GATEWAY DEMONSTRATIONS

Demonstration Assessment of Light-Emitting Diode (LED) Area Lights for a Commercial Garage

Host Site: Providence Portland Medical Center, Portland, Oregon

Final Report prepared in support of the U.S. DOE Solid State Lighting Technology Demonstration GATEWAY Program

Study Participants:
Pacific Northwest National Laboratory
U.S. Department of Energy
Energy Trust of Oregon
Providence Portland Medical Center
Lighting Science Group (LSG)

November 2008

Prepared for the U.S. Department of Energy by
Pacific Northwest National Laboratory

PNNL-17995

Demonstration Assessment of Light-Emitting Diode (LED) Area Lights for a Commercial Garage in the Providence Portland Medical Center, Portland, Oregon

Final Report prepared in support of the U.S. DOE Solid-State Lighting Technology Demonstration GATEWAY Program

Study Participants:
Pacific Northwest National Laboratory
U.S. Department of Energy
Energy Trust of Oregon
Providence Portland Medical Center
Lighting Sciences Group (LSG)

MK Ton
EE Richman
TL Gilbride

November 11, 2008

Prepared for
the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99352

DISCLAIMER

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information,
P.O. Box 62, Oak Ridge, TN 37831-0062;
ph: (865) 576-8401
fax: (865) 576-5728
email: reports@adonis.osti.gov

Available to the public from the National Technical Information Service,
U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161
ph: (800) 553-6847
fax: (703) 605-6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/ordering.htm

This document was printed on recycled paper.
(9/2003)

Preface

This document is a report of observations and results obtained from a lighting demonstration project conducted under the U.S. Department of Energy (DOE) SSL GATEWAY Demonstration Program. The program supports demonstrations of high-performance solid-state lighting (SSL) products in order to develop empirical data and experience with in-the-field applications of this advanced lighting technology. The program seeks to demonstrate SSL products in applications that save energy, are cost effective, and maintain or improve light levels in the tested lighting application. The DOE GATEWAY Demonstration Program focuses on providing a source of independent, third-party data for use in decision-making by lighting users and professionals; this data should be considered in combination with other information relevant to the particular site and application under examination. Each GATEWAY Demonstration compares one SSL product against the incumbent technology used in that location. Depending on available information and circumstances, the SSL product may also be compared to alternate lighting technologies. Although products demonstrated in the GATEWAY program have been prescreened and tested to verify their actual performance, DOE does not endorse any commercial product or in any way guarantee that users will achieve the same results through use of these products.

Executive Summary

This U.S. Department of Energy GATEWAY Demonstration project studied the applicability of light-emitting diode (LED) luminaires for commercial parking garage applications. High-pressure sodium (HPS) area luminaires were replaced with new LED area luminaires. The project was supported under the U.S. Department of Energy (DOE) Solid-State Lighting Program. Other participants in the demonstration project included Providence Portland Medical Center in Portland, Oregon, the Energy Trust of Oregon, and Lighting Sciences Group (LSG) Inc. Pacific Northwest National Laboratory (PNNL) conducted the measurements and analysis of the results. PNNL manages GATEWAY demonstrations for DOE and represents their perspective in the conduct of the work.

Quantitative and qualitative measurements of light and electrical power were taken at the site for both HPS and LED light sources. Garage users' responses to the new light sources were gauged with a survey.

Two versions of the LSG LED luminaires were used in this demonstration: an existing version (Version 1), which had been available on the market since 2007, and a newer version (Version 2), recently introduced, which has 30% more light output and uses about 8% less power. Six Version 1 luminaires were installed in the below-ground parking Level A, replacing six existing 150W HPS lamps spread out over two rows of parking spaces. Illuminance measurements were taken at floor level on an approximately 60-ft x 40-ft grid to measure the light output of these LED luminaires. Power measurements of the 6 LED luminaires were conducted, and it was determined that they drew an average of 82 W per fixture (versus 191 W for each of the HPS luminaire). Version 2 of the LSG luminaire was installed in Level B of the parking garage. Illuminance measurements were not made of this second luminaire on site due to higher traffic conditions; however, power and photometric measurements of this luminaire were made off-site by an independent laboratory.

Maximum and minimum light levels were measured for the HPS and LED Version 1 luminaires and projected for the Version 2 luminaires. Maximum light levels in foot-candles (fc) were 23.51 fc, 20.54 fc, and 26.7 fc respectively, and minimum light levels were 1.49 fc, 1.45 fc, and 1.88 fc. These results indicate very similar minimum light levels produced by Version 1 of the LED luminaires and HPS, and possibly slightly higher minimum light levels with Version 2 of the LED luminaires. All results were above the IES recommended level of 1 fc. User perceptions of the LED luminaires on Level B of the parking garage were collected via a written survey form given to maintenance and security personnel. More than half felt the LED luminaires provided more light than the HPS sources and a majority expressed a preference for the new fixtures when viewing the relamped area through a security camera. Respondents commented that the LED luminaires were less glary, created less shadows, had a positive impact on visibility, and improved the overall appearance of the area.

PNNL conducted an economic analysis and found that the Version 1 lamp produced annual energy savings of 955 kWh and annual energy cost savings of $62 per lamp at electricity rates of 6.5 cents per kWh (local rate), and $105.03 at 11 cents per kWh (national average rate). PNNL found that the Version 2 lamp produced annual energy savings of 991 kWh and energy cost savings of $64 per lamp at electricity rates of 6.5 cents per kWh and $109 at 11 cents per kWh. PNNL also calculated simple payback and found that Version 1 showed paybacks of 6.5 yrs at $0.065/kWh and 4.1 yrs at $0.11/kWh while Version 2 showed paybacks of 6.3 yrs at $0.065/kWh and 3.9 yrs at $0.11/kWh.

Contents

Figures

Tables

1.0 Introduction

This U.S. Department of Energy GATEWAY Demonstration project studied the applicability of light-emitting diode (LED) luminaires for commercial parking garage applications. High-pressure sodium (HPS) area luminaires were replaced with new light-emitting diode (LED) area luminaires. The project was supported under the U.S. Department of Energy (DOE) Solid State Lighting Program. Other participants in the demonstration project included Providence Portland Medical Center in Portland, Oregon, the Energy Trust of Oregon (ETO), and Lighting Sciences Group (LSG) Inc. Pacific Northwest National Laboratory (PNNL) conducted the measurements and analysis of the results. PNNL manages GATEWAY demonstrations for DOE and represents DOE's perspective in the conduct of the work.

1.1 Background

Parking lots and garages can be challenging environments to light. The lighting must accommodate both vehicular and pedestrian traffic, endure harsh operating environments, and take into account public safety considerations as well as light trespass issues. At the same time, all of these objectives must be met in the most economical way possible. Specific issues that parking lot lighting must address include the following:

- Vibration from vehicle traffic can create a harsh operating environment for light sources.
- Most parking garage lights operate 24 hours-a-day.
- Public safety concerns may favor white light and a high color rendering index (CRI) despite higher cost.
- Failed lamps can create safety hazards if not replaced.

Many commercial garages use area luminaires for general illumination, typically with high-pressure sodium (HPS), metal halide (MH), or linear fluorescent lamps. HPS lamps are used because of their low cost, high efficacy, and long life. MH or fluorescent sources typically have shorter lives but produce a whiter light.

A number of solid-state lighting-based (SSL-based) luminaires (products using a LED light source) are currently being introduced into the market. Well-designed SSL-based fixtures have the potential to provide:

- greater control of light distribution
- better lighting color quality
- longer life
- energy savings when compared to some traditional light sources.

Commercial applications for LEDs that can take advantage of these factors include indoor and outdoor area luminaires. Parking garage lighting is an excellent application for LED lighting for several reasons:

- LED sources have the potential for longer life, better color rendition, and lower energy use than HPS.
- Area lighting can take advantage of the inherently directional nature of light emitted from LEDs, minimizing light loss within the fixture.
- LED sources are not affected by vibration, compared to some traditional light sources.
- LEDs can be easily adapted to control systems such as motion sensors and photoelectric cells to further reduce electricity consumption, where applicable.
- LEDs function well in cold temperature environments.
- LED luminaires can be more resistant to breakage and vandalism, depending on their design and construction.

1.2 Project Objectives

The objective of the demonstration was to compare HPS and LED-based luminaires in a commercial parking garage. Performance was evaluated in three areas: energy usage, lighting, and economics, as detailed below:

- energy usage - luminaire wattage, estimated annual kWh usage
- lighting performance - illuminance, uniformity, correlated color temperature (CCT, in Kelvin), user satisfaction
- economic performance – simple payback for substitution in new installation or replacement scenarios, accounting for light source lifespan, maintenance costs, and electrical costs.

1.3 Overview of the Report

Chapter 2 describes the project methodology. Chapter 3 is a discussion of the results of the study. Chapter 4 presents the conclusions. Appendices A though F contain information on the luminaires, measurement data, and calculation details and assumptions.

2.0 Methodology

The Providence Portland Medical Center (PPMC) GATEWAY Demonstration Project was a joint project of DOE, Energy Trust of Oregon (ETO), Lighting Sciences Group Corporation (LSG – via its local distributor, Extra Effort Consulting), and PPMC's Physical Plant Department. The project was coordinated by PNNL. A description of the evaluation and methods used is provided below.

2.1 Demonstration Site

In early 2008, ETO's Commercial Efficiency Program contacted DOE regarding the viability and availability of commercially available LED lighting technologies and expressed interest in working with DOE on demonstrations of solid-state lighting. Based on the PPMC's expressed interest in incorporating LED lighting into their projects, ETO, along with the PPMC Physical Plant Department, approached DOE and offered the PPMC Portland garage as a potential demonstration location (see Figure 2.1). The Providence facility is evaluating a number of energy-efficient lighting options to replace its stock of aging HPS area lighting fixtures, and the use of LED luminaires was viewed as a straightforward option for this application.

Figure 2.1. Location of Providence Portland Medical Center, in Southeast Portland, Oregon. Arrow shows garage location. (Source: Google Maps)

PPMC is part of Providence Health & Services in Oregon, a not-for-profit network of hospitals, health plans, physicians, clinics, and affiliated health services. The NE Portland location is a large campus occupying about five city blocks by five city blocks (Figure 2.1). The parking garage is a six-story structure located on the northeast side of the campus with approximately 50,000 square feet of parking area. The garage is lit with about 400 HPS luminaires that operate 24 hours per day.[1] The PPMC garage is pictured in Figure 2.2 and Figure 2.3.

Figure 2.2. Exterior of the PPMC Garage, Portland, Oregon

2.2 Products Tested

The product selected for demonstration at the site is Lighting Science Group's pyramid-shaped "Low Bay" LED indoor area luminaire (30 degrees base angle). DOE tested one version of LSG's "Low Bay" product to verify its performance prior to accepting it into the demonstration program. The luminaires used in the demonstration are a mix of an existing version (Version 1), which had been available on the market since 2007, and a newer version (Version 2), recently introduced, which has 30% more light output (4700 rated lumens vs. 3600 rated lumens) and uses about 8% less power (78 watts rated power vs. 85 watts rated power).

[1] PPMC's Electrician noted that a number of luminaires on the outside perimeter of the parking levels have been retrofitted with photo sensors, so these luminaires would not be operating at 24 hours per day.

Figure 2.3. Interior of the PPMC Garage (Level A), with HPS fixtures, Portland Oregon

In the PPMC demonstration, the LED luminaires replaced existing HPS luminaires, which are at least 15 years old and were manufactured by Crouse-Hinds Lighting (Cat # LW/VLC15 120/277 Style # 7240D94G14, using GE LUCALOX 150W HPS lamps). These round-shaped luminaires are approximately 16 inches in outside diameter, and 10 inches in height. Each luminaire is pendant mounted to the roof of the garage via a short pole and conduit. The lamps are vertically oriented with the ballast located in its own compartment above the reflector, lamp, and cover assembly. The integral lenses of the luminaires in the garage appeared to be acrylic in various conditions (from dirty to cracked). The lens "bowl" provides dust sealing for the luminaires and the reflectors. The reflectors are painted metal. More information about the HPS lamps and ballasts can be found in Appendix A. Figure 2.4 shows a typical HPS parking garage luminaire similar to the Crouse-Hinds luminaires used at the PPMC parking garage.

Figure 2.4. Typical HPS Parking Garage Luminaire
Source: www.buylightfixtures.com

The HPS luminaires on Level A were cleaned and re-lamped with new HPS lamps about a week prior to being replaced by the LED fixtures. Because lamps on Level A operate 24 hours per day, when the illuminance measurements were taken a week later, the new HPS lamps had operated well over the 100 hours needed for normal "burn-in" of discharge lamps. Ballasts were not replaced for purposes of these measurements. Figure 2.6 shows the installed HPS luminaires.

Figure 2.5. Crouse-Hinds HPS Luminaires at the PPMC Garage.
(Note: X's on pavement show locations of illuminance measurement points)

The LSG Low Bay LED luminaire used in this project is a pyramid-shaped fixture 14 inches wide by 14 inches long, and about 8 inches in height, containing 108 LEDs per fixture (27 per side). The fixture is designed for area lighting in warehouses, stockrooms, parking garages, gyms, and other spaces. The Low Bay is available from the manufacturer in pendant, surface, and tilt installation mounting options for both new construction and retrofit applications (Figure 2.6).

Figure 2.6. Lighting Sciences Group's Pyramid Low Bay LED Fixture
Source: LSG Corp.

2.3 Measurements

Following development of a field measurement plan, PNNL conducted a preliminary site visit to the Providence garage to document the existing conditions. No potential issues were identified during this visit. The installation field visit and grid set-up for the luminaire measurements were combined and occurred on the same day. Initially, the installation location was the garage's below-ground parking level (Level A). This was considered to be an ideal location, as there would be no ambient light to interfere with illumination measurements or to affect users' perception of the new luminaires. A section of the garage away from the entrance and exit was selected as the test location. This section also had the advantage of being the nurses' parking area and was, therefore, potentially useful in obtaining qualitative feedback from garage users (Figure 2.7).

Six of the Low Bay LED luminaires were installed in the designated section of Level A and measurements were taken of both the existing luminaires and of the installed LED replacements. After the installation, LSG made available a number of higher output Low Bay LED luminaires. In addition, the security staff requested that the test luminaires be moved to another location on the ground floor observable by installed security cameras. The installed LED luminaires were moved from the original position on Level A to Level B, near the entrance to the garage to accommodate the security staff request. These LEDs were installed along with the newer Version 2 LED fixtures. Because the new location is a high traffic location, additional measurements were not taken.

In the original Level A location, illuminance measurements were taken on an approximately 50-ft by 30-ft grid, encompassing six luminaires and two rows of parking spaces. The distance between the luminaires is approximately 22 feet over the parking spaces and about 24 feet across the rows. Ideally, parking garage luminaires should be spaced equally for lighting uniformity; however, actual luminaire spacing is usually by the variable distances between concrete ceiling beams. The grid spacing was approximately 4 ft over the entire measurement area.

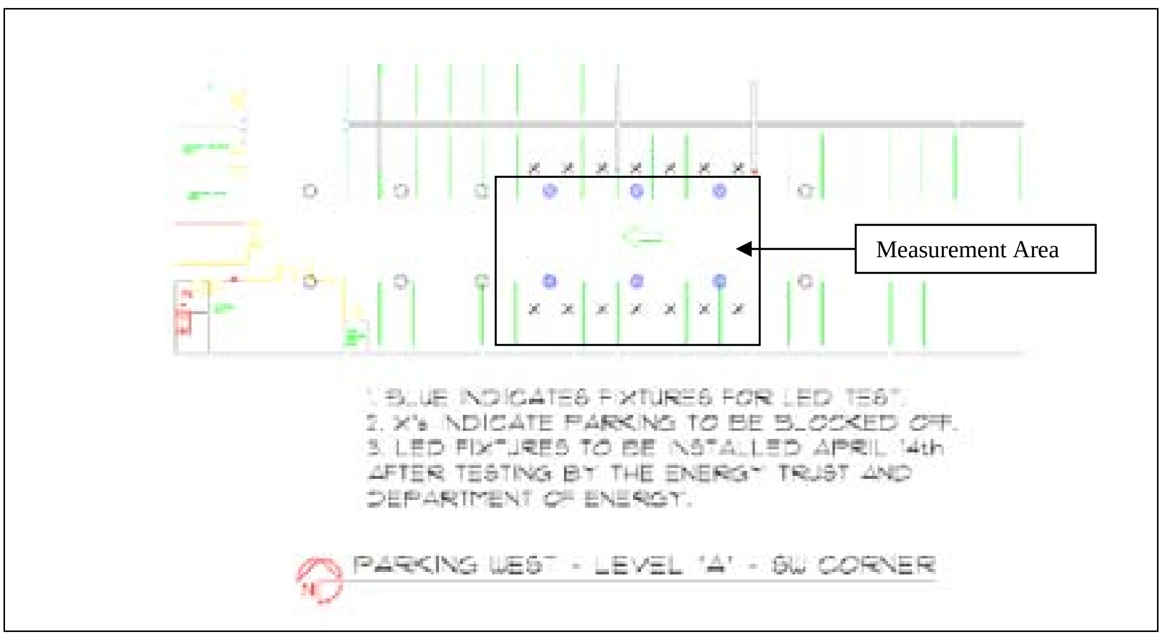


Figure 2.7. Drawing of Installation Area on Level A (not to scale)

The luminaires were located approximately 90 inches above the concrete floor of the garage, on 1.5-ft mounting poles. The light level measurements were taken with a Canon/Minolta illuminance meter at a uniform height of 2 inches above ground. Temperature measurements were measured with a portable thermometer. As the parking level was below ground, the temperature remained constant throughout the measuring period at about 63°F. Table 2.1 contains the details of the measurement areas. Appendix B contains a listing of equipment used, and Appendix C contains the detailed measured data and measurement areas.

Other measurements taken in the garage at Level A were CCT and power usage.[1] Power data were measured on site for the six HPS luminaires, as well as the six Version 1 LED luminaires. (Power usage for the Version 2 LED luminaire was measured at an independent testing laboratory.) Because all six luminaires were on one circuit, the power drawn on that circuit could be measured and an average per-lamp usage calculated both with the HPS lights installed and then with the LED fixtures installed. All pre- and post-retrofit measurements were taken within an eight-hour period because the Medical Center maintenance staff was able to install the new LED luminaires on the same day that PNNL took measurements. No corrections were required for ambient light, as the location was underground. Photometric results from independent laboratories for both the HPS and LED luminaires are included in Appendix D.

Table 2.1. Measurement Details for Providence Portland Medical Center Garage

Location	Approximate Grid Area	Approximate Grid Spacing	Measurement Height
Across Parking Spaces	60 ft x 30 ft	4 ft	2 inches above floor
Across Parking Lane	40ft x 20 ft	4ft	2 inches above floor

[1] The CCT values of two LSG Version 1 LED luminaires were measured on site at garage Level A. These two luminaires were in the center of the measurement grid and were at least 40 feet away from the nearest HPS luminaires.

3.0 Project Results and Discussion

3.1 Electrical Demand and Energy Savings

The HPS luminaires consumed an average of 191 watts each (lamp plus ballast). As a result, the estimated annual power consumption for each luminaire, assuming 8760 hours of operation annually, is 1674 kWh. Version 1 of the LSG LED luminaire consumed an average of 82 watts per luminaire. Over the same annual operating hours, the estimated annual power consumption for each of the LED luminaires is 719 kWh. Version 2 of the LSG LED luminaire is rated at 78 watts and its estimated annual power consumption at 8760 hours of operation is 683 kWh. Table 3.1 contains a summary of the electrical demand and energy savings of the luminaires.

Table 3.1. Electrical Demand and Energy Savings

	Lamp Watts	Hrs/day Use	Annual kWh	Annual kWh Savings	Percent Energy Savings
LSG Low Bay LED luminaire V1*	82*	24	719	955	57%
LSG Low Bay LED luminaire V2**	78**	24	683	991	59%
Crouse-Hinds HPS luminaire*	191*	24	1674		

Notes: * Measured; ** Rated

3.2 Lighting Performance

PNNL conducted illuminance testing on site in the garage at Level A, taking measurements for the six HPS fixtures and of the six Version 1 LED luminaires at ground level at each 4-ft point along the 30-ft by 50-ft measurement grid described in Section 2. No illuminance measurements were taken on site for the Version 2 LED luminaire; however, for evaluation purposes, this luminaire version was projected to produce 30% higher illuminance levels.[1]

The average illuminance levels for each luminaire spacing, and for the entire test area, were calculated and converted to foot-candles for ease of use. These average illuminance levels, along with the maximum and minimum measured values, were then used to calculate the average- and maximum-to-minimum uniformity ratios.

Overall, Version 1 of the LSG LED luminaires provided similar, if not somewhat lower measured minimum illuminance levels (across parking spaces) compared to the HPS luminaires they replaced. Version 2 of the LED luminaire, with its higher light output, is projected to provide slightly higher minimum illuminance level than the HPS luminaires. Note that all three luminaires provided higher minimum illuminance levels than the minimum level recommended by the Illuminating Engineering

[1] Note that this is only a projection based on Version 2's laboratory reported performance. Actual illuminance levels will depend on many factors.

Society of North America (IESNA) of 1 fc on the horizontal surface. Table 3.2 contains a summary comparison of the illuminance levels.

Table 3.2. Illuminance Level Comparison – across Parking Spaces

	Existing HPS Fixture	LSG Low Bay V.1	LSG Low Bay V.2 (Projected)
Max Light Level (fc)	23.51	20.54	26.70
Min Light Level (fc)	1.49	1.45	1.88
Average (fc)	7.35	4.05	5.26
Average to Min	4.94	2.79	2.79
Max to Min	15.81	14.17	14.17

Note: "average" is average of all points measured across the parking spaces, not maximum and minimum points only.

Both versions of the LSG LED luminaires provide lower average light levels than the installed HPS fixtures (about 45% less for the older version and about 28% less projected for the newer version), but the newer version of the LSG luminaire is projected to provide higher maximum and minimum illuminance levels. Lower averages do not necessarily mean that the garage will be dimmer with the new fixtures. Version 1 of the LED luminaires maintained minimum light levels across the parking spaces with slightly increased overall uniformity compared to the HPS (as indicated by the lower max to min uniformity ratios), thus providing slightly more even light distribution.[1] The new version of the LED luminaire is expected to provide slightly higher minimum illuminances than the HPS, with the same even distribution.

Some HPS luminaires typically over-light the area directly beneath the luminaires (creating "hot spots") in order to maintain minimum levels further away.[2] This can result in very noticeable variation in light levels in the illuminated area (this is indicated by a high max to min ratio). A more uniform light distribution is indicated by a lower uniformity ratio. The LED luminaires in this case are expected to provide a slightly better uniformity ratio, but the difference between the HPS and LED uniformity is slight and more than likely not easily discernible. Figure 3.1 and Figure 3.3 show the installed LSG Low Bay luminaires on PPMC Parking Garage Level A.

---

[1] Independent photometric testing results are available for all three luminaires. The Version 1 LED luminaire (drawing 82 W) produced 3,600 lumens of light. The Version 2 LED luminaire (drawing 75 W) produced 4,700 lumens of light, 30% more light output than Version 1 (an efficacy of 62 lumens/watt). In comparison the HPS lamp produced 9800 lumens, almost twice as much light output (for an efficacy of 53.7 lumens/watt).

[2] In practice, lighting installations such as parking garages are designed to achieve specific "maintained" illuminance levels, based on the mean lumen output of the lighting system. For HPS lamps, "mean lumens" is typically understood as light output at 50% of rated life. As a result, a lighting installation with new lamps will be initially "over lit."

Figure 3.1. Installed LSG Low Bay LED Luminaires on PPMC Parking Garage Level A

No vertical illuminance measurements were taken for either HPS or LED luminaires. However, according to the PPMC Electrician, Version 2 of the LSG LED luminaire provided noticeably more vertical illuminance (more light on the walls or better lateral dispersion) than the Version 1 LED luminaires that were installed on Level A. The color appearance of parked cars was also improved, as illustrated in Figure 3.2.

Figure 3.2. LED Luminaires at PPMC Parking Garage Entrance (Level B)

The CCT of two LSG LED luminaires was measured on site at garage Level A. These two LED luminaires were in the center of the grid and were at least 40 feet away from the nearest HPS luminaires.

The CCT measurements for these two luminaires were 5285 K and 5423 K, which is close to the 5600 K CCT claimed by the manufacturer. These CCT measurements indicate a much whiter light than the 2051 K and 2177 K measured for two HPS luminaires that had been installed at the same grid locations. The difference in color between the white light of the LED luminaires and the yellow light of the HPS luminaires is quite noticeable in Figures 3.1 and 3.2.

Figure 3.3. Installed LSG Low Bay LED Luminaires on PPMC Parking Garage Level A

Figure 3.4. Installed LSG Luminaire on PPMC Parking Garage Level B

3.3 Lamp Lifetime

Unlike conventional light sources, LEDs typically don't "burn out" and fail suddenly, but rather produce diminished light output over time.[1] HPS lamps also dim gradually over time before eventually failing completely. According to LSG Corporation, the LED luminaires used in this study have a life expectancy of 50,000 hours, meaning at 50,000 hours of use they will still be producing 70% of their initial light output (as measured at 25°C ambient temperature). High operating temperatures can reduce LED light output and shorten their operating life; conversely, cooler operating conditions may extend the life of the diodes.[2]

Note, however, that the long-term performance of LED luminaires is still largely untested. For example, a claimed product life of 50,000 hours translates to nearly six years of continuous operation. IESNA has only recently published an official test method for lumen depreciation testing (LM-80, released in September 2008). Consequently, no independent data is available to corroborate the manufacturer's lifetime estimates.

3.4 User Acceptance

The PPMC Electric Department managed the customer opinion survey for this assessment. Given the difficulty of surveying public users of the garage, the user survey was conducted only with maintenance and security personnel. Also, once the fixtures were moved to Level B, it was not possible to expand the survey to include the Medical Center nurses who use Level A parking, as originally planned. Two groups of security and maintenance personnel were surveyed: the first group was the night shift staff that routinely walk or drive through the area where the new luminaires were installed (6 total respondents); the second group was the night staff that viewed the area illuminated by the new luminaires on security monitors via installed security cameras in the garage (3 total respondents). A copy of the survey form is presented in Appendix E.

[1] Under normal operating conditions, the diodes themselves do not suffer from catastrophic failure such as an incandescent filament may experience. Rather, the LEDs simply produce less light. However, other components of an LED luminaire, such as the power supply, can still suffer from a catastrophic failure.

[2] The rated life of the HPS lamp used in this study is 24,000 hours. At 24,000 hours, the HPS lamp would be expected to provide 75%-85% of initial lumens. A LED luminaire, if the manufacturer's predictions are correct and ambient conditions average below 25°C, could still be providing a high percentage of its initial lumens at 24,000 hours. It should also be noted that these LED luminaires contain no replaceable parts. Replacement means the replacement of the full assembly, as opposed to the HPS luminaire, where the lamp, ballast, and lens can be individually replaced (at higher maintenance costs).

Figure 3.5. Installed LED Luminaire at PPMC Garage (Level B), with Security Camera in Background

The first question asked of both groups was if they had noticed the change in garage lighting. A "no" answer to this question meant skipping most of the remaining questions. Six respondents out of ten in the first group, and three out of six of the second group reported noticing the new lighting. The results below are, therefore, limited to these nine respondents, a number sufficient to note any developing trends but insufficient to perform any statistical extrapolation to a larger population.

Four of the nine respondents that expressed any preference felt that the new lights were at least as good as the old lights. Two of the three that observed the relamped area via the security video system expressed a preference for the new lights. Over half of the respondents thought that the LED luminaires provided somewhat more light than the incumbent HPS luminaires. Some of respondents also thought that the LED luminaires were less "glary" and created less shadow. There were also comments suggesting that the new light sources had a more positive impact on overall visibility and helped to improve the appearance of the illuminated area.

3.5 Economic Analysis

Economic performance was evaluated primarily by calculating the simple paybacks for the LED sources versus the HPS sources. To calculate simple payback, current energy and materials costs were used to calculate annual maintenance cost and energy cost. For these calculations, the LSG "quantity pricing" was used at $470 per unit for both versions of the Low Bay LED luminaire. The average price for a new HPS luminaire was assumed to be $275.[1]

To estimate annual and lifetime energy cost, two average electricity rates were used: a commercial rate local to northeast Portland by Portland General Electric (6.5 cents per kWh – Rate Schedule 89) and an average national rate (11 cents per kWh). Under these rates, the LSG LED luminaires yielded annual energy savings of about $62 to $109 per unit when compared to the existing HPS luminaires, based on 24 hours of use per day.[2] Table 3.3 below contains the cost calculations.

[1] The average was obtained through a survey of online merchants such as www.buylightfixtures.com, and Contractor Lighting & Supply (http://www.contractorlighting.com).
[2] Details on the calculations can be found in Appendix F: Payback Calculations.

Table 3.3. Operating Costs and Annual Energy Savings Estimates for LED Luminaires

	Lamp Watts	Hrs/day Use	Annual kWh	Annual kWh Savings	Annual Savings @ 6.5c/kWh	Annual Savings @ 11c/kWh
LSG Low Bay LED luminaire V1	82*	24	719	955	$ 62.06	$ 105.03
LSG Low Bay LED luminaire V2	78**	24	683	991	$ 64.40	$ 108.98
Crouse-Hinds HPS luminaire	191*	24	1674			

Notes: * Measured; ** Rated

Notes: See Appendix F for further details.

Because of the manufacturer's long claimed life (50,000 hrs), the LED modules were assumed to have zero lamp replacement cost over the course of their useful life (about 5.7 years if operated 24 hrs/day). Some maintenance will be required to periodically clean off dust and cobwebs; however, as this would require the same amount of maintenance time regardless of the luminaire type used, it was not figured into the calculations.

Three payback scenarios were calculated: a retrofit 24 hr/day scenario, a retrofit 12 hr/day scenario, and a new construction 24 hr/day scenario.

The first retrofit scenario is based on 24 hours per day of luminaire operation. The retrofit scenario assumes an operational HPS luminaire is already in place and is being replaced by the LED fixture; therefore, the full cost of the LED luminaire ($470) is figured into the payback calculation. The simple payback periods for the LED modules in the retrofit, 24 hr/day usage is between 3.9 and 6.5 years. Table 3.4 shows the cost calculations and payback results.

Table 3.4. Operating Costs and Payback Estimates for LED Low-Bay Luminaire Retrofits – 24-hrs/day Usage

	Estimated Unit Cost	Lamp Watts	Hrs/day Use	Annual kWh	Est. replace lamp costs/year (inc. maint.)	Annual Operating Costs @ 6.5c/kWh (elec + rep)	Annual Operating Costs @ 11c/kWh (elec + rep)	LEDs Payback @ 6.5c/kWh (Years)	LEDs Payback @ 11c/kWh (Years)
LSG Low Bay LED luminaire V1*	$ 470	82*	24	719		$ 46.75	$ 79.11	6.5	4.1
LSG Low Bay LED luminaire V2**	$ 470	78**	24	683		$ 44.41	$ 75.16	6.3	3.9
HPS luminaire*	$ 275	191*	24	1674	10.5	$ 119.32	$ 194.66		

Notes: * Measured; ** Rated

Notes: See Appendix F for assumptions.

The second retrofit scenario is based on 12 hours per day of operation and shows that the payback times will lengthen considerably with shorter daily operating hours (Table 3.5)

Table 3.5. Operating Costs and Payback Estimates for LED Low-Bay Luminaire Retrofits – 12 hrs/day Usage

	Estimated Unit Cost	Lamp Watts	Hrs/day Use	Annual kWh	Est. replace lamp costs/year (inc. maint.)	Annual Operating Costs @ 6.5c/kWh (elec + rep)	Annual Operating Costs @ 11c/kWh (elec + rep)	LEDs Payback @ 6.5c/kWh (Years)	LEDs Payback @ 11c/kWh (Years)
LSG Low Bay LED luminaire V1*	$ 470	82*	12	360		$ 23.37	$ 39.56		
LSG Low Bay LED luminaire V2**	$ 470	78**	12	342		$ 22.21	$ 37.58	11.0	7.2
HPS luminaire*	$ 275	191*	12	837	10.5	$ 64.92	$ 102.58	11.3	7.5

Notes: * Measured; ** Rated

Notes: See Appendix F for assumptions.

The third scenario is a new construction scenario, where it is assumed that the builder could install either kind of luminaire. Therefore, only the differential cost of the LED luminaire versus the HPS luminaire is taken into account, thus the unit cost used in the calculation of payback is $470 - $275 = $195. Based on this cost, the payback is between 1.6 and 2.7 years (Table 3.6).

Table 3.6. Operating Costs and Payback Estimates for LED Low-Bay Luminaires in New Construction – 24-hrs/day Usage

	Estimated Unit Cost	Lamp Watts	Hrs/day Use	Annual kWh	Est. replace lamp costs/year (inc. maint.)	Annual Operating Costs @ 6.5c/kWh (elec + rep)	Annual Operating Costs @ 11c/kWh (elec + rep)	LEDs Payback @ 6.5c/kWh (Years)	LEDs Payback @ 11c/kWh (Years)
LSG Low Bay LED luminaire V1*	$ 470	82*	12	360		$ 23.37	$ 39.56		
LSG Low Bay LED luminaire V2**	$ 470	78**	12	342		$ 22.21	$ 37.58	4.6	3.0
HPS luminaire*	$ 275	191*	12	837	10.5	$ 64.92	$ 102.58	4.7	3.1

Notes: * Measured; ** Rated

Notes: See Appendix F for assumptions.

4.0 Conclusions

In this GATEWAY Demonstration project conducted at Providence Portland Medical Center between April and September 2008, it was determined that the LSG LED area luminaires have the potential to offer significant energy savings over the HPS area luminaires currently in use at the PPMC parking garage. The project also demonstrated how swiftly one manufacturer was able to take advantage of advances in LED technologies within a short time period.

Of the two LED replacement luminaires used in this demonstration, the newer version can provide a higher minimum light level and a more uniform light distribution than the incumbent HPS luminaire. Specifically, the new version of the LSG Low Bay LED luminaire has the potential to improve the minimum light level up to 25% over the HPS luminaires currently used in the PPMC garage (1.88 fc versus 1.49 fc), while providing slightly better light uniformity (2.79 average to minimum ratio versus 4.94 for the HPS luminaire).

Economic analyses were performed and payback costs ranged from 1.6 to 11.3 years, depending on hours of operation per day and whether the luminaire was used in a retrofit or new construction situation. The shortest payback was with the LED luminaire operating 24 hrs/day in the new construction scenario with electricity rates at 11c/kWh (1.6 years). The new LED luminaires could save up to $109 per fixture annually in electricity cost savings, assuming 11c/kWh electricity rates.

The LED luminaires also provided a much whiter light than the HPS lamps; the average CCT for two LED fixtures measured on site was 5354 K versus 2114 K average for the two HPS lamps. The LED luminaires' light output and general lighting performance were commented upon by maintenance and security personnel through a survey. A number of the surveyed security and maintenance staff thought the LED-based fixtures improved the visibility in the garage, compared to the HPS luminaires, and a number indicated their preference for both the visibility and color of the new light source.

From an economic perspective, acceptance of these LED replacement fixtures may be limited by their initial purchase cost. Despite the significant reduction in annual energy consumption and maintenance costs that they can offer in this project, the high upfront cost of these LED products (and of LED products in general) can be a significant barrier to their adoption. Even with the improvements in light output seen in the newer version (at the same cost), the payback period for the LED luminaires used in this study remains slightly longer than its expected lifetime at the lowest electricity rate (6.3 years projected payback versus 5.7 years estimated lifetime). With the expected improvements in efficacy and a reduction in the cost of LED devices, the payback of any LED luminaire installation can improve. Utility incentive programs could also help bring the price down to a more attractive level for users in the near term.

Appendix A

Demonstration Site

Appendix A

Demonstration Site and Luminaire Data

Providence Portland Medical Center (PPMC) is part of Providence Health & Services in Oregon, a not-for-profit network of hospitals, health plans, physicians, clinics, and affiliated health services. The northeast Portland location is a large campus occupying about five city blocks by five city blocks (Figure A1). The garage is lit with about 400 HPS luminaires; most operate 24 hours per day. PPMC's electrician noted that a number of luminaires on the outside perimeter of the parking levels have been retrofitted with photo sensors, so these luminaires would not be operating at 24 hours per day. The Providence facility is evaluating a number of energy-efficient lighting options to replace its stock of aging HPS area lights.

Figure A1. Location of Providence Portland Medical Center, in Southeast Portland, Oregon. Arrow shows garage location.

Garage Specific Data:

- Approximate garage area: 50,000 square feet
- Number of parking levels: 6
- Approximate number of parking spaces: 900
- Parking space width: 9 feet
- Parking space length: 15 feet
- Width of traffic lane: 24 feet
- Garage operating hours: 24 hours/day, 7 days/week, 365 days/year
- Approximate number of luminaires: 410

Luminaire Specific Data:

Crouse-Hinds Lighting

- Cat # LW/VLC15 120/277
- Style # 7240D94G14HPS Parking garage luminaire
- White interior & metal reflector, prismatic truncated cone lens
- GE Magnetic Ballast
- GE 150W HPS lamp, Cat# LU150/55
- Fixture input: 120 VAC / 183 W / 1.7 A / 0.90 PF

Lighting Science Group

- Low Bay PSU/Luminaire
- 14" x 14” x 4-1/16"
- 9 ¼ " x 9 ¼” x 4 1/6” Pyramid shape Acrylic clear lens.
- 108 Cool white LEDs
- Lighting Science ballast
- 220 TO 277V 60Hz Electronic
- 78 W or 85 W

Appendix B

Measuring Equipment

Appendix B

Measuring Equipment

Date: April 13, 2008

Time: 9:45 AM – 4:30 PM

Temperature: 63 Degrees F

Conditions: Covered indoors conditions

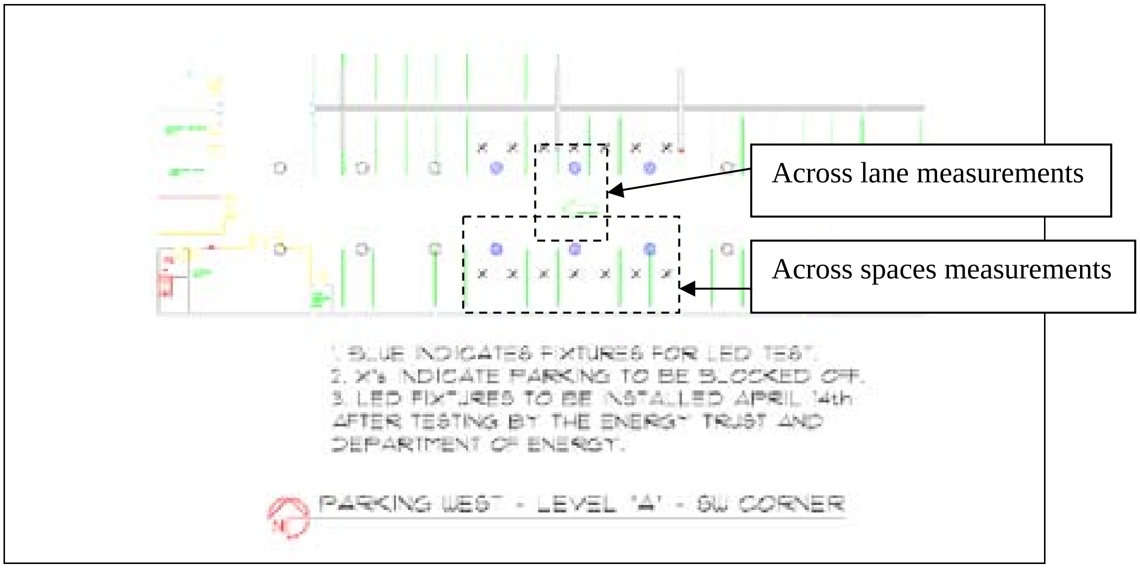
Illuminance Meter	Minolta Illuminance Meter, Model T-1
Chroma Meter	Konica Minolta Chroma Meter, Model CL-200
Power Meter	N/A
Temperature Meter	Indoor thermometer

Appendix C

Measurement Data

Appendix C

Measurement Data



PPMC HPS Data, Across Spaces

21.4	104.0	200.0	253.0
18.1	66.8	172.0	180.0
16.3	31.3	47.7	80.9
16.6	29.7	55.7	64.8
16.0	32.5	69.4	107.0
19.1	52.8	170.0	186.0
20.2	70.8	172.0	202.0
18.2	53.0	170.0	175.0
16.0	32.0	63.0	105.0
16.1	30.5	50.1	76.6
16.0	29.0	59.1	61.9
20.8	50.1	176.0	199.0
16.3	88.8	191.0	249.0

Calculated Values

Average	79.1	7.4
Max	253.0	23.5
Min	16.0	1.49
Ave to min	4.94	4.94
Max to min	15.81	15.81

PPMC LEDs Data, Across Spaces

20.8	44.2	122.0	214.0
18.7	34.7	76.1	124.0
17.8	22.7	36.9	52.1
16.5	20.9	29.6	44.2
16.7	19.7	32.5	38.6
15.9	18.3	36.6	41.4
16.1	26.8	69.2	99.5
16.4	29.3	88.8	175.0
15.9	27.8	57.7	112.0
15.6	20.1	31.9	47.1
15.8	19.3	31.6	40.7
17.1	18.4	35.2	36.9
18.6	21.3	39.9	49.5
20.5	31.7	80.3	123.0
22.8	40.7	121.0	221.0

Calculated Values

Average	43.55	4.05
Max	221.00	20.54
Min	15.60	1.45
Ave to min	2.8	2.8
Max to min	14.2	14.2

Appendix D

Test Data (from Independent Laboratories)

Intertek

REPORT

3933 US ROUTE 11   CORTLAND, NEW YORK 13045

Order No. 3170784   Date: January 21, 2009

REPORT NO. CALIPER TD 08-154 INTERTEK 3170784CRT-001

TEST OF ONE SSL PRODUCT

MODEL NO. CALIPER 08-154

RENDERED TO

PACIFIC NORTHWEST NATIONAL LABORATORY
620 SW 5TH AVENUE, SUITE 810
PORTLAND, OR 97204

TEST: Electrical and Photometric tests as required to the IESNA LM-79 test standard.

AUTHORIZATION: The testing performed was authorized by RDS contract number 41817M4238.

STANDARDS USED: The following American National Standards or Illuminating Engineering Society of North America Test Guides were used in part or totally to test each specimen:

ANSI NEMA ANSLG C78.377: Specifications of the Chromaticity of Solid State Lighting Products
IESNA LM-41: 1998 Approved Method for the Testing of Indoor Fluorescent Luminaires
IESNA LM-79: 2008 Approved Method for the Electrical and Photometric Measurements of Solid-State Lighting Products

DESCRIPTION OF SAMPLE: The client submitted one sample of model number CALIPER 08-154. The samples were received by Intertek on January 5, 2009, in undamaged condition, and one sample was tested as received. The sample designation was 08-152.

DATES OF TESTS: January 5, 2009 through January 21, 2009.

EQUIPMENT LIST

Equipment Used	Model Number	Control Number	Last Calibration Date	Calibration Due Date
Elgar AC Power Supply	1001SX	---	---	---
Xitron Power Analyzer	2503H	E235	03/20/08	03/20/09
Labsphere Diode Array	DAS 1100	N714	Before Use	Before Use
Leeds & Northup Standard Resistor	Manganin	Y089	01/31/08	01/31/09
Data Precision Digital Voltmeter	3600	V124	01/31/08	01/31/09
Fluke Multimeter	45	M133	01/31/08	01/31/09
Fluke Temperature Meter	52	T801	06/02/08	06/02/09
Kikusui DC Power Supply	35-10L	E160	---	---
Sorenson DC Power Supply	150-188	E161	---	---
UDT Optometer	S370	N301	Before Use	Before Use
ITS Two Meter Diameter Integrating Sphere	---	N308	Before Use	Before Use
NIST Luminous Flux Standard Sources	---	150-14, 200-12, 8043	09/19/07	09/19/08
NIST Spectral Flux Standard Source	RF0605	---	11/29/06	100 hours of use
LSI High Speed Mirror Goniophotometer	6440	--	Before Use	Before Use

TEST METHOD

Seasoning in Each Burn Orientation

No seasoning was performed in accordance with IESNA LM-79.

Photometric and Electrical Measurements – Integrating Sphere Method

A Labsphere Model DAS 1100 Diode Array Spectroradiometer and Two Meter or Ten Foot Sphere was used to measure correlated color temperature, chromaticity coordinates, and the color rendering index for each SSL unit.

Ambient temperature was measured at a position inside the sphere. Each SSL unit was operated on the client provided driver at the rated input voltage in its designated orientation. Each SSL unit was allowed to stabilize for at least thirty minutes before measurements were made. Electrical measurements including voltage, current, and power were measured using the Xitron or Yokogawa Power Analyzer.

The calibration of the sphere photometer-spectroradiometer system is traceable to the National Institute of Standards and Technology.

TEST METHODS (cont'd)

Photometric and Electrical measurements – Distribution Method

A LSI Type C High Speed Model 6440 Mirror Goniometer was used to measure the intensity (candelas) at each angle of distribution for each LED fixture, module or array.

Ambient temperature was measured equal to the height of the sample mounted on the Goniometer equipment. Each LED fixture or array was operated on the client provided driver at rated input volts in its designated orientation. Each LED fixture, module or array was allowed to stabilize for at least thirty minutes before measurements were made. Electrical measurements including voltage, current, and power were measured using the Xitron or Yokogawa Power Analyzer.

Some graphics were created with Photometrics Plus software.

Spectral Power Distribution

Spectral Power distribution through the visible wavelengths was measured with the Labsphere Diode Array software.

Temperature Measurements

Thermal measurements were made on the SSL product at the indicated hot spot included in this report. The hot spot diagram was found with a MikroScan 7200 Thermal Imaging Camera.

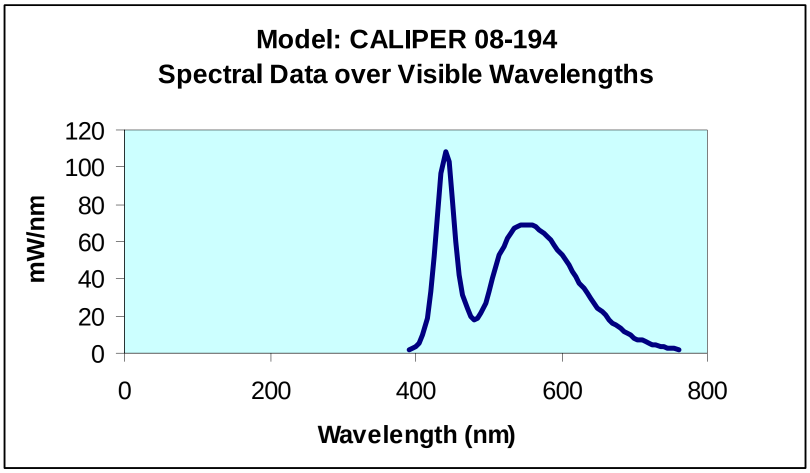
Total Operating Time

The chart below indicates the total number of hours that the product was energized.

Model No	Total Hours
CALIPER 08-154	4

RESULTS OF TESTS

SPECTRAL POWER DISTRIBUTION



RESULTS OF TESTS (cont'd)

Photometric, Temperature, and Electrical Measurements at 25°C – Integrating Sphere Method

Intertek Sample No.	Correlated Color Temperature (K)	CRI	CIE 31' Chromaticity Coordinate (x)	CIE 31' Chromaticity Coordinate (y)	CIE 76' Chromaticity Coordinate u'	CIE 76' Chromaticity Coordinate v'
Model: CALIPER 08-154						
08-154	6134	72.20	0.3188	0.3377	0.1988	0.4739

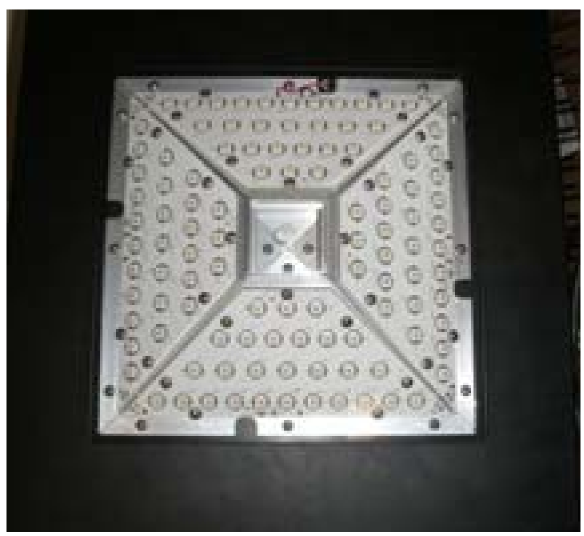
Intertek Sample No.	Hot Spot Temperature (°C)	Base Orientation	Input Voltage (Vac)	Input Current (mA)	Input Power (Watts)	Luminous Flux (Lumens)	Lumen Efficacy
Model: CALIPER 08-154							
08-154	33.5	Up	120.0	635.6	75.09	4764	63.44

Photometric, Temperature, and Electrical Measurements at 25°C – Distribution Method

Intertek Sample No.	Hot Spot Temperature (°C)	Base Orientation	Input Voltage (Vac)	Input Current (mA)	Input Power (Watts)	Luminous Flux (Lumens)	Lumen Efficacy
Model: CALIPER 08-154							
08-154	36.3	Up	120.0	633.0	74.77	4609	61.64

Hot Spot Diagram

Picture

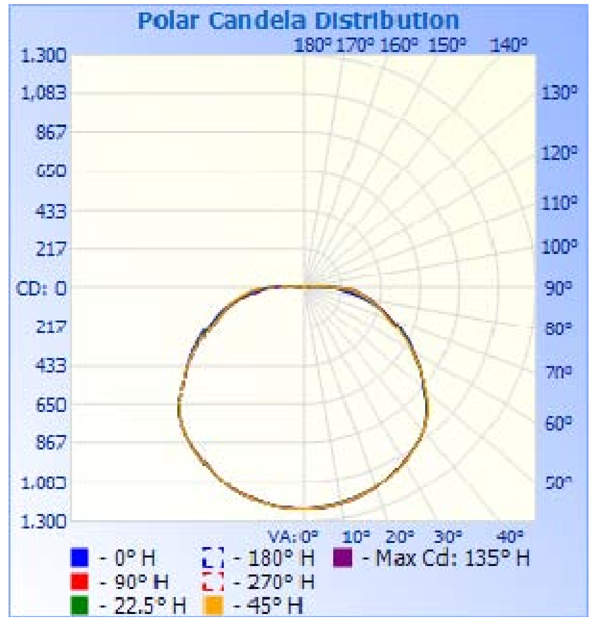


RESULTS OF TESTS (cont'd)

Photometric Measurements – Distribution Method

Intensity (Candlepower) Summary at 25°C

Angle	0	22.5	45	67.5	90	Output Lumens
			Model: CALIPER 08-154			
0	1232	1232	1232	1232	1232	
5	1229	1232	1234	1232	1227	119
10	1222	1223	1224	1222	1218	
15	1202	1206	1207	1204	1204	341
20	1183	1186	1186	1186	1185	
25	1153	1154	1156	1152	1155	533
30	1113	1126	1122	1129	1118	
35	1082	1086	1084	1085	1081	678
40	1045	1036	1038	1035	1043	
45	985	974	977	984	977	751
50	879	901	895	893	881	
55	797	810	804	798	800	713
60	704	693	693	693	710	
65	619	601	574	605	626	596
70	536	511	488	514	533	
75	452	436	428	439	456	465
80	342	372	404	375	344	
85	245	293	351	313	242	324
90	165	177	208	191	167	



Zonal Lumens and Percentages at 25°C

Zone	Lumens	% Luminaire
	Model: CALIPER 08-154	
0-30	992	21.52
0-40	1670	36.24
0-60	3134	67.99
0-90	4519	98.04
40-90	2848	61.80
60-90	1385	30.05
0-90	90	1.96
0-180	4609	100

Luminance Summary (cd/sq. meter)

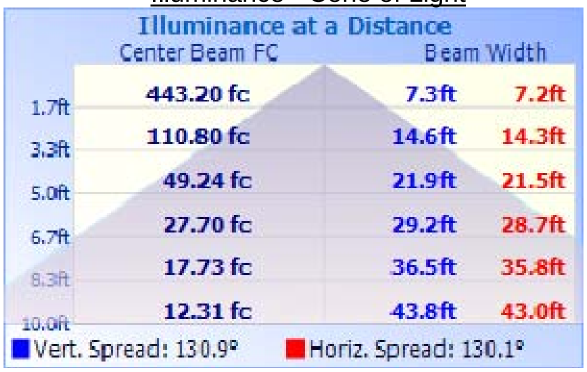
Angle	0	45	90
	Model: CALIPER 08-154		
45	21586	21483	21497
55	21530	21813	31712
65	22688	21135	23064
75	27059	25605	27418
85	43607	62615	43272

Intertek

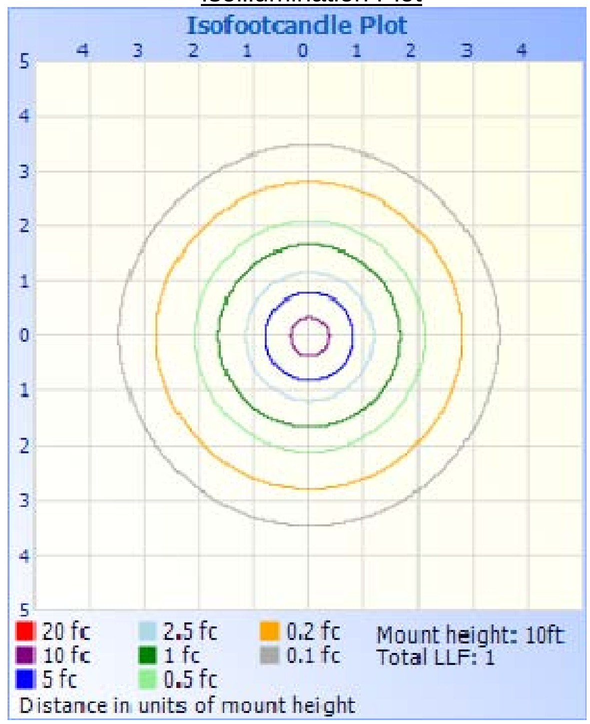
RESULTS OF TESTS (cont'd)

Model No.: CALIPER 08-194
Mounting Height: 10FT

Illuminance - Cone of Light



Isoillumination Plot



CONCLUSION

The results tabulated in this report are representative of the actual test samples submitted for this report only. The data is provided to the client for further evaluation. Compliance to the referenced specification requirements was not determined in this report.

In Charge Of Tests:

Jacki Swiernik
Project Engineer
Lighting Division

Report Reviewed By:

Dave Ellis
Senior Project Engineer
Lighting Division

Attachment: None

Appendix E

Survey of Users’ Perceptions of LED Lighting

Appendix E

Survey of Users' Perception of LED Lighting

Subject: Test Lighting Questionnaire

An alternative type of light fixture was recently installed by the PPMC Garage Entrance (Level B) and on Level A. The U.S. Department of Energy is interested in your opinions of the alternative light and has constructed a brief questionnaire to obtain your feedback.

1. Did you notice that new lights were installed?

   Yes --1
   No **(SKIP TO Q12)** 2

(ASK Q2-Q11 ONLY IF YES IN Q1)

2. Do you feel that the new light fixtures have improved or not improved overall visibility in the area where they are installed?

Strongly improved	--1
Somewhat improved	--2
Somewhat not improved	--3
Strongly not improved	--4
No change/about the same	--5
DK/NA	--6

3. Do you feel that the new fixtures have made it easier or more difficult to see faces?

Much easier	--1
Somewhat easier	--2
Somewhat more difficult	--3
Much more difficult	--4
No change/about the same	--5
DK/NA	--6

4. Do you feel that the new fixtures create less glare or more glare?

Much less glare	--1
Somewhat less glare	--2
Somewhat more glare	--3
Much more glare	--4
About the same as old lights	--5
DK/NA	--6

5. Do you feel that the new fixtures provide the right amount of light, or are they too bright or too dim?

Right amount of light	--1
Much too bright	--2
Somewhat too bright	--3
Somewhat too dim	--4
Much too dim	--5
DK/NA	--6

6. Do you feel that the new light fixtures create fewer or more shadows?

Many fewer	--1
Somewhat fewer	--2
Somewhat more	--3
Many more	--4
No change/about the same	--5
DK/NA	--6

7. Do you feel the new light fixtures have improved or not improved the overall <u>appearance</u> of the building and site?

Strongly improved	--1
Somewhat improved	--2
Somewhat not improved	--3
Strongly not improved	--4
No change/about the same	--5
DK/NA	--6

8. Do you feel the new light fixtures have improved or not improved the overall <u>safety</u> of the building and site?

Strongly improved	--1
Somewhat improved	--2
Somewhat not improved	--3
Strongly not improved	--4
No change/about the same	--5
DK/NA	--6

9. When all things are considered, do you prefer the <u>new</u> light fixtures that were installed or do you prefer the <u>old</u> light fixtures they replaced?

Strongly prefer new fixtures	--1
Somewhat prefer new fixtures	--2
Somewhat prefer old fixtures	--3
Strongly prefer old fixtures	--4
DK/NA	--5

10. In a few words of your own, why do you prefer the light fixtures you selected in the last question? (Skip if no preference.)

a. New fixtures

____

b. Old fixtures

____

Appendix F

Payback Calculations and Assumptions

Appendix F

Payback Calculations and Assumptions

Assumptions:
HPS luminaire cost: $275 (average)
HPS replacement lamp cost: $35 (www.grainger.com)
HPS lamp lifetime: 24,000 hrs
LED luminaire cost: $470
LED luminaire lifetime: 50,000 hrs

A. Retrofit Case, 24 hours operation:

	Estimated Unit Cost	Annual kWh	Cost of Electricity	Cost of Electricity	Energy Cost/Year @ 6.5c/kWh	Energy Cost/Year @ 11c/kWh	Annual Savings @ 6.5c/kWh	Annual Savings @ 11c/kWh	Est. replace lamp costs/year	Annual Operating Costs @ 6.5c/kWh (elec + rep)	Annual Operating Costs @ 11c/kWh (elec + rep)	LEDs Payback @ 6.5c/kWh (Years)	LEDs Payback @ 11c/kWh (Years)
LSG Low Bay LED luminaire V1*	$ 470	719	0.065	0.11	$ 46.75	$ 79.11	$ 62.06	$ 105.03		$ 46.75	$ 79.11	6.5	4.1
LSG Low Bay LED luminaire V2**	$ 470	683	0.065	0.11	$ 44.41	$ 75.16	$ 64.40	$ 108.98		$ 44.41	$ 75.16	6.3	3.9
Crouse-Hinds HPS luminaire*	$ 275	1674	0.065	0.11	$ 108.81	$ 184.14			10.5	$ 119.32	$ 194.66		

Notes: * Measured; ** Rated

B. Retrofit Case, 12 hours operation:

	Estimated Unit Cost	Annual kWh	Cost of Electricity	Cost of Electricity	Energy Cost/Year @ 6.5c/kWh	Energy Cost/Year @ 11c/kWh	Annual Savings @ 6.5c/kWh	Annual Savings @ 11c/kWh	Est. replace lamp costs/year	Annual Operating Costs @ 6.5c/kWh (elec + rep)	Annual Operating Costs @ 11c/kWh (elec + rep)	LEDs Payback @ 6.5c/kWh (Years)	LEDs Payback @ 11c/kWh (Years)
LSG Low Bay LED luminaire V1*	$ 470	360	0.065	0.11	$ 23.37	$ 39.56	$ 31.03	$ 52.52		$ 23.37	$ 39.56		
LSG Low Bay LED luminaire V2**	$ 470	342	0.065	0.11	$ 22.21	$ 37.58	$ 32.20	$ 54.49		$ 22.21	$ 37.58	11.0	7.2
Crouse-Hinds HPS luminaire*	$ 275	837	0.065	0.11	$ 54.41	$ 92.07			10.5	$ 64.92	$ 102.58	11.3	7.5

Notes: * Measured; ** Rated

C. New Construction Case, 24 hours operation:

	Estimated Unit Cost	Annual kWh	Cost of Electricity	Cost of Electricity	Energy Cost/Year @ 6.5c/kWh	Energy Cost/Year @ 11c/kWh	Annual Savings @ 6.5c/kWh	Annual Savings @ 11c/kWh	Est. replace lamp costs/year	Annual Operating Costs @ 6.5c/kWh (elec + rep)	Annual Operating Costs @ 11c/kWh (elec + rep)	LEDs Payback @ 6.5c/kWh (Years)	LEDs Payback @ 11c/kWh (Years)
LSG Low Bay LED luminaire V1	$ 470	719	0.065	0.11	$ 46.75	$ 79.11	$ 62.06	$ 105.03		$ 46.75	$ 79.11		
LSG Low Bay LED luminaire V2	$ 470	683	0.065	0.11	$ 44.41	$ 75.16	$ 64.40	$ 108.98		$ 44.41	$ 75.16	2.6	1.6
Crouse-Hinds HPS luminaire	$ 275	1674	0.065	0.11	$ 108.81	$ 184.14			10.5	$ 119.32	$ 194.66	2.7	1.7

Notes: * Measured; ** Rated