1025.2 | 2846 | 81 | 120 | | | | | | | |
| 389 | 44 | A-LAMP | U | 120 | 0.1023 | 12.106 | 0.9862 | 7.305 | 983.7 | 2831 | 81 | 120 | | | | | | | |
| 390 | 44 | A-LAMP | D | 120 | 0.1052 | 12.427 | 0.9844 | 9.252 | 1028.4 | 2841 | 81 | 120 | | | | | | | |
| 391 | 44 | A-LAMP | C | 120 | 0.1026 | 12.111 | 0.9837 | 7.769 | 964.8 | 2828 | 82 | 120 | | | | | | | |
| 392 | 44 | A-LAMP | C | 120 | 0.1027 | 12.142 | 0.9852 | 7.853 | 978 | 2848 | 82 | 120 | | | | | | | |
| 393 | 44 | A-LAMP | C | 120 | 0.1029 | 12.113 | 0.981 | 8.215 | 1023.8 | 2841 | 81 | 120 | | | | | | | |
| 394 | 44 | A-LAMP | R | 120 | 0.0995 | 11.76 | 0.9849 | 6.44 | 997.6 | 2824 | 81 | 120 | | | | | | | |
| 395 | 44 | A-LAMP | R | 120 | 0.1017 | 12.04 | 0.9866 | 7.118 | 983.1 | 2790 | 81 | 120 | | | | | | | |

| Test Units | | | | Initial Photometric Testing Results | | | | | | | | Final Photometric Testing Results | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | Initial Volts | Initial Amps | Initial Power | Initial pf | Initial THD | Initial Lumens | Initial CCT | Initial CRI | Final Volts | Final Amps | Final Power | Final pf | Final THD | Final Lumens | Final CCT | Final CRI |
| 396 | 44 | A-LAMP | R | 120 | 0.1027 | 12.124 | 0.9838 | 7.447 | 972 | 2808 | 82 | 120 | | | | | | | |
| 397 | 45 | A-LAMP | U | 120 | 0.1187 | 13.772 | 0.9669 | 22.123 | 1268.3 | 5240 | 82 | 120 | 0.071 | 8.4092 | 0.9806 | 8.1612 | 698.16 | 5359 | 82 |
| 398 | 45 | A-LAMP | D | 120 | 0.1151 | 13.44 | 0.9731 | 17.66 | 1220 | 5241 | 82 | 120 | | | | | | | |
| 399 | 45 | A-LAMP | U | 120 | 0.1096 | 12.92 | 0.9824 | 12.676 | 1184 | 5227 | 82 | 120 | | | | | | | |
| 400 | 45 | A-LAMP | C | 120 | 0.1027 | 12.133 | 0.9845 | 7.655 | 1120 | 5150 | 82 | 120 | | | | | | | |
| 401 | 45 | A-LAMP | C | 120 | 0.1063 | 12.568 | 0.9853 | 12.189 | 1201.8 | 5185 | 81 | 120 | 0.103 | 12.226 | 0.9856 | 9.8162 | 984.76 | 5586 | 83 |
| 402 | 45 | A-LAMP | C | 120 | 0.11 | 12.85 | 0.9735 | 12.934 | 1194 | 5262 | 82 | 120 | 0.117 | 13.61 | 0.9691 | 21.8 | 1069.6 | 5741 | 83 |
| 403 | 45 | A-LAMP | R | 120 | 0.1114 | 13.08 | 0.9785 | 15.276 | 1194 | 5277 | 82 | 120 | | | | | | | |
| 404 | 45 | A-LAMP | R | 120 | 0.1045 | 12.349 | 0.9848 | 8.707 | 1143 | 5157 | 81 | 120 | | | | | | | |
| 405 | 45 | A-LAMP | R | 120 | 0.1038 | 12.244 | 0.983 | 8.527 | 1165 | 5209 | 82 | 120 | 0.1 | 11.855 | 0.9863 | 7.2942 | 1018.9 | 5511 | 83 |
| 406 | 46 | A-LAMP | D | 120 | 0.1374 | 14.93 | 0.9055 | 44.684 | 1592 | 2729 | 82 | 120 | 0.138 | 14.949 | 0.9054 | 44.629 | 1603.8 | 2756 | 82 |
| 407 | 46 | A-LAMP | U | 120 | 0.1397 | 15.111 | 0.9014 | 46.18 | 1602.7 | 2727 | 82 | 120 | 0.14 | 15.132 | 0.899 | 46.317 | 1621.7 | 2724 | 81 |
| 408 | 46 | A-LAMP | D | 120 | 0.1373 | 14.889 | 0.9037 | 43.471 | 1604.6 | 2763 | 82 | 120 | | | | | | | |
| 409 | 46 | A-LAMP | C | 120 | 0.1376 | 14.989 | 0.9078 | 44.291 | 1580 | 2751 | 82 | 120 | | | | | | | |
| 410 | 46 | A-LAMP | C | 120 | 0.138 | 14.941 | 0.9022 | 45.122 | 1542 | 2693 | 82 | 120 | 0.139 | 15.082 | 0.9036 | 45.205 | 1560 | 2691 | 81 |
| 411 | 46 | A-LAMP | C | 120 | 0.1513 | 17.608 | 0.9698 | 24.48 | 1596 | 2729 | 81 | 120 | | | | | | | |
| 412 | 46 | A-LAMP | R | 120 | 0.1408 | 15.252 | 0.9027 | 45.895 | 1610 | 2729 | 82 | 120 | 0.142 | 15.295 | 0.9 | 46.187 | 1642.8 | 2738 | 82 |
| 413 | 46 | A-LAMP | R | 120 | 0.1502 | 17.552 | 0.9738 | 23.57 | 1610 | 2730 | 81 | 120 | | | | | | | |
| 414 | 46 | A-LAMP | R | 120 | 0.138 | 14.977 | 0.9044 | 45.603 | 1589.2 | 2773 | 82 | 120 | 0.139 | 15.065 | 0.9019 | 45.637 | 1631.6 | 2748 | 82 |
| 415 | 47 | A-LAMP | U | 120 | 0.14 | 16.146 | 0.9611 | 22.209 | 1502 | 2682 | 81 | 120 | 0.031 | 2.2095 | 0.5917 | 93.037 | 187.37 | 2927 | 86 |
| 416 | 47 | A-LAMP | D | 120 | 0.1427 | 16.247 | 0.9488 | 27.006 | 1498.2 | 2657 | 82 | 120 | 0.142 | 16.199 | 0.954 | 23.638 | 1520 | 2669 | 82 |
| 417 | 47 | A-LAMP | U | 120 | 0.1424 | 16.354 | 0.957 | 23.313 | 1539 | 2681 | 82 | 120 | 0.142 | 16.3 | 0.9574 | 22.987 | 1541.8 | 2687 | 82 |
| 418 | 47 | A-LAMP | C | 120 | 0.1431 | 16.448 | 0.9578 | 23.86 | 1528 | 2690 | 82 | 120 | | | | | | | |
| 419 | 47 | A-LAMP | C | 120 | 0.1438 | 16.278 | 0.9433 | 28.529 | 1530 | 2646 | 82 | 120 | | | | | | | |
| 420 | 47 | A-LAMP | C | 120 | 0.1456 | 16.616 | 0.951 | 22.955 | 1537 | 2645 | 82 | 120 | | | | | | | |
| 421 | 47 | A-LAMP | R | 120 | 0.139 | 15.781 | 0.9461 | 24.977 | 1495 | 2668 | 82 | 120 | | | | | | | |
| 422 | 47 | A-LAMP | R | 120 | 0.1412 | 16.016 | 0.9452 | 27.288 | 1445 | 2636 | 83 | 120 | 0.02 | 1.1281 | 0.4813 | 67.008 | 57.148 | 2578 | 83 |
| 423 | 47 | A-LAMP | R | 120 | 0.1393 | 15.922 | 0.9525 | 23.168 | 1520 | 2692 | 81 | 120 | 0.02 | 1.0651 | 0.4524 | 67.524 | 60.168 | 2633 | 81 |
| 424 | 48 | A-LAMP | D | 120 | 0.148 | 17.582 | 0.99 | 2.969 | 1445 | 2814 | 81 | 120 | | | | | | | |
| 425 | 48 | A-LAMP | U | 120 | 0.1501 | 17.837 | 0.9903 | 6.135 | 1545.7 | 2868 | 82 | 120 | | | | | | | |
| 426 | 48 | A-LAMP | D | 120 | 0.1492 | 17.676 | 0.9873 | 5.218 | 1501 | 2807 | 81 | 120 | | | | | | | |
| 427 | 48 | A-LAMP | C | 120 | 0.1495 | 17.755 | 0.9897 | 3.211 | 1494 | 2821 | 82 | 120 | | | | | | | |
| 428 | 48 | A-LAMP | C | 120 | 0.1472 | 17.499 | 0.9907 | 2.999 | 1494 | 2846 | 81 | 120 | | | | | | | |
| 429 | 48 | A-LAMP | C | 120 | 0.1502 | 17.791 | 0.9871 | 3.577 | 1551 | 2806 | 81 | 120 | | | | | | | |
| 430 | 48 | A-LAMP | R | 120 | 0.149 | 17.709 | 0.9904 | 3.108 | 1480 | 2857 | 82 | 120 | | | | | | | |
| 431 | 48 | A-LAMP | R | 120 | 0.1515 | 17.994 | 0.9898 | 3.993 | 1597 | 2802 | 82 | 120 | | | | | | | |
| 432 | 48 | A-LAMP | R | 120 | 0.1487 | 17.715 | 0.9928 | 3.34 | 1535 | 2872 | 82 | 120 | | | | | | | |
| 433 | 49 | A-LAMP | U | 120 | 0.1299 | 14.914 | 0.9568 | 27.769 | 1432 | 2715 | 90 | 120 | 0.129 | 14.83 | 0.9568 | 27.44 | 1435.4 | 2740 | 90 |
| 434 | 49 | A-LAMP | D | 120 | 0.1276 | 14.73 | 0.962 | 25.759 | 1383 | 2711 | 90 | 120 | 0.127 | 14.615 | 0.9617 | 25.395 | 1366.1 | 2784 | 90 |
| 435 | 49 | A-LAMP | U | 120 | 0.1285 | 14.779 | 0.9584 | 26.698 | 1393 | 2716 | 90 | 120 | 0.123 | 14.73 | 0.9951 | 26.386 | 1393.8 | 2751 | 90 |
| 436 | 49 | A-LAMP | C | 120 | 0.1295 | 14.948 | 0.9619 | 25.177 | 1382 | 2713 | 91 | 120 | 0.129 | 14.947 | 0.9631 | 24.97 | 1299.3 | 2807 | 91 |
| 437 | 49 | A-LAMP | C | 120 | 0.1319 | 15.166 | 0.9582 | 26.66 | 1407 | 2725 | 91 | 120 | | | | | | | |
| 438 | 49 | A-LAMP | C | 120 | 0.1297 | 14.996 | 0.9635 | 24.885 | 1388 | 2707 | 91 | 120 | | | | | | | |
| 439 | 49 | A-LAMP | R | 120 | 0.131 | 15.046 | 0.9571 | 27.581 | 1398 | 2699 | 92 | 120 | 0.131 | 15.03 | 0.9571 | 27.473 | 1350.1 | 2791 | 92 |
| 440 | 49 | A-LAMP | R | 120 | 0.1378 | 16.045 | 0.9703 | 22.139 | 1457 | 2706 | 92 | 120 | 0.128 | 14.826 | 0.9625 | 25.255 | 1364.1 | 2753 | 92 |
| 441 | 49 | A-LAMP | R | 120 | 0.1292 | 14.917 | 0.9621 | 25.784 | 1420 | 2723 | 90 | 120 | 0.128 | 14.754 | 0.9604 | 25.619 | 1189.6 | 2891 | 90 |
| 442 | 50 | GLOBE | D | 120 | 0.0449 | 4.887 | 0.907 | 39.178 | 339 | 2703 | 81 | 120 | 0.045 | 4.9151 | 0.9108 | 38.915 | 349.64 | 2755 | 82 |
| 443 | 50 | GLOBE | U | 120 | 0.0441 | 4.842 | 0.915 | 37.256 | 342.7 | 2693 | 82 | 120 | 0.044 | 4.8568 | 0.9144 | 37.095 | 350.2 | 2706 | 82 |
| 444 | 50 | GLOBE | D | 120 | 0.0445 | 4.866 | 0.9112 | 38.138 | 343.4 | 2727 | 82 | 120 | 0.044 | 4.8653 | 0.9132 | 38.045 | 347.44 | 2728 | 82 |
| 445 | 51 | GLOBE | U | 120 | 0.0515 | 4.449 | 0.7199 | 89.235 | 395.7 | 2665 | 81 | 120 | 0.054 | 4.54 | 0.6958 | 89.6 | 399.8 | 2683 | 81 |
| 446 | 51 | GLOBE | D | 120 | 0.0511 | 4.512 | 0.7358 | 87.651 | 392 | 2639 | 82 | 120 | 0.053 | 4.5645 | 0.7142 | 87.656 | 410.66 | 2698 | 82 |
| 447 | 51 | GLOBE | U | 120 | 0.0517 | 4.528 | 0.7299 | 87.832 | 385.4 | 2657 | 81 | 120 | 0.054 | 4.53 | 0.9336 | 87.85 | 402.1 | 2662 | 81 |
| 448 | 52 | GLOBE | D | 120 | 0.0448 | 4.421 | 0.8224 | 48.411 | 299 | 2746 | 81 | 120 | 0.045 | 4.4072 | 0.8224 | 48.693 | 307.83 | 2805 | 82 |
| 449 | 52 | GLOBE | U | 120 | 0.0446 | 4.362 | 0.815 | 48.719 | 300.5 | 2800 | 83 | 120 | 0.044 | 4.3796 | 0.8214 | 48.653 | 308.6 | 2771 | 82 |
| 450 | 52 | GLOBE | D | 120 | 0.0441 | 4.315 | 0.8154 | 48.697 | 289.8 | 2848 | 83 | 120 | 0.044 | 4.3013 | 0.8163 | 48.934 | 295.35 | 2852 | 83 |
| 451 | 53 | GLOBE | U | 120 | 0.06 | 4.361 | 0.6057 | 69.409 | 288.1 | 2718 | 83 | 120 | 0.06 | 4.4164 | 0.6145 | 68.372 | 292.57 | 2738 | 82 |
| 452 | 53 | GLOBE | D | 120 | 0.0585 | 4.265 | 0.6075 | 69.403 | 280.2 | 2723 | 83 | 120 | 0.058 | 4.2805 | 0.6127 | 68.104 | 280.34 | 2701 | 82 |
| 453 | 53 | GLOBE | U | 120 | 0.0592 | 4.31 | 0.6067 | 69.943 | 282.2 | 2732 | 83 | 120 | 0.059 | 4.3345 | 0.6132 | 69.061 | 283.72 | 2743 | 83 |
| 454 | 54 | GLOBE | D | 120 | 0.0735 | 7.445 | 0.8441 | 57.61 | 715.2 | 2759 | 81 | 120 | 0.075 | 7.5095 | 0.8393 | 57.975 | 739.72 | 2794 | 81 |
| 455 | 54 | GLOBE | U | 120 | 0.0728 | 7.393 | 0.8463 | 59.245 | 715.9 | 2762 | 81 | 120 | 0.074 | 7.3847 | 0.8306 | 59.375 | 753.65 | 2837 | 82 |
| 456 | 54 | GLOBE | D | 120 | 0.0742 | 7.47 | 0.8389 | 59.255 | 704.9 | 2771 | 82 | 120 | 0.069 | 7.3368 | 0.8901 | 48.385 | 731.79 | 2774 | 81 |
| 460 | 56 | GLOBE | D | 120 | 0.0855 | 7.171 | 0.6989 | 98.613 | 539.3 | 3021 | 80 | 120 | 0.086 | 7.216 | 0.6991 | 98.595 | 556.11 | 3012 | 80 |
| 461 | 56 | GLOBE | U | 120 | 0.0842 | 7.1 | 0.7027 | 99.202 | 533.6 | 3009 | 80 | 120 | 0.088 | 7.099 | 0.669 | 70.26 | 550.75 | 3006 | 80 |
| 462 | 56 | GLOBE | D | 120 | 0.0864 | 7.309 | 0.705 | 97.785 | 525.9 | 3021 | 80 | 120 | 0.087 | 7.3191 | 0.7017 | 97.131 | 544.05 | 3071 | 81 |
| 463 | 57 | GLOBE | U | 120 | 0.0635 | 7.555 | 0.9915 | 6.852 | 526.4 | 2733 | 91 | 120 | | | | | | | |
| 464 | 57 | GLOBE | D | 120 | 0.066 | 7.818 | 0.9871 | 8.084 | 524.9 | 2740 | 91 | 120 | 0.066 | 7.8598 | 0.989 | 7.1037 | 529.14 | 2750 | 90 |
| 465 | 57 | GLOBE | U | 120 | 0.0649 | 7.658 | 0.9833 | 7.454 | 508.8 | 2721 | 90 | 120 | 0.065 | 7.6637 | 0.9874 | 8.3971 | 523.49 | 2748 | 91 |
| 466 | 58 | GLOBE | D | 120 | 0.0682 | 7.436 | 0.9086 | 40.359 | 681.3 | 2701 | 81 | 120 | 0.068 | 7.4468 | 0.9098 | 40.131 | 697.7 | 2741 | 81 |
| 467 | 58 | GLOBE | U | 120 | 0.0671 | 7.33 | 0.9103 | 39.456 | 696.9 | 2797 | 82 | 120 | 0.067 | 7.3463 | 0.9119 | 39.203 | 710.64 | 2820 | 82 |
| 468 | 58 | GLOBE | D | 120 | 0.0682 | 7.435 | 0.9085 | 40.131 | 686 | 2704 | 82 | 120 | 0.068 | 7.4035 | 0.9077 | 40.326 | 695.49 | 2721 | 82 |
| 469 | 59 | GLOBE | U | 120 | 0.0563 | 6.655 | 0.9851 | 6.885 | 516.5 | 3076 | 83 | 120 | 0.056 | 6.676 | 0.9869 | 6.9614 | 547.4 | 3064 | 83 |
| 470 | 59 | GLOBE | D | 120 | 0.0523 | 6.207 | 0.989 | 6.841 | 513.7 | 3057 | 82 | 120 | 0.053 | 6.2059 | 0.9843 | 7.866 | 532.32 | 3052 | 82 |
| 471 | 59 | GLOBE | D | 120 | 0.0904 | 7.744 | 0.7139 | 95.773 | 461.5 | 3151 | 83 | 120 | 0.091 | 7.688 | 0.7075 | 95.437 | 449.49 | 3195 | 83 |
| 472 | 60 | TORPEDO/BULLET | D | 120 | 0.0383 | 1.834 | 0.399 | 43.478 | 130.1 | 2767 | 84 | 120 | 0.037 | 1.8136 | 0.4043 | 45.112 | 108.63 | 2599 | 81 |

| Test Units | | | | Initial Photometric Testing Results | | | | | | | | Final Photometric Testing Results | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | Initial Volts | Initial Amps | Initial Power | Initial pf | Initial THD | Initial Lumens | Initial CCT | Initial CRI | Final Volts | Final Amps | Final Power | Final pf | Final THD | Final Lumens | Final CCT | Final CRI |
| 473 | 60 | TORPEDO/BULLET | U | 120 | 0.0393 | 1.868 | 0.3961 | 43.455 | 130.8 | 2688 | 82 | 120 | 0.039 | 1.8715 | 0.3982 | 43.523 | 139 | 3193 | 88 |
| 474 | 60 | TORPEDO/BULLET | D | 120 | 0.0391 | 1.853 | 0.3949 | 43.114 | 127.9 | 2654 | 83 | 120 | 0.039 | 1.856 | 0.397 | 43.315 | 136.01 | 2687 | 82 |
| 475 | 60 | TORPEDO/BULLET | C | 120 | 0.0387 | 1.841 | 0.3964 | 43.276 | 123.7 | 2679 | 82 | 120 | 0.039 | 1.8454 | 0.3964 | 43.22 | 133.4 | 2803 | 83 |
| 476 | 60 | TORPEDO/BULLET | C | 120 | 0.039 | 1.865 | 0.3985 | 43.441 | 126.7 | 2655 | 83 | 120 | 0.039 | 1.8702 | 0.3985 | 43.319 | 137.38 | 2779 | 84 |
| 477 | 60 | TORPEDO/BULLET | C | 120 | 0.0388 | 1.861 | 0.3997 | 43.595 | 129.8 | 2777 | 84 | 120 | 0.039 | 1.8541 | 0.399 | 43.814 | 136.27 | 2810 | 84 |
| 478 | 61 | TORPEDO/BULLET | U | 120 | 0.0438 | 3.342 | 0.6358 | 77.217 | 149.3 | 2583 | 78 | 120 | 0.043 | 3.3467 | 0.6445 | 76.652 | 147.36 | 3176 | 85 |
| 479 | 61 | TORPEDO/BULLET | D | 120 | 0.0435 | 3.353 | 0.6423 | 77.521 | 156.6 | 2752 | 79 | 120 | 0.043 | 3.3267 | 0.6387 | 77.284 | 130.49 | 2793 | 79 |
| 480 | 61 | TORPEDO/BULLET | U | 120 | 0.0435 | 3.365 | 0.6446 | 77.541 | 154.1 | 2665 | 78 | 120 | 0.043 | 3.3479 | 0.6497 | 76.003 | 148.24 | 3235 | 85 |
| 481 | 61 | TORPEDO/BULLET | C | 120 | 0.0434 | 3.338 | 0.6409 | 74.769 | 161.2 | 2845 | 80 | 120 | 0.044 | 3.3668 | 0.6449 | 74.384 | 143.54 | 2954 | 80 |
| 482 | 61 | TORPEDO/BULLET | C | 120 | 0.0442 | 3.384 | 0.638 | 76.731 | 161.6 | 2673 | 79 | 120 | 0.044 | 3.391 | 0.6414 | 76.381 | 137.3 | 2749 | 79 |
| 483 | 61 | TORPEDO/BULLET | C | 120 | 0.044 | 3.383 | 0.6407 | 75.971 | 157.3 | 2590 | 77 | 120 | 0.044 | 3.4026 | 0.645 | 75.416 | 124.87 | 2743 | 79 |
| 484 | 62 | TORPEDO/BULLET | D | 120 | 0.0362 | 3.035 | 0.6987 | 94.682 | 300.7 | 4887 | 82 | 120 | 0.037 | 3.0467 | 0.694 | 95.169 | 304.1 | 5009 | 82 |
| 485 | 62 | TORPEDO/BULLET | U | 120 | 0.036 | 3.005 | 0.6956 | 95.456 | 304.2 | 4900 | 81 | 120 | 0.036 | 3.0043 | 0.6932 | 96.324 | 325.65 | 5415 | 84 |
| 486 | 62 | TORPEDO/BULLET | D | 120 | 0.0353 | 2.969 | 0.7009 | 92.756 | 294.9 | 5000 | 82 | 120 | 0.035 | 2.9555 | 0.6988 | 93.296 | 304.49 | 5068 | 82 |
| 487 | 62 | TORPEDO/BULLET | C | 120 | 0.0356 | 3.018 | 0.7065 | 92.145 | 311.3 | 4910 | 82 | 120 | 0.036 | 3.0077 | 0.7023 | 92.704 | 313.77 | 5024 | 82 |
| 488 | 62 | TORPEDO/BULLET | C | 120 | 0.0359 | 3.001 | 0.6966 | 94.01 | 291.7 | 4969 | 83 | 120 | 0.036 | 3.0086 | 0.6968 | 94.387 | 296.76 | 5067 | 82 |
| 489 | 62 | TORPEDO/BULLET | C | 120 | 0.0358 | 3.006 | 0.6997 | 94.159 | 290.1 | 4948 | 82 | 120 | 0.036 | 3.0218 | 0.6971 | 94.836 | 298.63 | 5077 | 81 |
| 490 | 63 | TORPEDO/BULLET | U | 120 | 0.0308 | 3.291 | 0.8904 | 45.692 | 246.7 | 2674 | 79 | 120 | 0.031 | 3.2919 | 0.8893 | 45.997 | 257.52 | 2736 | 80 |
| 491 | 63 | TORPEDO/BULLET | D | 120 | 0.0313 | 3.341 | 0.8895 | 47.065 | 220.6 | 2749 | 83 | 120 | 0.031 | 3.3442 | 0.8871 | 47.193 | 237.89 | 2761 | 82 |
| 492 | 63 | TORPEDO/BULLET | U | 120 | 0.0314 | 3.33 | 0.8838 | 48.287 | 244 | 2711 | 80 | 120 | 0.032 | 3.3315 | 0.8807 | 48.515 | 267.14 | 2972 | 84 |
| 493 | 63 | TORPEDO/BULLET | C | 120 | 0.031 | 3.311 | 0.8901 | 46.221 | 222.5 | 2464 | 83 | | | | | | | | |
| 494 | 63 | TORPEDO/BULLET | C | 120 | 0.0308 | 3.291 | 0.8904 | 45.918 | 250.8 | 2722 | 81 | 120 | 0.031 | 3.2869 | 0.888 | 46.182 | 259.4 | 2742 | 81 |
| 495 | 63 | TORPEDO/BULLET | C | 120 | 0.0311 | 3.341 | 0.8952 | 45.242 | 238 | 2679 | 80 | 120 | 0.031 | 3.3486 | 0.892 | 45.483 | 247.54 | 2708 | 81 |
| 496 | 64 | TORPEDO/BULLET | D | 120 | 0.0422 | 4.137 | 0.8169 | 46.474 | 360.5 | 4926 | 84 | 120 | 0.042 | 4.1193 | 0.8172 | 46.443 | 374.99 | 5050 | 84 |
| 497 | 64 | TORPEDO/BULLET | U | 120 | 0.0425 | 4.139 | 0.8116 | 47.681 | 359.6 | 4908 | 82 | 120 | 0.042 | 4.1431 | 0.8174 | 47.369 | 363.44 | 5035 | 82 |
| 498 | 64 | TORPEDO/BULLET | D | 120 | 0.0416 | 4.07 | 0.8153 | 46.567 | 368 | 4955 | 84 | 120 | 0.042 | 4.0926 | 0.8195 | 46.047 | 372.05 | 5039 | 84 |
| 499 | 64 | TORPEDO/BULLET | C | 120 | 0.043 | 4.206 | 0.8151 | 46.625 | 371.6 | 4988 | 83 | 120 | 0.042 | 4.1723 | 0.8199 | 46.531 | 370.98 | 5085 | 83 |
| 500 | 64 | TORPEDO/BULLET | C | 120 | 0.0425 | 4.225 | 0.8284 | 46.805 | 377.8 | 5043 | 83 | 120 | 0.042 | 4.1906 | 0.825 | 46.93 | 377.78 | 5157 | 84 |
| 501 | 64 | TORPEDO/BULLET | C | 120 | 0.0427 | 4.185 | 0.8167 | 47.317 | 370.5 | 4964 | 83 | 120 | 0.042 | 4.1682 | 0.8181 | 47.014 | 370.91 | 5060 | 83 |
| 508 | 66 | TORPEDO/BULLET | U | 120 | 0.0473 | 5.23 | 0.9214 | 37.727 | 412.9 | 2723 | 82 | 120 | 0.047 | 5.2066 | 0.9206 | 37.455 | 434.43 | 2736 | 82 |
| 509 | 66 | TORPEDO/BULLET | D | 120 | 0.047 | 5.202 | 0.9223 | 36.902 | 394.5 | 2740 | 83 | 120 | 0.047 | 5.2235 | 0.9223 | 36.709 | 367.23 | 2828 | 82 |
| 510 | 66 | TORPEDO/BULLET | D | 120 | 0.0464 | 5.139 | 0.923 | 35.899 | 411.5 | 2759 | 82 | 120 | 0.046 | 5.1543 | 0.9245 | 35.889 | 432.8 | 2772 | 82 |
| 511 | 66 | TORPEDO/BULLET | C | 120 | 0.0455 | 5.036 | 0.9223 | 36.056 | 404.2 | 2730 | 82 | 120 | 0.046 | 5.0584 | 0.9228 | 36.161 | 415.72 | 2738 | 82 |
| 512 | 66 | TORPEDO/BULLET | C | 120 | 0.0467 | 5.161 | 0.9209 | 37.601 | 413.1 | 2743 | 82 | 120 | 0.047 | 5.1797 | 0.9202 | 37.485 | 416.29 | 2776 | 82 |
| 513 | 66 | TORPEDO/BULLET | C | 120 | 0.046 | 5.06 | 0.9167 | 35.827 | 412.2 | 2725 | 82 | 120 | 0.046 | 5.0978 | 0.9256 | 35.678 | 387.51 | 2811 | 82 |
| 514 | 67 | TORPEDO/BULLET | D | 120 | 0.0524 | 4.887 | 0.7772 | 73.63 | 421.9 | 2760 | 82 | 120 | 0.052 | 4.8841 | 0.7777 | 73.903 | 419.42 | 2776 | 81 |
| 515 | 67 | TORPEDO/BULLET | D | 120 | 0.0456 | 5.049 | 0.9227 | 36.803 | 414.8 | 2773 | 83 | 120 | 0.046 | 5.0489 | 0.9219 | 36.745 | 412.36 | 2777 | 82 |
| 516 | 67 | TORPEDO/BULLET | U | 120 | 0.0524 | 4.957 | 0.7883 | 72.364 | 430.6 | 2748 | 81 | 120 | 0.053 | 4.9501 | 0.7853 | 72.705 | 436.18 | 2912 | 83 |
| 517 | 67 | TORPEDO/BULLET | C | 120 | 0.0529 | 4.952 | 0.7801 | 73.161 | 395.5 | 2763 | 82 | 120 | | | | | | | |
| 518 | 67 | TORPEDO/BULLET | C | 120 | 0.052 | 4.889 | 0.7835 | 72.185 | 399 | 2774 | 82 | 120 | 0.052 | 4.8888 | 0.7822 | 72.391 | 393.19 | 2810 | 81 |
| 519 | 67 | TORPEDO/BULLET | C | 120 | 0.0523 | 4.947 | 0.7882 | 71.717 | 405.6 | 2753 | 82 | 120 | | | | | | | |
| 520 | 68 | TORPEDO/BULLET | U | 120 | 0.052 | 4.9 | 0.7853 | 72.93 | 473.7 | 5302 | 82 | 120 | 0.052 | 4.9336 | 0.7843 | 72.821 | 489.24 | 5507 | 83 |
| 521 | 68 | TORPEDO/BULLET | U | 120 | 0.0522 | 4.89 | 0.7807 | 73.139 | 488.3 | 5187 | 81 | 120 | 0.053 | 4.9308 | 0.7814 | 73.013 | 502.43 | 5465 | 83 |
| 522 | 68 | TORPEDO/BULLET | D | 120 | 0.0521 | 4.917 | 0.7865 | 72.5 | 465 | 5264 | 83 | 120 | 0.052 | 4.9273 | 0.785 | 72.684 | 479.65 | 5203 | 82 |
| 523 | 68 | TORPEDO/BULLET | C | 120 | 0.0531 | 5.017 | 0.7874 | 71.898 | 479.7 | 5315 | 82 | 120 | 0.053 | 5.0449 | 0.7872 | 71.867 | 471.44 | 5441 | 82 |
| 524 | 68 | TORPEDO/BULLET | C | 120 | 0.0529 | 4.947 | 0.7793 | 72.912 | 459.2 | 5310 | 82 | 120 | | | | | | | |
| 525 | 68 | TORPEDO/BULLET | C | 120 | 0.053 | 4.963 | 0.7803 | 73.896 | 467.4 | 5166 | 81 | 120 | 0.053 | 5.0054 | 0.7813 | 73.884 | 470.61 | 5282 | 81 |
| 532 | 70 | TORPEDO/BULLET | U | 120 | 0.0388 | 4.616 | 0.9914 | 5.062 | 312.2 | 2692 | 92 | 120 | 0.039 | 4.6236 | 0.9878 | 4.9619 | 345.46 | 2894 | 94 |
| 533 | 70 | TORPEDO/BULLET | U | 120 | 0.0368 | 4.374 | 0.9905 | 4.936 | 305.8 | 2697 | 92 | 120 | 0.046 | 4.4313 | 0.8076 | 64.245 | 322.01 | 2755 | 92 |
| 534 | 70 | TORPEDO/BULLET | D | 120 | 0.0396 | 4.72 | 0.9933 | 4.524 | 312.6 | 2660 | 92 | 120 | 0.04 | 4.6918 | 0.9876 | 4.9226 | 328.29 | 2710 | 92 |
| 535 | 70 | TORPEDO/BULLET | C | 120 | 0.0376 | 4.456 | 0.9876 | 5.158 | 301.8 | 2725 | 93 | 120 | 0.038 | 4.4837 | 0.9869 | 5.242 | 313.53 | 2751 | 93 |
| 536 | 70 | TORPEDO/BULLET | C | 120 | 0.0383 | 4.529 | 0.9854 | 5.705 | 304.8 | 2702 | 92 | 120 | 0.048 | 4.604 | 0.8061 | 64.697 | 317.9 | 2760 | 92 |
| 537 | 70 | TORPEDO/BULLET | C | 120 | 0.0391 | 4.636 | 0.9881 | 4.481 | 300.3 | 2750 | 93 | 120 | 0.039 | 4.6374 | 0.9876 | 4.8635 | 313.75 | 2772 | 93 |
| 538 | 71 | TORPEDO/BULLET | D | 120 | 0.0592 | 3.987 | 0.5612 | 131.72 | 304 | 2963 | 82 | 120 | 0.059 | 3.9938 | 0.5641 | 129.43 | 306.63 | 3031 | 82 |
| 539 | 71 | TORPEDO/BULLET | U | 120 | 0.0586 | 3.959 | 0.563 | 129.94 | 306.3 | 2964 | 82 | 120 | 0.058 | 3.9884 | 0.5693 | 126.59 | 316.79 | 3212 | 85 |
| 540 | 71 | TORPEDO/BULLET | D | 120 | 0.0583 | 3.959 | 0.5659 | 127.44 | 302.7 | 2946 | 82 | 120 | 0.058 | 3.972 | 0.5706 | 125.77 | 295.05 | 3008 | 82 |
| 541 | 71 | TORPEDO/BULLET | C | 120 | 0.059 | 3.958 | 0.559 | 132.96 | 294.5 | 2955 | 82 | 120 | 0.058 | 3.9657 | 0.5698 | 128.61 | 286.68 | 3076 | 82 |
| 542 | 71 | TORPEDO/BULLET | C | 120 | 0.0598 | 4.033 | 0.562 | 130.67 | 310.6 | 2946 | 83 | 120 | 0.059 | 4.048 | 0.5703 | 127.52 | 308 | 3012 | 83 |
| 543 | 71 | TORPEDO/BULLET | C | 120 | 0.0595 | 4.012 | 0.5619 | 131.06 | 299.7 | 2939 | 82 | 120 | 0.059 | 4.0146 | 0.5694 | 127.76 | 294.27 | 3033 | 83 |
| 544 | 72 | TORPEDO/BULLET | D | 120 | 0.0395 | 3.803 | 0.8023 | 49.113 | 338.7 | 5250 | 83 | 120 | 0.039 | 3.7845 | 0.801 | 48.965 | 339.68 | 5351 | 83 |
| 545 | 72 | TORPEDO/BULLET | U | 120 | 0.0389 | 3.699 | 0.7924 | 49.642 | 334.5 | 5265 | 83 | 120 | 0.039 | 3.6663 | 0.7915 | 49.481 | 339 | 5289 | 83 |
| 546 | 72 | TORPEDO/BULLET | D | 120 | 0.0436 | 4.292 | 0.8203 | 47.283 | 367 | 4902 | 82 | 120 | 0.043 | 4.2438 | 0.8152 | 47.591 | 364.76 | 4995 | 82 |
| 547 | 73 | TORPEDO/BULLET | U | 120 | 0.0414 | 4.061 | 0.8174 | 47.509 | 344.3 | 5213 | 82 | 120 | 0.041 | 4.0409 | 0.8186 | 47.377 | 353.65 | 5311 | 82 |
| 548 | 73 | TORPEDO/BULLET | D | 120 | 0.0435 | 4.268 | 0.8176 | 46.703 | 367.5 | 4866 | 82 | 120 | 0.043 | 4.2681 | 0.8228 | 46.207 | 360.76 | 4874 | 82 |
| 549 | 73 | TORPEDO/BULLET | U | 120 | 0.0443 | 4.314 | 0.8115 | 48.954 | 341.7 | 4955 | 82 | 120 | 0.044 | 4.2861 | 0.8119 | 48.697 | 367.49 | 5258 | 84 |
| 550 | 74 | TORPEDO/BULLET | D | 120 | 0.0439 | 4.321 | 0.8202 | 48.063 | 286.9 | 2796 | 82 | 120 | 0.044 | 4.2756 | 0.819 | 48.065 | 292.35 | 2812 | 82 |
| 551 | 74 | TORPEDO/BULLET | U | 120 | 0.0445 | 4.347 | 0.814 | 48.823 | 288.2 | 2743 | 81 | 120 | 0.044 | 4.3204 | 0.8166 | 48.52 | 291.25 | 2953 | 84 |
| 552 | 74 | TORPEDO/BULLET | D | 120 | 0.0438 | 4.289 | 0.816 | 48.537 | 281.6 | 2751 | 81 | 120 | 0.043 | 4.2523 | 0.8159 | 48.551 | 280.19 | 2733 | 81 |
| 553 | 75 | TORPEDO/BULLET | U | 120 | 0.0449 | 4.447 | 0.8254 | 48.155 | 329.2 | 2744 | 81 | 120 | 0.044 | 4.3865 | 0.8227 | 48.071 | 352.15 | 2912 | 83 |
| 554 | 75 | TORPEDO/BULLET | D | 120 | 0.0447 | 4.399 | 0.8201 | 47.011 | 329.1 | 2722 | 81 | 120 | 0.044 | 4.3612 | 0.8204 | 47.008 | 336.51 | 2747 | 81 |
| 555 | 75 | TORPEDO/BULLET | U | 120 | 0.0443 | 4.389 | 0.8256 | 47.053 | 317.1 | 2734 | 81 | 120 | 0.044 | 4.407 | 0.8297 | 46.179 | 342.74 | 2896 | 83 |
| 556 | 76 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0885 | 9.602 | 0.9041 | 41.252 | 675 | 2644 | 91 | 120 | 0.08 | 9.62 | 0.9041 | 41.12 | 691.73 | 2709 | 91 |
| 557 | 76 | SPOTLIGHT/REFLECTOR | U | 120 | 0.0862 | 9.363 | 0.9052 | 40.945 | 671.8 | 2680 | 92 | 120 | 0.085 | 9.2369 | 0.906 | 40.595 | 682.66 | 2710 | 92 |
| 558 | 76 | SPOTLIGHT/REFLECTOR | D | 120 | 0.087 | 9.347 | 0.8953 | 43.544 | 690.7 | 2696 | 92 | 120 | 0.086 | 9.2741 | 0.8962 | 43.41 | 675.25 | 2791 | 92 |

| Test Units | | | | Initial Photometric Testing Results | | | | | | | | Final Photometric Testing Results | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | Initial Volts | Initial Amps | Initial Power | Initial pf | Initial THD | Initial Lumens | Initial CCT | Initial CRI | Final Volts | Final Amps | Final Power | Final pf | Final THD | Final Lumens | Final CCT | Final CRI |
| 559 | 76 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0864 | 9.401 | 0.9067 | 40.878 | 670.2 | 2662 | 92 | 120 | 0.085 | 9.2617 | 0.9069 | 40.472 | 692.75 | 2729 | 92 |
| 560 | 76 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0833 | 9.011 | 0.9015 | 41.123 | 656.5 | 2665 | 92 | 120 | 0.082 | 8.8782 | 0.9025 | 40.812 | 660.09 | 2692 | 91 |
| 561 | 76 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0862 | 9.354 | 0.9043 | 40.958 | 669.1 | 2652 | 92 | 120 | 0.085 | 9.2083 | 0.9053 | 40.426 | 674.26 | 2670 | 91 |
| 562 | 77 | SPOTLIGHT/REFLECTOR | U | 120 | 0.08 | 9.494 | 0.989 | 7.341 | 729.7 | 2745 | 83 | 120 | 0.08 | 9.5887 | 0.9928 | 8.195 | 762.29 | 2760 | 83 |
| 563 | 77 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0767 | 9.078 | 0.9863 | 8.595 | 697.2 | 2747 | 83 | 120 | 0.078 | 9.211 | 0.9883 | 8.9059 | 720.97 | 2754 | 83 |
| 564 | 77 | SPOTLIGHT/REFLECTOR | U | 120 | 0.0777 | 9.284 | 0.9957 | 7.644 | 709.7 | 2757 | 82 | 120 | 0.078 | 9.2559 | 0.9905 | 7.3271 | 724.19 | 2789 | 82 |
| 565 | 77 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0774 | 9.206 | 0.9912 | 7.233 | 702.9 | 2742 | 83 | 120 | 0.078 | 9.31 | 0.9927 | 7.6236 | 732.44 | 2758 | 83 |
| 566 | 77 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0769 | 9.119 | 0.9882 | 8.499 | 705.6 | 2750 | 83 | 120 | 0.077 | 9.188 | 0.9934 | 8.355 | 732.74 | 2768 | 83 |
| 567 | 77 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0757 | 9 | 0.9908 | 8.462 | 696.8 | 2752 | 81 | 120 | 0.077 | 9.1196 | 0.9927 | 8.4184 | 725.9 | 2774 | 83 |
| 568 | 78 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0779 | 9.229 | 0.9873 | 7.168 | 690.8 | 2817 | 82 | 120 | 0.078 | 9.299 | 0.9882 | 7.0345 | 673.35 | 2879 | 82 |
| 569 | 78 | SPOTLIGHT/REFLECTOR | U | 120 | 0.0778 | 9.243 | 0.99 | 7.178 | 694.1 | 2762 | 81 | 120 | 0.078 | 9.269 | 0.9884 | 7.0316 | 692.34 | 2922 | 83 |
| 570 | 78 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0785 | 9.258 | 0.9828 | 6.988 | 683.1 | 2808 | 81 | 120 | 0.078 | 9.304 | 0.9887 | 6.8451 | 665.33 | 2891 | 82 |
| 571 | 78 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0775 | 9.178 | 0.9869 | 7.147 | 695.9 | 2815 | 82 | 120 | | | | | | | |
| 572 | 78 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0783 | 9.254 | 0.9849 | 7.256 | 689.7 | 2795 | 82 | 120 | 0.082 | 9.692 | 0.989 | 6.9148 | 646.89 | 2909 | 82 |
| 573 | 78 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0771 | 9.156 | 0.9896 | 7.324 | 685.5 | 2752 | 81 | 120 | 0.079 | 9.3652 | 0.9891 | 6.9743 | 639.84 | 2872 | 82 |
| 574 | 79 | SPOTLIGHT/REFLECTOR | U | 120 | 0.086 | 9.772 | 0.9469 | 32.903 | 748.3 | 2681 | 81 | 120 | 0.086 | 9.7765 | 0.9432 | 32.996 | 731.98 | 2729 | 81 |
| 575 | 79 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0856 | 9.684 | 0.9428 | 33.1 | 739.1 | 2731 | 82 | 120 | 0.086 | 9.6786 | 0.9416 | 33.254 | 729.38 | 2759 | 82 |
| 576 | 79 | SPOTLIGHT/REFLECTOR | U | 120 | 0.086 | 9.74 | 0.9438 | 32.357 | 754.6 | 2726 | 82 | 120 | 0.086 | 9.7648 | 0.9455 | 32.422 | 768.53 | 2760 | 82 |
| 577 | 79 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0852 | 9.711 | 0.9498 | 31.057 | 763 | 2743 | 82 | 120 | 0.085 | 9.6966 | 0.9474 | 31.168 | 762.08 | 2786 | 82 |
| 578 | 79 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0867 | 9.81 | 0.9429 | 32.671 | 742 | 2714 | 82 | 120 | 0.087 | 9.8115 | 0.9441 | 32.748 | 756.71 | 2765 | 82 |
| 579 | 79 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0859 | 9.761 | 0.9469 | 32.577 | 774.1 | 2743 | 82 | 120 | 0.086 | 9.7388 | 0.9438 | 32.747 | 780.6 | 2783 | 82 |
| 580 | 80 | SPOTLIGHT/REFLECTOR | U | 120 | 0.0864 | 10.316 | 0.995 | 7.776 | 735.4 | 2775 | 83 | 120 | 0.086 | 10.226 | 0.9879 | 9.0923 | 758.32 | 2784 | 82 |
| 581 | 80 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0869 | 10.38 | 0.9954 | 7.603 | 722.8 | 2743 | 82 | 120 | 0.088 | 10.388 | 0.9887 | 8.0303 | 766.17 | 2779 | 83 |
| 582 | 80 | SPOTLIGHT/REFLECTOR | U | 120 | 0.0864 | 10.316 | 0.995 | 7.576 | 727.4 | 2752 | 82 | 120 | 0.088 | 10.453 | 0.9892 | 8.3847 | 763.13 | 2777 | 82 |
| 583 | 80 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0836 | 9.947 | 0.9915 | 7.776 | 700.2 | 2744 | 82 | 120 | 0.084 | 10.053 | 0.9926 | 8.1797 | 711.54 | 2766 | 82 |
| 584 | 80 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0876 | 10.409 | 0.9902 | 8.024 | 733.5 | 2793 | 82 | | | | | | | | |
| 585 | 80 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0858 | 10.206 | 0.9913 | 8.978 | 715 | 2783 | 82 | 120 | 0.086 | 10.24 | 0.9886 | 8.9363 | 744.42 | 2777 | 82 |
| 586 | 81 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0859 | 10.226 | 0.992 | 10.295 | 755.9 | 2613 | 92 | 120 | 0.086 | 10.216 | 0.9893 | 10.548 | 777.7 | 2621 | 92 |
| 587 | 81 | SPOTLIGHT/REFLECTOR | U | 120 | 0.0865 | 10.252 | 0.9877 | 10.243 | 765.1 | 2629 | 93 | 120 | 0.086 | 10.257 | 0.9894 | 10.247 | 789.31 | 2648 | 93 |
| 588 | 81 | SPOTLIGHT/REFLECTOR | D | 120 | 0.086 | 10.265 | 0.9947 | 9.632 | 782.7 | 2654 | 91 | 120 | 0.11 | 10.874 | 0.8201 | 65.705 | 802.15 | 2663 | 91 |
| 589 | 81 | SPOTLIGHT/REFLECTOR | R | 120 | 0.087 | 10.33 | 0.9894 | 10.59 | 779.2 | 2642 | 92 | 120 | 0.087 | 10.361 | 0.9897 | 10.312 | 798.83 | 2667 | 92 |
| 590 | 81 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0822 | 9.776 | 0.9911 | 9.912 | 646.4 | 2620 | 93 | 120 | 0.082 | 9.7262 | 0.9885 | 10.114 | 670.01 | 2651 | 93 |
| 591 | 81 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0821 | 9.715 | 0.9861 | 10.461 | 685.5 | 2649 | 92 | 120 | 0.082 | 9.7244 | 0.9882 | 10.449 | 693.83 | 2693 | 92 |
| 592 | 82 | SPOTLIGHT/REFLECTOR | U | 120 | 0.0979 | 11.654 | 0.992 | 7.938 | 763.9 | 2704 | 92 | 120 | 0.098 | 11.716 | 0.9919 | 8.4308 | 793.54 | 2741 | 92 |
| 593 | 82 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0986 | 11.699 | 0.9888 | 9.912 | 778.1 | 2705 | 91 | 120 | 0.099 | 11.832 | 0.9935 | 9.2724 | 805.36 | 2733 | 91 |
| 594 | 82 | SPOTLIGHT/REFLECTOR | U | 120 | 0.0997 | 11.919 | 0.9962 | 11.921 | 745.8 | 2688 | 92 | 120 | 0.101 | 11.989 | 0.9867 | 12.461 | 763.48 | 2723 | 92 |
| 595 | 82 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0996 | 11.805 | 0.9877 | 11.98 | 758.3 | 2718 | 92 | 120 | 0.099 | 11.765 | 0.9872 | 12.123 | 765.11 | 2733 | 92 |
| 596 | 82 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1015 | 12.01 | 0.986 | 11.704 | 777 | 2717 | 91 | 120 | 0.102 | 12.227 | 0.9942 | 9.0794 | 802.22 | 2746 | 91 |
| 597 | 82 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0966 | 11.473 | 0.9897 | 8.919 | 752.4 | 2710 | 92 | 120 | 0.096 | 11.439 | 0.9919 | 8.3187 | 763.32 | 2734 | 92 |
| 598 | 83 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0872 | 10.357 | 0.9898 | 7.723 | 714.6 | 2772 | 83 | 120 | 0.087 | 10.359 | 0.9894 | 7.6451 | 747.72 | 2808 | 83 |
| 599 | 83 | SPOTLIGHT/REFLECTOR | U | 120 | 0.0844 | 10.096 | 0.9968 | 7.889 | 730.9 | 2775 | 82 | 120 | 0.085 | 10.174 | 0.9942 | 7.6153 | 769.78 | 2778 | 82 |
| 600 | 83 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0857 | 10.238 | 0.9955 | 7.469 | 722 | 2784 | 83 | 120 | 0.086 | 10.293 | 0.9945 | 7.482 | 749.31 | 2800 | 83 |
| 601 | 83 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0846 | 10.064 | 0.9913 | 8.001 | 707.9 | 2760 | 83 | 120 | 0.084 | 10.07 | 0.9934 | 8.1091 | 736.85 | 2761 | 82 |
| 602 | 83 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0867 | 10.364 | 0.9962 | 8.039 | 738.1 | 2761 | 83 | 120 | 0.086 | 10.297 | 0.9934 | 7.8209 | 745.76 | 2765 | 82 |
| 603 | 83 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0843 | 9.992 | 0.9877 | 7.923 | 703.8 | 2775 | 82 | 120 | 0.084 | 9.9767 | 0.9875 | 7.981 | 714.81 | 2781 | 82 |
| 616 | 86 | SPOTLIGHT/REFLECTOR | D | 120 | 0.1107 | 12.601 | 0.9486 | 28.588 | 1170.4 | 5132 | 83 | 120 | 0.111 | 12.665 | 0.9493 | 28.188 | 1165.3 | 5194 | 82 |
| 617 | 86 | SPOTLIGHT/REFLECTOR | U | 120 | 0.1154 | 13.138 | 0.9487 | 29.654 | 1214.1 | 5069 | 82 | 120 | 0.117 | 13.332 | 0.9474 | 29.494 | 1203.2 | 5194 | 82 |
| 618 | 86 | SPOTLIGHT/REFLECTOR | D | 120 | 0.1115 | 12.601 | 0.9418 | 28.686 | 1165.7 | 5066 | 82 | 120 | 0.112 | 12.719 | 0.9481 | 28.634 | 1157.1 | 5168 | 82 |
| 619 | 86 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1154 | 13.062 | 0.9432 | 29.179 | 1215.1 | 5121 | 82 | 120 | | | | | | | |
| 620 | 86 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1232 | 14.014 | 0.9479 | 29.562 | 1284 | 5028 | 82 | 120 | 0.124 | 14.154 | 0.949 | 29.359 | 1289 | 5143 | 83 |
| 621 | 86 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1234 | 14.016 | 0.9465 | 29.708 | 1250 | 5022 | 83 | 120 | 0.125 | 14.196 | 0.9488 | 29.43 | 1278.7 | 5122 | 82 |
| 622 | 87 | SPOTLIGHT/REFLECTOR | U | 120 | 0.132 | 15.769 | 0.9955 | 6.676 | 1028 | 2725 | 93 | 120 | 0.132 | 15.719 | 0.9938 | 6.8469 | 1065 | 2732 | 93 |
| 623 | 87 | SPOTLIGHT/REFLECTOR | D | 120 | 0.1313 | 15.657 | 0.9937 | 6.644 | 1046 | 2723 | 93 | 120 | 0.13 | 15.596 | 0.9961 | 6.7732 | 1055.4 | 2730 | 93 |
| 624 | 87 | SPOTLIGHT/REFLECTOR | U | 120 | 0.1294 | 15.496 | 0.9979 | 6.504 | 1015 | 2738 | 93 | 120 | 0.13 | 15.545 | 0.9937 | 6.4982 | 1044.5 | 2758 | 93 |
| 625 | 87 | SPOTLIGHT/REFLECTOR | R | 120 | 0.131 | 15.68 | 0.997 | 6.788 | 1013 | 2740 | 93 | 120 | 0.133 | 15.8 | 0.9935 | 6.9021 | 1046.2 | 2748 | 93 |
| 626 | 87 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1305 | 15.572 | 0.9944 | 6.898 | 1020 | 2705 | 93 | 120 | 0.13 | 15.517 | 0.9932 | 7.1153 | 1059.4 | 2723 | 93 |
| 627 | 87 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1282 | 15.333 | 0.9967 | 6.569 | 1011 | 2724 | 93 | 120 | 0.129 | 15.407 | 0.9933 | 6.9449 | 1048.5 | 2725 | 93 |
| 634 | 89 | SPOTLIGHT/REFLECTOR | D | 120 | 0.1517 | 16.549 | 0.9091 | 42.911 | 925.6 | 3152 | 93 | 120 | 0.15 | 16.438 | 0.913 | 41.353 | 896.58 | 3239 | 93 |
| 635 | 89 | SPOTLIGHT/REFLECTOR | U | 120 | 0.1514 | 16.566 | 0.9118 | 41.196 | 1043.3 | 2982 | 92 | 120 | 0.15 | 16.435 | 0.9136 | 40.998 | 1042 | 3034 | 92 |
| 636 | 89 | SPOTLIGHT/REFLECTOR | D | 120 | 0.1499 | 16.425 | 0.9131 | 41.813 | 930.3 | 3070 | 92 | 120 | 0.15 | 16.377 | 0.9125 | 41.465 | 940.33 | 3113 | 92 |
| 637 | 89 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1498 | 16.394 | 0.912 | 41.981 | 933.6 | 3117 | 93 | 120 | 0.149 | 16.354 | 0.9125 | 41.54 | 920.57 | 3223 | 93 |
| 638 | 89 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1214 | 13.774 | 0.9455 | 26.953 | 1016.7 | 3100 | 95 | 120 | 0.12 | 13.588 | 0.9455 | 26.466 | 1047.9 | 3115 | 95 |
| 639 | 89 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1343 | 14.924 | 0.926 | 33.329 | 1067.7 | 3108 | 95 | 120 | 0.135 | 14.972 | 0.9276 | 33.845 | 1114.1 | 3121 | 95 |
| 640 | 90 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0558 | 6.522 | 0.974 | 10.726 | 567.5 | 2763 | 82 | 120 | 0.055 | 6.4814 | 0.9733 | 10.584 | 584.17 | 2778 | 82 |
| 641 | 90 | SPOTLIGHT/REFLECTOR | U | 120 | 0.057 | 6.666 | 0.9746 | 10.787 | 575.5 | 2763 | 82 | 120 | 0.057 | 6.6165 | 0.9743 | 10.505 | 599.19 | 2837 | 83 |
| 642 | 90 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0579 | 6.793 | 0.9777 | 10.501 | 586.6 | 2754 | 82 | 120 | 0.058 | 6.7849 | 0.9755 | 10.218 | 590.31 | 2789 | 82 |
| 643 | 90 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0597 | 7.001 | 0.9772 | 9.921 | 566.2 | 2762 | 82 | 120 | 0.06 | 6.9841 | 0.977 | 9.6908 | 584.82 | 2767 | 82 |
| 644 | 90 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0601 | 7.071 | 0.9804 | 9.774 | 590 | 2455 | 82 | 120 | 0.06 | 7.0038 | 0.9774 | 9.5892 | 611.98 | 2760 | 82 |
| 645 | 90 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0575 | 6.718 | 0.9736 | 10.726 | 585.5 | 2746 | 82 | 120 | 0.057 | 6.6693 | 0.9741 | 10.413 | 601.47 | 2760 | 82 |
| 646 | 91 | SPOTLIGHT/REFLECTOR | U | 120 | 0.0698 | 7.978 | 0.9525 | 28.431 | 520.1 | 2984 | 84 | 120 | 0.07 | 7.9963 | 0.9527 | 28.398 | 535.28 | 3134 | 85 |
| 647 | 91 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0696 | 7.868 | 0.942 | 30.124 | 484.7 | 2972 | 84 | 120 | 0.07 | 7.9052 | 0.9467 | 30.31 | 497.01 | 3015 | 84 |
| 648 | 91 | SPOTLIGHT/REFLECTOR | U | 120 | 0.071 | 8.04 | 0.9437 | 30.305 | 500.9 | 2973 | 83 | 120 | 0.071 | 8.0857 | 0.9474 | 30.408 | 514.53 | 3126 | 85 |
| 649 | 91 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0704 | 8.01 | 0.9482 | 30.656 | 509.3 | 2978 | 84 | 120 | 0.071 | 8.0085 | 0.946 | 30.782 | 513.53 | 3009 | 84 |
| 650 | 91 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0695 | 7.931 | 0.951 | 29.45 | 503 | 2923 | 83 | 120 | 0.07 | 7.9226 | 0.949 | 29.487 | 507.54 | 2973 | 84 |

| Test Units | | | | Initial Photometric Testing Results | | | | | | | | Final Photometric Testing Results | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | Initial Volts | Initial Amps | Initial Power | Initial pf | Initial THD | Initial Lumens | Initial CCT | Initial CRI | Final Volts | Final Amps | Final Power | Final pf | Final THD | Final Lumens | Final CCT | Final CRI |
| 651 | 91 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0688 | 7.848 | 0.9506 | 28.799 | 491.8 | 2925 | 83 | 120 | 0.07 | 7.87 | 0.952 | 28.801 | 506.53 | 2985 | 84 |
| 658 | 93 | SPOTLIGHT/REFLECTOR | U | 120 | 0.0643 | 7.089 | 0.9187 | 35.823 | 512.8 | 3011 | 84 | 120 | 0.064 | 7.0603 | 0.9192 | 35.941 | 518.8 | 3055 | 84 |
| 659 | 93 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0638 | 7.033 | 0.9186 | 35.338 | 514 | 3008 | 83 | 120 | 0.064 | 7.0504 | 0.9178 | 35.4 | 519.3 | 3073 | 84 |
| 660 | 93 | SPOTLIGHT/REFLECTOR | U | 120 | 0.065 | 7.185 | 0.9212 | 35.814 | 526.9 | 2978 | 83 | 120 | 0.065 | 7.2088 | 0.9212 | 35.661 | 532 | 3054 | 83 |
| 661 | 93 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0656 | 7.172 | 0.9111 | 38.297 | 516.3 | 2989 | 83 | 120 | 0.067 | 7.18 | 0.912 | 38.299 | 525.29 | 3058 | 83 |
| 662 | 93 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0653 | 7.136 | 0.9107 | 38.544 | 548.8 | 3008 | 83 | 120 | 0.065 | 7.13 | 0.911 | 38.48 | 547.97 | 3061 | 83 |
| 663 | 93 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0647 | 7.111 | 0.9159 | 36.935 | 521.5 | 2996 | 83 | 120 | 0.065 | 7.0919 | 0.915 | 37.119 | 520.08 | 3068 | 83 |
| 664 | 94 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0681 | 8.118 | 0.9934 | 9.51 | 469.3 | 3086 | 81 | 120 | 0.069 | 8.154 | 0.9892 | 8.605 | 449.28 | 3140 | 82 |
| 665 | 94 | SPOTLIGHT/REFLECTOR | U | 120 | 0.0694 | 8.238 | 0.9892 | 9.118 | 472.5 | 3031 | 80 | 120 | 0.07 | 8.2649 | 0.9892 | 8.8059 | 467.39 | 3082 | 81 |
| 666 | 94 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0663 | 7.884 | 0.991 | 4.77 | 476.3 | 3044 | 81 | 120 | 0.066 | 7.9095 | 0.9934 | 3.8365 | 479.75 | 3093 | 81 |
| 667 | 94 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0627 | 7.457 | 0.9911 | 4.045 | 468.2 | 3049 | 81 | 120 | | | | | | | |
| 668 | 94 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0697 | 8.306 | 0.9931 | 8.284 | 467.3 | 3097 | 81 | 120 | | | | | | | |
| 669 | 94 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0688 | 8.146 | 0.9867 | 9.866 | 469.7 | 3042 | 80 | 120 | | | | | | | |
| 670 | 95 | SPOTLIGHT/REFLECTOR | U | 120 | 0.1019 | 11.416 | 0.9336 | 33.905 | 867.6 | 2998 | 82 | 120 | 0.102 | 11.44 | 0.9334 | 33.699 | 878.45 | 3038 | 82 |
| 671 | 95 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0975 | 10.984 | 0.9388 | 31.581 | 799.4 | 2972 | 82 | 120 | 0.098 | 10.985 | 0.9377 | 31.364 | 820.83 | 3028 | 82 |
| 672 | 95 | SPOTLIGHT/REFLECTOR | U | 120 | 0.1021 | 11.407 | 0.931 | 33.54 | 837.6 | 2978 | 82 | 120 | 0.103 | 11.508 | 0.9337 | 33.466 | 848.89 | 3028 | 82 |
| 673 | 95 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0977 | 10.996 | 0.9379 | 31.934 | 785.3 | 2958 | 82 | 120 | 0.098 | 11.039 | 0.9365 | 31.843 | 816.11 | 3012 | 82 |
| 674 | 95 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1002 | 11.233 | 0.9342 | 32.856 | 888.2 | 2964 | 82 | 120 | 0.1 | 11.262 | 0.9357 | 32.511 | 867.06 | 3020 | 82 |
| 675 | 95 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1015 | 11.325 | 0.9298 | 34.914 | 843 | 2972 | 82 | | | | | | | | |
| 676 | 96 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0995 | 11.086 | 0.9285 | 33.018 | 828.5 | 2972 | 83 | 120 | 0.099 | 11.151 | 0.9342 | 33.266 | 822.77 | 3004 | 83 |
| 677 | 96 | SPOTLIGHT/REFLECTOR | U | 120 | 0.0995 | 11.108 | 0.9303 | 33.219 | 811 | 2953 | 82 | 120 | 0.099 | 11.142 | 0.9336 | 33.4 | 807.84 | 2993 | 82 |
| 678 | 96 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0997 | 11.14 | 0.9311 | 33.839 | 826.6 | 2968 | 83 | 120 | 0.1 | 11.159 | 0.933 | 33.73 | 820.36 | 3001 | 82 |
| 679 | 96 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0984 | 11.068 | 0.9373 | 32.477 | 798 | 2971 | 83 | 120 | 0.098 | 11.053 | 0.9365 | 32.387 | 774.65 | 3054 | 84 |
| 680 | 96 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0986 | 11.014 | 0.9309 | 33.834 | 800.1 | 2968 | 83 | 120 | 0.099 | 11.093 | 0.9317 | 33.966 | 804.78 | 3023 | 83 |
| 681 | 96 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0974 | 10.913 | 0.9337 | 32.414 | 816.9 | 2996 | 83 | 120 | 0.097 | 10.939 | 0.9357 | 32.245 | 812.3 | 3062 | 83 |
| 682 | 97 | SPOTLIGHT/REFLECTOR | U | 120 | 0.1071 | 12.763 | 0.9931 | 7.402 | 755.4 | 3078 | 95 | 120 | 0.106 | 12.724 | 0.9956 | 6.7132 | 764.07 | 3118 | 95 |
| 683 | 97 | SPOTLIGHT/REFLECTOR | D | 120 | 0.1089 | 13.009 | 0.9955 | 6.949 | 786.8 | 3051 | 95 | 120 | 0.11 | 13.055 | 0.9922 | 7.6994 | 805.95 | 3082 | 95 |
| 684 | 97 | SPOTLIGHT/REFLECTOR | U | 120 | 0.1083 | 12.876 | 0.9908 | 7.218 | 728.4 | 3060 | 96 | 120 | 0.108 | 12.861 | 0.9921 | 7.5738 | 744.09 | 3099 | 96 |
| 685 | 97 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1064 | 12.711 | 0.9955 | 6.651 | 783.7 | 3055 | 95 | 120 | 0.106 | 12.704 | 0.9954 | 7.3279 | 812.64 | 3107 | 95 |
| 686 | 97 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1154 | 13.806 | 0.997 | 5.406 | 802.2 | 3107 | 95 | 120 | 0.116 | 13.852 | 0.9965 | 5.5942 | 815.47 | 3143 | 94 |
| 687 | 97 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1105 | 13.175 | 0.9936 | 5.726 | 785.2 | 3110 | 95 | | | | | | | | |
| 688 | 98 | SPOTLIGHT/REFLECTOR | D | 120 | 0.1221 | 14 | 0.9555 | 30.296 | 816.5 | 2962 | 83 | 120 | 0.12 | 13.811 | 0.9578 | 29.36 | 833.26 | 3024 | 83 |
| 689 | 98 | SPOTLIGHT/REFLECTOR | U | 120 | 0.1224 | 14.004 | 0.9534 | 30.133 | 816.7 | 3001 | 83 | 120 | 0.122 | 14.014 | 0.9556 | 30.116 | 833.05 | 3061 | 84 |
| 690 | 98 | SPOTLIGHT/REFLECTOR | D | 120 | 0.1239 | 14.187 | 0.9542 | 31.078 | 771.8 | 3001 | 83 | 120 | 0.124 | 14.181 | 0.9533 | 31.15 | 793.39 | 3041 | 83 |
| 691 | 98 | SPOTLIGHT/REFLECTOR | R | 120 | 0.124 | 14.187 | 0.9534 | 30.288 | 816.5 | 2993 | 83 | 120 | 0.124 | 14.253 | 0.9548 | 30.603 | 826.91 | 3046 | 83 |
| 692 | 98 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1235 | 14.148 | 0.9547 | 29.829 | 849.8 | 2995 | 83 | 120 | 0.123 | 14.161 | 0.957 | 29.634 | 857.9 | 3068 | 83 |
| 693 | 98 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1226 | 14.096 | 0.9581 | 29.32 | 854 | 3013 | 84 | 120 | 0.123 | 14.108 | 0.9576 | 29.428 | 877.91 | 3063 | 84 |
| 694 | 99 | SPOTLIGHT/REFLECTOR | U | 120 | 0.1351 | 14.802 | 0.913 | 35.813 | 1018.4 | 3047 | 84 | 120 | 0.135 | 14.867 | 0.921 | 35.948 | 1037.7 | 3034 | 83 |
| 695 | 99 | SPOTLIGHT/REFLECTOR | D | 120 | 0.1352 | 14.897 | 0.9182 | 36.526 | 1009.9 | 3036 | 84 | 120 | 0.135 | 14.88 | 0.9198 | 36.524 | 1052.9 | 3041 | 84 |
| 696 | 99 | SPOTLIGHT/REFLECTOR | U | 120 | 0.1337 | 14.851 | 0.9256 | 33.569 | 1039.3 | 3016 | 83 | 120 | 0.133 | 14.814 | 0.925 | 35.455 | 1075.5 | 3015 | 83 |
| 697 | 99 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1319 | 14.64 | 0.9249 | 35.947 | 985.2 | 3058 | 84 | 120 | 0.131 | 14.581 | 0.9251 | 34.801 | 1001.4 | 3015 | 83 |
| 698 | 99 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1345 | 14.851 | 0.9201 | 36.333 | 983.9 | 3050 | 84 | 120 | 0.135 | 14.883 | 0.9221 | 35.407 | 1000.1 | 3013 | 83 |
| 699 | 99 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1379 | 15.276 | 0.9231 | 36.068 | 865.9 | 3081 | 84 | | | | | | | | |
| 700 | 100 | SPOTLIGHT/REFLECTOR | D | 120 | 0.1188 | 14.169 | 0.9939 | 7.531 | 870.4 | 3091 | 81 | 120 | 0.12 | 14.237 | 0.9901 | 8.6818 | 890.8 | 3131 | 81 |
| 701 | 100 | SPOTLIGHT/REFLECTOR | U | 120 | 0.1251 | 14.915 | 0.9935 | 7.123 | 956.7 | 3104 | 81 | 120 | 0.125 | 14.916 | 0.996 | 7.3021 | 969.47 | 3118 | 81 |
| 702 | 100 | SPOTLIGHT/REFLECTOR | D | 120 | 0.1206 | 14.325 | 0.9898 | 8.246 | 933.3 | 3098 | 82 | 120 | 0.122 | 14.444 | 0.9905 | 8.0882 | 944.04 | 3118 | 82 |
| 703 | 100 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1227 | 14.655 | 0.9953 | 6.721 | 906.2 | 3031 | 82 | 120 | 0.124 | 14.729 | 0.9911 | 7.1428 | 873.72 | 3106 | 82 |
| 704 | 100 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1224 | 14.586 | 0.9931 | 7.493 | 944.4 | 3073 | 81 | 120 | 0.123 | 14.601 | 0.9901 | 8.2143 | 919.2 | 3150 | 82 |
| 705 | 100 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1243 | 14.743 | 0.9884 | 7.166 | 921.2 | 3077 | 82 | 120 | 0.123 | 14.737 | 0.9952 | 7.1305 | 905.3 | 3126 | 82 |
| 706 | 101 | SPOTLIGHT/REFLECTOR | U | 120 | 0.1 | 11.848 | 0.9873 | 7.271 | 1022.2 | 3094 | 84 | 120 | 0.1 | 11.862 | 0.9896 | 7.1755 | 1041.5 | 3121 | 84 |
| 707 | 101 | SPOTLIGHT/REFLECTOR | D | 120 | 0.1007 | 11.935 | 0.9877 | 7.251 | 1007 | 3103 | 84 | 120 | 0.1 | 11.902 | 0.9892 | 7.1513 | 1024.2 | 3126 | 84 |
| 708 | 101 | SPOTLIGHT/REFLECTOR | U | 120 | 0.0991 | 11.783 | 0.9908 | 7.366 | 1008.9 | 3090 | 84 | 120 | 0.099 | 11.751 | 0.989 | 7.2513 | 1035 | 3120 | 84 |
| 709 | 101 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0999 | 11.84 | 0.9877 | 7.466 | 991.8 | 3107 | 84 | 120 | 0.1 | 11.808 | 0.9889 | 7.4128 | 1004.3 | 3117 | 84 |
| 710 | 101 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1003 | 11.887 | 0.9876 | 7.203 | 1002.3 | 3091 | 84 | 120 | 0.1 | 11.855 | 0.9896 | 7.0601 | 1025.9 | 3135 | 84 |
| 711 | 101 | SPOTLIGHT/REFLECTOR | R | 120 | 0.097 | 11.487 | 0.9869 | 7.449 | 988.6 | 3079 | 84 | 120 | 0.097 | 11.486 | 0.9887 | 7.3524 | 992.3 | 3117 | 84 |
| 712 | 102 | SPOTLIGHT/REFLECTOR | D | 120 | 0.1304 | 15.554 | 0.994 | 7.439 | 943.6 | 3106 | 93 | 120 | 0.13 | 15.457 | 0.993 | 7.6958 | 935.91 | 3164 | 93 |
| 713 | 102 | SPOTLIGHT/REFLECTOR | U | 120 | 0.136 | 16.244 | 0.9953 | 7.809 | 941.4 | 3076 | 93 | 120 | 0.136 | 16.172 | 0.992 | 8.0677 | 970.09 | 3169 | 93 |
| 714 | 102 | SPOTLIGHT/REFLECTOR | D | 120 | 0.1255 | 15.001 | 0.9961 | 7.265 | 893.7 | 3080 | 94 | 120 | 0.127 | 15.179 | 0.9927 | 7.5551 | 930.64 | 3164 | 93 |
| 715 | 102 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1311 | 15.669 | 0.996 | 7.01 | 930.1 | 3069 | 93 | 120 | 0.132 | 15.694 | 0.9932 | 6.8921 | 833.38 | 3201 | 93 |
| 716 | 102 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1388 | 16.582 | 0.9956 | 6.421 | 933.3 | 3107 | 93 | 120 | | | | | | | |
| 717 | 102 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1379 | 16.461 | 0.9947 | 6.617 | 880.3 | 3079 | 93 | 120 | 0.14 | 16.658 | 0.9947 | 6.2651 | 917.88 | 3150 | 93 |
| 724 | 104 | SPOTLIGHT/REFLECTOR | D | 120 | 0.134 | 13.672 | 0.8502 | 58.83 | 993.3 | 3102 | 85 | 120 | 0.135 | 13.725 | 0.8444 | 58.755 | 959.01 | 3108 | 85 |
| 725 | 104 | SPOTLIGHT/REFLECTOR | U | 120 | 0.1329 | 13.592 | 0.8523 | 58.507 | 1001.6 | 3109 | 86 | 120 | 0.134 | 13.683 | 0.8505 | 58.264 | 969.47 | 3133 | 85 |
| 726 | 104 | SPOTLIGHT/REFLECTOR | D | 120 | 0.1342 | 13.68 | 0.8495 | 59.082 | 973.1 | 3095 | 86 | 120 | 0.135 | 13.75 | 0.8461 | 58.86 | 938.54 | 3126 | 85 |
| 727 | 104 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1323 | 13.461 | 0.8479 | 59.196 | 979.6 | 3089 | 85 | 120 | 0.133 | 13.541 | 0.8453 | 59.159 | 968.02 | 3139 | 85 |
| 728 | 104 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1348 | 13.772 | 0.8514 | 58.805 | 1001.2 | 3092 | 85 | 120 | 0.135 | 13.73 | 0.8464 | 58.991 | 984.75 | 3130 | 85 |
| 729 | 104 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1311 | 13.391 | 0.8512 | 59.149 | 979.6 | 3064 | 85 | 120 | 0.132 | 13.439 | 0.8462 | 58.931 | 953.04 | 3122 | 85 |
| 730 | 105 | SPOTLIGHT/REFLECTOR | U | 120 | 0.145 | 15.872 | 0.9122 | 42.437 | 1502 | 3126 | 82 | 120 | 0.145 | 15.841 | 0.9107 | 42.502 | 1537.1 | 3158 | 82 |
| 731 | 105 | SPOTLIGHT/REFLECTOR | D | 120 | 0.149 | 16.101 | 0.9005 | 43.74 | 1533.3 | 3097 | 82 | 120 | 0.149 | 16.207 | 0.9054 | 44.181 | 1565.3 | 3136 | 82 |
| 732 | 105 | SPOTLIGHT/REFLECTOR | U | 120 | 0.1461 | 15.957 | 0.9102 | 43.346 | 1482.3 | 3115 | 82 | 120 | 0.147 | 15.99 | 0.9073 | 43.4 | 1518.7 | 3153 | 82 |
| 733 | 105 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1494 | 16.447 | 0.9174 | 40.851 | 1530.5 | 3125 | 82 | 120 | 0.15 | 16.496 | 0.9163 | 40.802 | 1520.9 | 3188 | 82 |
| 734 | 105 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1484 | 16.138 | 0.9062 | 43.512 | 1487 | 3115 | 82 | 120 | 0.149 | 16.192 | 0.9072 | 43.66 | 1510.9 | 3142 | 82 |
| 735 | 105 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1513 | 16.575 | 0.9129 | 41.898 | 1566 | 3104 | 82 | 120 | 0.151 | 16.594 | 0.9129 | 42.074 | 1514.1 | 3164 | 83 |
| 736 | 106 | SPOTLIGHT/REFLECTOR | D | 120 | 0.1477 | 16.106 | 0.9087 | 43.986 | 1622 | 5161 | 81 | 120 | 0.149 | 16.146 | 0.9058 | 44.086 | 1591.4 | 5257 | 81 |

| Test Units | | | | Initial Photometric Testing Results | | | | | | | | Final Photometric Testing Results | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | Initial Volts | Initial Amps | Initial Power | Initial pf | Initial THD | Initial Lumens | Initial CCT | Initial CRI | Final Volts | Final Amps | Final Power | Final pf | Final THD | Final Lumens | Final CCT | Final CRI |
| 737 | 106 | SPOTLIGHT/REFLECTOR | U | 120 | 0.1454 | 15.833 | 0.9074 | 43.036 | 1632.1 | 5147 | 81 | 120 | 0.145 | 15.844 | 0.9084 | 43 | 1592.1 | 5243 | 81 |
| 738 | 106 | SPOTLIGHT/REFLECTOR | D | 120 | 0.1474 | 16.084 | 0.9093 | 42.797 | 1649 | 5170 | 81 | 120 | 0.148 | 16.137 | 0.9093 | 42.943 | 1614.6 | 5269 | 81 |
| 739 | 106 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1464 | 16.048 | 0.9135 | 42.746 | 1618 | 5163 | 81 | 120 | | | | | | | |
| 740 | 106 | SPOTLIGHT/REFLECTOR | R | 120 | 0.146 | 15.915 | 0.9084 | 42.076 | 1620.7 | 5219 | 81 | 120 | 0.146 | 15.969 | 0.9111 | 42.54 | 1594 | 5219 | 81 |
| 741 | 106 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1477 | 16.105 | 0.9087 | 43.363 | 1662.5 | 5188 | 81 | 120 | 0.148 | 16.143 | 0.9077 | 43.625 | 1704.7 | 5201 | 81 |
| 742 | 107 | SPOTLIGHT/REFLECTOR | U | 120 | 0.1319 | 15.628 | 0.9874 | 7.285 | 1027 | 2996 | 82 | 120 | 0.149 | 15.74 | 0.8803 | 50.267 | 1012.5 | 3056 | 82 |
| 743 | 107 | SPOTLIGHT/REFLECTOR | D | 120 | 0.1294 | 15.419 | 0.993 | 6.415 | 1018.4 | 3025 | 82 | 120 | 0.13 | 15.498 | 0.9963 | 5.1185 | 987.6 | 3100 | 83 |
| 744 | 107 | SPOTLIGHT/REFLECTOR | U | 120 | 0.1291 | 15.404 | 0.9943 | 7.426 | 1037.4 | 2995 | 82 | 120 | 0.129 | 15.41 | 0.9931 | 7.46 | 921.1 | 3040 | 82 |
| 745 | 107 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1306 | 15.508 | 0.9895 | 7.508 | 1021 | 3006 | 83 | 120 | 0.13 | 15.543 | 0.9927 | 7.6674 | 935.11 | 3139 | 83 |
| 746 | 107 | SPOTLIGHT/REFLECTOR | R | 120 | 0.1296 | 15.489 | 0.9959 | 5.891 | 1003 | 3010 | 82 | 120 | 0.129 | 15.406 | 0.9936 | 7.0095 | 904.12 | 3165 | 83 |
| 747 | 107 | SPOTLIGHT/REFLECTOR | R | 120 | 0.13 | 15.509 | 0.9942 | 7.232 | 1020 | 3004 | 82 | 120 | 0.13 | 15.576 | 0.9959 | 6.1395 | 935.89 | 3137 | 83 |
| 748 | 108 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0669 | 6.956 | 0.8665 | 51.173 | 607.1 | 5049 | 85 | 120 | 0.067 | 7.0278 | 0.8691 | 50.695 | 634.29 | 5094 | 84 |
| 749 | 108 | SPOTLIGHT/REFLECTOR | U | 120 | 0.064 | 6.721 | 0.8751 | 47.981 | 605.5 | 5089 | 85 | 120 | 0.064 | 6.704 | 0.8758 | 47.56 | 633.4 | 5117 | 84 |
| 750 | 108 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0668 | 6.998 | 0.873 | 49.35 | 615.1 | 5030 | 85 | 120 | 0.067 | 7.001 | 0.8726 | 49.204 | 638.28 | 5066 | 85 |
| 751 | 108 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0665 | 6.995 | 0.8766 | 48.927 | 603.6 | 5037 | 85 | 120 | 0.068 | 7.03 | 0.876 | 48.91 | 620.85 | 5118 | 85 |
| 752 | 108 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0676 | 7.001 | 0.863 | 50.825 | 602.2 | 4991 | 84 | 120 | 0.0676 | 7.01 | 0.862 | 50.48 | 582.04 | 5057 | 84 |
| 753 | 108 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0669 | 7.017 | 0.8741 | 49.036 | 605.1 | 5049 | 86 | 120 | 0.067 | 7.0321 | 0.876 | 48.91 | 583.03 | 5150 | 86 |
| 754 | 109 | SPOTLIGHT/REFLECTOR | U | 120 | 0.0705 | 7.626 | 0.9014 | 41.936 | 613.8 | 2695 | 81 | 120 | 0.07 | 7.6481 | 0.9043 | 41.772 | 632.59 | 2715 | 81 |
| 755 | 109 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0704 | 7.618 | 0.9018 | 42.972 | 607.5 | 2719 | 82 | 120 | 0.07 | 7.6123 | 0.9011 | 42.839 | 584.04 | 2689 | 81 |
| 756 | 109 | SPOTLIGHT/REFLECTOR | U | 120 | 0.0705 | 7.657 | 0.9051 | 41.625 | 628.2 | 2703 | 82 | 120 | 0.07 | 7.642 | 0.907 | 41.477 | 654.63 | 2802 | 83 |
| 757 | 109 | SPOTLIGHT/REFLECTOR | R | 120 | 0.07 | 7.628 | 0.9081 | 41.229 | 627.7 | 2710 | 82 | 120 | 0.07 | 7.5812 | 0.9082 | 41.117 | 629.01 | 2747 | 82 |
| 758 | 109 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0702 | 7.626 | 0.9053 | 41.54 | 629.9 | 2709 | 81 | 120 | 0.07 | 7.5912 | 0.9058 | 41.52 | 628.28 | 2743 | 82 |
| 759 | 109 | SPOTLIGHT/REFLECTOR | R | 120 | 0.07 | 7.6 | 0.9048 | 42.27 | 616.3 | 2712 | 82 | 120 | 0.07 | 7.6155 | 0.904 | 42.017 | 628.5 | 2745 | 81 |
| 760 | 110 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0625 | 7.248 | 0.9664 | 11.817 | 528.1 | 2731 | 82 | 120 | 0.063 | 7.2651 | 0.9673 | 11.601 | 550.21 | 2765 | 82 |
| 761 | 110 | SPOTLIGHT/REFLECTOR | U | 120 | 0.0628 | 7.324 | 0.9719 | 10.351 | 527.9 | 2745 | 82 | 120 | 0.067 | 7.4011 | 0.9177 | 18.025 | 553.69 | 2871 | 83 |
| 762 | 110 | SPOTLIGHT/REFLECTOR | D | 120 | 0.062 | 7.2 | 0.9677 | 10.819 | 546 | 2744 | 82 | 120 | 0.062 | 7.2154 | 0.9697 | 10.655 | 558.92 | 2755 | 82 |
| 763 | 110 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0627 | 7.248 | 0.9633 | 7.268 | 548.2 | 2768 | 83 | 120 | 0.062 | 7.2546 | 0.9692 | 11.033 | 555.2 | 2797 | 83 |
| 764 | 110 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0624 | 7.202 | 0.9618 | 7.199 | 535.8 | 2769 | 83 | 120 | 0.062 | 7.1882 | 0.9663 | 11.451 | 550.27 | 2777 | 83 |
| 765 | 110 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0623 | 7.241 | 0.9686 | 11.409 | 539.7 | 2739 | 82 | 120 | 0.067 | 7.2817 | 0.91 | 18.947 | 545.09 | 2767 | 82 |
| 766 | 111 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0592 | 7.025 | 0.9889 | 5.591 | 451 | 2730 | 91 | 120 | 0.0592 | 7.04 | 0.994 | 5.62 | 461.04 | 2753 | 91 |
| 767 | 111 | SPOTLIGHT/REFLECTOR | U | 120 | 0.0584 | 6.941 | 0.9904 | 5.003 | 431 | 2716 | 92 | 120 | 0.059 | 7.0103 | 0.985 | 7.0694 | 446.9 | 2729 | 91 |
| 768 | 111 | SPOTLIGHT/REFLECTOR | D | 120 | 0.0669 | 7.929 | 0.9877 | 8.956 | 475.8 | 2689 | 92 | 120 | 0.068 | 7.95 | 0.992 | 8.98 | 489.01 | 2717 | 92 |
| 769 | 111 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0654 | 7.748 | 0.9873 | 9.422 | 481.6 | 2726 | 92 | 120 | 0.065 | 7.6431 | 0.9866 | 9.0747 | 480.49 | 2746 | 92 |
| 770 | 111 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0644 | 7.476 | 0.9674 | 9.18 | 466.5 | 2709 | 92 | 120 | 0.064 | 7.4222 | 0.97 | 9.117 | 480.7 | 2729 | 92 |
| 771 | 111 | SPOTLIGHT/REFLECTOR | R | 120 | 0.0633 | 7.478 | 0.9845 | 9.382 | 477.6 | 2683 | 91 | 120 | 0.063 | 7.4164 | 0.9818 | 9.4789 | 491.34 | 2728 | 92 |
| 1001 | 201 | TRIM KIT | R | 120 | 0.089 | 10.5 | 0.983 | 18.57 | 765 | 3087 | 84 | 120 | 0.089 | 10.54 | 0.983 | 18.55 | 783 | 3051 | 83 |
| 1002 | 201 | TRIM KIT | R | 120 | 0.09 | 10.6 | 0.983 | 18.59 | 763 | 3078 | 84 | 120 | 0.09 | 10.56 | 0.983 | 18.53 | 781 | 3052 | 83 |
| 1003 | 201 | TRIM KIT | R | 120 | 0.088 | 10.4 | 0.9829 | 18.61 | 552 | 3000 | 93 | 120 | 0.088 | 10.4 | 0.9829 | 18.61 | 567 | 2974 | 93 |
| 1004 | 202 | TRIM KIT | R | 120 | 0.138 | 16.4 | 0.985 | 17.741 | 864 | 3023 | 94 | 120 | 0.138 | 16.28 | 0.984 | 17.92 | 883 | 2998 | 93 |
| 1005 | 202 | TRIM KIT | R | 120 | 0.138 | 16.4 | 0.9844 | 17.76 | 893 | 3058 | 94 | 120 | 0.138 | 16.35 | 0.984 | 17.78 | 919 | 3033 | 93 |
| 1006 | 202 | TRIM KIT | R | 120 | 0.139 | 16.4 | 0.9842 | 17.84 | 899 | 3052 | 94 | 120 | 0.139 | 16.45 | 0.984 | 17.78 | 923 | 3023 | 93 |
| 1007 | 203 | TRIM KIT | R | 120 | 0.086 | 10.2 | 0.9879 | 15.52 | 642 | 3020 | 93 | 120 | 0.086 | 10.18 | 0.988 | 15.45 | 653 | 3009 | 93 |
| 1008 | 203 | TRIM KIT | R | 120 | 0.085 | 10 | 0.9869 | 15.9 | 626 | 3051 | 93 | 120 | 0.085 | 10.03 | 0.987 | 16.06 | 650 | 3042 | 93 |
| 1009 | 203 | TRIM KIT | R | 120 | 0.084 | 10 | 0.9867 | 16.08 | 614 | 3020 | 93 | 120 | 0.084 | 9.96 | 0.987 | 15.87 | 637 | 3011 | 93 |
| 1010 | 204 | TRIM KIT | R | 120 | 0.089 | 10.5 | 0.9803 | 10.51 | 589 | 2723 | 93 | 120 | 0.089 | 10.49 | 0.981 | 10.17 | 601 | 2761 | 92 |
| 1011 | 204 | TRIM KIT | R | 120 | 0.089 | 10.5 | 0.9807 | 10.05 | 585 | 2735 | 93 | 120 | 0.089 | 10.51 | 0.981 | 9.78 | 599 | 2764 | 93 |
| 1012 | 204 | TRIM KIT | R | 120 | 0.09 | 10.5 | 0.9804 | 9.91 | 593 | 2697 | 93 | 120 | 0.089 | 10.52 | 0.981 | 9.46 | 604 | 2730 | 92 |
| 1013 | 205 | TRIM KIT | R | 120 | 0.081 | 9.6 | 0.9814 | 6.18 | 699.9 | 2783 | 92 | 120 | 0.081 | 9.59 | 0.982 | 6.11 | 710 | 2795 | 92 |
| 1014 | 205 | TRIM KIT | R | 120 | 0.081 | 9.6 | 0.983 | 5.75 | 699.6 | 2797 | 92 | 120 | 0.081 | 9.58 | 0.983 | 5.7 | 707 | 2805 | 92 |
| 1015 | 205 | TRIM KIT | R | 120 | 0.091 | 10.7 | 0.9798 | 11.15 | 627 | 2733 | 93 | 120 | 0.09 | 10.64 | 0.98 | 11.06 | 665 | 2765 | 92 |
| 1016 | 206 | TRIM KIT | R | 120 | 0.081 | 9.5 | 0.9807 | 10.27 | 523 | 2743 | 93 | 120 | 0.081 | 9.55 | 0.98 | 10.32 | 531 | 2740 | 92 |
| 1017 | 206 | TRIM KIT | R | 120 | 0.079 | 9.3 | 0.9809 | 9.33 | 479 | 2841 | 94 | 120 | 0.079 | 9.32 | 0.982 | 9.08 | 478 | 2855 | 94 |
| 1018 | 206 | TRIM KIT | R | 120 | 0.078 | 9.4 | 0.9952 | 9.7 | 502 | 2736 | 91 | 120 | 0.079 | 9.38 | 0.994 | 3.63 | 506 | 2741 | 91 |
| 1019 | 207 | TRIM KIT | R | 120 | 0.179 | 21.3 | 0.9938 | 7.4 | 1314 | 2767 | 91 | 120 | 0.18 | 21.5 | 0.995 | 6.82 | 1318 | 2764 | 91 |
| 1020 | 207 | TRIM KIT | R | 120 | 0.178 | 21.3 | 0.9947 | 6.73 | 1308 | 2777 | 92 | 120 | 0.181 | 21.64 | 0.996 | 5.74 | 1319 | 2774 | 92 |
| 1021 | 207 | TRIM KIT | R | 120 | 0.177 | 21.1 | 0.9943 | 6.76 | 1304 | 2782 | 92 | 120 | 0.178 | 21.23 | 0.995 | 6.65 | 1299 | 2781 | 92 |
| 1022 | 208 | TRIM KIT | R | 120 | 0.108 | 11.7 | 0.9066 | 36.19 | 659 | 2687 | 92 | 120 | 0.107 | 11.66 | 0.908 | 35.54 | 673 | 2712 | 92 |
| 1023 | 208 | TRIM KIT | R | 120 | 0.109 | 12 | 0.9081 | 35.68 | 679 | 2694 | 92 | 120 | 0.109 | 11.86 | 0.908 | 35.86 | 674 | 2708 | 91 |
| 1024 | 208 | TRIM KIT | R | 120 | 0.110 | 12 | 0.9061 | 36.91 | 666 | 2692 | 92 | 120 | 0.109 | 11.93 | 0.908 | 36.33 | 651 | 2731 | 92 |
| 1025 | 209 | TRIM KIT | R | 120 | 0.144 | 16 | 0.929 | 34.38 | 1048 | 2682 | 92 | 120 | 0.142 | 15.9 | 0.931 | 33.63 | 1074 | 2682 | 92 |
| 1026 | 209 | TRIM KIT | R | 120 | 0.147 | 16.4 | 0.9285 | 34.34 | 1039 | 2671 | 92 | 120 | 0.145 | 16.23 | 0.93 | 33.93 | 1065 | 2667 | 92 |
| 1027 | 209 | TRIM KIT | R | 120 | 0.146 | 16.3 | 0.9272 | 34.47 | 1055 | 2678 | 92 | 120 | 0.145 | 16.19 | 0.928 | 34.35 | 1075 | 2673 | 92 |
| 1028 | 210 | TRIM KIT | R | 120 | 0.088 | 9.6 | 0.9056 | 39.1 | 629 | 2755 | 93 | 120 | 0.088 | 9.54 | 0.905 | 38.98 | 622 | 2784 | 93 |
| 1029 | 210 | TRIM KIT | R | 120 | 0.087 | 9.5 | 0.9073 | 38.79 | 622 | 2747 | 93 | 120 | 0.087 | 9.45 | 0.908 | 38.61 | 613 | 2766 | 93 |
| 1030 | 210 | TRIM KIT | R | 120 | 0.087 | 9.5 | 0.9069 | 38.36 | 619 | 2763 | 93 | 120 | 0.087 | 9.44 | 0.908 | 38.18 | 617 | 2784 | 93 |
| 1031 | 211 | TRIM KIT | R | 120 | 0.071 | 7.7 | 0.9083 | 33.7 | 507 | 2722 | 93 | 120 | 0.071 | 7.77 | 0.91 | 33.63 | 508 | 2758 | 93 |
| 1032 | 211 | TRIM KIT | R | 120 | 0.071 | 7.8 | 0.9096 | 33.94 | 524 | 2730 | 93 | 120 | 0.071 | 7.78 | 0.911 | 33.9 | 519 | 2771 | 93 |
| 1033 | 211 | TRIM KIT | R | 120 | 0.072 | 7.9 | 0.9095 | 33.78 | 527 | 2740 | 92 | 120 | 0.072 | 7.89 | 0.911 | 33.7 | 525 | 2773 | 92 |
| 1034 | 212 | TRIM KIT | R | 120 | 0.09 | 10.5 | 0.9674 | 17.33 | 725 | 2658 | 92 | 120 | 0.09 | 10.5 | 0.968 | 17.12 | 752 | 2671 | 92 |
| 1035 | 212 | TRIM KIT | R | 120 | 0.089 | 10.4 | 0.973 | 15.06 | 691 | 2641 | 91 | 120 | 0.089 | 10.4 | 0.974 | 14.7 | 726 | 2648 | 91 |
| 1036 | 212 | TRIM KIT | R | 120 | 0.088 | 10.3 | 0.9704 | 16.34 | 696 | 2673 | 91 | 120 | 0.089 | 10.33 | 0.971 | 15.99 | 719 | 2680 | 91 |
| 1037 | 213 | TRIM KIT | R | 120 | 0.079 | 9.1 | 0.9578 | 18.58 | 601 | 2675 | 91 | 120 | 0.079 | 9.14 | 0.96 | 18.16 | 630 | 2686 | 91 |
| 1038 | 213 | TRIM KIT | R | 120 | 0.08 | 9.2 | 0.9618 | 18.17 | 605 | 2699 | 92 | 120 | 0.08 | 9.26 | 0.968 | 18.56 | 632 | 2704 | 92 |
| 1039 | 213 | TRIM KIT | R | 120 | 0.08 | 9.2 | 0.9601 | 19.69 | 602 | 2683 | 92 | 120 | 0.08 | 9.24 | 0.963 | 18.74 | 630 | 2691 | 92 |

| Test Units | | | | Early Failure Timing | | | | | | Calculated Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | Burn Time | Fail Time | Pre-Fail Time | Pre-Fail Mode | Pre-Fail Only? | Zombie? | Lumen Maintenance | Color Shift | Initial Efficacy | Final Efficacy | Efficacy Change |
| 1 | 1 | A-LAMP | U | 3938:34 | | | | no | no | 97.1% | 27 | 72.25 | 70.88 | -1.90% |
| 2 | 1 | A-LAMP | D | 4290:03 | | | | no | no | 104.3% | -14 | 74.13 | 77.11 | 4.01% |
| 3 | 1 | A-LAMP | U | 3938:34 | | | | no | no | 105.9% | 17 | 73.73 | 77.15 | 4.64% |
| 4 | 1 | A-LAMP | C | 4103:22 | | | | no | no | 96.6% | 29 | 69.36 | 67.06 | -3.32% |
| 5 | 1 | A-LAMP | C | 4103:22 | | | | no | no | 97.5% | 46 | 70.00 | 68.91 | -1.55% |
| 6 | 1 | A-LAMP | C | 4103:22 | | | | no | no | 99.4% | 49 | 70.05 | 69.69 | -0.52% |
| 7 | 1 | A-LAMP | R | 3845:44 | | | | no | no | 99.2% | 46 | 71.72 | 71.94 | 0.31% |
| 8 | 1 | A-LAMP | R | 3845:44 | | | | no | no | 99.3% | 18 | 70.80 | 70.54 | -0.36% |
| 9 | 1 | A-LAMP | R | 3845:44 | | | | no | no | 100.7% | 48 | 73.25 | 74.33 | 1.47% |
| 10 | 2 | A-LAMP | D | 4534:51 | | | | no | no | 100.2% | -20 | 68.44 | 69.20 | 1.12% |
| 11 | 2 | A-LAMP | U | 4414:26 | | | | no | no | 97.6% | 33 | 66.67 | 65.63 | -1.56% |
| 12 | 2 | A-LAMP | D | 4534:51 | | 3206:47 | <70% L.O. | yes | no | 68.4% | 22 | 69.90 | 44.65 | -36.12% |
| 13 | 2 | A-LAMP | C | 4103:22 | | | | no | no | 84.0% | 51 | 66.92 | 52.68 | -21.29% |
| 14 | 2 | A-LAMP | C | 4103:22 | | | | no | no | 103.7% | 27 | 65.54 | 68.25 | 4.14% |
| 15 | 2 | A-LAMP | C | 4103:22 | | | | no | no | 98.0% | 30 | 70.82 | 69.79 | -1.45% |
| 16 | 2 | A-LAMP | R | 3845:44 | | | | no | no | 102.2% | 85 | 66.71 | 68.50 | 2.67% |
| 17 | 2 | A-LAMP | R | 3845:44 | | | | no | no | 103.4% | 39 | 69.65 | 72.48 | 4.07% |
| 18 | 2 | A-LAMP | R | 3845:44 | | | | no | no | 98.9% | 78 | 68.48 | 68.39 | -0.14% |
| 19 | 3 | A-LAMP | U | 4368:55 | | | | no | no | 99.6% | -17 | 76.45 | 75.99 | -0.61% |
| 20 | 3 | A-LAMP | D | 4290:03 | | | | no | no | 101.4% | -41 | 76.32 | 77.19 | 1.14% |
| 21 | 3 | A-LAMP | U | 4368:55 | | | | no | no | 102.9% | 11 | 77.53 | 79.79 | 2.91% |
| 22 | 3 | A-LAMP | C | 4103:22 | | | | no | no | 101.5% | 48 | 75.09 | 75.79 | 0.93% |
| 23 | 3 | A-LAMP | C | 4103:22 | | | | no | no | 100.3% | 46 | 75.40 | 75.47 | 0.09% |
| 24 | 3 | A-LAMP | C | 4103:22 | | | | no | no | 102.5% | 35 | 76.42 | 78.10 | 2.21% |
| 25 | 3 | A-LAMP | R | 3938:34 | | | | no | no | 101.4% | 36 | 76.68 | 77.52 | 1.10% |
| 26 | 3 | A-LAMP | R | 3938:34 | | | | no | no | 102.9% | 27 | 75.52 | 77.89 | 3.13% |
| 27 | 3 | A-LAMP | R | 3938:34 | | | | no | no | 100.6% | 33 | 75.53 | 72.14 | -4.48% |
| 28 | 4 | A-LAMP | D | 4290:03 | | | | no | no | 92.3% | 66 | 89.81 | 83.84 | -6.64% |
| 29 | 4 | A-LAMP | U | 4368:55 | | | | no | no | 99.2% | 354 | 85.07 | 85.52 | 0.53% |
| 30 | 4 | A-LAMP | D | 4290:03 | | | | no | no | 96.2% | 21 | 86.27 | 84.00 | -2.64% |
| 31 | 4 | A-LAMP | C | 4103:22 | | | | no | no | 97.6% | 59 | 79.11 | 77.48 | -2.06% |
| 32 | 4 | A-LAMP | C | 4103:22 | | | | no | no | 97.2% | 75 | 84.53 | 82.63 | -2.24% |
| 33 | 4 | A-LAMP | C | 4103:22 | | | | no | no | 100.9% | 69 | 86.74 | 87.32 | 0.67% |
| 34 | 4 | A-LAMP | R | 3845:44 | | | | no | no | 95.8% | 120 | 88.20 | 84.92 | -3.72% |
| 35 | 4 | A-LAMP | R | 3845:44 | | | | no | no | 101.5% | 136 | 86.10 | 88.36 | 2.63% |
| 36 | 4 | A-LAMP | R | 3845:44 | | | | no | no | 97.7% | 164 | 86.91 | 85.31 | -1.84% |
| 37 | 5 | A-LAMP | U | 4368:55 | | | | no | no | 103.0% | 58 | 76.09 | 78.47 | 3.13% |
| 38 | 5 | A-LAMP | D | 4290:03 | | | | no | no | 103.4% | 10 | 75.54 | 78.57 | 4.01% |
| 39 | 5 | A-LAMP | U | 4368:55 | | | | no | no | 104.1% | 126 | 77.35 | 80.62 | 4.22% |
| 40 | 5 | A-LAMP | C | 4222:32 | | | | no | no | 100.2% | 59 | 75.99 | 76.41 | 0.55% |
| 41 | 5 | A-LAMP | C | 4222:32 | | | | no | no | 101.0% | 38 | 76.10 | 77.22 | 1.46% |
| 42 | 5 | A-LAMP | C | 4222:32 | | center contact broke | | no | no | 0.0% | | 77.89 | #DIV/0! | #DIV/0! |
| 43 | 5 | A-LAMP | R | 3845:44 | | | | no | no | 103.5% | 45 | 73.54 | 76.54 | 4.08% |
| 44 | 5 | A-LAMP | R | 3845:44 | | | | no | no | 100.9% | 9 | 75.25 | 76.54 | 1.71% |
| 45 | 5 | A-LAMP | R | 3845:44 | | | | no | no | 101.4% | 38 | 74.98 | 76.17 | 1.59% |
| 46 | 6 | A-LAMP | D | 4534:51 | | 2992:51 | CYCLING | yes | no | 102.9% | 37 | 59.64 | 61.77 | 3.58% |
| 47 | 6 | A-LAMP | U | 4368:55 | | | | no | no | 104.5% | 218 | 58.14 | 61.42 | 5.65% |
| 48 | 6 | A-LAMP | D | 4534:51 | | | | no | no | 99.3% | 66 | 61.10 | 60.46 | -1.04% |
| 49 | 6 | A-LAMP | C | 676:58 | 676:58 | | | no | no | 0.0% | | 56.50 | #DIV/0! | #DIV/0! |
| 50 | 6 | A-LAMP | C | 4554:56 | | | | no | no | 97.3% | 83 | 59.09 | 57.57 | -2.57% |
| 51 | 6 | A-LAMP | C | 78:00 | 78:00 | | | no | yes | 0.0% | | 60.72 | #DIV/0! | #DIV/0! |
| 52 | 6 | A-LAMP | R | 3938:34 | | | | no | no | 98.2% | 92 | 58.19 | 56.58 | -2.76% |
| 53 | 6 | A-LAMP | R | 3938:34 | | | | no | no | 99.3% | 75 | 58.71 | 58.41 | -0.51% |
| 54 | 6 | A-LAMP | R | 3938:34 | | | | no | no | 96.3% | 117 | 59.48 | 57.55 | -3.24% |
| 64 | 8 | A-LAMP | D | 4290:03 | | | | no | no | 102.9% | 22 | 79.70 | 82.32 | 3.29% |
| 65 | 8 | A-LAMP | U | 4057:07 | | | | no | no | 101.8% | 222 | 79.13 | 81.06 | 2.44% |
| 66 | 8 | A-LAMP | D | 4290:03 | | | | no | no | 96.0% | 49 | 81.74 | 79.17 | -3.14% |
| 67 | 8 | A-LAMP | C | 4008:18 | | | | no | no | 99.0% | 59 | 81.97 | 81.46 | -0.62% |
| 68 | 8 | A-LAMP | C | 4008:18 | | | | no | no | 99.2% | 60 | 83.04 | 83.08 | 0.05% |
| 69 | 8 | A-LAMP | C | 4008:18 | | | | no | no | 99.9% | 46 | 80.83 | 81.33 | 0.62% |
| 70 | 8 | A-LAMP | R | 3938:34 | | | | no | no | 98.8% | 20 | 80.15 | 79.67 | -0.61% |
| 71 | 8 | A-LAMP | R | 3938:34 | | | | no | no | 101.5% | 73 | 81.45 | 81.55 | 0.13% |
| 72 | 8 | A-LAMP | R | 3938:34 | | | | no | no | 101.2% | 60 | 80.96 | 82.67 | 2.11% |
| 73 | 9 | A-LAMP | U | 4414:26 | | | | no | no | 98.5% | 60 | 74.75 | 75.71 | 1.28% |
| 74 | 9 | A-LAMP | D | 4225:25 | | | | no | no | 93.1% | 72 | 76.32 | 74.53 | -2.35% |

| Test Units | | | | Early Failure Timing | | | | | | Calculated Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | Burn Time | Fail Time | Pre-Fail Time | Pre-Fail Mode | Pre-Fail Only? | Zombie? | Lumen Maintenance | Color Shift | Initial Efficacy | Final Efficacy | Efficacy Change |
| 75 | 9 | A-LAMP | U | 3938:34 | | | | no | no | 98.3% | 81 | 75.93 | 74.53 | -1.84% |
| 76 | 9 | A-LAMP | C | 4079:12 | | | | no | no | 95.4% | 88 | 76.26 | 73.89 | -3.10% |
| 77 | 9 | A-LAMP | C | 4079:12 | | | | no | no | 99.6% | 38 | 73.08 | 74.05 | 1.33% |
| 78 | 9 | A-LAMP | C | 4079:12 | | | | no | no | 97.7% | 90 | 75.81 | 73.80 | -2.64% |
| 79 | 9 | A-LAMP | R | 2818:47 | | | | no | no | 97.4% | 69 | 75.65 | 73.64 | -2.65% |
| 80 | 9 | A-LAMP | R | 2818:47 | | | | no | no | 97.3% | 25 | 71.16 | 70.29 | -1.22% |
| 81 | 9 | A-LAMP | R | 2818:47 | | | | no | no | 98.7% | 57 | 75.57 | 74.68 | -1.17% |
| 100 | 12 | A-LAMP | D | 4290:03 | | | | no | no | 102.4% | 42 | 84.76 | 87.21 | 2.89% |
| 101 | 12 | A-LAMP | U | 4414:26 | | | | no | no | 109.5% | 158 | 83.68 | 91.55 | 9.41% |
| 102 | 12 | A-LAMP | D | 4290:03 | | | | no | no | 103.6% | 27 | 80.43 | 83.00 | 3.19% |
| 103 | 12 | A-LAMP | C | 4103:22 | | | | no | no | 102.5% | 60 | 78.07 | 80.38 | 2.96% |
| 104 | 12 | A-LAMP | C | 4103:22 | | | | no | no | 99.0% | 112 | 75.55 | 75.15 | -0.52% |
| 105 | 12 | A-LAMP | C | 4103:22 | | | | no | no | 102.6% | 63 | 75.11 | 77.72 | 3.46% |
| 106 | 12 | A-LAMP | R | 3845:44 | | | | no | no | 99.9% | 90 | 76.21 | 76.98 | 1.01% |
| 107 | 12 | A-LAMP | R | 3845:44 | | | | no | no | 98.1% | 60 | 77.17 | 77.21 | 0.05% |
| 108 | 12 | A-LAMP | R | 3845:44 | | | | no | no | 101.4% | 80 | 72.61 | 74.86 | 3.09% |
| 109 | 13 | A-LAMP | U | 2572:18 | 2572:18 | | | no | no | 0.0% | | 67.75 | #DIV/0! | #DIV/0! |
| 110 | 13 | A-LAMP | D | 1742:05 | 1742:05 | | | no | no | 0.0% | | 70.53 | #DIV/0! | #DIV/0! |
| 111 | 13 | A-LAMP | U | 4414:26 | too low to | 4090:24 | CYCLING | no | no | 0.0% | | 68.76 | #DIV/0! | #DIV/0! |
| 112 | 13 | A-LAMP | C | 1057:59 | 1057:59 | | | no | no | 0.0% | | 64.04 | #DIV/0! | #DIV/0! |
| 113 | 13 | A-LAMP | C | 666:09 | 666:09 | | | no | no | 0.0% | | 69.25 | #DIV/0! | #DIV/0! |
| 114 | 13 | A-LAMP | C | 2811:30 | 2811:30 | | | no | no | 0.0% | | 64.33 | #DIV/0! | #DIV/0! |
| 115 | 13 | A-LAMP | R | 1958:32 | 1958:32 | | | no | no | 0.0% | | 68.70 | #DIV/0! | #DIV/0! |
| 116 | 13 | A-LAMP | R | 1652:28 | 1652:28 | | | no | no | 0.0% | | 66.07 | #DIV/0! | #DIV/0! |
| 117 | 13 | A-LAMP | R | 1487:10 | 1487:10 | | | no | no | 0.0% | | 71.54 | #DIV/0! | #DIV/0! |
| 118 | 14 | A-LAMP | D | 4534:51 | | | | no | no | 103.6% | 41 | 69.55 | 71.90 | 3.39% |
| 119 | 14 | A-LAMP | U | 4414:26 | | | | no | no | 103.4% | 90 | 71.68 | 74.17 | 3.48% |
| 120 | 14 | A-LAMP | D | 4534:51 | | | | no | no | 101.7% | 9 | 70.95 | 72.26 | 1.85% |
| 121 | 14 | A-LAMP | C | 4222:32 | | | | no | no | 100.6% | 51 | 70.97 | 71.48 | 0.71% |
| 122 | 14 | A-LAMP | C | 2207:41 | 2207:41 | | | no | no | 0.0% | | 70.04 | #DIV/0! | #DIV/0! |
| 123 | 14 | A-LAMP | C | 4222:32 | | | | no | no | 98.7% | 59 | 72.75 | 71.84 | -1.24% |
| 124 | 14 | A-LAMP | R | 4534:32 | | | | no | no | 99.9% | 34 | 69.28 | 69.43 | 0.22% |
| 125 | 14 | A-LAMP | R | 4534:32 | | | | no | no | 99.0% | 21 | 69.39 | 68.64 | -1.09% |
| 126 | 14 | A-LAMP | R | 3167:46 | 3167:46 | | | no | no | 0.0% | | 65.25 | #DIV/0! | #DIV/0! |
| 127 | 15 | A-LAMP | U | 4414:26 | | | | no | no | 105.0% | 118 | 66.22 | 69.68 | 5.23% |
| 128 | 15 | A-LAMP | D | 3845:44 | | | | no | no | 102.2% | 50 | 65.04 | 67.01 | 3.03% |
| 129 | 15 | A-LAMP | U | 4414:26 | | | | no | no | 105.1% | 102 | 66.16 | 69.63 | 5.24% |
| 130 | 15 | A-LAMP | C | 4103:22 | | | | no | no | 97.7% | 37 | 69.47 | 68.30 | -1.69% |
| 131 | 15 | A-LAMP | C | 4103:22 | | | | no | no | 99.6% | 25 | 67.97 | 67.98 | 0.02% |
| 132 | 15 | A-LAMP | C | 4103:22 | | | | no | no | 101.6% | 28 | 69.56 | 70.69 | 1.63% |
| 133 | 15 | A-LAMP | R | 3666:39 | 3666:39 | 2584:41 | <70% L.O. | no | no | 0.0% | | 64.99 | #DIV/0! | #DIV/0! |
| 134 | 15 | A-LAMP | R | 3845:44 | | | | no | no | 102.8% | 40 | 65.58 | 67.82 | 3.42% |
| 135 | 15 | A-LAMP | R | 2959:30 | 2950:20 | | | no | no | 0.0% | | 67.60 | #DIV/0! | #DIV/0! |
| 136 | 16 | A-LAMP | D | 4055:30 | | | | no | no | 105.2% | 213 | 81.52 | 85.70 | 5.13% |
| 137 | 16 | A-LAMP | U | 4057:07 | | | | no | no | 103.8% | 78 | 85.05 | 89.03 | 4.67% |
| 138 | 16 | A-LAMP | D | 4055:30 | | | | no | no | 105.7% | 123 | 108.13 | 114.03 | 5.46% |
| 139 | 16 | A-LAMP | C | 4103:22 | | | | no | no | 104.6% | 98 | 95.92 | 100.39 | 4.66% |
| 140 | 16 | A-LAMP | C | 4103:22 | | | | no | no | 104.3% | 148 | 88.43 | 92.39 | 4.48% |
| 141 | 16 | A-LAMP | C | 4103:22 | | | | no | no | 107.0% | 119 | 88.44 | 94.47 | 6.81% |
| 142 | 16 | A-LAMP | R | 3938:34 | | | | no | no | 104.6% | 107 | 84.21 | 87.83 | 4.29% |
| 143 | 16 | A-LAMP | R | 3938:34 | | | | no | no | 105.9% | 91 | 82.65 | 88.78 | 7.42% |
| 144 | 16 | A-LAMP | R | 3938:34 | | | | no | no | 104.9% | 119 | 106.85 | 111.49 | 4.34% |
| 145 | 17 | A-LAMP | D | 4534:51 | | | | no | no | 104.2% | 48 | 64.29 | 66.05 | 2.73% |
| 146 | 17 | A-LAMP | U | 4368:55 | | | | no | no | 106.0% | 179 | 66.43 | 70.00 | 5.39% |
| 147 | 17 | A-LAMP | D | 4534:51 | | | | no | no | 103.0% | 54 | 65.36 | 66.83 | 2.25% |
| 148 | 17 | A-LAMP | C | 4222:32 | | | | no | no | 99.9% | 72 | 67.02 | 66.57 | -0.67% |
| 149 | 17 | A-LAMP | C | 4222:32 | | | | no | no | 101.8% | 79 | 64.36 | 65.12 | 1.19% |
| 150 | 17 | A-LAMP | C | 4222:32 | | | | no | no | 100.7% | 42 | 65.04 | 65.47 | 0.66% |
| 151 | 17 | A-LAMP | R | 3938:34 | | | | no | no | 100.9% | 69 | 66.38 | 67.19 | 1.22% |
| 152 | 17 | A-LAMP | R | 3938:34 | | | | no | no | 102.9% | 47 | 62.78 | 63.82 | 1.65% |
| 153 | 17 | A-LAMP | R | 3938:34 | | | | no | no | 101.4% | 63 | 65.27 | 64.67 | -0.92% |
| 154 | 18 | A-LAMP | D | 4290:03 | | | | no | no | 102.5% | 30 | 87.57 | 89.60 | 2.31% |
| 155 | 18 | A-LAMP | U | 3938:34 | | | | no | no | 103.8% | 28 | 86.37 | 89.72 | 3.87% |
| 156 | 18 | A-LAMP | D | 4290:03 | | | | no | no | 102.7% | 27 | 86.36 | 88.85 | 2.89% |
| 157 | 18 | A-LAMP | C | 4008:18 | | | | no | no | 101.7% | 17 | 88.08 | 89.39 | 1.49% |

| Test Units | | | | Early Failure Timing | | | | | | Calculated Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | Burn Time | Fail Time | Pre-Fail Time | Pre-Fail Mode | Pre-Fail Only? | Zombie? | Lumen Maintenance | Color Shift | Initial Efficacy | Final Efficacy | Efficacy Change |
| 158 | 18 | A-LAMP | C | 4008:18 | | | | no | no | 100.2% | 36 | 89.28 | 88.83 | -0.50% |
| 159 | 18 | A-LAMP | C | 4008:18 | | | | no | no | 100.2% | 29 | 88.47 | 88.21 | -0.30% |
| 160 | 18 | A-LAMP | R | 4225:25 | | | | no | no | 99.5% | 22 | 89.51 | 88.93 | -0.65% |
| 161 | 18 | A-LAMP | R | 4225:25 | | | | no | no | 96.3% | 27 | 89.74 | 86.43 | -3.68% |
| 162 | 18 | A-LAMP | R | 4225:25 | | | | no | no | 100.0% | 25 | 89.78 | 89.06 | -0.81% |
| 163 | 19 | A-LAMP | U | 4368:55 | | | | no | no | 98.5% | 9 | 74.31 | 73.52 | -1.06% |
| 164 | 19 | A-LAMP | D | 4290:03 | | | | no | no | 97.6% | 5 | 75.24 | 74.38 | -1.15% |
| 165 | 19 | A-LAMP | U | 4368:55 | | | | no | no | 101.4% | 81 | 75.04 | 76.10 | 1.42% |
| 166 | 19 | A-LAMP | C | 1594:11 | 1594:11 | | | no | no | 0.0% | | 73.11 | #DIV/0! | #DIV/0! |
| 167 | 19 | A-LAMP | C | 1850:28 | 1850:28 | | | no | yes | 0.0% | | 77.14 | #DIV/0! | #DIV/0! |
| 168 | 19 | A-LAMP | C | 4008:18 | | | | no | no | 91.2% | 11 | 71.71 | 67.04 | -6.51% |
| 169 | 19 | A-LAMP | R | 3938:34 | | | | no | no | 93.2% | 0 | 73.92 | 68.66 | -7.12% |
| 170 | 19 | A-LAMP | R | 3225:49 | 3225:49 | | | no | no | 0.0% | | 74.84 | #DIV/0! | #DIV/0! |
| 171 | 19 | A-LAMP | R | 1392:50 | 1392:50 | | | no | no | 0.0% | | 74.95 | #DIV/0! | #DIV/0! |
| 172 | 20 | A-LAMP | D | 1989:21 | 1989:21 | | | no | no | 0.0% | | 63.35 | #DIV/0! | #DIV/0! |
| 173 | 20 | A-LAMP | U | 2276:47 | 2276:47 | | | no | no | 0.0% | | 62.26 | #DIV/0! | #DIV/0! |
| 174 | 20 | A-LAMP | D | 1862:48 | 1862:48 | | | no | no | 0.0% | | 61.47 | #DIV/0! | #DIV/0! |
| 175 | 20 | A-LAMP | C | 2750:33 | 2750:33 | | | no | no | 0.0% | | 64.87 | #DIV/0! | #DIV/0! |
| 176 | 20 | A-LAMP | C | 1933:52 | 1933:52 | | | no | no | 0.0% | | 61.90 | #DIV/0! | #DIV/0! |
| 177 | 20 | A-LAMP | C | 2751:14 | 2751:14 | | | no | no | 0.0% | | 63.18 | #DIV/0! | #DIV/0! |
| 178 | 20 | A-LAMP | R | 1806:30 | 1806:30 | | | no | no | 0.0% | | 63.87 | #DIV/0! | #DIV/0! |
| 179 | 20 | A-LAMP | R | 1548:35 | 1548:35 | | | no | no | 0.0% | | 64.24 | #DIV/0! | #DIV/0! |
| 180 | 20 | A-LAMP | R | 1213:14 | 1213:14 | | | no | yes | 0.0% | | 61.90 | #DIV/0! | #DIV/0! |
| 190 | 22 | A-LAMP | D | 3740:36 | 3740:36 | | | no | no | 0.0% | | 87.91 | #DIV/0! | #DIV/0! |
| 191 | 22 | A-LAMP | U | 4362:49 | 4362:49 | | | no | no | 0.0% | | 89.82 | #DIV/0! | #DIV/0! |
| 192 | 22 | A-LAMP | D | 4534:51 | | | | no | no | 97.7% | 66 | 92.07 | 89.88 | -2.38% |
| 193 | 22 | A-LAMP | C | 3505:47 | 3505:47 | | | no | no | 0.0% | | 92.91 | #DIV/0! | #DIV/0! |
| 194 | 22 | A-LAMP | C | 4222:32 | | | | no | no | 87.7% | 77 | 89.96 | 83.61 | -7.05% |
| 195 | 22 | A-LAMP | C | 1485:13 | 1485:13 | | | no | no | 0.0% | | 92.21 | #DIV/0! | #DIV/0! |
| 196 | 22 | A-LAMP | R | 2818:47 | | | | no | no | 87.1% | 127 | 83.19 | 70.85 | -14.83% |
| 197 | 22 | A-LAMP | R | 2818:47 | | | | no | no | 86.1% | 121 | 82.86 | 67.84 | -18.13% |
| 198 | 22 | A-LAMP | R | 2818:47 | | | | no | no | 96.1% | 81 | 91.01 | 84.40 | -7.26% |
| 199 | 23 | A-LAMP | U | 3994:21 | 3998:34 | 3994:21 | <70% L.O. | no | no | 0.0% | | 80.29 | #DIV/0! | #DIV/0! |
| 200 | 23 | A-LAMP | D | 3607:51 | 3612:04 | | CYCLING | no | no | 0.0% | | 83.50 | #DIV/0! | #DIV/0! |
| 201 | 23 | A-LAMP | U | 3057:54 | 3057:54 | | | no | yes | 0.0% | | 84.89 | #DIV/0! | #DIV/0! |
| 202 | 23 | A-LAMP | C | 2381:05 | 2381:05 | | | no | no | 0.0% | | 85.83 | #DIV/0! | #DIV/0! |
| 203 | 23 | A-LAMP | C | 3010:50 | 3010:50 | | | no | no | 0.0% | | 84.53 | #DIV/0! | #DIV/0! |
| 204 | 23 | A-LAMP | C | 2777:03 | 2777:03 | | | no | no | 0.0% | | 80.45 | #DIV/0! | #DIV/0! |
| 205 | 23 | A-LAMP | R | 2317:30 | 2317:30 | | | no | no | 0.0% | | 82.41 | #DIV/0! | #DIV/0! |
| 206 | 23 | A-LAMP | R | 3048:34 | 3038:48 | | | no | no | 0.0% | | 77.52 | #DIV/0! | #DIV/0! |
| 207 | 23 | A-LAMP | R | 3273:57 | 3273:57 | | | no | no | 0.0% | | 86.23 | #DIV/0! | #DIV/0! |
| 208 | 24 | A-LAMP | D | 4534:32 | | | | no | no | 101.0% | -1 | 62.04 | 62.37 | 0.54% |
| 209 | 24 | A-LAMP | U | 4085:12 | | | | no | no | 102.0% | 3 | 61.44 | 62.90 | 2.38% |
| 210 | 24 | A-LAMP | D | 4534:32 | | | | no | no | 98.1% | 95 | 63.08 | 61.85 | -1.94% |
| 211 | 24 | A-LAMP | C | 4252:08 | | | | no | no | 93.7% | 0 | 61.46 | 57.44 | -6.54% |
| 212 | 24 | A-LAMP | C | 4252:08 | | | | no | no | 96.1% | 38 | 65.21 | 62.47 | -4.20% |
| 213 | 24 | A-LAMP | C | 4252:08 | | | | no | no | 96.4% | 70 | 62.95 | 60.39 | -4.08% |
| 214 | 24 | A-LAMP | R | 4085:12 | | | | no | no | 97.4% | -17 | 60.30 | 58.51 | -2.97% |
| 215 | 24 | A-LAMP | R | 4085:12 | | | | no | no | 98.0% | 4 | 64.03 | 62.40 | -2.54% |
| 216 | 24 | A-LAMP | R | 4085:12 | | | | no | no | 97.7% | -18 | 67.69 | 66.22 | -2.18% |
| 235 | 27 | A-LAMP | U | 4414:26 | | | | no | no | 104.7% | 82 | 85.21 | 90.20 | 5.86% |
| 236 | 27 | A-LAMP | D | 4534:51 | | | | no | no | 102.4% | 11 | 86.34 | 89.39 | 3.53% |
| 237 | 27 | A-LAMP | U | 4414:26 | | | | no | no | 104.4% | 76 | 83.74 | 87.67 | 4.69% |
| 238 | 27 | A-LAMP | C | 4554:56 | | | | no | no | 98.5% | 13 | 86.94 | 87.18 | 0.27% |
| 239 | 27 | A-LAMP | C | 4554:56 | | | | no | no | 101.3% | 11 | 83.33 | 85.68 | 2.82% |
| 240 | 27 | A-LAMP | C | 4554:56 | | | | no | no | 99.0% | 19 | 86.11 | 86.69 | 0.67% |
| 241 | 27 | A-LAMP | R | 4534:32 | | 392:56 | <5 CYCLE E | yes | no | 98.7% | 11 | 85.46 | 85.72 | 0.30% |
| 242 | 27 | A-LAMP | R | 4534:32 | | | | no | no | 96.5% | 5 | 85.64 | 84.14 | -1.75% |
| 243 | 27 | A-LAMP | R | 4534:32 | | | | no | no | 96.4% | 10 | 85.86 | 84.17 | -1.98% |
| 253 | 29 | A-LAMP | D | 4534:51 | | | | no | no | 102.4% | 40 | 74.41 | 76.68 | 3.06% |
| 254 | 29 | A-LAMP | U | 4414:26 | | | | no | no | 101.3% | 110 | 75.57 | 77.65 | 2.74% |
| 255 | 29 | A-LAMP | D | 4534:51 | | | | no | no | 98.8% | 58 | 75.40 | 74.61 | -1.04% |
| 256 | 29 | A-LAMP | C | 4079:12 | | | | no | no | 97.8% | 53 | 76.59 | 75.99 | -0.78% |
| 257 | 29 | A-LAMP | C | 4079:12 | | | | no | no | 99.8% | 54 | 76.69 | 76.22 | -0.61% |
| 258 | 29 | A-LAMP | C | 4079:12 | | | | no | no | 99.4% | 57 | 75.41 | 74.66 | -0.99% |

| Test Units | | | | Early Failure Timing | | | | | | Calculated Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | Burn Time | Fail Time | Pre-Fail Time | Pre-Fail Mode | Pre-Fail Only? | Zombie? | Lumen Maintenance | Color Shift | Initial Efficacy | Final Efficacy | Efficacy Change |
| 259 | 29 | A-LAMP | R | 2818:47 | | | | no | no | 102.3% | 57 | 76.38 | 77.17 | 1.04% |
| 260 | 29 | A-LAMP | R | 2818:47 | | | | no | no | 101.7% | 35 | 75.01 | 76.95 | 2.59% |
| 261 | 29 | A-LAMP | R | 2818:47 | | | | no | no | 101.1% | 44 | 75.08 | 75.28 | 0.26% |
| 262 | 30 | A-LAMP | D | 4055:30 | | | | no | no | 98.4% | 319 | 98.00 | 96.17 | -1.87% |
| 263 | 30 | A-LAMP | U | 2781:20 | 2781:20 | | | no | no | 0.0% | | 98.83 | #DIV/0! | #DIV/0! |
| 264 | 30 | A-LAMP | D | 4055:30 | | | | no | no | 100.0% | 254 | 100.66 | 99.45 | -1.20% |
| 265 | 30 | A-LAMP | C | 3348:06 | 3348:06 | | | no | no | 0.0% | | 95.15 | #DIV/0! | #DIV/0! |
| 266 | 30 | A-LAMP | C | 2858:00 | 2858:00 | | | no | no | 0.0% | | 99.73 | #DIV/0! | #DIV/0! |
| 267 | 30 | A-LAMP | C | 3003:10 | 3003:10 | | | no | no | 0.0% | | 95.23 | #DIV/0! | #DIV/0! |
| 268 | 30 | A-LAMP | R | 3258:32 | 3258:32 | | | no | no | 0.0% | | 96.27 | #DIV/0! | #DIV/0! |
| 269 | 30 | A-LAMP | R | 776:13 | 776:13 | | | no | no | 0.0% | | 100.31 | #DIV/0! | #DIV/0! |
| 270 | 30 | A-LAMP | R | 2405:50 | 2405:50 | | | no | no | 0.0% | | 96.80 | #DIV/0! | #DIV/0! |
| 271 | 31 | A-LAMP | D | 3292:70 | 3792:70 | 2698:25 | CYCLING | no | no | 0.0% | | 74.34 | #DIV/0! | #DIV/0! |
| 272 | 31 | A-LAMP | U | 3613:00 | 3613:00 | | | no | yes | 0.0% | | 73.42 | #DIV/0! | #DIV/0! |
| 273 | 31 | A-LAMP | D | 4290:03 | | | | no | no | 97.7% | 24 | 74.08 | 73.27 | -1.09% |
| 274 | 31 | A-LAMP | C | 1478:15 | 1478:15 | | | no | yes | 0.0% | | 71.05 | #DIV/0! | #DIV/0! |
| 275 | 31 | A-LAMP | C | 1009:05 | 1009:05 | | | no | yes | 0.0% | | 71.77 | #DIV/0! | #DIV/0! |
| 276 | 31 | A-LAMP | C | 3355:40 | 3355:40 | | | no | no | 0.0% | | 72.03 | #DIV/0! | #DIV/0! |
| 277 | 31 | A-LAMP | R | 1643:38 | 1643:38 | | | no | yes | 0.0% | | 69.18 | #DIV/0! | #DIV/0! |
| 278 | 31 | A-LAMP | R | 2629:34 | 2629:34 | | | no | no | 0.0% | | 73.00 | #DIV/0! | #DIV/0! |
| 279 | 31 | A-LAMP | R | 1029:56 | 1029:56 | | | no | no | 0.0% | | 72.02 | #DIV/0! | #DIV/0! |
| 289 | 33 | A-LAMP | U | 1082:46 | 1082:46 | | | no | yes | 0.0% | | 83.32 | #DIV/0! | #DIV/0! |
| 290 | 33 | A-LAMP | D | 4534:51 | | | | no | no | 101.2% | -31 | 82.01 | 83.74 | 2.11% |
| 291 | 33 | A-LAMP | U | 3938:34 | | | | no | no | 101.4% | -3 | 79.63 | 81.45 | 2.29% |
| 292 | 33 | A-LAMP | C | 1403:43 | 1403:43 | | | no | yes | 0.0% | | 83.69 | #DIV/0! | #DIV/0! |
| 293 | 33 | A-LAMP | C | 999:40 | 999:40 | | | no | yes | 0.0% | | 80.89 | #DIV/0! | #DIV/0! |
| 294 | 33 | A-LAMP | C | 4008:18 | | | | no | no | 97.2% | -32 | 78.94 | 76.79 | -2.72% |
| 295 | 33 | A-LAMP | R | 2092:22 | 2092:22 | | | no | yes | 0.0% | | 84.39 | #DIV/0! | #DIV/0! |
| 296 | 33 | A-LAMP | R | 975:56 | 975:56 | | | no | yes | 0.0% | | 86.10 | #DIV/0! | #DIV/0! |
| 297 | 33 | A-LAMP | R | 1343:10 | 1343:10 | | | no | no | 0.0% | | 84.58 | #DIV/0! | #DIV/0! |
| 316 | 36 | A-LAMP | D | 4055:30 | | | | no | no | 99.8% | 15 | 113.89 | 113.88 | 0.00% |
| 317 | 36 | A-LAMP | U | 4085:12 | | | | no | no | 101.5% | 14 | 114.95 | 116.42 | 1.28% |
| 318 | 36 | A-LAMP | D | 4055:30 | | | | no | no | 100.8% | 18 | 113.40 | 114.65 | 1.10% |
| 319 | 36 | A-LAMP | C | 4252:08 | | | | no | no | 100.1% | -20 | 117.07 | 116.56 | -0.43% |
| 320 | 36 | A-LAMP | C | 1091:01 | 1091:01 | | | no | yes | 0.0% | | 116.57 | #DIV/0! | #DIV/0! |
| 321 | 36 | A-LAMP | C | 4252:08 | | | | no | no | 100.5% | 23 | 117.89 | 118.11 | 0.19% |
| 322 | 36 | A-LAMP | R | 2275:43 | 2275:43 | | | no | yes | 0.0% | | 115.59 | #DIV/0! | #DIV/0! |
| 323 | 36 | A-LAMP | R | 4173:08 | | 3887:58 | CYCLING | yes | no | 102.2% | -47 | 116.97 | 120.76 | 3.24% |
| 324 | 36 | A-LAMP | R | 4173:08 | | | | no | no | 102.4% | -22 | 110.25 | 112.06 | 1.64% |
| 325 | 37 | A-LAMP | U | 4368:55 | | | | no | no | 103.8% | 44 | 61.01 | 63.34 | 3.83% |
| 326 | 37 | A-LAMP | D | 4055:30 | | | | no | no | 103.3% | 7 | 60.89 | 62.52 | 2.69% |
| 327 | 37 | A-LAMP | U | 4368:55 | | | | no | no | 106.6% | 53 | 62.79 | 66.77 | 6.33% |
| 328 | 37 | A-LAMP | C | 4252:08 | | | | no | no | 68.4% | 163 | 62.35 | 42.29 | -32.17% |
| 329 | 37 | A-LAMP | C | 4252:08 | | | | no | no | 69.9% | 114 | 61.37 | 42.41 | -30.89% |
| 330 | 37 | A-LAMP | C | 4252:08 | | | | no | no | 76.0% | 88 | 61.39 | 46.11 | -24.90% |
| 331 | 37 | A-LAMP | R | 4252:48 | | | | no | no | 90.3% | 16 | 61.29 | 54.77 | -10.64% |
| 332 | 37 | A-LAMP | R | 4252:48 | | | | no | no | 81.7% | 52 | 61.39 | 49.78 | -18.91% |
| 333 | 37 | A-LAMP | R | 4252:48 | | | | no | no | 60.3% | 363 | 60.26 | 36.07 | -40.15% |
| 334 | 38 | A-LAMP | D | 4534:51 | | | | no | no | 100.7% | 38 | 77.29 | 78.38 | 1.40% |
| 335 | 38 | A-LAMP | U | 4368:55 | | | | no | no | 100.2% | 21 | 78.06 | 78.32 | 0.33% |
| 336 | 38 | A-LAMP | D | 1942:49 | 1942:49 | | | no | no | 0.0% | | 76.81 | #DIV/0! | #DIV/0! |
| 337 | 38 | A-LAMP | C | 1481:34 | 1481:34 | | | no | no | 0.0% | | 79.41 | #DIV/0! | #DIV/0! |
| 338 | 38 | A-LAMP | C | 2052:22 | 2052:22 | | | no | no | 0.0% | | 79.31 | #DIV/0! | #DIV/0! |
| 339 | 38 | A-LAMP | C | 1570:40 | 1570:40 | | | no | no | 0.0% | | 77.28 | #DIV/0! | #DIV/0! |
| 340 | 38 | A-LAMP | R | 1619:26 | 1619:26 | | | no | no | 0.0% | | 78.23 | #DIV/0! | #DIV/0! |
| 341 | 38 | A-LAMP | R | 1280:41 | 1280:41 | | | no | no | 0.0% | | 78.48 | #DIV/0! | #DIV/0! |
| 342 | 38 | A-LAMP | R | 1483:11 | 1483:11 | | | no | no | 0.0% | | 80.39 | #DIV/0! | #DIV/0! |
| 343 | 39 | A-LAMP | U | 4368:55 | | | | no | no | 97.8% | 32 | 80.84 | 78.92 | -2.37% |
| 344 | 39 | A-LAMP | D | 4534:51 | | | | no | no | 96.6% | 94 | 69.96 | 68.29 | -2.38% |
| 345 | 39 | A-LAMP | U | 4074:28 | 4074:28 | 3827:15 | CYCLING | no | no | 0.0% | | 70.79 | #DIV/0! | #DIV/0! |
| 346 | 39 | A-LAMP | C | 4079:12 | | | | no | no | 94.7% | 102 | 69.29 | 65.12 | -6.01% |
| 347 | 39 | A-LAMP | C | 4079:12 | | | | no | no | 93.8% | 88 | 70.09 | 66.78 | -4.72% |
| 348 | 39 | A-LAMP | C | 4079:12 | | | | no | no | 94.1% | 86 | 72.13 | 68.36 | -5.23% |
| 349 | 39 | A-LAMP | R | 2818:47 | | | | no | no | 96.7% | 64 | 70.66 | 68.18 | -3.51% |
| 350 | 39 | A-LAMP | R | 2818:47 | | | | no | no | 97.8% | 87 | 70.48 | 68.66 | -2.59% |

| Test Units | | | | Early Failure Timing | | | | | | Calculated Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | Burn Time | Fail Time | Pre-Fail Time | Pre-Fail Mode | Pre-Fail Only? | Zombie? | Lumen Maintenance | Color Shift | Initial Efficacy | Final Efficacy | Efficacy Change |
| 351 | 39 | A-LAMP | R | 2818:47 | | | | no | no | 96.8% | 66 | 70.73 | 68.38 | -3.33% |
| 352 | 40 | A-LAMP | D | 4290:03 | | | | no | no | 91.7% | 121 | 92.69 | 85.92 | -7.30% |
| 353 | 40 | A-LAMP | U | 1497:56 | 1497:56 | | | no | no | 0.0% | | 92.69 | #DIV/0! | #DIV/0! |
| 354 | 40 | A-LAMP | D | 4290:03 | | | | no | no | 91.1% | 100 | 93.94 | 86.18 | -8.27% |
| 355 | 40 | A-LAMP | C | 4008:18 | | | | no | no | 96.1% | 65 | 90.69 | 87.33 | -3.71% |
| 356 | 40 | A-LAMP | C | 4008:18 | | | | no | no | 100.6% | 47 | 90.69 | 92.02 | 1.46% |
| 357 | 40 | A-LAMP | C | 2562:55 | 2562:55 | | | no | no | 0.0% | | 92.39 | #DIV/0! | #DIV/0! |
| 358 | 40 | A-LAMP | R | 4534:32 | | | | no | no | 94.5% | 58 | 94.24 | 89.84 | -4.66% |
| 359 | 40 | A-LAMP | R | 4534:32 | | | | no | no | 92.3% | 101 | 91.51 | 85.19 | -6.91% |
| 360 | 40 | A-LAMP | R | 4534:32 | | | | no | no | 91.8% | 89 | 92.55 | 79.30 | -14.31% |
| 361 | 41 | A-LAMP | U | 4057:07 | | | | no | no | 102.7% | -1 | 97.71 | 100.08 | 2.43% |
| 362 | 41 | A-LAMP | D | 4055:30 | | | | no | no | 102.5% | 10 | 95.28 | 97.28 | 2.09% |
| 363 | 41 | A-LAMP | U | 4057:07 | | | | no | no | 103.9% | -6 | 97.82 | 101.66 | 3.92% |
| 364 | 41 | A-LAMP | C | 4252:08 | | | | no | no | 98.8% | 25 | 97.42 | 95.87 | -1.60% |
| 365 | 41 | A-LAMP | C | 4252:08 | | 3386:48 | CYCLING | yes | no | 100.0% | 11 | 100.10 | 100.40 | 0.30% |
| 366 | 41 | A-LAMP | C | 2786:50 | 2786:50 | | | no | no | 0.0% | | 97.09 | #DIV/0! | #DIV/0! |
| 367 | 41 | A-LAMP | R | 4173:08 | | | | no | no | 99.7% | -2 | 99.72 | 99.16 | -0.56% |
| 368 | 41 | A-LAMP | R | 4134:22 | | 4134:22 | CYCLING | no | no | 101.6% | 0 | 98.68 | 99.64 | 0.97% |
| 369 | 41 | A-LAMP | R | 86:04 | 86:04 | | | no | no | 0.0% | | 95.89 | #DIV/0! | #DIV/0! |
| 379 | 43 | A-LAMP | U | 3540:04 | 3540:04 | | | no | no | 0.0% | | 70.63 | #DIV/0! | #DIV/0! |
| 380 | 43 | A-LAMP | D | 4055:30 | | | | no | no | 100.7% | 21 | 73.62 | 73.15 | -0.64% |
| 381 | 43 | A-LAMP | U | 4057:07 | | | | no | no | 101.7% | 7 | 72.41 | 72.79 | 0.52% |
| 382 | 43 | A-LAMP | C | 3333:56 | 3333:56 | 3151:34 | CYCLING | no | no | 0.0% | | 81.38 | #DIV/0! | #DIV/0! |
| 383 | 43 | A-LAMP | C | 4252:08 | Failed when prewarming for fina | | | no | no | 0.0% | | 69.65 | #DIV/0! | #DIV/0! |
| 384 | 43 | A-LAMP | C | 4252:08 | | | | no | no | 95.8% | -3 | 73.10 | 69.96 | -4.29% |
| 385 | 43 | A-LAMP | R | 1787:11 | 1787:11 | | | no | no | 0.0% | | 72.51 | #DIV/0! | #DIV/0! |
| 386 | 43 | A-LAMP | R | 4085:12 | | | | no | no | 94.8% | -16 | 72.41 | 68.40 | -5.54% |
| 387 | 43 | A-LAMP | R | 3303:54 | 3303:54 | | | no | no | 0.0% | | 72.65 | #DIV/0! | #DIV/0! |
| 388 | 44 | A-LAMP | D | 1473:17 | 1473:17 | | | no | no | 0.0% | | 80.33 | #DIV/0! | #DIV/0! |
| 389 | 44 | A-LAMP | U | 2047:08 | 2047:08 | | | no | no | 0.0% | | 81.26 | #DIV/0! | #DIV/0! |
| 390 | 44 | A-LAMP | D | 1660:27 | 1660:27 | | | no | no | 0.0% | | 82.76 | #DIV/0! | #DIV/0! |
| 391 | 44 | A-LAMP | C | 2667:07 | 2667:07 | | | no | no | 0.0% | | 79.66 | #DIV/0! | #DIV/0! |
| 392 | 44 | A-LAMP | C | 2363:48 | 2363:48 | | | no | no | 0.0% | | 80.55 | #DIV/0! | #DIV/0! |
| 393 | 44 | A-LAMP | C | 773:34 | 773:34 | | | no | no | 0.0% | | 84.52 | #DIV/0! | #DIV/0! |
| 394 | 44 | A-LAMP | R | 2246:23 | 2246:23 | 1882:54 | CYCLING | no | no | 0.0% | | 84.83 | #DIV/0! | #DIV/0! |
| 395 | 44 | A-LAMP | R | 1557:14 | 1557:14 | | | no | no | 0.0% | | 81.65 | #DIV/0! | #DIV/0! |
| 396 | 44 | A-LAMP | R | 1902:43 | 1902:43 | | | no | no | 0.0% | | 80.17 | #DIV/0! | #DIV/0! |
| 397 | 45 | A-LAMP | U | 4368:55 | | 3892:31 | <70% L.O. | yes | no | 55.0% | 119 | 92.09 | 83.02 | -9.85% |
| 398 | 45 | A-LAMP | D | 2875:31 | 2875:31 | | | no | no | 0.0% | | 90.77 | #DIV/0! | #DIV/0! |
| 399 | 45 | A-LAMP | U | 3530:52 | 3530:52 | 3109:27 | <70% L.O. | no | no | 0.0% | | 91.64 | #DIV/0! | #DIV/0! |
| 400 | 45 | A-LAMP | C | 3636:41 | 3636:41 | | | no | no | 0.0% | | 92.31 | #DIV/0! | #DIV/0! |
| 401 | 45 | A-LAMP | C | 4008:18 | | | | no | no | 81.9% | 401 | 95.62 | 80.55 | -15.77% |
| 402 | 45 | A-LAMP | C | 4008:18 | | | | no | no | 89.6% | 479 | 92.92 | 78.59 | -15.42% |
| 403 | 45 | A-LAMP | R | 2345:00 | 2345:00 | | | no | no | 0.0% | | 91.28 | #DIV/0! | #DIV/0! |
| 404 | 45 | A-LAMP | R | 2239:12 | 2239:12 | 2208:42 | <70% L.O. | no | no | 0.0% | | 92.56 | #DIV/0! | #DIV/0! |
| 405 | 45 | A-LAMP | R | 2818:47 | | 2620:31 | CYCLING | yes | no | 87.5% | 302 | 95.15 | 85.95 | -9.67% |
| 406 | 46 | A-LAMP | D | 4534:32 | | 4486:39 | CYCLING | yes | no | 100.7% | 27 | 106.63 | 107.28 | 0.61% |
| 407 | 46 | A-LAMP | U | 4085:12 | | | | no | no | 101.2% | -3 | 106.06 | 107.17 | 1.04% |
| 408 | 46 | A-LAMP | D | 1802:20 | 1802:20 | | | no | no | 0.0% | | 107.77 | #DIV/0! | #DIV/0! |
| 409 | 46 | A-LAMP | C | 1991:50 | 1991:50 | | | no | no | 0.0% | | 105.41 | #DIV/0! | #DIV/0! |
| 410 | 46 | A-LAMP | C | 4252:08 | | 1910:52 | CYCLING | yes | no | 101.2% | -2 | 103.21 | 103.43 | 0.22% |
| 411 | 46 | A-LAMP | C | 394:00 | 394:00 | | | no | no | 0.0% | | 90.64 | #DIV/0! | #DIV/0! |
| 412 | 46 | A-LAMP | R | 4173:08 | | | | no | no | 102.0% | 9 | 105.56 | 107.40 | 1.75% |
| 413 | 46 | A-LAMP | R | 886:14 | 886:14 | | | no | yes | 0.0% | | 91.73 | #DIV/0! | #DIV/0! |
| 414 | 46 | A-LAMP | R | 4173:08 | | 3678:47 | CYCLING | yes | no | 102.7% | -25 | 106.11 | 108.30 | 2.07% |
| 415 | 47 | A-LAMP | U | 4368:55 | | 3456:40 | CYCLING | yes | no | 12.5% | 245 | 93.03 | 84.80 | -8.84% |
| 416 | 47 | A-LAMP | D | 4290:03 | | | | no | no | 101.5% | 12 | 92.21 | 93.83 | 1.76% |
| 417 | 47 | A-LAMP | U | 4368:55 | | | | no | no | 100.2% | 6 | 94.11 | 94.59 | 0.52% |
| 418 | 47 | A-LAMP | C | 1666:46 | 1666:46 | | | no | no | 0.0% | | 92.90 | #DIV/0! | #DIV/0! |
| 419 | 47 | A-LAMP | C | 1013:19 | 1013:19 | | | no | yes | 0.0% | | 93.99 | #DIV/0! | #DIV/0! |
| 420 | 47 | A-LAMP | C | 1005:05 | 1005:05 | | | no | yes | 0.0% | | 92.50 | #DIV/0! | #DIV/0! |
| 421 | 47 | A-LAMP | R | 1389:21 | 1389:21 | | | no | no | 0.0% | | 94.73 | #DIV/0! | #DIV/0! |
| 422 | 47 | A-LAMP | R | 4085:12 | | 786:01 | <70% L.O | yes | no | 4.0% | -58 | 90.22 | 50.66 | -43.85% |
| 423 | 47 | A-LAMP | R | 4085:12 | | 1058:43 | <70% L.O | yes | no | 4.0% | -59 | 95.47 | 56.49 | -40.83% |
| 424 | 48 | A-LAMP | D | 1443:19 | 1443:19 | | | no | no | 0.0% | | 82.19 | #DIV/0! | #DIV/0! |

| Test Units | | | | Early Failure Timing | | | | | | Calculated Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | Burn Time | Fail Time | Pre-Fail Time | Pre-Fail Mode | Pre-Fail Only? | Zombie? | Lumen Maintenance | Color Shift | Initial Efficacy | Final Efficacy | Efficacy Change |
| 425 | 48 | A-LAMP | U | 1520:06 | 1520:06 | | | no | no | 0.0% | | 86.66 | #DIV/0! | #DIV/0! |
| 426 | 48 | A-LAMP | D | 1853:05 | 1853:05 | | | no | no | 0.0% | | 84.92 | #DIV/0! | #DIV/0! |
| 427 | 48 | A-LAMP | C | 1778:20 | 1778:20 | | | no | no | 0.0% | | 84.15 | #DIV/0! | #DIV/0! |
| 428 | 48 | A-LAMP | C | 2320:06 | 2320:06 | | | no | no | 0.0% | | 85.38 | #DIV/0! | #DIV/0! |
| 429 | 48 | A-LAMP | C | 2210:49 | 2210:49 | | | no | no | 0.0% | | 87.18 | #DIV/0! | #DIV/0! |
| 430 | 48 | A-LAMP | R | 1674:11 | 1674:11 | | | no | no | 0.0% | | 83.57 | #DIV/0! | #DIV/0! |
| 431 | 48 | A-LAMP | R | 1504:39 | 1504:39 | | | no | no | 0.0% | | 88.75 | #DIV/0! | #DIV/0! |
| 432 | 48 | A-LAMP | R | 1243:10 | 1243:10 | | | no | no | 0.0% | | 86.65 | #DIV/0! | #DIV/0! |
| 433 | 49 | A-LAMP | U | 4057:07 | | | | no | no | 100.2% | 25 | 96.02 | 96.79 | 0.81% |
| 434 | 49 | A-LAMP | D | 4055:30 | | | | no | no | 98.8% | 73 | 93.89 | 93.48 | -0.44% |
| 435 | 49 | A-LAMP | U | 4057:07 | | | | no | no | 100.1% | 35 | 94.26 | 94.62 | 0.39% |
| 436 | 49 | A-LAMP | C | 4252:08 | | | | no | no | 94.0% | 94 | 92.45 | 86.93 | -5.98% |
| 437 | 49 | A-LAMP | C | 725:47 | 725:47 | | | no | no | 0.0% | | 92.77 | #DIV/0! | #DIV/0! |
| 438 | 49 | A-LAMP | C | 2204:22 | 2204:22 | | | no | no | 0.0% | | 92.56 | #DIV/0! | #DIV/0! |
| 439 | 49 | A-LAMP | R | 4173:08 | | | | no | no | 96.6% | 92 | 92.92 | 89.83 | -3.32% |
| 440 | 49 | A-LAMP | R | 4173:08 | | | | no | no | 93.6% | 47 | 90.81 | 92.01 | 1.33% |
| 441 | 49 | A-LAMP | R | 4173:08 | | 3974:24 | CYCLING | yes | no | 83.8% | 168 | 95.19 | 80.63 | -15.30% |
| 442 | 50 | GLOBE | D | 4534:51 | | | | no | no | 103.1% | 52 | 69.37 | 71.14 | 2.55% |
| 443 | 50 | GLOBE | U | 4414:26 | | 392:56 | <5 CYCLE E | yes | no | 102.2% | 13 | 70.78 | 72.10 | 1.88% |
| 444 | 50 | GLOBE | D | 4534:51 | | | | no | no | 101.2% | 1 | 70.57 | 71.41 | 1.19% |
| 445 | 51 | GLOBE | U | 4057:07 | | | | no | no | 101.0% | 18 | 88.94 | 88.06 | -0.99% |
| 446 | 51 | GLOBE | D | 4055:30 | | | | no | no | 104.8% | 59 | 86.88 | 89.97 | 3.55% |
| 447 | 51 | GLOBE | U | 4057:07 | | | | no | no | 104.3% | 5 | 85.11 | 88.76 | 4.29% |
| 448 | 52 | GLOBE | D | 4534:51 | | | | no | no | 103.0% | 59 | 67.63 | 69.85 | 3.28% |
| 449 | 52 | GLOBE | U | 4368:55 | | | | no | no | 102.7% | -29 | 68.89 | 70.46 | 2.28% |
| 450 | 52 | GLOBE | D | 4534:51 | | | | no | no | 101.9% | 4 | 67.16 | 68.66 | 2.24% |
| 451 | 53 | GLOBE | U | 3938:34 | | | | no | no | 101.6% | 20 | 66.06 | 66.25 | 0.28% |
| 452 | 53 | GLOBE | D | 4290:03 | | | | no | no | 100.0% | -22 | 65.70 | 65.49 | -0.31% |
| 453 | 53 | GLOBE | U | 3938:34 | | | | no | no | 100.5% | 11 | 65.48 | 65.46 | -0.03% |
| 454 | 54 | GLOBE | D | 4534:51 | | | | no | no | 103.4% | 35 | 96.06 | 98.50 | 2.54% |
| 455 | 54 | GLOBE | U | 4414:26 | | | | no | no | 105.3% | 75 | 96.83 | 102.06 | 5.39% |
| 456 | 54 | GLOBE | D | 4534:51 | | | | no | no | 103.8% | 3 | 94.36 | 99.74 | 5.70% |
| 460 | 56 | GLOBE | D | 4055:30 | | | | no | no | 103.1% | -9 | 75.21 | 77.07 | 2.47% |
| 461 | 56 | GLOBE | U | 4057:07 | | | | no | no | 103.2% | -3 | 75.15 | 77.58 | 3.23% |
| 462 | 56 | GLOBE | D | 4055:30 | | | | no | no | 103.5% | 50 | 71.95 | 74.33 | 3.31% |
| 463 | 57 | GLOBE | U | 940:22 | 940:22 | | | no | no | 0.0% | | 69.68 | #DIV/0! | #DIV/0! |
| 464 | 57 | GLOBE | D | 4290:03 | | | | no | no | 100.8% | 10 | 67.14 | 67.32 | 0.27% |
| 465 | 57 | GLOBE | U | 4414:26 | | | | no | no | 102.9% | 27 | 66.44 | 68.31 | 2.81% |
| 466 | 58 | GLOBE | D | 4534:51 | | | | no | no | 102.4% | 40 | 91.62 | 93.69 | 2.26% |
| 467 | 58 | GLOBE | U | 3938:34 | | | | no | no | 102.0% | 23 | 95.08 | 96.73 | 1.75% |
| 468 | 58 | GLOBE | D | 4534:51 | | | | no | no | 101.4% | 17 | 92.27 | 93.94 | 1.81% |
| 469 | 59 | GLOBE | U | 4368:55 | | | | no | no | 106.0% | -12 | 77.61 | 82.00 | 5.65% |
| 470 | 59 | GLOBE | D | 4290:03 | | | | no | no | 103.6% | -5 | 82.76 | 85.78 | 3.64% |
| 471 | 59 | GLOBE | D | 4290:03 | | | | no | no | 97.4% | 44 | 59.59 | 58.47 | -1.89% |
| 472 | 60 | TORPEDO/BULLET | D | 4534:51 | | | | no | no | 83.5% | -168 | 70.94 | 59.90 | -15.56% |
| 473 | 60 | TORPEDO/BULLET | U | 4414:26 | | | | no | no | 106.3% | 505 | 70.02 | 74.27 | 6.07% |
| 474 | 60 | TORPEDO/BULLET | D | 4534:51 | | | | no | no | 106.3% | 33 | 69.02 | 73.28 | 6.17% |
| 475 | 60 | TORPEDO/BULLET | C | 4079:12 | | | | no | no | 107.8% | 124 | 67.19 | 72.29 | 7.58% |
| 476 | 60 | TORPEDO/BULLET | C | 4079:12 | | | | no | no | 108.4% | 124 | 67.94 | 73.46 | 8.13% |
| 477 | 60 | TORPEDO/BULLET | C | 4079:12 | | | | no | no | 105.0% | 33 | 69.75 | 73.50 | 5.38% |
| 478 | 61 | TORPEDO/BULLET | U | 4414:26 | | | | no | no | 98.7% | 593 | 44.67 | 44.03 | -1.44% |
| 479 | 61 | TORPEDO/BULLET | D | 4534:51 | | | | no | no | 83.3% | 41 | 46.70 | 39.23 | -16.01% |
| 480 | 61 | TORPEDO/BULLET | U | 4414:26 | | | | no | no | 96.2% | 570 | 45.79 | 44.28 | -3.31% |
| 481 | 61 | TORPEDO/BULLET | C | 4554:56 | | | | no | no | 89.0% | 109 | 48.29 | 42.63 | -11.72% |
| 482 | 61 | TORPEDO/BULLET | C | 4554:56 | | | | no | no | 85.0% | 76 | 47.75 | 40.49 | -15.21% |
| 483 | 61 | TORPEDO/BULLET | C | 4554:56 | | | | no | no | 79.4% | 153 | 46.50 | 36.70 | -21.07% |
| 484 | 62 | TORPEDO/BULLET | D | 4534:51 | | | | no | no | 101.1% | 122 | 99.08 | 99.81 | 0.74% |
| 485 | 62 | TORPEDO/BULLET | U | 4414:26 | | | | no | no | 107.1% | 515 | 101.23 | 108.39 | 7.08% |
| 486 | 62 | TORPEDO/BULLET | D | 4534:51 | | | | no | no | 103.3% | 68 | 99.33 | 103.03 | 3.72% |
| 487 | 62 | TORPEDO/BULLET | C | 4079:12 | | | | no | no | 100.8% | 114 | 103.15 | 104.32 | 1.14% |
| 488 | 62 | TORPEDO/BULLET | C | 4079:12 | | | | no | no | 101.7% | 98 | 97.20 | 98.64 | 1.48% |
| 489 | 62 | TORPEDO/BULLET | C | 4079:12 | | | | no | no | 102.9% | 129 | 96.51 | 98.83 | 2.40% |
| 490 | 63 | TORPEDO/BULLET | U | 4414:26 | | 323:14 | CYCLING | yes | no | 104.4% | 62 | 74.96 | 78.23 | 4.36% |
| 491 | 63 | TORPEDO/BULLET | D | 4534:51 | | 1662:55 | <5 CYCLE E | yes | no | 107.8% | 12 | 66.03 | 71.14 | 7.74% |
| 492 | 63 | TORPEDO/BULLET | U | 4414:26 | | | | no | no | 109.5% | 261 | 73.27 | 80.19 | 9.44% |

| Test Units | | | | Early Failure Timing | | | | | | Calculated Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | Burn Time | Fail Time | Pre-Fail Time | Pre-Fail Mode | Pre-Fail Only? | Zombie? | Lumen Maintenance | Color Shift | Initial Efficacy | Final Efficacy | Efficacy Change |
| 493 | 63 | TORPEDO/BULLET | C | 1351:43 | 1351:43 | | | no | no | 0.0% | | 67.20 | #DIV/0! | #DIV/0! |
| 494 | 63 | TORPEDO/BULLET | C | 4222:32 | | 551.12 | CYCLING | yes | no | 103.4% | 20 | 76.21 | 78.92 | 3.56% |
| 495 | 63 | TORPEDO/BULLET | C | 4222:32 | | 556.56 | CYCLING | yes | no | 104.0% | 29 | 71.24 | 73.92 | 3.77% |
| 496 | 64 | TORPEDO/BULLET | D | 4534:51 | | | | no | no | 104.0% | 124 | 87.14 | 91.03 | 4.47% |
| 497 | 64 | TORPEDO/BULLET | U | 4414:26 | | | | no | no | 101.1% | 127 | 86.88 | 87.72 | 0.97% |
| 498 | 64 | TORPEDO/BULLET | D | 4534:51 | | | | no | no | 101.1% | 84 | 90.42 | 90.91 | 0.54% |
| 499 | 64 | TORPEDO/BULLET | C | 4222:32 | | | | no | no | 99.8% | 97 | 88.35 | 88.91 | 0.64% |
| 500 | 64 | TORPEDO/BULLET | C | 4222:32 | | | | no | no | 100.0% | 114 | 89.42 | 90.15 | 0.81% |
| 501 | 64 | TORPEDO/BULLET | C | 4222:32 | | | | no | no | 100.1% | 96 | 88.53 | 88.99 | 0.51% |
| 508 | 66 | TORPEDO/BULLET | U | 4414:26 | | | | no | no | 105.2% | 13 | 78.95 | 83.44 | 5.69% |
| 509 | 66 | TORPEDO/BULLET | D | 4534:51 | | | | no | no | 93.1% | 88 | 75.84 | 70.30 | -7.30% |
| 510 | 66 | TORPEDO/BULLET | D | 4534:51 | | | | no | no | 105.2% | 13 | 80.07 | 83.97 | 4.86% |
| 511 | 66 | TORPEDO/BULLET | C | 4554:56 | | | | no | no | 102.9% | 8 | 80.26 | 82.18 | 2.39% |
| 512 | 66 | TORPEDO/BULLET | C | 4554:56 | | | | no | no | 100.8% | 33 | 80.04 | 80.37 | 0.41% |
| 513 | 66 | TORPEDO/BULLET | C | 4554:56 | | | | no | no | 94.0% | 86 | 81.46 | 76.02 | -6.69% |
| 514 | 67 | TORPEDO/BULLET | D | 4534:51 | | | | no | no | 99.4% | 16 | 86.33 | 85.87 | -0.53% |
| 515 | 67 | TORPEDO/BULLET | D | 4534:51 | | | | no | no | 99.4% | 4 | 82.15 | 81.67 | -0.59% |
| 516 | 67 | TORPEDO/BULLET | U | 4414:26 | | | | no | no | 101.3% | 164 | 86.87 | 88.12 | 1.44% |
| 517 | 67 | TORPEDO/BULLET | C | 3122:01 | 3122:01 | | | no | no | 0.0% | | 79.87 | #DIV/0! | #DIV/0! |
| 518 | 67 | TORPEDO/BULLET | C | 4554:56 | | | | no | no | 98.5% | 36 | 81.61 | 80.43 | -1.45% |
| 519 | 67 | TORPEDO/BULLET | C | 3685:26 | 3685:26 | | | no | no | 0.0% | | 81.99 | #DIV/0! | #DIV/0! |
| 520 | 68 | TORPEDO/BULLET | U | 4414:26 | | | | no | no | 103.3% | 205 | 96.67 | 99.16 | 2.58% |
| 521 | 68 | TORPEDO/BULLET | U | 4414:26 | | | | no | no | 102.9% | 278 | 99.86 | 101.90 | 2.04% |
| 522 | 68 | TORPEDO/BULLET | D | 4534:51 | | | | no | no | 103.2% | -61 | 94.57 | 97.35 | 2.94% |
| 523 | 68 | TORPEDO/BULLET | C | 4554:56 | | | | no | no | 98.3% | 126 | 95.61 | 93.45 | -2.27% |
| 524 | 68 | TORPEDO/BULLET | C | 4489:02 | 4489:02 | 4283:56 | CYCLING | no | no | 0.0% | | 92.82 | #DIV/0! | #DIV/0! |
| 525 | 68 | TORPEDO/BULLET | C | 4554:56 | | | | no | no | 100.7% | 116 | 94.18 | 94.02 | -0.17% |
| 532 | 70 | TORPEDO/BULLET | U | 4414:26 | | | | no | no | 110.7% | 202 | 67.63 | 74.72 | 10.47% |
| 533 | 70 | TORPEDO/BULLET | U | 4414:26 | | | | no | no | 105.3% | 58 | 69.91 | 72.67 | 3.94% |
| 534 | 70 | TORPEDO/BULLET | D | 4534:51 | | | | no | no | 105.0% | 50 | 66.23 | 69.97 | 5.65% |
| 535 | 70 | TORPEDO/BULLET | C | 4079:12 | | | | no | no | 103.9% | 26 | 67.73 | 69.93 | 3.24% |
| 536 | 70 | TORPEDO/BULLET | C | 4079:12 | | | | no | no | 104.3% | 58 | 67.30 | 69.05 | 2.60% |
| 537 | 70 | TORPEDO/BULLET | C | 4079:12 | | | | no | no | 104.5% | 22 | 64.78 | 67.66 | 4.45% |
| 538 | 71 | TORPEDO/BULLET | D | 4534:51 | | | | no | no | 100.9% | 68 | 76.25 | 76.78 | 0.69% |
| 539 | 71 | TORPEDO/BULLET | U | 4368:55 | | | | no | no | 103.4% | 248 | 77.37 | 79.43 | 2.66% |
| 540 | 71 | TORPEDO/BULLET | D | 4534:51 | | | | no | no | 97.5% | 62 | 76.46 | 74.28 | -2.85% |
| 541 | 71 | TORPEDO/BULLET | C | 4554:56 | | | | no | no | 97.3% | 121 | 74.41 | 72.29 | -2.85% |
| 542 | 71 | TORPEDO/BULLET | C | 4554:56 | | | | no | no | 99.2% | 66 | 77.01 | 76.09 | -1.20% |
| 543 | 71 | TORPEDO/BULLET | C | 4554:56 | | | | no | no | 98.2% | 94 | 74.70 | 73.30 | -1.88% |
| 544 | 72 | TORPEDO/BULLET | D | 3845:44 | | | | no | no | 100.3% | 101 | 89.06 | 89.76 | 0.78% |
| 545 | 72 | TORPEDO/BULLET | U | 4368:55 | | | | no | no | 101.3% | 24 | 90.43 | 92.46 | 2.25% |
| 546 | 72 | TORPEDO/BULLET | D | 3845:44 | | | | no | no | 99.4% | 93 | 85.51 | 85.95 | 0.52% |
| 547 | 73 | TORPEDO/BULLET | U | 4414:26 | | | | no | no | 102.7% | 98 | 84.78 | 87.52 | 3.23% |
| 548 | 73 | TORPEDO/BULLET | D | 4534:51 | | | | no | no | 98.2% | 8 | 86.11 | 84.52 | -1.84% |
| 549 | 73 | TORPEDO/BULLET | U | 4414:26 | | | | no | no | 107.5% | 303 | 79.21 | 85.74 | 8.25% |
| 550 | 74 | TORPEDO/BULLET | D | 4534:51 | | | | no | no | 101.9% | 16 | 66.40 | 68.38 | 2.98% |
| 551 | 74 | TORPEDO/BULLET | U | 4414:26 | | | | no | no | 101.1% | 210 | 66.30 | 67.41 | 1.68% |
| 552 | 74 | TORPEDO/BULLET | D | 4534:51 | | | | no | no | 99.5% | -18 | 65.66 | 65.89 | 0.36% |
| 553 | 75 | TORPEDO/BULLET | U | 4414:26 | | | | no | no | 107.0% | 168 | 74.03 | 80.28 | 8.45% |
| 554 | 75 | TORPEDO/BULLET | D | 4534:51 | | | | no | no | 102.3% | 25 | 74.81 | 77.16 | 3.14% |
| 555 | 75 | TORPEDO/BULLET | U | 4414:26 | | | | no | no | 108.1% | 162 | 72.25 | 77.77 | 7.64% |
| 556 | 76 | SPOTLIGHT/REFLECTOR | D | 4534:32 | | | | no | no | 102.5% | 65 | 70.30 | 71.91 | 2.29% |
| 557 | 76 | SPOTLIGHT/REFLECTOR | U | 4414:26 | | | | no | no | 101.6% | 30 | 71.75 | 73.91 | 3.00% |
| 558 | 76 | SPOTLIGHT/REFLECTOR | D | 4534:32 | | | | no | no | 97.8% | 95 | 73.90 | 72.81 | -1.47% |
| 559 | 76 | SPOTLIGHT/REFLECTOR | R | 3845:44 | | | | no | no | 103.4% | 67 | 71.29 | 74.80 | 4.92% |
| 560 | 76 | SPOTLIGHT/REFLECTOR | R | 3845:44 | | | | no | no | 100.5% | 27 | 72.86 | 74.35 | 2.05% |
| 561 | 76 | SPOTLIGHT/REFLECTOR | R | 3845:44 | | | | no | no | 100.8% | 18 | 71.53 | 73.22 | 2.37% |
| 562 | 77 | SPOTLIGHT/REFLECTOR | U | 4379:08 | | | | no | no | 104.5% | 15 | 76.86 | 79.50 | 3.43% |
| 563 | 77 | SPOTLIGHT/REFLECTOR | D | 4173:08 | | | | no | no | 103.4% | 7 | 76.80 | 78.27 | 1.92% |
| 564 | 77 | SPOTLIGHT/REFLECTOR | U | 4379:08 | | | | no | no | 102.0% | 32 | 76.44 | 78.24 | 2.35% |
| 565 | 77 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 104.2% | 16 | 76.35 | 78.67 | 3.04% |
| 566 | 77 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 103.8% | 18 | 77.38 | 79.75 | 3.07% |
| 567 | 77 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 104.2% | 22 | 77.42 | 79.60 | 2.81% |
| 568 | 78 | SPOTLIGHT/REFLECTOR | D | 4534:51 | | | | no | no | 97.5% | 62 | 74.85 | 72.41 | -3.26% |
| 569 | 78 | SPOTLIGHT/REFLECTOR | U | 4414:26 | | | | no | no | 99.7% | 160 | 75.09 | 74.69 | -0.53% |

| Test Units | | | | Early Failure Timing | | | | | | Calculated Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | Burn Time | Fail Time | Pre-Fail Time | Pre-Fail Mode | Pre-Fail Only? | Zombie? | Lumen Maintenance | Color Shift | Initial Efficacy | Final Efficacy | Efficacy Change |
| 570 | 78 | SPOTLIGHT/REFLECTOR | D | 4534:51 | | | | no | no | 97.4% | 83 | 73.78 | 71.51 | -3.08% |
| 571 | 78 | SPOTLIGHT/REFLECTOR | R | 3401:17 | 3401:17 | | | no | no | 0.0% | | 75.82 | #DIV/0! | #DIV/0! |
| 572 | 78 | SPOTLIGHT/REFLECTOR | R | 3845:44 | | | | no | no | 93.8% | 114 | 74.53 | 66.74 | -10.45% |
| 573 | 78 | SPOTLIGHT/REFLECTOR | R | 3845:44 | | | | no | no | 93.3% | 120 | 74.87 | 68.32 | -8.75% |
| 574 | 79 | SPOTLIGHT/REFLECTOR | U | 3938:34 | | | | no | no | 97.8% | 48 | 76.58 | 74.87 | -2.23% |
| 575 | 79 | SPOTLIGHT/REFLECTOR | D | 4534:32 | | | | no | no | 98.7% | 28 | 76.32 | 75.36 | -1.26% |
| 576 | 79 | SPOTLIGHT/REFLECTOR | U | 3938:34 | | | | no | no | 101.8% | 34 | 77.47 | 78.70 | 1.59% |
| 577 | 79 | SPOTLIGHT/REFLECTOR | R | 4225:25 | | | | no | no | 99.9% | 43 | 78.57 | 78.59 | 0.03% |
| 578 | 79 | SPOTLIGHT/REFLECTOR | R | 4225:25 | | | | no | no | 102.0% | 51 | 75.64 | 77.12 | 1.97% |
| 579 | 79 | SPOTLIGHT/REFLECTOR | R | 4225:25 | | | | no | no | 100.8% | 40 | 79.31 | 80.15 | 1.07% |
| 580 | 80 | SPOTLIGHT/REFLECTOR | U | 4085:12 | | | | no | no | 103.1% | 9 | 71.29 | 74.16 | 4.03% |
| 581 | 80 | SPOTLIGHT/REFLECTOR | D | 4055:30 | | | | no | no | 106.0% | 36 | 69.63 | 73.75 | 5.92% |
| 582 | 80 | SPOTLIGHT/REFLECTOR | U | 4085:12 | | | | no | no | 104.9% | 25 | 70.51 | 73.01 | 3.54% |
| 583 | 80 | SPOTLIGHT/REFLECTOR | R | 4379:08 | | | | no | no | 101.6% | 22 | 70.39 | 70.78 | 0.55% |
| 584 | 80 | SPOTLIGHT/REFLECTOR | R | 3511:08 | 3511:08 | | | no | no | 0.0% | | 70.47 | #DIV/0! | #DIV/0! |
| 585 | 80 | SPOTLIGHT/REFLECTOR | R | 4379:08 | | | | no | no | 104.1% | -6 | 70.06 | 72.70 | 3.77% |
| 586 | 81 | SPOTLIGHT/REFLECTOR | D | 4290:03 | | | | no | no | 102.9% | 8 | 73.92 | 76.13 | 2.99% |
| 587 | 81 | SPOTLIGHT/REFLECTOR | U | 4085:12 | | | | no | no | 103.2% | 19 | 74.63 | 76.96 | 3.12% |
| 588 | 81 | SPOTLIGHT/REFLECTOR | D | 4290:03 | | | | no | no | 102.5% | 9 | 76.25 | 73.77 | -3.26% |
| 589 | 81 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 102.5% | 25 | 75.43 | 77.10 | 2.21% |
| 590 | 81 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 103.7% | 31 | 66.12 | 68.89 | 4.18% |
| 591 | 81 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 101.2% | 44 | 70.56 | 71.35 | 1.12% |
| 592 | 82 | SPOTLIGHT/REFLECTOR | U | 4085:12 | | | | no | no | 103.9% | 37 | 65.55 | 67.73 | 3.33% |
| 593 | 82 | SPOTLIGHT/REFLECTOR | D | 4055:30 | | | | no | no | 103.5% | 28 | 66.51 | 68.07 | 2.34% |
| 594 | 82 | SPOTLIGHT/REFLECTOR | U | 4085:12 | | | | no | no | 102.4% | 35 | 62.57 | 63.68 | 1.78% |
| 595 | 82 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 100.9% | 15 | 64.24 | 65.03 | 1.24% |
| 596 | 82 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 103.2% | 29 | 64.70 | 65.61 | 1.41% |
| 597 | 82 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 101.5% | 24 | 65.58 | 66.73 | 1.76% |
| 598 | 83 | SPOTLIGHT/REFLECTOR | D | 4055:30 | | | | no | no | 104.6% | 36 | 69.00 | 72.18 | 4.61% |
| 599 | 83 | SPOTLIGHT/REFLECTOR | U | 4368:55 | | | | no | no | 105.3% | 3 | 72.40 | 75.66 | 4.51% |
| 600 | 83 | SPOTLIGHT/REFLECTOR | D | 4055:30 | | | | no | no | 103.8% | 16 | 70.52 | 72.80 | 3.23% |
| 601 | 83 | SPOTLIGHT/REFLECTOR | R | 4173:08 | | | | no | no | 104.1% | 1 | 70.34 | 73.17 | 4.03% |
| 602 | 83 | SPOTLIGHT/REFLECTOR | R | 4173:08 | | | | no | no | 101.0% | 4 | 71.22 | 72.43 | 1.70% |
| 603 | 83 | SPOTLIGHT/REFLECTOR | R | 4173:08 | | | | no | no | 101.6% | 6 | 70.44 | 71.65 | 1.72% |
| 616 | 86 | SPOTLIGHT/REFLECTOR | D | 4173:08 | | | | no | no | 99.6% | 62 | 92.88 | 92.01 | -0.94% |
| 617 | 86 | SPOTLIGHT/REFLECTOR | U | 4379:08 | | | | no | no | 99.1% | 125 | 92.41 | 90.25 | -2.34% |
| 618 | 86 | SPOTLIGHT/REFLECTOR | D | 4173:08 | | | | no | no | 99.3% | 102 | 92.51 | 90.97 | -1.66% |
| 619 | 86 | SPOTLIGHT/REFLECTOR | R | 2293:25 | 2293:25 | | | no | yes | 0.0% | | 93.03 | #DIV/0! | #DIV/0! |
| 620 | 86 | SPOTLIGHT/REFLECTOR | R | 4379:08 | | | | no | no | 100.4% | 115 | 91.62 | 91.07 | -0.60% |
| 621 | 86 | SPOTLIGHT/REFLECTOR | R | 4379:08 | | | | no | no | 102.3% | 100 | 89.18 | 90.07 | 1.00% |
| 622 | 87 | SPOTLIGHT/REFLECTOR | U | 4414:56 | | | | no | no | 103.6% | 7 | 65.19 | 67.75 | 3.93% |
| 623 | 87 | SPOTLIGHT/REFLECTOR | D | 4173:08 | | | | no | no | 100.9% | 7 | 66.81 | 67.67 | 1.29% |
| 624 | 87 | SPOTLIGHT/REFLECTOR | U | 4414:56 | | | | no | no | 102.9% | 20 | 65.50 | 67.19 | 2.58% |
| 625 | 87 | SPOTLIGHT/REFLECTOR | R | 4252:48 | | | | no | no | 103.3% | 8 | 64.60 | 66.21 | 2.49% |
| 626 | 87 | SPOTLIGHT/REFLECTOR | R | 4252:48 | | | | no | no | 103.9% | 18 | 65.50 | 68.27 | 4.23% |
| 627 | 87 | SPOTLIGHT/REFLECTOR | R | 4252:48 | | | | no | no | 103.7% | 1 | 65.94 | 68.05 | 3.21% |
| 634 | 89 | SPOTLIGHT/REFLECTOR | D | 4173:08 | | | | no | no | 96.9% | 87 | 55.93 | 54.54 | -2.48% |
| 635 | 89 | SPOTLIGHT/REFLECTOR | U | 4379:08 | | | | no | no | 99.9% | 52 | 62.98 | 63.40 | 0.67% |
| 636 | 89 | SPOTLIGHT/REFLECTOR | D | 4173:08 | | | | no | no | 101.1% | 43 | 56.64 | 57.42 | 1.38% |
| 637 | 89 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 98.6% | 106 | 56.95 | 56.29 | -1.15% |
| 638 | 89 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 103.1% | 15 | 73.81 | 77.12 | 4.48% |
| 639 | 89 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 104.3% | 13 | 71.54 | 74.41 | 4.01% |
| 640 | 90 | SPOTLIGHT/REFLECTOR | D | 4055:30 | | | | no | no | 102.9% | 15 | 87.01 | 90.13 | 3.58% |
| 641 | 90 | SPOTLIGHT/REFLECTOR | U | 4368:55 | | | | no | no | 104.1% | 74 | 86.33 | 90.56 | 4.90% |
| 642 | 90 | SPOTLIGHT/REFLECTOR | D | 4055:30 | | | | no | no | 100.6% | 35 | 86.35 | 87.00 | 0.75% |
| 643 | 90 | SPOTLIGHT/REFLECTOR | R | 4085:12 | | | | no | no | 103.3% | 5 | 80.87 | 83.74 | 3.54% |
| 644 | 90 | SPOTLIGHT/REFLECTOR | R | 4085:12 | | | | no | no | 103.7% | 305 | 83.44 | 87.38 | 4.72% |
| 645 | 90 | SPOTLIGHT/REFLECTOR | R | 4085:12 | | | | no | no | 102.7% | 14 | 87.15 | 90.18 | 3.48% |
| 646 | 91 | SPOTLIGHT/REFLECTOR | U | 4368:55 | | | | no | no | 102.9% | 150 | 65.19 | 66.94 | 2.68% |
| 647 | 91 | SPOTLIGHT/REFLECTOR | D | 4534:51 | | | | no | no | 102.5% | 43 | 61.60 | 62.87 | 2.06% |
| 648 | 91 | SPOTLIGHT/REFLECTOR | U | 4368:55 | | | | no | no | 102.7% | 153 | 62.30 | 63.63 | 2.14% |
| 649 | 91 | SPOTLIGHT/REFLECTOR | R | 4534:32 | | | | no | no | 100.8% | 31 | 63.58 | 64.12 | 0.85% |
| 650 | 91 | SPOTLIGHT/REFLECTOR | R | 4534:32 | | | | no | no | 100.9% | 50 | 63.42 | 64.06 | 1.01% |
| 651 | 91 | SPOTLIGHT/REFLECTOR | R | 4534:32 | | | | no | no | 103.0% | 60 | 62.67 | 64.36 | 2.71% |
| 658 | 93 | SPOTLIGHT/REFLECTOR | U | 3938:34 | | | | no | no | 101.2% | 44 | 72.34 | 73.48 | 1.58% |

| Test Units | | | | Early Failure Timing | | | | | | Calculated Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | Burn Time | Fail Time | Pre-Fail Time | Pre-Fail Mode | Pre-Fail Only? | Zombie? | Lumen Maintenance | Color Shift | Initial Efficacy | Final Efficacy | Efficacy Change |
| 659 | 93 | SPOTLIGHT/REFLECTOR | D | 4055:30 | | 847:12 | CYCLING | yes | no | 101.0% | 65 | 73.08 | 73.66 | 0.78% |
| 660 | 93 | SPOTLIGHT/REFLECTOR | U | 3938:34 | | | | no | no | 101.0% | 76 | 73.33 | 73.80 | 0.64% |
| 661 | 93 | SPOTLIGHT/REFLECTOR | R | 4534:32 | | | | no | no | 101.7% | 69 | 71.99 | 73.16 | 1.63% |
| 662 | 93 | SPOTLIGHT/REFLECTOR | R | 4534:32 | | | | no | no | 99.8% | 53 | 76.91 | 76.85 | -0.07% |
| 663 | 93 | SPOTLIGHT/REFLECTOR | R | 4534:32 | | | | no | no | 99.7% | 72 | 73.34 | 73.33 | 0.00% |
| 664 | 94 | SPOTLIGHT/REFLECTOR | D | 4290:03 | | | | no | no | 95.7% | 54 | 57.81 | 55.10 | -4.69% |
| 665 | 94 | SPOTLIGHT/REFLECTOR | U | 4085:12 | | | | no | no | 98.9% | 51 | 57.36 | 56.55 | -1.40% |
| 666 | 94 | SPOTLIGHT/REFLECTOR | D | 4290:03 | | | | no | no | 100.7% | 49 | 60.41 | 60.65 | 0.40% |
| 667 | 94 | SPOTLIGHT/REFLECTOR | R | 3943:16 | 3943:16 | | | no | no | 0.0% | | 62.79 | #DIV/0! | #DIV/0! |
| 668 | 94 | SPOTLIGHT/REFLECTOR | R | 3536:43 | 3536:43 | | | no | no | 0.0% | | 56.26 | #DIV/0! | #DIV/0! |
| 669 | 94 | SPOTLIGHT/REFLECTOR | R | 3869:13 | 3869:13 | | | no | no | 0.0% | | 57.66 | #DIV/0! | #DIV/0! |
| 670 | 95 | SPOTLIGHT/REFLECTOR | U | 3938:34 | | | | no | no | 101.3% | 40 | 76.00 | 76.78 | 1.03% |
| 671 | 95 | SPOTLIGHT/REFLECTOR | D | 4055:30 | | | | no | no | 102.7% | 56 | 72.78 | 74.72 | 2.67% |
| 672 | 95 | SPOTLIGHT/REFLECTOR | U | 3938:34 | | | | no | no | 101.3% | 50 | 73.43 | 73.76 | 0.46% |
| 673 | 95 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 103.9% | 54 | 71.42 | 73.93 | 3.51% |
| 674 | 95 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 97.6% | 56 | 79.07 | 76.99 | -2.63% |
| 675 | 95 | SPOTLIGHT/REFLECTOR | R | 3574:35 | 3574:35 | | | no | no | 0.0% | | 74.44 | #DIV/0! | #DIV/0! |
| 676 | 96 | SPOTLIGHT/REFLECTOR | D | 4055:30 | | 1778:14 | CYCLING | yes | no | 99.3% | 32 | 74.73 | 73.79 | -1.27% |
| 677 | 96 | SPOTLIGHT/REFLECTOR | U | 4057:07 | | | | no | no | 99.6% | 40 | 73.01 | 72.50 | -0.69% |
| 678 | 96 | SPOTLIGHT/REFLECTOR | D | 4055:30 | | | | no | no | 99.2% | 33 | 74.20 | 73.52 | -0.92% |
| 679 | 96 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 97.1% | 83 | 72.10 | 70.09 | -2.79% |
| 680 | 96 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | 4312:53 | CYCLING | yes | no | 100.6% | 55 | 72.64 | 72.55 | -0.13% |
| 681 | 96 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 99.4% | 66 | 74.86 | 74.26 | -0.79% |
| 682 | 97 | SPOTLIGHT/REFLECTOR | U | 4414:56 | | | | no | no | 101.1% | 40 | 59.19 | 60.05 | 1.46% |
| 683 | 97 | SPOTLIGHT/REFLECTOR | D | 4173:08 | | | | no | no | 102.4% | 31 | 60.48 | 61.74 | 2.08% |
| 684 | 97 | SPOTLIGHT/REFLECTOR | U | 4414:56 | | | | no | no | 102.2% | 39 | 56.57 | 57.86 | 2.28% |
| 685 | 97 | SPOTLIGHT/REFLECTOR | R | 4379:08 | | | | no | no | 103.7% | 52 | 61.66 | 63.97 | 3.75% |
| 686 | 97 | SPOTLIGHT/REFLECTOR | R | 4379:08 | | | | no | no | 101.7% | 36 | 58.11 | 58.87 | 1.32% |
| 687 | 97 | SPOTLIGHT/REFLECTOR | R | 2533:07 | 2533:07 | | | no | no | 0.0% | | 59.60 | #DIV/0! | #DIV/0! |
| 688 | 98 | SPOTLIGHT/REFLECTOR | D | 4290:03 | | | | no | no | 102.1% | 62 | 58.32 | 60.33 | 3.45% |
| 689 | 98 | SPOTLIGHT/REFLECTOR | U | 4368:55 | | | | no | no | 102.0% | 60 | 58.32 | 59.44 | 1.93% |
| 690 | 98 | SPOTLIGHT/REFLECTOR | D | 4290:03 | | | | no | no | 102.8% | 40 | 54.40 | 55.95 | 2.84% |
| 691 | 98 | SPOTLIGHT/REFLECTOR | R | 4225:25 | | | | no | no | 101.3% | 53 | 57.55 | 58.02 | 0.81% |
| 692 | 98 | SPOTLIGHT/REFLECTOR | R | 4225:25 | | | | no | no | 101.0% | 73 | 60.07 | 60.58 | 0.86% |
| 693 | 98 | SPOTLIGHT/REFLECTOR | R | 4225:25 | | | | no | no | 102.8% | 50 | 60.58 | 62.23 | 2.71% |
| 694 | 99 | SPOTLIGHT/REFLECTOR | U | 4085:12 | | | | no | no | 101.9% | -13 | 68.80 | 69.80 | 1.45% |
| 695 | 99 | SPOTLIGHT/REFLECTOR | D | 4055:30 | | | | no | no | 104.3% | 5 | 67.79 | 70.76 | 4.38% |
| 696 | 99 | SPOTLIGHT/REFLECTOR | U | 4085:12 | | | | no | no | 103.5% | -1 | 69.98 | 72.60 | 3.74% |
| 697 | 99 | SPOTLIGHT/REFLECTOR | R | 4379:08 | | | | no | no | 101.6% | -43 | 67.30 | 68.68 | 2.06% |
| 698 | 99 | SPOTLIGHT/REFLECTOR | R | 4379:08 | | | | no | no | 101.6% | -37 | 66.25 | 67.20 | 1.43% |
| 699 | 99 | SPOTLIGHT/REFLECTOR | R | 1663:06 | 1663:06 | | | no | no | 0.0% | | 56.68 | #DIV/0! | #DIV/0! |
| 700 | 100 | SPOTLIGHT/REFLECTOR | D | 4225:25 | | | | no | no | 102.3% | 40 | 61.43 | 62.57 | 1.86% |
| 701 | 100 | SPOTLIGHT/REFLECTOR | U | 4085:12 | | | | no | no | 101.3% | 14 | 64.14 | 65.00 | 1.33% |
| 702 | 100 | SPOTLIGHT/REFLECTOR | D | 4225:25 | | | | no | no | 101.2% | 20 | 65.15 | 65.36 | 0.32% |
| 703 | 100 | SPOTLIGHT/REFLECTOR | R | 4252:48 | | | | no | no | 96.4% | 75 | 61.84 | 59.32 | -4.07% |
| 704 | 100 | SPOTLIGHT/REFLECTOR | R | 4252:48 | | | | no | no | 97.3% | 77 | 64.75 | 62.96 | -2.77% |
| 705 | 100 | SPOTLIGHT/REFLECTOR | R | 4252:48 | | | | no | no | 98.3% | 49 | 62.48 | 61.43 | -1.69% |
| 706 | 101 | SPOTLIGHT/REFLECTOR | U | 4085:12 | | | | no | no | 101.9% | 27 | 86.28 | 87.80 | 1.77% |
| 707 | 101 | SPOTLIGHT/REFLECTOR | D | 4055:30 | | | | no | no | 101.7% | 23 | 84.37 | 86.06 | 1.99% |
| 708 | 101 | SPOTLIGHT/REFLECTOR | U | 4085:12 | | | | no | no | 102.6% | 30 | 85.62 | 88.08 | 2.87% |
| 709 | 101 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 101.3% | 10 | 83.77 | 85.05 | 1.53% |
| 710 | 101 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 102.4% | 44 | 84.32 | 86.54 | 2.63% |
| 711 | 101 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 100.4% | 38 | 86.06 | 86.40 | 0.39% |
| 712 | 102 | SPOTLIGHT/REFLECTOR | D | 4173:08 | | | | no | no | 99.2% | 58 | 60.67 | 60.55 | -0.19% |
| 713 | 102 | SPOTLIGHT/REFLECTOR | U | 4085:12 | | | | no | no | 103.0% | 93 | 57.95 | 59.99 | 3.51% |
| 714 | 102 | SPOTLIGHT/REFLECTOR | D | 4173:08 | | | | no | no | 104.1% | 84 | 59.58 | 61.31 | 2.91% |
| 715 | 102 | SPOTLIGHT/REFLECTOR | R | 4252:48 | | | | no | no | 89.6% | 132 | 59.36 | 53.10 | -10.54% |
| 716 | 102 | SPOTLIGHT/REFLECTOR | R | 3638:24 | 3638:24 | 2522:05 | CYCLING | no | no | 0.0% | | 56.28 | #DIV/0! | #DIV/0! |
| 717 | 102 | SPOTLIGHT/REFLECTOR | R | 4252:48 | | | | no | no | 104.3% | 71 | 53.48 | 55.10 | 3.03% |
| 724 | 104 | SPOTLIGHT/REFLECTOR | D | 4173:08 | | | | no | no | 96.5% | 6 | 72.65 | 69.87 | -3.82% |
| 725 | 104 | SPOTLIGHT/REFLECTOR | U | 4085:12 | | | | no | no | 96.8% | 24 | 73.69 | 70.85 | -3.85% |
| 726 | 104 | SPOTLIGHT/REFLECTOR | D | 4173:08 | | | | no | no | 96.4% | 31 | 71.13 | 68.26 | -4.04% |
| 727 | 104 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 98.8% | 50 | 72.77 | 71.49 | -1.76% |
| 728 | 104 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 98.4% | 38 | 72.70 | 71.72 | -1.34% |
| 729 | 104 | SPOTLIGHT/REFLECTOR | R | 4414:56 | | | | no | no | 97.3% | 58 | 73.15 | 70.92 | -3.06% |

| Test Units | | | | Early Failure Timing | | | | | | Calculated Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | Burn Time | Fail Time | Pre-Fail Time | Pre-Fail Mode | Pre-Fail Only? | Zombie? | Lumen Maintenance | Color Shift | Initial Efficacy | Final Efficacy | Efficacy Change |
| 730 | 105 | SPOTLIGHT/REFLECTOR | U | 4414:56 | | | | no | no | 102.3% | 32 | 94.63 | 97.03 | 2.54% |
| 731 | 105 | SPOTLIGHT/REFLECTOR | D | 4173:08 | | | | no | no | 102.1% | 39 | 95.23 | 96.58 | 1.42% |
| 732 | 105 | SPOTLIGHT/REFLECTOR | U | 4414:56 | | | | no | no | 102.5% | 38 | 92.89 | 94.98 | 2.24% |
| 733 | 105 | SPOTLIGHT/REFLECTOR | R | 4379:08 | | | | no | no | 99.4% | 63 | 93.06 | 92.20 | -0.92% |
| 734 | 105 | SPOTLIGHT/REFLECTOR | R | 4379:08 | | | | no | no | 101.6% | 27 | 92.14 | 93.31 | 1.27% |
| 735 | 105 | SPOTLIGHT/REFLECTOR | R | 4379:08 | | | | no | no | 96.7% | 60 | 94.48 | 91.24 | -3.42% |
| 736 | 106 | SPOTLIGHT/REFLECTOR | D | 4173:08 | | | | no | no | 98.1% | 96 | 100.71 | 98.56 | -2.13% |
| 737 | 106 | SPOTLIGHT/REFLECTOR | U | 4414:56 | | | | no | no | 97.5% | 96 | 103.08 | 100.49 | -2.52% |
| 738 | 106 | SPOTLIGHT/REFLECTOR | D | 4173:08 | | | | no | no | 97.9% | 99 | 102.52 | 100.06 | -2.41% |
| 739 | 106 | SPOTLIGHT/REFLECTOR | R | 3160:21 | 3160:21 | 3160:21 | <70% L.O | no | no | 0.0% | | 100.82 | #DIV/0! | #DIV/0! |
| 740 | 106 | SPOTLIGHT/REFLECTOR | R | 4252:48 | | | | no | no | 98.4% | 0 | 101.83 | 99.82 | -1.98% |
| 741 | 106 | SPOTLIGHT/REFLECTOR | R | 4252:48 | | | | no | no | 102.5% | 13 | 103.23 | 105.60 | 2.30% |
| 742 | 107 | SPOTLIGHT/REFLECTOR | U | 4057:07 | | | | no | no | 98.6% | 60 | 65.72 | 64.33 | -2.11% |
| 743 | 107 | SPOTLIGHT/REFLECTOR | D | 4534:32 | | | | no | no | 97.0% | 75 | 66.05 | 63.73 | -3.52% |
| 744 | 107 | SPOTLIGHT/REFLECTOR | U | 4057:07 | | | | no | no | 88.8% | 45 | 67.35 | 59.77 | -11.25% |
| 745 | 107 | SPOTLIGHT/REFLECTOR | R | 4379:08 | | | | no | no | 91.6% | 133 | 65.84 | 60.16 | -8.62% |
| 746 | 107 | SPOTLIGHT/REFLECTOR | R | 4379:08 | | | | no | no | 90.1% | 155 | 64.76 | 58.69 | -9.37% |
| 747 | 107 | SPOTLIGHT/REFLECTOR | R | 4379:08 | | | | no | no | 91.8% | 133 | 65.77 | 60.09 | -8.64% |
| 748 | 108 | SPOTLIGHT/REFLECTOR | D | 3845:44 | | | | no | no | 104.5% | 45 | 87.28 | 90.25 | 3.41% |
| 749 | 108 | SPOTLIGHT/REFLECTOR | U | 4057:07 | | | | no | no | 104.6% | 28 | 90.09 | 94.48 | 4.87% |
| 750 | 108 | SPOTLIGHT/REFLECTOR | D | 3845:44 | | | | no | no | 103.8% | 36 | 87.90 | 91.17 | 3.72% |
| 751 | 108 | SPOTLIGHT/REFLECTOR | R | 4534:32 | | | | no | no | 102.9% | 81 | 86.29 | 88.31 | 2.35% |
| 752 | 108 | SPOTLIGHT/REFLECTOR | R | 4534:32 | | | | no | no | 96.7% | 66 | 86.02 | 83.03 | -3.47% |
| 753 | 108 | SPOTLIGHT/REFLECTOR | R | 4534:32 | | | | no | no | 96.4% | 101 | 86.23 | 82.91 | -3.85% |
| 754 | 109 | SPOTLIGHT/REFLECTOR | U | 4414:26 | | 562:05 | <5 CYCLE E | yes | no | 103.1% | 20 | 80.49 | 82.71 | 2.76% |
| 755 | 109 | SPOTLIGHT/REFLECTOR | D | 4290:03 | | | | no | no | 96.1% | -30 | 79.75 | 76.72 | -3.79% |
| 756 | 109 | SPOTLIGHT/REFLECTOR | U | 4414:26 | | 705:44 | <5 CYCLE E | yes | no | 104.2% | 99 | 82.04 | 85.66 | 4.41% |
| 757 | 109 | SPOTLIGHT/REFLECTOR | R | 4225:25 | | | | no | no | 100.2% | 37 | 82.29 | 82.97 | 0.83% |
| 758 | 109 | SPOTLIGHT/REFLECTOR | R | 4225:25 | | | | no | no | 99.7% | 34 | 82.60 | 82.76 | 0.20% |
| 759 | 109 | SPOTLIGHT/REFLECTOR | R | 4225:25 | | | | no | no | 102.0% | 33 | 81.09 | 82.53 | 1.77% |
| 760 | 110 | SPOTLIGHT/REFLECTOR | D | 4055:30 | | | | no | no | 104.2% | 34 | 72.86 | 75.73 | 3.94% |
| 761 | 110 | SPOTLIGHT/REFLECTOR | U | 4368:55 | | | | no | no | 104.9% | 126 | 72.08 | 74.81 | 3.79% |
| 762 | 110 | SPOTLIGHT/REFLECTOR | D | 4055:30 | | | | no | no | 102.4% | 11 | 75.83 | 77.46 | 2.15% |
| 763 | 110 | SPOTLIGHT/REFLECTOR | R | 4225:25 | | | | no | no | 101.3% | 29 | 75.63 | 76.53 | 1.18% |
| 764 | 110 | SPOTLIGHT/REFLECTOR | R | 4225:25 | | | | no | no | 102.7% | 8 | 74.40 | 76.55 | 2.90% |
| 765 | 110 | SPOTLIGHT/REFLECTOR | R | 4225:25 | | | | no | no | 101.0% | 28 | 74.53 | 74.86 | 0.43% |
| 766 | 111 | SPOTLIGHT/REFLECTOR | D | 4534:32 | | | | no | no | 102.2% | 23 | 64.20 | 65.49 | 2.01% |
| 767 | 111 | SPOTLIGHT/REFLECTOR | U | 4085:12 | | | | no | no | 103.7% | 13 | 62.09 | 63.75 | 2.66% |
| 768 | 111 | SPOTLIGHT/REFLECTOR | D | 4534:32 | | | | no | no | 102.8% | 28 | 60.01 | 61.51 | 2.50% |
| 769 | 111 | SPOTLIGHT/REFLECTOR | R | 4085:12 | | | | no | no | 99.8% | 20 | 62.16 | 62.87 | 1.14% |
| 770 | 111 | SPOTLIGHT/REFLECTOR | R | 4085:12 | | | | no | no | 103.0% | 20 | 62.40 | 64.77 | 3.79% |
| 771 | 111 | SPOTLIGHT/REFLECTOR | R | 4085:12 | | | | no | no | 102.9% | 45 | 63.87 | 66.25 | 3.73% |
| 1001 | 201 | TRIM KIT | R | 4252:48 | | | | no | no | 102.4% | -36 | 72.86 | 74.29 | 1.96% |
| 1002 | 201 | TRIM KIT | R | 4252:48 | | | | no | no | 102.4% | -26 | 71.98 | 73.96 | 2.75% |
| 1003 | 201 | TRIM KIT | R | 4252:48 | | | | no | no | 102.7% | -26 | 53.08 | 54.52 | 2.72% |
| 1004 | 202 | TRIM KIT | R | 4085:12 | | | | no | no | 102.2% | -25 | 52.68 | 54.24 | 2.95% |
| 1005 | 202 | TRIM KIT | R | 4085:12 | | | | no | no | 102.9% | -25 | 54.45 | 56.21 | 3.23% |
| 1006 | 202 | TRIM KIT | R | 4085:12 | | | | no | no | 102.7% | -29 | 54.82 | 56.11 | 2.36% |
| 1007 | 203 | TRIM KIT | R | 4173:08 | | | | no | no | 101.7% | -11 | 62.94 | 64.15 | 1.91% |
| 1008 | 203 | TRIM KIT | R | 4173:08 | | | | no | no | 103.8% | -9 | 62.60 | 64.81 | 3.52% |
| 1009 | 203 | TRIM KIT | R | 4173:08 | | | | no | no | 103.7% | -9 | 61.40 | 63.96 | 4.16% |
| 1010 | 204 | TRIM KIT | R | 4379:08 | | | | no | no | 102.0% | 38 | 56.10 | 57.29 | 2.13% |
| 1011 | 204 | TRIM KIT | R | 4379:08 | | | | no | no | 102.4% | 29 | 55.71 | 56.99 | 2.30% |
| 1012 | 204 | TRIM KIT | R | 4379:08 | | | | no | no | 101.9% | 33 | 56.48 | 57.41 | 1.66% |
| 1013 | 205 | TRIM KIT | R | 4085:12 | | | | no | no | 101.4% | 12 | 72.91 | 74.04 | 1.55% |
| 1014 | 205 | TRIM KIT | R | 4085:12 | | | | no | no | 101.1% | 8 | 72.88 | 73.80 | 1.27% |
| 1015 | 205 | TRIM KIT | R | 4085:12 | | | | no | no | 106.1% | 32 | 58.60 | 62.50 | 6.66% |
| 1016 | 206 | TRIM KIT | R | 4379:08 | | | | no | no | 101.5% | -3 | 55.05 | 55.60 | 1.00% |
| 1017 | 206 | TRIM KIT | R | 4379:08 | | | | no | no | 99.8% | 14 | 51.51 | 51.29 | -0.42% |
| 1018 | 206 | TRIM KIT | R | 4379:08 | | | | no | no | 100.8% | 5 | 53.40 | 53.94 | 1.01% |
| 1019 | 207 | TRIM KIT | R | 4085:12 | | | | no | no | 100.3% | -3 | 61.69 | 61.30 | -0.63% |
| 1020 | 207 | TRIM KIT | R | 4085:12 | | | | no | no | 100.8% | -3 | 61.41 | 60.95 | -0.74% |
| 1021 | 207 | TRIM KIT | R | 4085:12 | | | | no | no | 99.6% | -1 | 61.80 | 61.19 | -0.99% |
| 1022 | 208 | TRIM KIT | R | 4379:08 | | | | no | no | 102.1% | 25 | 56.32 | 57.72 | 2.47% |
| 1023 | 208 | TRIM KIT | R | 4379:08 | | | | no | no | 99.3% | 14 | 56.58 | 56.83 | 0.44% |

| Test Units | | | | Early Failure Timing | | | | | | Calculated Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lamp # | Model # | Lamp Type | Test Fixture | Burn Time | Fail Time | Pre-Fail Time | Pre-Fail Mode | Pre-Fail Only? | Zombie? | Lumen Maintenance | Color Shift | Initial Efficacy | Final Efficacy | Efficacy Change |
| 1024 | 208 | TRIM KIT | R | 4379:08 | | | | no | no | 97.7% | 39 | 55.50 | 54.57 | -1.68% |
| 1025 | 209 | TRIM KIT | R | 4085:12 | | | | no | no | 102.5% | 0 | 65.50 | 67.55 | 3.13% |
| 1026 | 209 | TRIM KIT | R | 4085:12 | | | | no | no | 102.5% | -4 | 63.35 | 65.62 | 3.58% |
| 1027 | 209 | TRIM KIT | R | 4173:08 | | | | no | no | 101.9% | -5 | 64.72 | 66.40 | 2.59% |
| 1028 | 210 | TRIM KIT | R | 4173:08 | | | | no | no | 98.9% | 29 | 65.52 | 65.20 | -0.49% |
| 1029 | 210 | TRIM KIT | R | 4173:08 | | | | no | no | 98.6% | 19 | 65.47 | 64.87 | -0.93% |
| 1030 | 210 | TRIM KIT | R | 4173:08 | | | | no | no | 99.7% | 21 | 65.16 | 65.36 | 0.31% |
| 1031 | 211 | TRIM KIT | R | 4252:48 | | | | no | no | 100.2% | 36 | 65.84 | 65.38 | -0.71% |
| 1032 | 211 | TRIM KIT | R | 4252:48 | | | | no | no | 99.0% | 41 | 67.18 | 66.71 | -0.70% |
| 1033 | 211 | TRIM KIT | R | 4252:48 | | | | no | no | 99.6% | 33 | 66.71 | 66.54 | -0.25% |
| 1034 | 212 | TRIM KIT | R | 4173:08 | | | | no | no | 103.7% | 13 | 69.05 | 71.62 | 3.72% |
| 1035 | 212 | TRIM KIT | R | 4173:08 | | | | no | no | 105.1% | 7 | 66.44 | 69.81 | 5.07% |
| 1036 | 212 | TRIM KIT | R | 4173:08 | | | | no | no | 103.3% | 7 | 67.57 | 69.60 | 3.00% |
| 1037 | 213 | TRIM KIT | R | 4252:48 | | | | no | no | 104.8% | 11 | 66.04 | 68.93 | 4.37% |
| 1038 | 213 | TRIM KIT | R | 4252:48 | | | | no | no | 104.5% | 5 | 65.76 | 68.25 | 3.79% |
| 1039 | 213 | TRIM KIT | R | 4252:48 | | | | no | no | 104.7% | 8 | 65.43 | 68.18 | 4.20% |

# APPENDIX B NOTABLE EVENTS DURING MAINTENANCE TESTING

While the experiment mainly proceeded as planned during the maintenance test, there were a few notable events during this 15-month period that are worthy of mention. Specifically:

- Due to power outages at the facility or equipment failures (e.g. relay failures, control computer failures, etc.) there were several periods in which the testing was temporarily suspended. In most cases the duration of these shutdowns was less than 48 hours. There was one equipment failure that led to 2 of the 22 test cycles being down for nearly one month before it was identified and repaired. In all cases, power to lamps was interrupted during the suspensions, so these periods were effectively “long cool down periods” that neither impacted the lamp operating hours nor the number of thermal cycles. All time lost to these suspensions was recovered by added equivalent testing time at the end of the test so that all circuits were operated for a full 15 month duration.

- A key database for tracking results was corrupted midway through testing. This required laboratory staff to recreate a database of failures from raw data (preserved in the control computer file systems and back up data systems) and to double-check these results with physically inspections of all test lamps.

- While most lamps that failed during testing did so in a non-ambiguous manner (e.g. they were functioning as expected and then suddenly stopped functioning entirely), a significant number exhibited behavior that was not always easy for laboratory personnel to classify as a failure or not. This is relevant as the failure time is only recorded when lamps transition from “working” to “failed.” Ambiguous failure behaviors included:
  - Lamps operating normally most of the time but occasionally flickering or cycling on and off.
  - Lamps experiencing a sudden drop in light output but still providing a significant amount of light (e.g. more than 50% of initial light output)
  - Lamps that appeared to have failed later were found to be functional.

For sudden drops in light output and cycling, the laboratory noted the time that these “pre-failure” conditions first occurred and continued maintenance testing these lamps. In many cases, these pre-failures were followed shortly with full failures, and the time of the final failure was also recorded. In the case of the lamps that appeared to be failed but were later found to be working (19 lamps total) these were not identified until lamps were prepared for failure analysis testing. The laboratory practice to verify failures was for a technician to physically check lamps after the data acquisition system measured a sudden drop in light output for a lamp. Technicians would observe that the lamp was non-functional in the test location and them remove the lamp and attempt to operate it again in a separately powered socket. If the lamp was still not responsive, then it would be considered a failure with a failure time as specified by the data acquisition system. For the 19 lamps in question, all failed these physically checks but then were found to be functional at the end of the maintenance testing when they were checked a third time prior to being inspected for failure analysis. It is likely that these lamps had some sort of thermal protection within their circuitry that caused them to be non-operational soon after they were initially flagged as failures which was reset some time later (when they were fully cool).

In the results discussion, we provide a further explanation of how we grouped and analyzed these “grey area” failures.

# APPENDIX C   LOGIT MODEL REGRESSION RESULTS

| Parameter | Model 1 | | | | | Model 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Max Rescaled R square - 0.4606 | | | | | Max Rescaled R square - 0.6449 | | | | |
| | Estimate | Standard Error | P Value | Marginal Change in Odds Ratio | Marginal % Change in Likelihood of Failure | Estimate | Standard Error | P Value | Marginal Change in Odds Ratio | Marginal % Change in Likelihood of Failure |
| Intercept | -36.0821 | 8.6478 | <.0001 | 0.00 | -100% | - | - | - | - | - |
| 95% Warm Time | -0.034 | 0.0139 | 0.0146 | 0.97 | -3% | -0.034 | 0.0139 | 0.0146 | 0.97 | -3% |
| Maximum Temperature | 0.057 | 0.0168 | 0.0007 | 1.06 | 6% | 0.0569 | 0.0168 | 0.0007 | 1.06 | 6% |
| Power | 0.1061 | 0.0954 | 0.2665 | 1.11 | 11% | 0.106 | 0.0954 | 0.2665 | 1.11 | 11% |
| Lumens | 0.000607 | 0.000864 | 0.4825 | 1.00 | 0% | 0.000607 | 0.000864 | 0.4825 | 1.00 | 0% |
| Power Factor | 14.5232 | 7.6791 | 0.0586 | 2029297.03 | 202929603% | 14.5321 | 7.6804 | 0.0585 | 2047438.38 | 204743738% |
| THD | 0.00502 | 0.0215 | 0.8156 | 1.01 | 1% | 0.00504 | 0.0215 | 0.8149 | 1.01 | 1% |
| CRI | 0.1152 | 0.047 | 0.0141 | 1.12 | 12% | 0.1152 | 0.047 | 0.0141 | 1.12 | 12% |
| R Fixture Flag | 0.8974 | 0.4502 | 0.0462 | 2.45 | 145% | -35.1938 | 8.6091 | <.0001 | 0.00 | -100% |
| D Fixture Flag | 0.0595 | 0.4349 | 0.8913 | 1.06 | 6% | -36.0319 | 8.6615 | <.0001 | 0.00 | -100% |
| C Fixture Flag | 0.527 | 0.4017 | 0.1895 | 1.69 | 69% | -35.5642 | 8.6672 | <.0001 | 0.00 | -100% |
| U Fixture Flag | - | - | - | - | - | -36.0913 | 8.649 | <.0001 | 0.00 | -100% |
| CEC Compliant Flag | -2.6709 | 0.5563 | <.0001 | 0.07 | -93% | -2.6709 | 0.5563 | <.0001 | 0.07 | -93% |
| A-Lamp Flag | 1.4744 | 0.8711 | 0.0906 | 4.37 | 337% | 1.4745 | 0.8712 | 0.0905 | 4.37 | 337% |
| Torpedo/Bullet Flag | 1.3412 | 1.0483 | 0.2008 | 3.82 | 282% | 1.3413 | 1.0484 | 0.2008 | 3.82 | 282% |
| Reflector Flag | -0.0459 | 0.8607 | 0.9575 | 0.96 | -4% | -0.0459 | 0.8607 | 0.9575 | 0.96 | -4% |
| Cycles per Day | 0.00784 | 0.1042 | 0.9400 | 1.01 | 1% | 0.00785 | 0.1042 | 0.9400 | 1.01 | 1% |
| Number of Hours On per Day | 0.7525 | 0.1931 | <.0001 | 2.12 | 112% | 0.7525 | 0.1931 | <.0001 | 2.12 | 112% |
| Power/D Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Power/C Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Power/U Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Power/A-Lamp Interaction | - | - | - | - | - | - | - | - | - | - |
| Power/Torpedo Interaction | - | - | - | - | - | - | - | - | - | - |
| Power/Reflector Interaction | - | - | - | - | - | - | - | - | - | - |
| Power/Globe Interaction | - | - | - | - | - | - | - | - | - | - |
| A-Lamp/R Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| A-Lamp/D Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| A-Lamp/C Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| A-Lamp/U Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Reflector/D Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Reflector/R Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Reflector/U Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Torpedo/D Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Torpedo/U Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Torpedo/C Fixture Interaction | - | - | - | - | - | - | - | - | - | - |

*Model 8 does not contain any A-Lamps in the data used for the logit regression modeling

| Parameter | Model 3 | | | | | Model 4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Max Rescaled R square - 0.6382 | | | | | Max Rescaled R square - 0.6383 | | | | |
| | Estimate | Standard Error | P Value | Marginal Change in Odds Ratio | Marginal % Change in Likelihood of Failure | Estimate | Standard Error | P Value | Marginal Change in Odds Ratio | Marginal % Change in Likelihood of Failure |
| Intercept | - | - | - | - | - | - | - | - | - | - |
| 95% Warm Time | - | - | - | - | - | -0.0354 | 0.0139 | 0.0110 | 0.97 | -3% |
| Maximum Temperature | 0.0603 | 0.0167 | 0.0003 | 1.06 | 6% | 0.0507 | 0.0164 | 0.0020 | 1.05 | 5% |
| Power | 0.0791 | 0.095 | 0.4049 | 1.08 | 8% | 0.1666 | 0.0911 | 0.0676 | 1.18 | 18% |
| Lumens | 0.000807 | 0.00085 | 0.3424 | 1.00 | 0% | -5.73E-08 | 0.000818 | 0.9999 | 1.00 | 0% |
| Power Factor | 15.1124 | 7.6297 | 0.0476 | 3657900.84 | 365789984% | 15.0099 | 7.5477 | 0.0467 | 3301541.37 | 330154037% |
| THD | 0.00531 | 0.0214 | 0.8035 | 1.01 | 1% | 0.00605 | 0.0211 | 0.7748 | 1.01 | 1% |
| CRI | 0.1198 | 0.0468 | 0.0106 | 1.13 | 13% | - | - | - | - | - |
| R Fixture Flag | -37.348 | 8.563 | <.0001 | 0.00 | -100% | -25.9227 | 7.6146 | 0.0007 | 0.00 | -100% |
| D Fixture Flag | -37.8644 | 8.6231 | <.0001 | 0.00 | -100% | -26.879 | 7.6912 | 0.0005 | 0.00 | -100% |
| C Fixture Flag | -37.5851 | 8.6178 | <.0001 | 0.00 | -100% | -26.3334 | 7.6868 | 0.0006 | 0.00 | -100% |
| U Fixture Flag | -37.8516 | 8.6122 | <.0001 | 0.00 | -100% | -26.9079 | 7.6733 | 0.0005 | 0.00 | -100% |
| CEC Compliant Flag | -2.9289 | 0.5519 | <.0001 | 0.05 | -95% | -1.6556 | 0.3524 | <.0001 | 0.19 | -81% |
| A-Lamp Flag | 1.3111 | 0.8384 | 0.1179 | 3.71 | 271% | 1.763 | 0.886 | 0.0466 | 5.83 | 483% |
| Torpedo/Bullet Flag | 1.1502 | 1.0095 | 0.2545 | 3.16 | 216% | 1.6583 | 1.0671 | 0.1202 | 5.25 | 425% |
| Reflector Flag | -0.437 | 0.8219 | 0.5949 | 0.65 | -35% | 0.0749 | 0.8777 | 0.9320 | 1.08 | 8% |
| Cycles per Day | 0.1787 | 0.0799 | 0.0253 | 1.20 | 20% | -0.0104 | 0.1026 | 0.9190 | 0.99 | -1% |
| Number of Hours On per Day | 0.5157 | 0.1668 | 0.0020 | 1.67 | 67% | 0.7634 | 0.1914 | <.0001 | 2.15 | 115% |
| Power/D Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Power/C Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Power/U Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Power/A-Lamp Interaction | - | - | - | - | - | - | - | - | - | - |
| Power/Torpedo Interaction | - | - | - | - | - | - | - | - | - | - |
| Power/Reflector Interaction | - | - | - | - | - | - | - | - | - | - |
| Power/Globe Interaction | - | - | - | - | - | - | - | - | - | - |
| A-Lamp/R Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| A-Lamp/D Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| A-Lamp/C Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| A-Lamp/U Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Reflector/D Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Reflector/R Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Reflector/U Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Torpedo/D Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Torpedo/U Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Torpedo/C Fixture Interaction | - | - | - | - | - | - | - | - | - | - |

*Model 8 does not contain any A-Lamps in the data used for the logit regression modeling

| Parameter | Model 5 | | | | | Model 6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Max Rescaled R square - 0.6528 | | | | | Max Rescaled R square -0.6288 | | | | |
| | Estimate | Standard Error | P Value | Marginal Change in Odds Ratio | Marginal % Change in Likelihood of Failure | Estimate | Standard Error | P Value | Marginal Change in Odds Ratio | Marginal % Change in Likelihood of Failure |
| Intercept | - | - | - | - | - | - | | - | - | - |
| 95% Warm Time | -0.0322 | 0.0144 | 0.0253 | 0.97 | -3% | -0.037 | 0.0140 | 0.0081 | 0.96 | -4% |
| Maximum Temperature | 0.0431 | 0.0178 | 0.0152 | 1.04 | 4% | 0.03 | 0.0173 | 0.0832 | 1.03 | 3% |
| Power | - | - | - | - | - | - | - | - | - | - |
| Lumens | -0.00051 | 0.0009 | 0.5548 | 1.00 | 0% | -0.00101 | 0.0009 | 0.2642 | 1.00 | 0% |
| Power Factor | 11.6695 | 7.5420 | 0.1218 | 116949.79 | 11694879% | -2.3208 | 2.1038 | 0.2700 | 0.10 | -90% |
| THD | 0.000266 | 0.0213 | 0.9900 | 1.00 | 0% | -0.0374 | 0.0093 | <.0001 | 0.96 | -4% |
| CRI | 0.097 | 0.0469 | 0.0389 | 1.10 | 10% | -0.0532 | 0.0279 | 0.0566 | 0.95 | -5% |
| R Fixture Flag | -29.7709 | 8.5240 | 0.0005 | 0.00 | -100% | - | - | - | - | - |
| D Fixture Flag | -31.0282 | 8.5449 | 0.0003 | 0.00 | -100% | - | - | - | - | - |
| C Fixture Flag | -30.2586 | 8.5661 | 0.0004 | 0.00 | -100% | - | - | - | - | - |
| U Fixture Flag | -30.9172 | 8.5408 | 0.0003 | 0.00 | -100% | - | - | - | - | - |
| CEC Compliant Flag | -2.5364 | 0.5522 | <.0001 | 0.08 | -92% | -1.0324 | 0.3999 | 0.0098 | 0.36 | -64% |
| A-Lamp Flag | - | - | - | - | - | - | - | - | - | - |
| Torpedo/Bullet Flag | - | - | - | - | - | - | - | - | - | - |
| Reflector Flag | - | - | - | - | - | - | - | - | - | - |
| Cycles per Day | 0.0227 | 0.1047 | 0.8287 | 1.02 | 2% | -0.0988 | 0.0916 | 0.2807 | 0.91 | -9% |
| Number of Hours On per Day | 0.7878 | 0.1948 | <.0001 | 2.20 | 120% | 0.6189 | 0.1835 | 0.0007 | 1.86 | 86% |
| Power/D Fixture Interaction | - | - | - | - | - | 0.0033 | 0.1172 | 0.9776 | 1.00 | 0% |
| Power/C Fixture Interaction | - | - | - | - | - | 0.0802 | 0.1189 | 0.5000 | 1.08 | 8% |
| Power/U Fixture Interaction | - | - | - | - | - | 0.00448 | 0.1179 | 0.9697 | 1.00 | 0% |
| Power/A-Lamp Interaction | 0.2797 | 0.1011 | 0.0056 | 1.32 | 32% | 0.2704 | 0.0922 | 0.0034 | 1.31 | 31% |
| Power/Torpedo Interaction | 0.2817 | 0.1791 | 0.1158 | 1.33 | 33% | 0.2093 | 0.1530 | 0.1715 | 1.23 | 23% |
| Power/Reflector Interaction | 0.11 | 0.0891 | 0.2170 | 1.12 | 12% | 0.0882 | 0.0896 | 0.3249 | 1.09 | 9% |
| Power/Globe Interaction | 0.2481 | 0.1650 | 0.1328 | 1.28 | 28% | - | - | - | - | - |
| A-Lamp/R Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| A-Lamp/D Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| A-Lamp/C Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| A-Lamp/U Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Reflector/D Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Reflector/R Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Reflector/U Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Torpedo/D Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Torpedo/U Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Torpedo/C Fixture Interaction | - | - | - | - | - | - | - | - | - | - |

*Model 8 does not contain any A-Lamps in the data used for the logit regression modeling

| Parameter | Model 7 | | | | | Model 8* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Max Rescaled R square - 0.6164 | | | | | Max Rescaled R square - 0.8000 | | | | |
| | Estimate | Standard Error | P Value | Marginal Change in Odds Ratio | Marginal % Change in Likelihood of Failure | Estimate | Standard Error | P Value | Marginal Change in Odds Ratio | Marginal % Change in Likelihood of Failure |
| Intercept | - | | - | - | - | - | - | - | - | - |
| 95% Warm Time | -0.0517 | 0.0138 | 0.0002 | 0.95 | -5% | 0.033 | 0.0242 | 0.1732 | 1.03 | 3% |
| Maximum Temperature | 0.0479 | 0.0168 | 0.0043 | 1.05 | 5% | 0.0604 | 0.0269 | 0.0245 | 1.06 | 6% |
| Power | 0.1809 | 0.0932 | 0.0521 | 1.20 | 20% | 0.0376 | 0.1811 | 0.8356 | 1.04 | 4% |
| Lumens | 0.000065 | 0.0008 | 0.9387 | 1.00 | 0% | -0.00225 | 0.00218 | 0.3018 | 1.00 | 0% |
| Power Factor | -1.1238 | 2.3514 | 0.6327 | 0.33 | -67% | 20.8766 | 7.8534 | 0.0079 | 1165714452.57 | 116571445157% |
| THD | -0.0361 | 0.0094 | 0.0001 | 0.96 | -4% | 0.057 | 0.0291 | 0.0504 | 1.06 | 6% |
| CRI | -0.0908 | 0.0256 | 0.0004 | 0.91 | -9% | -0.3196 | 0.1019 | 0.0017 | 0.73 | -27% |
| R Fixture Flag | - | - | - | - | - | - | - | - | - | - |
| D Fixture Flag | - | - | - | - | - | - | - | - | - | - |
| C Fixture Flag | - | - | - | - | - | - | - | - | - | - |
| U Fixture Flag | - | - | - | - | - | - | - | - | - | - |
| CEC Compliant Flag | - | - | - | - | - | 0.7363 | 1.0188 | 0.4698 | 2.09 | 109% |
| A-Lamp Flag | - | - | - | - | - | - | - | - | - | - |
| Torpedo/Bullet Flag | - | - | - | - | - | - | - | - | - | - |
| Reflector Flag | - | - | - | - | - | - | - | - | - | - |
| Cycles per Day | -0.1372 | 0.0930 | 0.1399 | 0.87 | -13% | 0.2131 | 0.2129 | 0.3168 | 1.24 | 24% |
| Number of Hours On per Day | 0.6797 | 0.1859 | 0.0003 | 1.97 | 97% | -0.2987 | 0.5146 | 0.5616 | 0.74 | -26% |
| Power/D Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Power/C Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Power/U Fixture Interaction | - | - | - | - | - | - | - | - | - | - |
| Power/A-Lamp Interaction | - | - | - | - | - | - | - | - | - | - |
| Power/Torpedo Interaction | - | - | - | - | - | - | - | - | - | - |
| Power/Reflector Interaction | - | - | - | - | - | - | - | - | - | - |
| Power/Globe Interaction | - | - | - | - | - | - | - | - | - | - |
| A-Lamp/R Fixture Interaction | 2.2675 | 0.8670 | 0.0089 | 9.66 | 866% | - | - | - | - | - |
| A-Lamp/D Fixture Interaction | 1.5612 | 0.7882 | 0.0476 | 4.76 | 376% | - | - | - | - | - |
| A-Lamp/C Fixture Interaction | 1.8808 | 0.8383 | 0.0249 | 6.56 | 556% | - | - | - | - | - |
| A-Lamp/U Fixture Interaction | 1.2753 | 0.8157 | 0.1179 | 3.58 | 258% | - | - | - | - | - |
| Reflector/D Fixture Interaction | -0.1443 | 1.0229 | 0.8878 | 0.87 | -13% | - | - | - | - | - |
| Reflector/R Fixture Interaction | 0.9534 | 0.8362 | 0.2543 | 2.59 | 159% | - | - | - | - | - |
| Reflector/U Fixture Interaction | -0.3356 | 1.0117 | 0.7401 | 0.71 | -29% | - | - | - | - | - |
| Torpedo/D Fixture Interaction | 0.1768 | 1.3405 | 0.8951 | 1.19 | 19% | - | - | - | - | - |
| Torpedo/U Fixture Interaction | 0.0504 | 1.3316 | 0.9698 | 1.05 | 5% | - | - | - | - | - |
| Torpedo/C Fixture Interaction | 2.3839 | 1.0085 | 0.0181 | 10.85 | 985% | - | - | - | - | - |

*Model 8 does not contain any A-Lamps in the data used for the logit regression modeling

# APPENDIX D POST MORTEM FORENSIC ANALYSIS

August 2017

# Light-Emitting Diode (LED) Lamp Failure Analysis for the California Public Utilities Commission LED Laboratory Test Study

## Report

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RTI INTERNATIONAL

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## FIGURES

# LIST OF ACRONYMS

| | |
|---|---|
| °C | degree Celsius |
| A | ampere |
| AC | alternating current |
| CPUC | California Public Utilities Commission |
| DC | direct current |
| IC | integrated circuit |
| LED | light-emitting diode |
| MOSFET | metal-oxide semiconductor field-effect transistor |
| PCB | printed circuit board |
| SEM | scanning electron microscopy |
| SSL | solid-state lighting |
| V | volt |
| W | watt |

# 1. INTRODUCTION

A determination of failure location for light-emitting diode (LED) test lamps provides insight into LED-based lighting product robustness and is essential to the development of better solid-state lighting (SSL) technologies for illuminating homes and offices. This report summarizes failure analysis studies of LED lamps subjected to four different test conditions as part of an investigation, led by Itron Inc., for the California Public Utilities Commission (CPUC).[1] There are two main assemblies in an LED lamp where a failure can occur: the LED drivers and the LED modules. Understanding how these two assemblies function, both together and apart, is necessary to identify failure location and improve the reliability of SSL products. Such information not only benefits manufacturers of LED-based lighting products and their customers, but it also benefits electric utilities due to the potential of SSL technologies to significantly reduce electricity consumption from lighting.

## 1.1 LED Driver

Most LED lighting devices use a driver to convert mains electricity to the proper voltage and current necessary to capitalize on the efficiency of LEDs. These drivers are typically constant current providers, meaning that the driver will vary the voltage across its load (i.e., the LEDs) to maintain a constant electric current. A consistent power supply is essential to these devices because it maintains regulated light output and ensures device reliability. There are some common driver topologies that use switched-mode power supplies to deliver high electrical efficiencies. The common driver topologies are boost, buck, buck-boost, and flyback. These drivers rely on an integrated circuit (IC) controller to operate a transistor. The transistor is responsible for regulating the device, and it achieves this by switching on and off at high frequency.

Within each driver, there are five (or more) electronic circuits that are used to convert mains electricity to the power necessary to operate LEDs. Failure of a component, or loss of electrical connection between components, in any of these circuits would be catastrophic to overall device performance. These circuits include the following:[2]

- **Filter and condition** — the input mains electricity (often alternating current [AC] power) is filtered by inductors and capacitors. A fuse is in this circuit to protect the driver from sudden power surges.

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[1] Ting, M. and E. Page. 2016. EnergyStar Lighting Webinar titled *CPUC LED Lab Test Study Update*. September 29. Available at https://www.energystar.gov/sites/default/files/asset/document/Michael%20Ting%20CPUC%20LED%20Lab%20Test.pdf

[2] Davis, J.L., K. Mills, R. Yaga, C. Johnson, and J. Young. 2017. Chapter 15: Assessing the reliability of electrical drivers used in LED–based lighting devices. *Solid State Lighting Reliability Part 2: Components to Systems*. doi: 10.1007/978-3-319-58174-3_15

- **Rectify** — the input AC electricity is converted to direct current (DC) electricity by a diode bridge, capacitors, resistors, and diodes.
- **Shaping and power factor correction (PFC)** — the rectified DC power is shaped by the control IC, capacitors, inductors, and/or resistors to reduce ripple and to provide PFC.
- **Switched-mode control** — the switching transistor is operated by the control IC to regulate output power. Other components (e.g., inductors, capacitors, diodes) help with this operation.
- **Final Filtering** — the DC output power is filtered by components such as electrolytic capacitors, film capacitors, inductors, transformers, and/or opto-isolators.

Each of the previously mentioned driver topologies use different component configurations within the five electrical circuits to convert mains electricity to a desired DC output power. Boost driver topologies are step-up drivers (i.e., they convert mains voltage to a higher output voltage), whereas buck drivers are step-down drivers (i.e., they convert mains voltage to a lower output voltage). Both driver topologies typically have electrically coupled AC mains and DC outputs, but they can be distinguished by an inductor in the switched-mode control circuit that is characteristic of buck topologies. Flyback driver topologies can be step-up or step-down drivers, and they have a distinguishable isolation transformer that electrically isolates the AC mains from the DC output. Because there are different high-stress locations for each driver topology, this report will focus on categorizing failure location by electronic circuit and driver topology.

## 1.2 LED Module

An LED module is an assembly of LED packages on a printed circuit board (PCB) and additional thermal, mechanical, and electrical interfaces to connect to the load side of an LED driver. Interruption of the electrical or thermal connections provided by the LED module could result in abrupt failure of the device. Additionally, loss of contact between the module and individual LEDs or LED packages (e.g., in the way of solder failure) would also be detrimental to the operation of the LED lamp. The information in this report can be used to identify any such connection losses in the failed test lamps.

# 2. METHODS

A three-step analysis process was proposed to identify the point of failure for each failed LED lamp. These three steps involved (1) initial inspection and disassembly, (2) interior inspection, and (3) electrical continuity testing of key components. Each of these three steps is further described in Subsections 2.1 through 2.3 of this report. Although this proposed method has been very successful at identifying LED device failure location in the past, the failed lamps examined herein had a much lower component failure rate than expected. Therefore, additional analysis beyond the proposed process was performed to identify the location of the failure. This additional analysis included some thermal, electrical, and surface composition testing.

## 2.1 Initial Inspection and Disassembly

The first step in this analysis was an inspection of the as-received lamps that included an electrical power consumption test as described in Subsection 2.1.1 of this report. The second step in this analysis was to disassemble the device as described in Subsection 2.1.2. Because of the high force needed to disassemble some of the failed LED test lamps, the condition of each lamp was carefully documented prior to and over the course of disassembly to detect and record any artificial damage induced during disassembly. For example, if too much force is applied when breaking the glass globe, the impact of the shattering glass could induce LED solder failure.

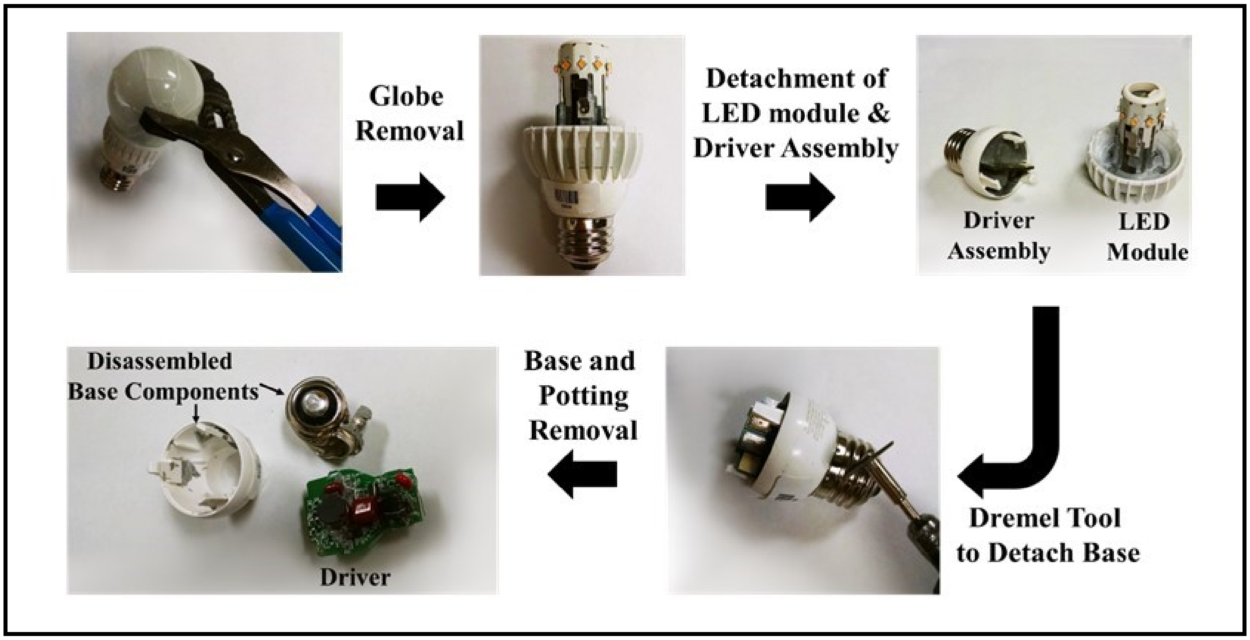
### *2.1.1 Initial Inspection*

The failed LED test lamps received by RTI International were configured in a base-up, bare-socket fixture, and power was supplied to perform an initial electrical test. Power consumption analysis of the failed test lamp was performed with a Kill A Watt™ EZ Power Meter. As described in Subsection 2.1.2, most lamps exhibited residual power consumption, which indicates some level of electrical function in the device even if light is not produced. For devices that did illuminate, perceived brightness, flicker rate, and other signs of damage (e.g., audible rattling within the lamp, discoloration) were noted.

### *2.1.2 Lamp Disassembly Procedure*

The steps involved in the disassembly of a sample test lamp are presented in **Figure 2-1**. Briefly, the globe of the test lamp was removed via a bandsaw (for plastic globes) or groove-joint pliers (for glass globes). The test lamps were then powered in a base-up, bare-socket fixture to examine the LED module and record any defects (e.g., solder failure, brittle encapsulation, discolorations, reduced light output) within individual LED packages. The LED module and heatsink assembly were removed from the driver and base assembly (by pin-and-clip detachment or wire cutting). Finally, the base was disconnected from the driver with a Dremel tool. In some instances, the driver was encapsulated in a silicone potting material, which was removed with a flathead screwdriver.

**Figure 2-1. Key steps in the disassembly of LED test lamps.**




## 2.2 Interior Inspection

The driver electronics, LED module, individual LEDs, and all interconnections were visually inspected for signs of discoloration, solder failure in components, and charred or heat-stressed components, and other issues. The observed deformities were documented and, in some cases, photographed if many lamps experienced the same types of deformities. The topology of the driver was determined at this stage by looking for characteristic components such as a flyback transformer or a buck inductor. Examination of the controller IC also helped to determine driver typology.

## 2.3 Electrical Continuity Testing of Key Components

The continuity and functionality of major driver components (i.e., fuses, inductors, transformers, transistors, diodes, diode bridges, and the control IC) were examined with a Radioshack True RMS Digital Multimeter. If a component failed and/or if there was a continuity failure between components, then the failure location was assigned to the electrical circuit that encompassed that component (some devices had more than one component failure and were thus assigned more than one failure location). For devices in which the main electrical components functioned properly, and the LEDs did not experience solder failure, more testing was performed (see Subsection 2.4 of this report).

## 2.4 Further Testing

When the failure location for test lamps could not be determined from the initial testing, the control lamps of the corresponding model number were compared with the failed lamps from the CPUC tests (i.e., test lamps). The operating temperature of each control lamp (on the surface of the globe, within the globe, and sometimes by the control IC) was recorded, and then compared with the test lamp. The globes of the test and control lamps were then removed to enable additional comparisons.

The Radioshack True RMS Digital Multimeter was used to measure the DC output voltage produced by the control and test drivers connected to control and test the LED module loads. As such, four output voltages were measured (see **Figure 2-2**). These output voltages are of the

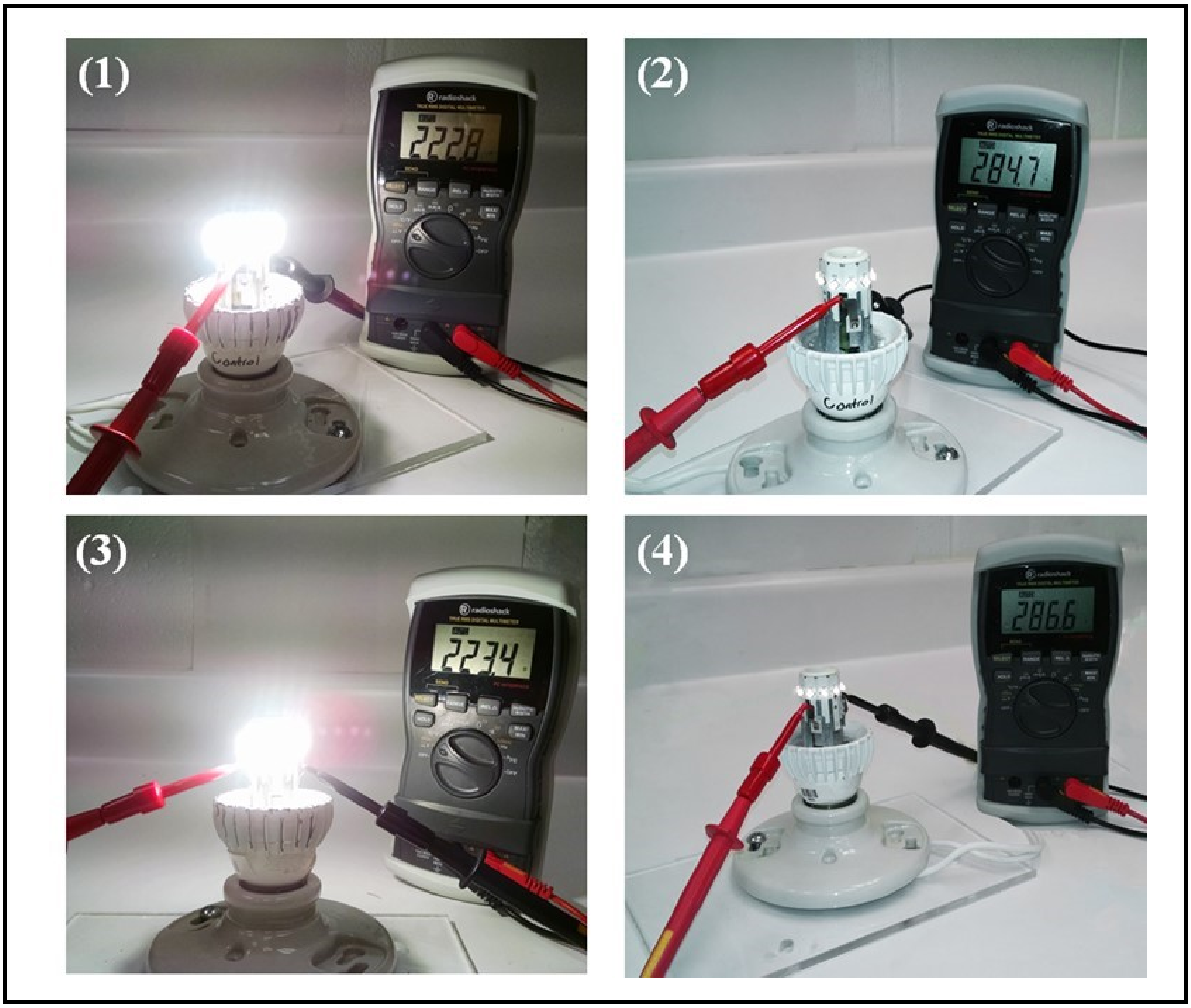
1. Control driver connected with the control LED module
2. Control driver connected with the test LED module
3. Test driver connected with the control LED module
4. Test driver connected with the test LED module.

In addition, the power consumptions of the four configurations were recorded with a Kill A Watt EZ Power Meter. The ideal operating voltage and power consumption for each lamp model were assigned as the voltage measured between the control driver and control LED module load and the corresponding power consumption, respectively. Deviations from the ideal operating voltage were assessed to narrow failure location to the test driver (if the test driver was unable to operate the control LED module) or test LED module (if the control and test drivers operated the control LED module, but could not operate the test LED module).

The example shown in **Figure 2-2** highlights a test lamp in which failure was limited to the LED module. For this test lamp, both the control and test LED drivers reached a voltage much higher than the ideal voltage when paired with the test LED module, but were still unable to produce significant illumination (**Figure 2-2**, panels 2 and 4, respectively). When paired with the control LED module, both the control and test driver operated at a much lower voltage (223 V) and with far greater illumination (**Figure 2-2**, panels 1 and 3, respectively). In constant current drivers, a forward current is preset, and the driver varies the voltage to an appropriate level to provide the preset forward current. If illumination from a device is low at the maximum operating voltage of the driver, then this suggests that an inadequate amount of current is being supplied to the LED module. Inadequate current output could be the result of a defective driver or a change in the LED module load. To distinguish the two, it is necessary to understand that drivers have a maximum operating voltage. Because the voltages supplied by the drivers connected with the test LED module in **Figure 2-2** are significantly greater than the ideal voltage, this implies that there has been a change in load. The supplied voltage is higher because the drivers are attempting to deliver an appropriate current to the load. Ultimately, the drivers cannot deliver the appropriate current within their designed voltage range (i.e., the driver voltage is being maximized; thus, the current can only reach a specific value). Such behavior usually indicates a change in the LED module.

Because many failures were localized to the LED module, scanning electron microscopy (SEM) was used to determine the surface topology and composition of LED solder joints and the LED contacts and pads (when applicable). These results are discussed further in Section 3 of this report.

**Figure 2-2. Output voltages of the control driver (1 and 2) and the test driver (3 and 4) with a control LED module load and test LED module load, respectively.**



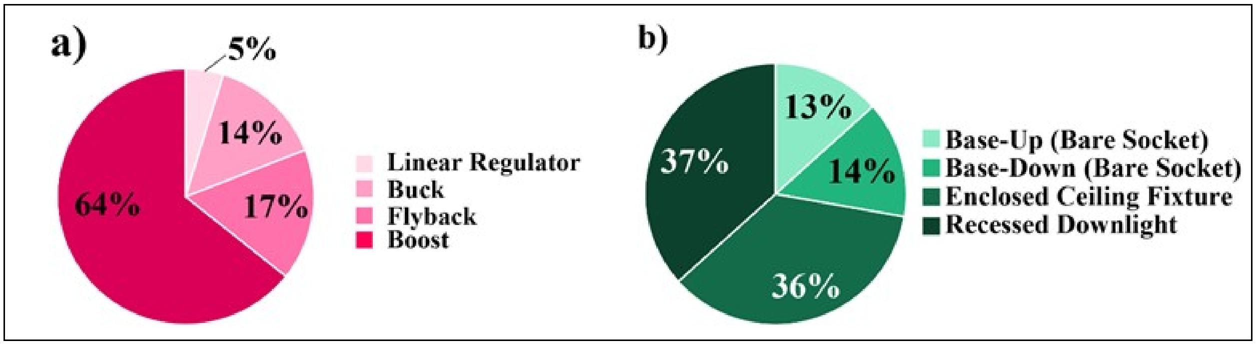

# 3. RESULTS

The location of test lamp failure was investigated for 26 LED lamp models, which consisted of a total of 84 failed devices. The drivers for most of the failed devices (64%) had a boost topology (**Figure 3-1a**). Additionally, more than two-thirds of the failed test lamps were operated in an enclosed ceiling fixture or recessed downlight (**Figure 3-1b**). These fixtures thermally isolate lamps, increasing operating temperatures by 20°C or more. This finding suggests that thermal stress has a significant impact on device failure time.

Failure location analysis of the test LED lamps revealed the following three major trends that will be discussed in more detail throughout this section of the report:

1. There were few catastrophic failures of the driver components or LEDs.
2. There were many solder and/or contact failures.
3. There were correlations between driver topology and failure location and between model number and failure location.

**Figure 3-1. Categorization of failed test lamps by (a) driver topology and (b) luminary fixture type.**




## 3.1 Abrupt Failures

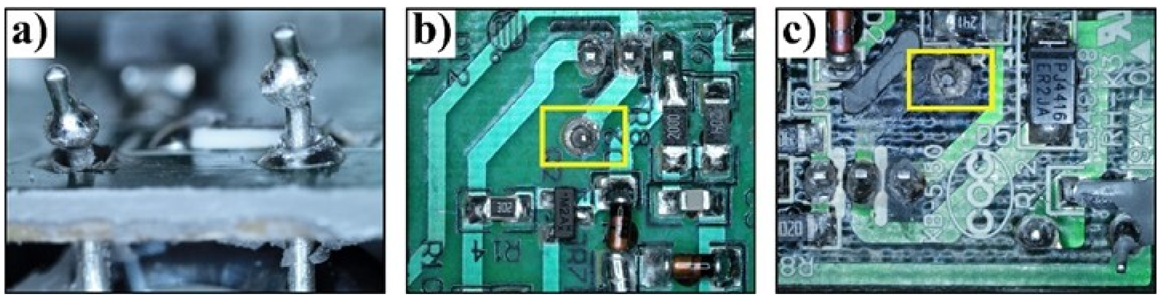
Interestingly, initial visual and electrical analysis of the LED modules and drivers (as described in Subsections 2.1 through 2.3) confirmed failure location for only one-third of the devices. In addition, 20 devices exhibited continuity or functionality failure of a driver component, and another 12 devices showed confirmed signs of LED module failure (e.g., complete solder failure, extreme discoloration, signs of excessive heat).

### *3.1.1 Driver Continuity Failures*

Abrupt continuity and/or functionality failure of a driver component was prevalent in devices using a flyback topology (10 out of the 14 failed driver devices with a flyback typology experienced this type of failure). Typical continuity failures for tested flyback driver topologies included through-hole solder failure and localized signs of heat stress near the transformer and metal-oxide semiconductor field-effect transistor (MOSFET) components (**Figure 3-2**). Other through-hole solder failure (e.g., capacitors, inductors, power lines), as well as open fuses, broken diode bridges, or any combination thereof, were also found on flyback driver topologies and on failed devices with boost (six devices) and buck (four devices) topologies. Through-hole failures were often manifested as visible cracks in the solder joint, often of a circular nature (see **Figures 3-2b and 3-2c**). In some instances, the solder joint fractured completely, and the lead separated from the joint (see **Figure 3-2a**).

The continuity failures were likely the result of localized heat induced by switching cycles in the switched-mode control and final filtering stages, as evidenced by the large number of transformer to MOSFET and inductor to MOSFET solder failures and localized signs of heat stress on the driver at these locations (**Figure 3-2c**).

**Figure 3-2. Major continuity failures for drivers: (a) capacitor solder failure, (b) transformer solder failure, and (c) multiple solder and component failure (transformer and capacitor solder failures with localized heat stress are shown). Yellow boxes highlight the solder failure.**




### *3.1.2 LED Module Continuity Failures*

Care was taken to minimize damage to the LED module during disassembly, and signs of complete LED package solder failure (i.e., a loose LED in the globe) were noted, if possible, before disassembly. In two cases, it was difficult to determine whether the LED solder failed before disassembly (for these two devices, we assumed that failure occurred on the LED module, but we did not classify the failure as abrupt or intermittent). Other LED packages on these failed devices had such brittle solder that simply touching them, or the shock of removing the globe, caused complete solder failure. Brittle solder joints were prevalent in specific model numbers and, in some cases, particular LEDs within that model number. This problem suggests that there was a manufacturing or design issue. Drivers with a boost topology were most likely to have LED modules that experienced complete LED solder failure (**Figure 3-3a**). In two cases, an abrupt failure occurred even when all LED packages still appeared to be attached to the module (**Figure 3-3b**). In these cases, the encapsulant was dislodged, leaving behind a black carbon residue. Subsequent LED failure resulted.

In addition, an examination of the solder pads of some failed parts showed incomplete wetting of the solder on the gold pad as shown in **Figure 3-4**. In some cases, such solder joints were observed to be dull with poorly formed fillets, whereas in other areas of the same component, appropriate solder fillets were found. Poor solder wetting can arise from several manufacturing issues, including insufficient solder paste application, surface contamination on the gold pads, and insufficient dwell time above the solder liquidus point during reflow. These issues will contribute to poor solder joint quality and increase the likelihood of intermittent or complete joint failure.

**Figure 3-3. Main mechanisms of abrupt failure for LED modules: (a) complete LED solder failure and (b) LED failure.**

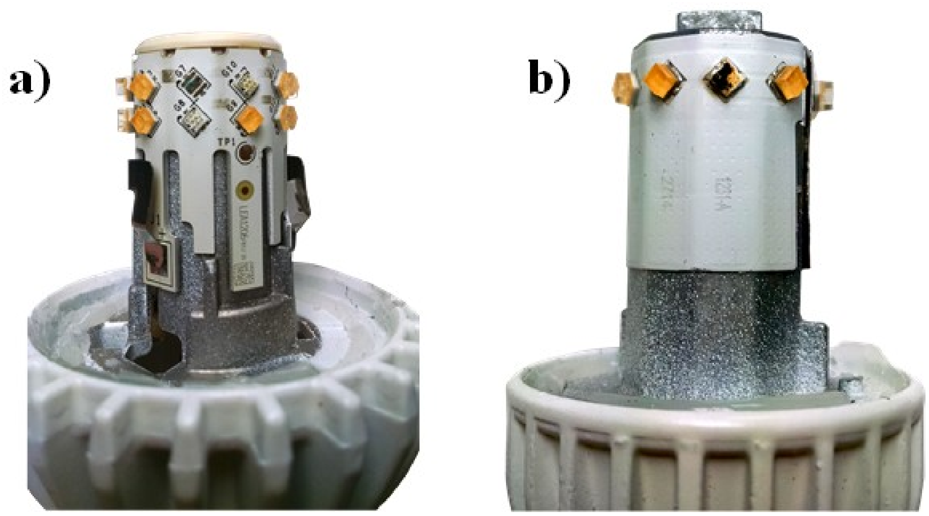
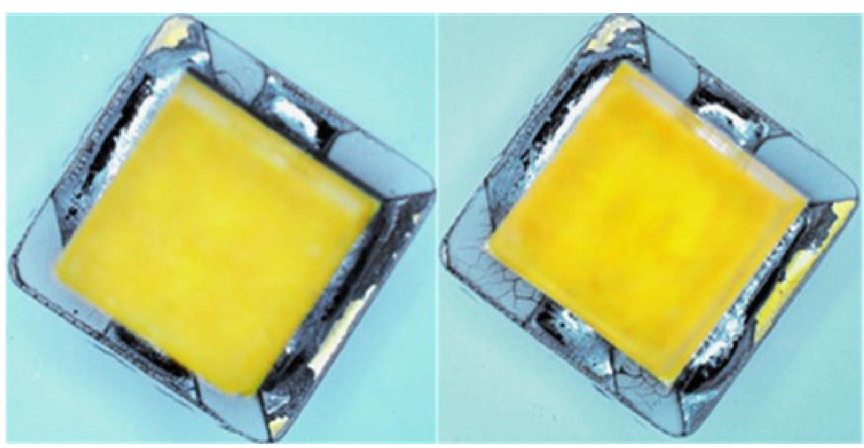


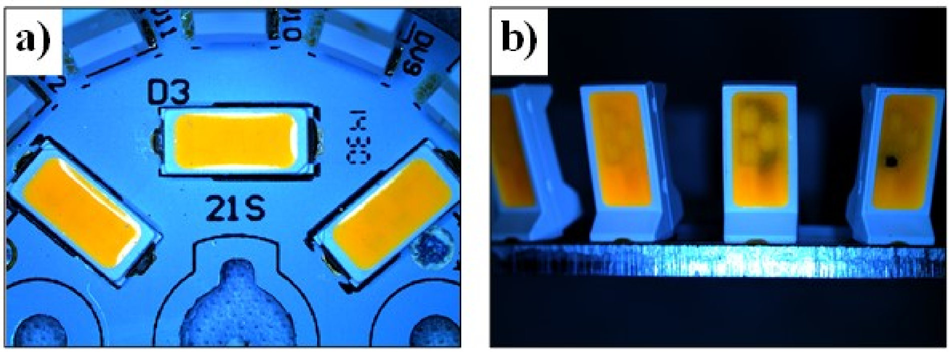

**Figure 3-4. Two LEDs showing poor solder wetting on the gold pad.**



## 3.2 Reduced Light Output Failures

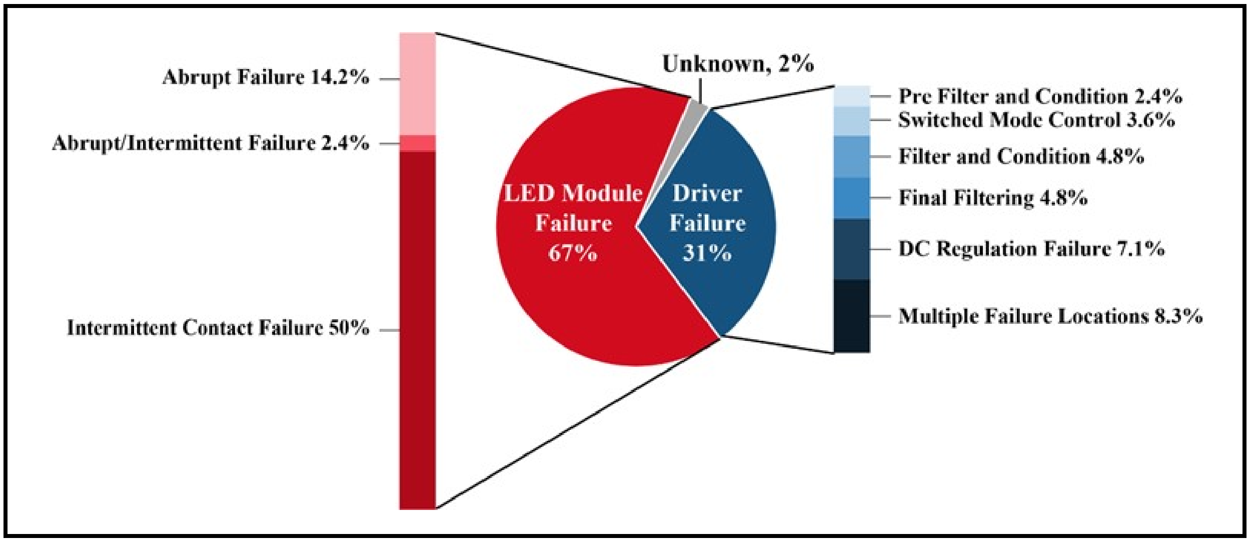
Devices that did not experience driver or LED module component discontinuity issues still provided some lumen output, but this light was often very dim, it flickered wildly, and/or there were signs of encapsulation and lead frame discoloration (**Figure 3-5**). In some cases, extreme signs of damage were observed in the encapsulation (**Figure 3-5b**, dark black spot on right side). These devices were analyzed further through an electrical test (as described in Subsection 2.4 of this report). Briefly, the test was designed to narrow the failure location to the LED module or to the driver. After this analysis, only a small fraction (2%) of the failure locations were still unknown.

**Figure 3-5. LED packages with silicon encapsulation that is (a) ideal and (b) damaged. Images were obtained with an Olympus 6Z61 microscope under identical conditions. A blue saturation layer was added over the images to highlight defects.**




A compilation of failure locations for all examined failed test lamps is described in this paragraph and provided in **Figure 3-6**. Failure location was sorted into the following three main categories: LED module failures, driver failures, and unknown failures. LED module failure was the most prevalent failure mechanism for the test lamps in this study (67%). Failures that occurred on the LED module could be further classified by whether the failure was abrupt or because of an intermittent contact issue. Abrupt failures were previously discussed in Subsection 3.1.2, and intermittent contact failures are discussed in Subsection 3.2.1. For two of the devices that experienced LED module failure, the failure location was not classified as abrupt or intermittent. The failure location for these devices was classified as an abrupt/intermittent failure to account for the uncertainty in whether the device was damaged during disassembly. Failures that occurred on the driver were classified into six categories: pre-filter and condition, switched-mode control, filter and condition, final filtering, DC regulation failure, and multiple failure locations. These six categories, except for DC regulation failure, pinpoint an exact location on the driver where failure location occurred (i.e., these were abrupt failures [see Subsection 3.1.1]). The DC regulation failure category is further described in Subsection 3.2.2. Finally, the location of failure for two devices could not be determined through our tests; therefore, the assignment of failure location for these devices was classified as unknown.

**Figure 3-6. Failure location by category for test LED lamps.**




### *3.2.1 Reduced Light Output Failure Due to the LED Module*

Surprisingly, failures occurred on the LED module for most (67%) of the failed test lamps (**Figure 3-6**). Approximately one-fourth of these lamps failed catastrophically because of complete solder and/or LED failures (see Subsection 3.1.2). The remainder of the LED module failures were determined through electrical tests. These tests showed that failure was not introduced at any point within the driver and must be within the LED module.

Although the electrical test did not reveal an exact failure location on the LED module, there is strong evidence to support that solder embrittlement and contact oxidation led to lower device performance (**Figure 3-7**). We believe that these failures were at least partially the result of high, localized heat near the LED packages that resulted in the formation of intermetallics in the solder and soldered surface metals. Such intermetallics are known to be brittle and can introduce micro-cracks into the solder joints.[3] In particular, many of these lamps used gold pads as solder surfaces, and it is well known that gold dissolves in many solders to form brittle intermetallics (see Subsection 3.1.2).

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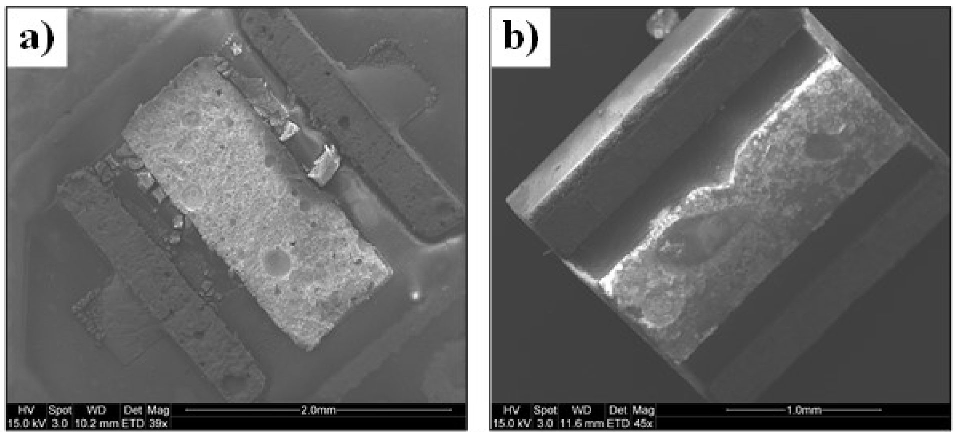
[2] Bradley, E. 2003. Lead-free solder assembly: Impact and opportunity. In *Proceedings of the 53rd Electronics Component Technology Conference*. doi: 10.1109/ECTC.2003.1216254

**Figure 3-7. SEM images of (a) an LED contact pad that shows embrittlement, an inhomogeneous contact surface, and alloy whiskering and (b) an LED with an inhomogeneous contact surface**



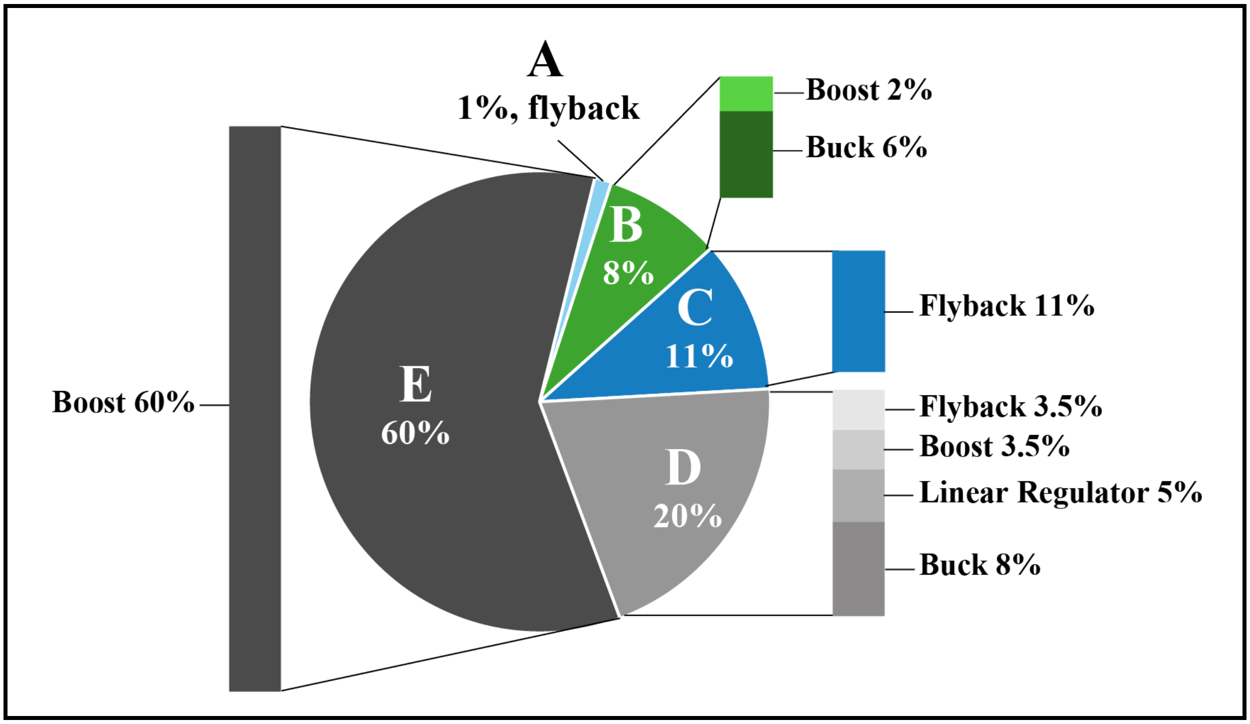

### *3.2.2 Reduced Light Output Failures Due to the Driver*

Most of the LED driver failures were because of discontinuity and component failures (**Figure 3-6**). However, approximately one-fourth of the failed drivers were DC regulation failures. This failure mode was detected and assigned when the output voltage of the test driver (connected to the control LED module load) was much lower than the voltage necessary to operate the control LED module (as determined by the control driver). Notably, the tested electrical components on these drivers passed initial continuity and electrical tests. However, there could have been an undetected component failure that rendered the driver incapable of regulating direct current at the proper level when power was supplied. Half of the DC regulation failures occurred on drivers with a flyback topology, and the other half occurred on drivers with a boost topology. It is hypothesized that localized heat around the transformer and inductor, respectively, and MOSFET damaged the control IC. Most control ICs contain a temperature sensor that reduces current when the temperature is too high. More investigation was not pursued regarding whether the control IC failed or cause of DC regulation failure.

## 3.3 Common Failure Sites for Each Driver Topology

Among the examined test lamps, a strong correlation between failure location (i.e., LED module versus driver failure) and driver topology was identified. Within the buck and flyback topologies, we found that specific driver failure location (e.g., component failure, solder failure, DC regulation failure) varied with respect to the manufacturer. Because of the correlation between the manufacturer, driver topology, and failure location, a chart has been developed to document the percentages of examined test lamps produced by each manufacturer (the manufacturers are labeled as A through E in **Figure 3-8**). Some manufacturers (i.e., B and D) used different driver topologies to build different lamp models, but other manufacturers (i.e., A, C, and E) used the same driver topology for all of the examined test lamp models.

**Figure 3-8. Failed test lamps categorized by manufacturer (A through E), and then subcategorized by driver topology.**




The remainder of Subsection 3.3 discusses the common failure locations for flyback (Subsection 3.3.1), boost (Subsection 3.3.2), and buck (Subsection 3.3.3) topologies, and a correlation between the manufacturer and the failure location, when applicable, is provided congruently. Although there were also a few lamps with a linear regulator topology, failure location assignment for these devices was only successful for two of them (limiting any useful trends).

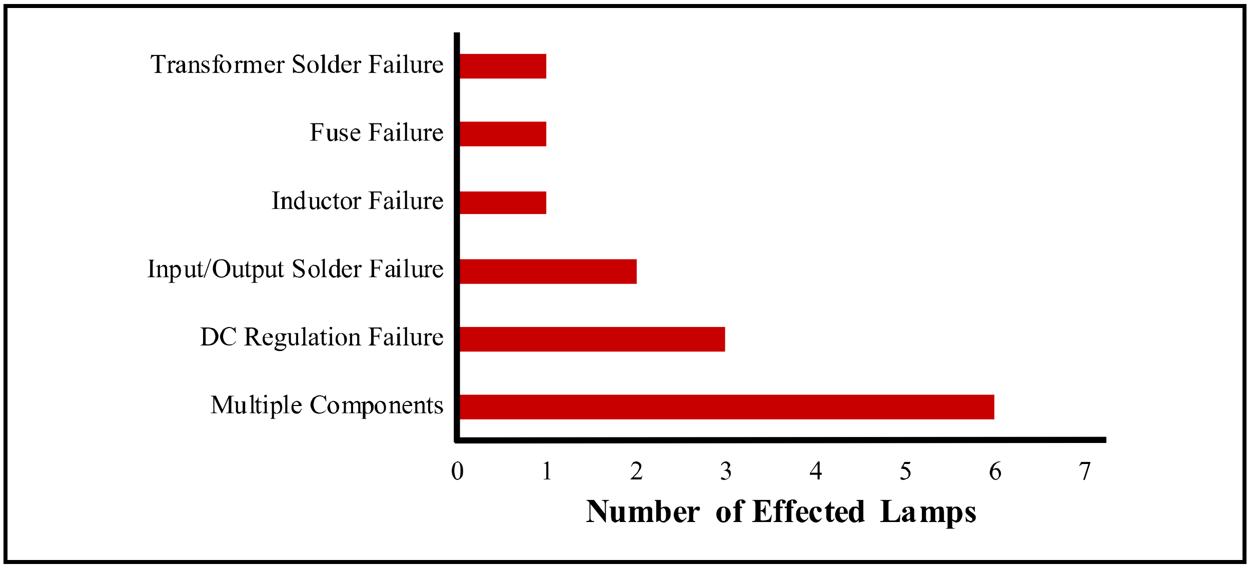
### *3.3.1 Flyback Topologies*

As previously discussed in Subsections 3.1.1 and 3.2.2, flyback topologies account for most of the failures within the drivers, and all failed flyback samples examined in this study failed somewhere within the driver (**Figure 3-9**). Flyback driver topology was predominantly used by two different manufacturers (C and D in **Figure 3-8**), and the failure location on the driver was correlated to which manufacturer produced the driver. However, it is important to note that although manufacturer A also used a flyback driver topology, there was only one failed device; therefore, it will not be discussed in this report.

For manufacturer C, there was often evidence (e.g., board discoloration and/or solder joint failure on the PCB) of localized heat near the transformer, but surprisingly, the transformer and MOSFET components did not fail. Instead, continuity was disrupted between these two components by solder failure (**Figure 3-2**), and a cascade of other components failures and solder failures ensued. For manufacturer D, DC regulation failure occurred on all devices. It is possible that the control IC for these devices was harmed by the high temperatures around the device; however, no additional investigation of the control IC was performed.

We believe that both failure mechanisms were caused by extreme, localized heat. Luminaire assemblies with a flyback topology had the highest operating surface temperatures in comparison with other lamps—nine out of the 10 hottest failed lamps had a flyback topology, with surface temperatures as high as 103.5°C. The elevated operating temperatures suggest that flyback topologies can produce damaging levels of heat in the switched-mode control and final filtering electrical stages. This damage has been observed to manifest as solder failure (manufacturer C) or DC regulation failure (manufacturer D).

**Figure 3-9. The failure location for each of the examined test lamps with a flyback topology.**

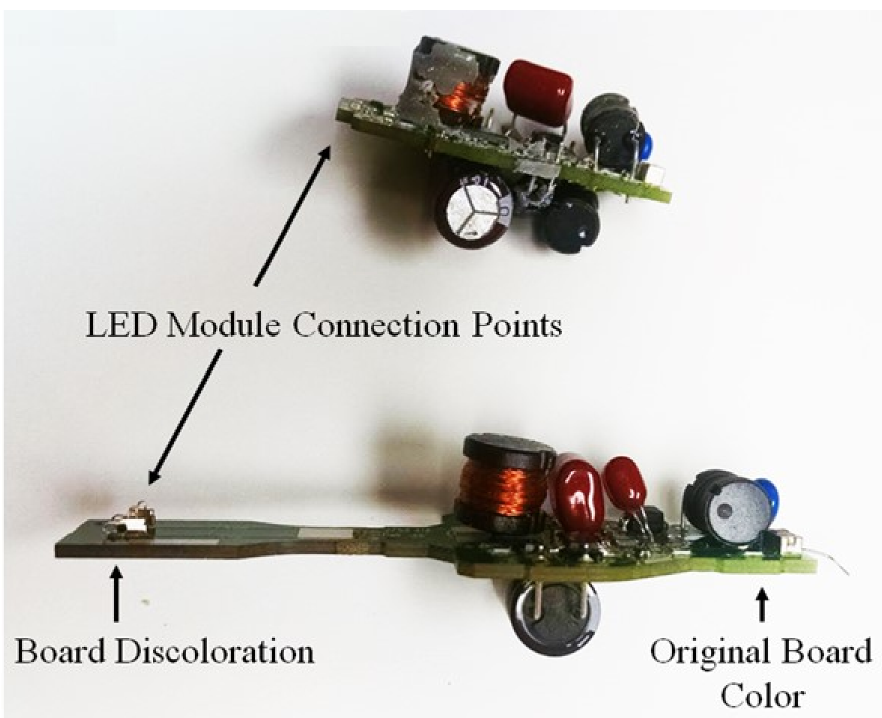



### *3.3.2 Boost Topologies*

Boost topologies comprised the largest number of failed lamps (64%, **Figure 3-1**) and were distributed between 13 different models and three different manufacturers (B, D, and E). Most of these models (approximately 91%) were produced by the same manufacturer (i.e., E [**Figure 3-8**]). Within each model of devices produced by manufacturer E, a power consumption analysis of the drivers revealed similar power factors and consumption of power and current. All failed test lamps that were analyzed had low power factors (≤0.5) and consumed low amounts of power (≤0.6 W) and current (approximately 0.01 A). Fully operational control lamps had significantly higher power factors (approximately 0.98), power consumption (≥8 W, actual consumption based upon the model), and current consumption (approximately 0.1 A).

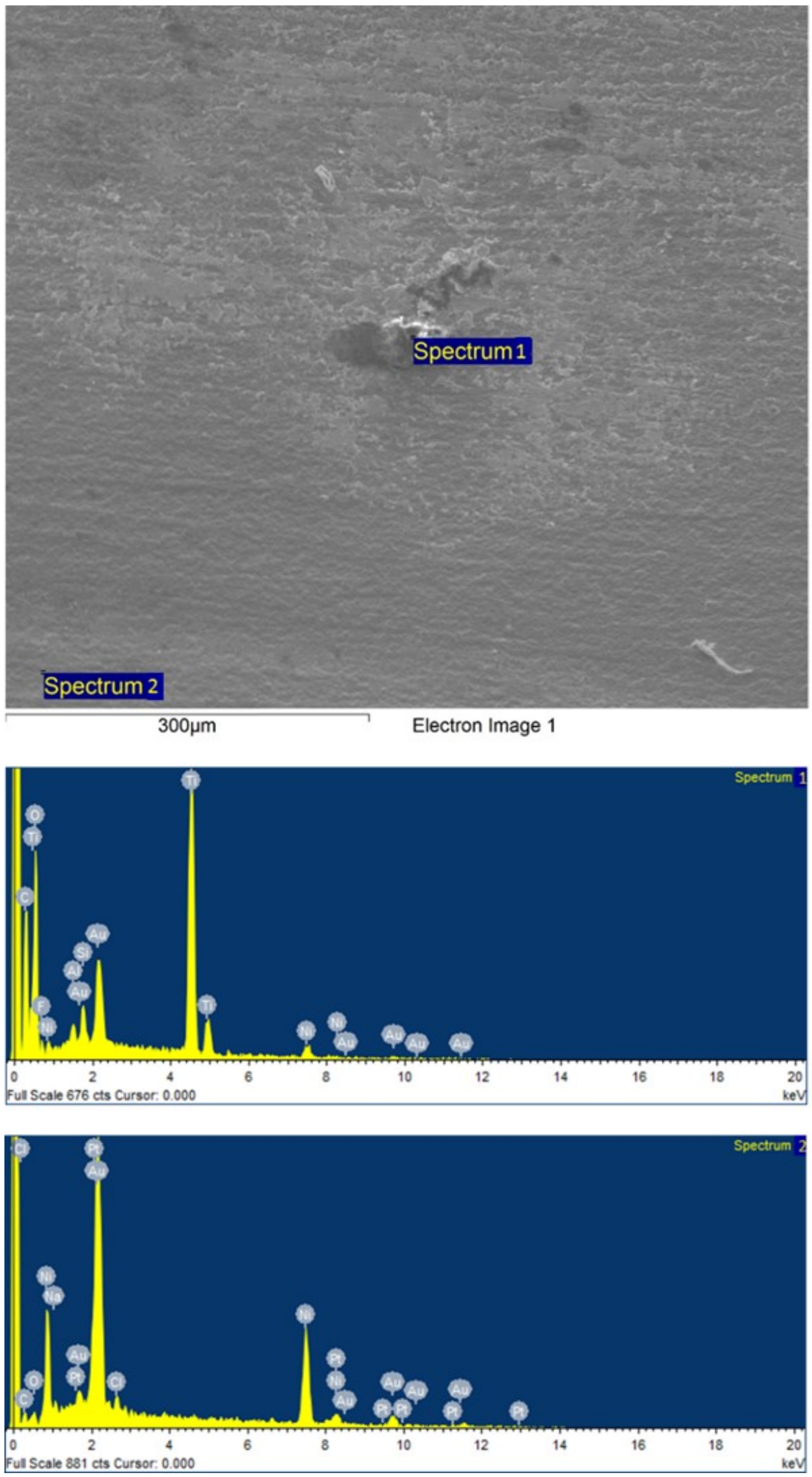
Failure location for most of these devices (85%) was determined to be somewhere on the LED module for manufacturers D and E. For manufacturer B, device failure occurred because of driver component failure, which was consistent with all of the other lamps produced by this manufacturer. An examination of the temperatures within select lamps from manufacturer E revealed that the LED packages experienced much higher temperatures (between 90–95°C) than driver components (60–65°C) for lamps operated in a base-up, bare-socket fixture. Severe discoloration of the driver PCB near the LED module connection site supports the observation that heat is localized around the LED module (**Figure 3-10**). Furthermore, it is expected that the actual operating temperature of the LEDs was higher than that measured during these experiments for two reasons. First, many of the failed lamps were operated in enclosed ceiling fixtures and recessed downlights, which adds approximately 20–25°C). Second, the temperature in this analysis was measured slightly above the LED module to prevent short circuiting of the thermocouple with the metal LED module.

**Figure 3-10. Two representative drivers with a boost topology where board discoloration is localized to the LED connection points.**



As discussed in Subsection 3.2.1 of this report, we believe that intermittent interconnect failure induced by high thermal stress is a leading cause of failure for these devices. This conclusion is supported by the analysis of temperatures within selected lamps and SEM surface analysis of LED solder joints (**Figure 3-7**). For many of the samples, intermittent contact failure could also be introduced at both sides of the connectors used to connect the driver to the LED module. To validate this conclusion, we used SEM to map surface topology and composition of driver and LED module connection points. Surface composition of a representative LED module pad is shown in two locations: where it contacts the driver pin and on the perimeter of the pad (see **Figure 3-11**, Spectrums 1 and 2, respectively). High concentrations of titanium and oxygen were found on the driver contact point (Spectrum 1), but the remainder of the pad was comprised of primarily of gold and nickel (Spectrum 2); nickel was likely transferred from the driver contact to the LED module pad (SEM image not shown). The increased titanium concentration at the driver contact point suggests that the driver contact scratched away the gold layer on the pad to reveal the titanium layer beneath it. The titanium was likely coated beneath the gold layer to reduce intermetallic mixing of gold and copper. However, when the gold layer was scratched away, titanium was exposed to air and readily oxidized, forming an electrically insulating layer on the LED module pad. A combination of these intermittent contact failures is most likely the cause of the decrease in light output observed for these lamps.

**Figure 3-11. An SEM image of an LED module contact pad (top). Surface composition is provided when the boost driver pin touches the gold pad (Spectrum 1, middle) and around the perimeter of the pad (Spectrum 2, bottom).**



### *3.3.3 Buck Topologies*

Overall, there were a few failed test lamps with a buck topology (12 devices total). These devices were manufactured by two different companies (i.e., B and D [see **Figure 3-8**]), and failure location was correlated to the manufacturer.

Manufacturer D made seven of the failed test lamps, which all had the same model number. The failure location for these lamps was determined to be somewhere on the LED module. This finding was surprising because the lamps operated at much lower temperatures than the lamps with a boost topology that failed in a similar location. The measured temperatures were approximately 50°C on the globe surface, 77°C near the LEDs, and 65°C near the control IC. The LED modules for these seven test lamps provided little physical evidence regarding why they failed. The only notable observation was significant degradation of the silicone encapsulant for many of the LED packages (**Figure 3-5**). It is possible that the expansion associated with this degradation caused stress on the gold wires used to connect the LEDs in a package (although direct evidence of broken gold wires was not observed). It is also possible that the solder connections between some LED packages and LED modules were compromised (although the solder joints appeared to be physically intact).

The other five devices, produced by manufacturer B, spanned three different model numbers and experienced driver component failure. Diode, inductor, and fuse failures were among the list of component failures, which was consistent with the failures observed for this manufacturer for boost and flyback topologies (see Subsections 3.3.2 and 3.4).

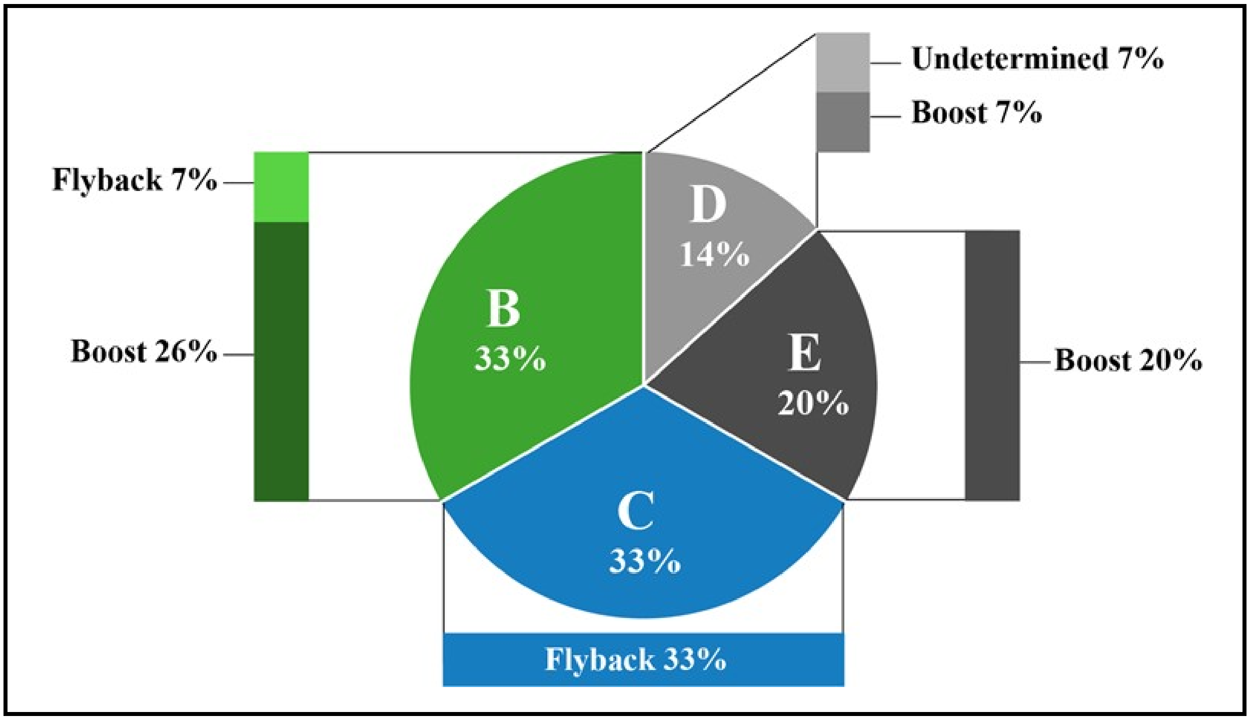
## 3.4 Intermittent Failure Analysis

In addition to the 84 failed devices discussed in Subsections 3.1 through 3.3 of this report, we examined 15 devices that were prone to fail intermittently. Often, these devices operated without incident for minutes or hours, and then shut off. Within the 15 intermittent devices, there were 13 different models produced by manufacturers B through E (**Figure 3-12**).

Overall, we found that the intermittent devices failed in the same location as failed test lamps. All devices produced by manufacturer B experienced driver component failures, regardless of driver topology, as previously mentioned. The remainder of the devices produced by manufacturers C and E followed similar failure mechanisms as previously mentioned. For example, intermittent devices with a flyback driver topology experienced extreme, localized heat near the transformer and MOSFET components. These intermittent devices experienced MOSFET failure, transformer through-hole partial solder failure, and through-hole partial solder failure on the pins that connect to the LED module. These findings were consistent with the failed test lamp analysis of flyback driver topologies produced by manufacturer C. Furthermore, the intermittent devices with a boost topology failed somewhere along the LED module. This finding was consistent with the failed test lamp analysis of boost driver topologies produced by manufacturer E.

Two intermittent devices were produced by manufacturer D. A failure location could not be assigned for the device with boost topology, and a different driver topology was used for the second device. The latter device experienced MOSFET failure.

**Figure 3-12. The intermittent test lamps categorized by manufacturer (B through E), and then subcategorized by driver topology.**




Finally, it should be noted that at least 66% of the intermittent devices had a driver component or solder failure (compared with a mere 24% of failed devices, **Figure 3-6**). Part of the failure location shift can be attributed to a shift in driver topology. The intermittent failure population represented a lower percentage of boost drivers than the failed test lamp population (53% vs 64%, respectively). Additionally, there were more drivers with a flyback topology in the intermittent group (40% vs 17%). Another part of the failure location shift can be attributed to a shift in manufacturer. There was a significant decrease in lamps produced by manufacturer E in the intermittent failure group compared to the failed test lamp population (20% vs 60%, respectively). Because manufacturer E only produced drivers with a boost topology (in this study), we believe that the failure rate for LED modules with a boost topology (especially those produced by manufacturer E) is higher than the failure rate associated with component solder or functionality failure for all other topologies. Therefore, we expect that the increase in driver component solder or functionality failure for intermittent devices was simply due to fewer LED module failure devices being left at the point of intermittent failure.

# 4. CONCLUSIONS

Market acceptance of LED-based lighting technologies has grown significantly in the past decade because this technology enables significantly reduced electricity consumption attributable to illumination. However, total market penetration of SSL technologies is still less than 20% in many applications due to the exceeding large installed base. Consequently, low-quality products that exhibit excessive rates of premature failure could dampen enthusiasm for this still nascent technology and slow market penetration. Such action would have the impact of requiring more electricity generation assets to meet the load requirements of less efficient light sources. Therefore, it is beneficial for manufacturers, customers, and lighting stakeholders to have a knowledge of potential failure mechanisms in SSL technology to negate future issues. This study reports on findings from failure analysis investigations of LED lamps tested by CPUC in a project led by Itron, Inc.

In this study, an examination of the failed test devices revealed a clear correlation between model number and failure location and between driver topology and failure location. It was also found that the percentage of driver component failures (approximately 24%) was less than expected and that most failures (67%) occurred on the LED module. These results were surprising because we anticipated that more test lamps would experience driver component failure than LED module failure. Upon examination of devices that failed intermittently, we found that more devices experienced driver component failures (66%) than LED module failures (20%). However, failure location did not change for intermittent devices produced by the same manufacturer and with the same topology. Therefore, for LED lamps, we postulate that the rate for LED module failure is higher than the rate for driver component solder or functionality failure under the conditions used in the CPUC LED laboratory tests. An examination of the failed lamps also revealed that the driver and LED modules often failed because of a solder or contact issue; we have identified high-stress locations where manufacturers can improve the solder technique. In particular, flyback topologies were susceptible to through-hole component solder failure—transformer and MOSFET solder joints were often damaged because of localized heating around these components. Additionally, solder technique could be improved between the LED packages and the LED module for devices with a boost driver topology. By improving solder technique in these high-stress areas, it is likely that manufacturers could improve LED lamp lifetime substantially and capitalize on the robustness of individual LEDs. Such actions would benefit LED-device manufacturers and their customers, but would also provide benefits to lighting industry stakeholders in California including taxpayers, municipalities, and public utility companies.