INCORPORATING NEW AGE TECHNOLOGY INTO CAMPUS LIGHTING

by

DANIEL W. MATLACK

B.S., KANSAS STATE UNIVERSITY, 2009

A REPORT

submitted in partial fulfillment of the requirements for the degree

MASTER OF ARCHITECTURAL ENGINEERING

DEPARTMENT OF ARCHITECTURAL ENGINEERING AND CONSTRUCTION SCIENCE
COLLEGE OF ENGINEERING

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2009

Approved by:

Major Professor
Raphael A. Yunk, P.E., LEED A.P.

Abstract

Sustainable design and green engineering practices have become a priority in the architectural design industry over the past few years. Energy codes and standards have become more stringent as energy costs rise and buildings become larger, consuming more energy and having a larger impact on the environment. One major area for improvement to meet these new requirements is in the lighting area. Kansas State University (KSU) in Manhattan, KS has had the same campus walkway lighting system for over 50 years and it does not meet the current energy codes and standards. This paper will perform a case study of the current walkway lighting system on the KSU campus, specifically focusing on the Quad area and applying the same principles to the entire campus. The illumination and fixture distribution characteristics will first be established and analyzed to determine an accurate baseline for later comparison. Issues regarding the illumination, efficiency, aesthetics, maintenance, and landscaping will be addressed once the current conditions are established. Lighting technology has changed dramatically in the past year with the development of high efficiency fluorescent, induction, and light emitting diode (LED) lighting. New LED technology has proven to be the most efficient and has been adapted to create outdoor LED fixtures that could help KSU surpass the current energy standards and improve the overall quality of light to correct some of the current issues the existing lighting creates. A full analysis of the illumination, efficiency, aesthetics, and economic feasibility will be performed. The economic analysis will compare existing maintenance and energy costs to that of the first-cost with maintenance, and energy costs to determine an estimated payback. Once the analysis is complete, future options for KSU to implement new lighting technology will be discussed. By creating a more environmentally conscious campus, using high efficiency lighting, KSU could set an example for other universities to pursue sustainable technology and design.

Table of Contents

List of Figures

List of Tables

Acknowledgements

Thank you to Ray Yunk, P.E. LEED A.P., Fred Hasler, P.E., Rhonda Wilkinson, P.E. LEED A.P., and David Fritchen for providing their expertise and support for this report. Also thank you to Kyle Gach for editing this report and Larry Milton, Dale Boggs, Dan Sanders, William Hirsch, Ellen Stephens, Kendra Stephenson, Karen McVey, and Ryan Diediker for their contributions.

Dedication

For my wife, Rachel Matlack, and my parents, Rex and Lynda Matlack.

Introduction

The purpose of this paper is to provide a case study and a suggested redesign of the existing Kansas State University (KSU) walkway lighting system in order to inform KSU officials of the benefits of installing a modern technology lighting system. This case study will include a full analysis of the existing lighting system, including problems that have developed with this system, factors that could be improved upon in the lighting on the KSU campus, and an economic study. As the KSU campus is very large, the study will primarily focus on an area called the Quad, refer to Appendix A.1 and A.2 for its location and site plan. This is a high traffic area that has a number of long, straight walkways where the lighting can easily be studied and the results can be applied throughout the campus. The redesign of the system will include a full economic analysis, looking at energy and maintenance savings, as well as a comparison to the existing system. Providing reasons for replacing the existing lighting system by implementing new lighting technology and using sustainable design principles through the use of light emitting diode (LED) will be the focus of this paper.

This paper is intended for Kansas State University (KSU) officials, lighting engineers and designers, and the KSU Facilities Planning Department that performs the maintenance of the current KSU exterior lighting system who have been exposed to basic lighting design terminology. It is also intended to provide information to professional and student engineers and other university officials who wish to further pursue and understand issues that can develop with older lighting systems and the potential for green design to improve the quality and save money in the maintenance and energy costs of these systems.

Lighting technology has changed dramatically in the past few years. The first interior and exterior LED fixtures have been introduced to the lighting market and sustainable design has become a hot topic in the world today. Many universities across the nation have had the same lighting system for many years, and have been unable to find reason and/or resources to replace it. With technology becoming more efficient and energy prices rising, LED technology has made these renovations possible. Specifically looking at the KSU campus, there is the ability to reduce light pollution using full cutoff fixtures rather than the current fixtures with unrestricted light distribution. Bringing the campus up-to-date with building codes, design standards and guidelines is also important. The U.S. Green Building Counsel (USGBC) Leadership in Energy and Environmental Design (LEED) program is creating tools and standards for green design, going above and beyond these codes. The federal, state, and local governments across the U.S. are also creating incentives for sustainable building design.

To summarize the information in this report, Chapter 1 will provide a brief history and detailed description of the current lighting system on the KSU campus, including a determination of its light loss factor and photometrics. Footcandle readings will be given in a 30 ft by 30ft grid around two fixtures in the Quad area to determine the actual photometrics. The manufacturers photometrics will then be compared to the calculated photometrics using the AGI32 (v. 2.03) program to determine its accuracy and to provide a photometric map of the rest of the Quad area. Using this existing information, Chapter 2 will analyze the problems that have developed with this system. It will include a comparison to the current building codes and design standards, and a discussion of maintenance, efficiency, and aesthetic issues. Chapter 3 will then provide goals and criteria that should be met for redesigning the system. These include safety, security, efficiency, and green goals.

Chapters 4 and 5 will provide two options to redesign the lighting in the KSU Quad area, including a full economic analysis and comparison to the existing system. It will also discuss benefits for each system and the effects it will have in correcting the issues discussed in Chapter 2 and improving upon the existing system as described in Chapter 1. Chapter 6 will then provide the final conclusion and recommendation to KSU regarding the existing walkway lighting system.

The information provided will allow university officials to educate themselves and other key members of design and construction committees to make informed decisions based on the capabilities of green lighting technology as well as economic and environmental effects provided by their use. Lighting engineers, designers, and students can use this information to educate themselves or communicate the significance of replacing older exterior lighting systems with green technology to owners and architects.

CHAPTER 1 - Existing Lighting Design Analysis

The Kansas State University (KSU) campus covers approximately 664 acres and contains various sizes of parking lots, walkways, bikeways, and roadways (Location & History, 1999). The campus itself contains thousands of linear feet of walkway and/or bikeway that must be illuminated. Refer to Appendix A.1 for a campus map. Within the campus boundaries, there are more than 751 light poles serving walkways, bikeways, parking lots, and roadways. Of those 751, there are 336 light poles that serve the walkways. (Milton, Larry) The overall campus lighting scheme is fairly uniform with metal halide lamping; only the roadways contain high-pressure sodium lamping.

The following sections introduce a detailed description and analysis of the existing campus lighting scheme narrowed to the walkway lighting system.

1.1 Existing Walkway Lighting System

KSU, as is common on most university campuses, has a very complex walkway system that creates many difficulties when lighting. Each walkway must be illuminated to meet standard safety and security requirements along with illuminating the surrounding area and buildings to create a safer campus environment. These criteria will be further discussed later in this report. Acrylic globes up to 22-inches in diameter line a majority of the walkways. Most of these fixtures are post-top mounted with only a few being pendant or wall mounted. This system was established in 1894 when the university was relocated to its current site. (Location and History, 1999) Since then it has expanded and undergone hundreds of renovations to form the campus that exists today.

Tracking these changes throughout the history of this university is difficult; each renovation requires approval from state and university officials, followed by approval of the engineering and construction firms hired to design and construct the projects. This creates confusion because most areas of campus have been designed and then redesigned by multiple engineering firms as well as in-house engineering and landscaping, each with their own submittals and master plans. Bringing all of these together to create a single master plan on such a large scale is very difficult and at times can be inaccurate. For the purposes of research for this report, the KSU Facilities Planning Department provided the master site plan currently being used for all campus projects. A partial view of this plan can be seen in Appendix A.2. This is the area known as the Quad, which is studied in this report. Its location on campus is also noted in Appendix A.1.

Due to the vast size of the KSU campus, acquiring existing conditions in its entirety is very difficult. As the same lighting infrastructure is used throughout the campus, only a few areas must be evaluated to gain an accurate understanding of the system and simplify this analysis. The area selected was the KSU Quad for its large open space and various unobstructed long walkways. Surrounding the Quad are some of the largest buildings on campus, those being Hale Library, Willard Hall, and Waters Hall, creating a very highly trafficked area. The space uses will be analyzed when the design strategies are discussed. Lighting characteristics and descriptions of the existing luminaries can be found in the following section.

1.2 Walkway Fixture Description

The Quad area contains only single post-top globe fixtures, compared to the many places on campus that may contain two to five lamp arms for a single post. KSU has established a contract with American Electric Lighting Company to provide all the walkway fixtures on campus grounds. The specific model used is the American Electric Lighting Cresthill Sphere, Series LCR. Specifications for these fixtures, as downloaded from the American Electric Lighting Company webpage can be found in Appendix B.1 and are described as follows.

As shown in Figure 1.1 on the following page, the Cresthill Sphere is composed of a 22 inch (in) white acrylic, post top globe with a single 175 watt (W) ED-28 metal halide lamp. It stands on a 12 foot (ft) tall round aluminum post with a black or gray powdercoat finish. The globe itself contains no optical reflectors creating a symmetric, unrestricted light distribution, a full 360 degrees in all planes. The lamp has a 65 CRI with no form of coating, and a 4000K color temperature.

Figure 1.1 American Electric Lighting Cresthill Sphere

(http://www.americanelectriclighting.com/)

This kind of light distribution in this fixture is more commonly known as a distribution with no cutoff, or unrestricted cutoff. Many outdoor fixtures have different distribution types that can more efficiently illuminate an area. These types are of distribution, Type I, Type II, Type III, Type IV, and Type V. They can be seen in Figure 1.2 below. (Bosela, 2003).

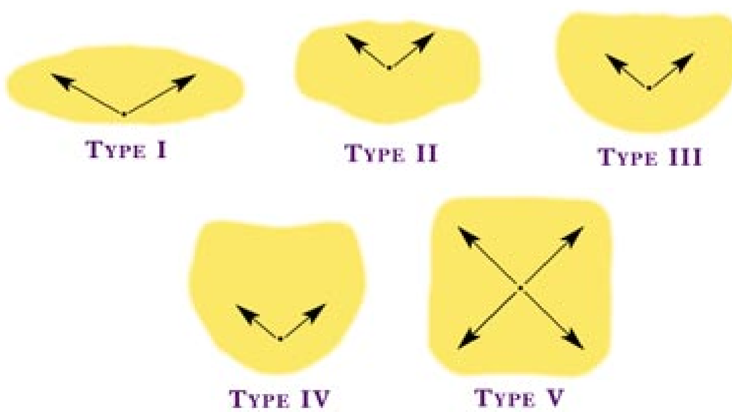


Figure 1.2 Light Distribution Types

(PSEG, 2008)

Under contract, KSU's ballast and lamp suppliers are Advance and Phillips Lighting. A standard pulse start metal halide mogul ED28 base lamp from Phillips Lighting is rated for 11,500 hrs of operation, 12,800 initial lumens, and 8,960 design mean lumens. The hours of operation are calculated based on the survival – the number of hours after which 50% of the lamps being tested are left illuminated – according to Phillips Lighting testing procedures. Design mean lumens are then calculated from this group at 40% of the rated average hours of lamp life. Each lamp requires an Advance pulse start ballast rated for a 175 watt(W) metal halide lamp. This ballast is not rated for outdoor use, but is protected from all elements by the surrounding acrylic globe and seal. The input wattage for this ballast is 208 W with a 90% power factor. Figure 1.3 below shows photos of the lamp and ballast. Specifications, as downloaded from the Phillips Lighting and Advance web pages, for this lamp and ballast combination can be found in Appendix B.2 and B.3.

Figure 1.3 Phillips Lighting 175 W Metal Halide and Advance Ballast Kit

(www.phillipsligting.com & www.drillspot.com)

To further analyze the space and provide a means to compare other lighting schemes to the existing system, the photometrics and efficiency calculations are discussed from a design standpoint in the following sections.

1.2.1 Design Photometrics

To accurately compare the photometrics of a new lighting system to that of the existing system, the initial design of the system must be determined and analyzed. This will also help to determine what the effects of time have done to this system as it will be compared in the later sections.

As described above, a 175 W ED-28 lamp will emit 12,800 initial lumens and 8,960 design mean lumens. Over the life of the lamp, the filaments become weaker and yield less light. The design mean lumens provided by the manufacturer have taken this into account. However, other factors must also be considered to calculate accurate design photometrics. These are:

luminaire dirt depreciation factor (LDD), lamp lumen depreciation (LLD), luminaire ambient temperature factor (LAT), voltage factor (VF), ballast factor (BF), and luminaire surface depreciation factor (LSD) which are described later in this section. These factors can then be multiplied together to create a total light loss factor (LLF) as show in Equation No. 1 (Bosela, 2003). Various other factors do exist for indoor applications and/or applications concerning fluorescent lighting, but have not been mentioned as they do not apply to the design conditions for the lighting system being studied in this report.

$$LLF = LDD \times LLD \times VF \times BF \times LSD \times LPF \qquad \text{(Equation No. 1)}$$

where

LDD = Luminaire Dirt Depreciation Factor

LLD = Lamp Lumen Depreciation Factor

VF = Voltage Factor

BF = Ballast Factor

LSD = Luminaire Surface Depreciation Factor

LPF = Lamp Position Factor

Various tests and experiments have been performed to gain an accurate value for each of the factors above and are compiled into tables that set the engineering standard for the calculation. The exact light loss factor can only be determined by field measurements, not through design analysis, which will be discussed later in the next section of this report. It is important to make this calculation so that a worst-case scenario can be formed based on the output of light. This will assure that the fixture will provide adequate illumination for safety and task reasons even under non-ideal conditions.

The LDD is dependent upon the maintenance and general upkeep of the fixture along with the characteristics of the fixture housing and casing. Outdoor fixtures tend to be completely enclosed and sealed to prevent water penetration and damage to the electrical components, but can accumulate dirt and dust over time from air leaks and also collect various bugs and insects that break into the fixture. Typically these are specified as having a wet or damp location listing by the manufacturer. To measure a depreciation value, maintenance categories have been established by the Illuminating Engineering Society (IES) ranging from 1 to 5. Each of these categories is then further broken down to consider the overall cleanliness of the space which diminishes over time (given in months). For fully enclosed and weatherproof fixtures, a Category 1 is selected. Refer to Figure 1.4 for the depreciation values of fixtures within this category. As any outdoor fixture can be susceptible to slow dirt and insect buildup, a medium cleanliness category will be used. (IESNA Lighting Handbook Reference Volume, 2000)

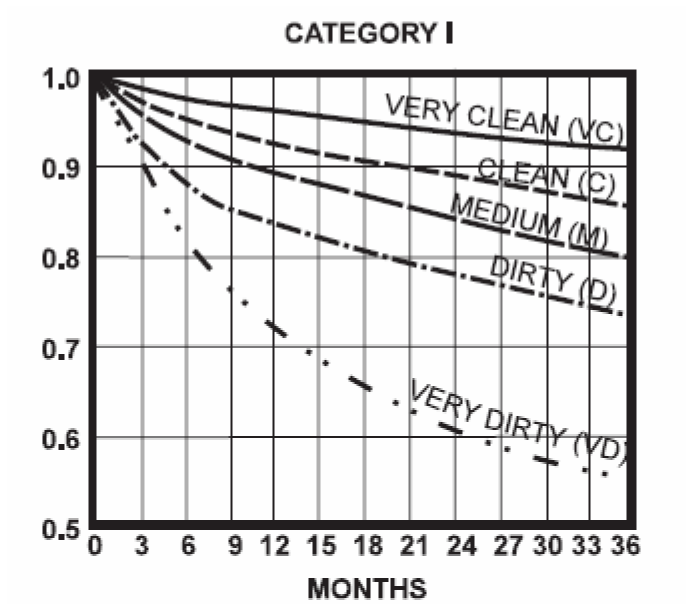


Figure 1.4 Luminaire Dirt Depreciation Factors

(IESNA Lighting Handbook Reference and Application, 2000)

The KSU Facilities Planning Department is responsible for the general upkeep and maintenance of the walkway fixtures throughout the campus. They clean the fixture each time it is serviced, during lamp and ballast repairs, and other general fixture repairs. Using the average life of the lamp it can be determined that the fixtures are cleaned approximately every 30 months. Looking at the chart above, a 0.82 LDD is determined. This means that a maximum of 18% of the light will be blocked in the fixture due to dirt, insect, and other debris accumulation.

The LLD is dependent solely on the lamp source. Depending on the type of lamp being used, the light output will diminish at a certain rate over time. This varies for each manufacturer. However, the National Lighting Bureau publishes a chart for this data that is widely used in the lighting industry and shown in Figure 1.5 on the next page. It is difficult to gain an exact value from the manufacturer unless it is guaranteed that the same lamp manufacturer will be used throughout the life of the fixture. So by looking at the chart and using the 175 W, Phillips Lighting, metal halide, with a specified mean life of 11,500 hrs, it can be determine that the LLD factor will be equal to approximately 0.59.

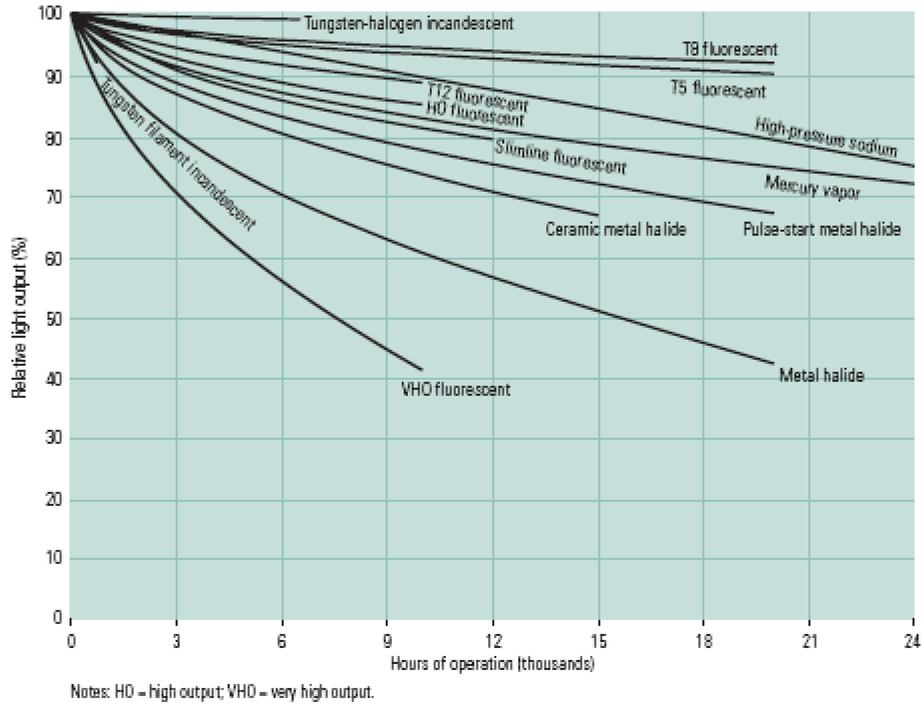


Figure 1.5 Lamp Lumen Depreciation Factors

(National Lighting Bureau, http://www.reliant.com)

The VF depends on the voltage supplied to the lamp or ballast and is primarily dependent on the voltage drop in the feeders and branch circuits that supply the luminaries. Also, the normal voltage drop for long circuit lengths can affect this value. The voltage supplied to the walkway fixtures throughout the campus is 208 volts (V), 277 V, or 480 V depending on the location. Typically this factor will not significantly impact the light output as most ballasts today are regulated. In this case a factor of 1.0 will be assumed. (Bosela, 2003)

The BF is used to adjust the light output due to the ballast not providing the full energy to the lamp therefore decreasing the output lumens. It is defined as the percentage of the initial lamp lumens that is produced by the connecting ballast. In other words, the light output by the selected ballast divided by the light output of the reference ballast as used by Phillips Lighting. For the purposes of this research, defining the exact BF is very difficult so an approximation will be used. More commonly, florescent lighting ballasts will have a greater impact on light output compared to that of HID sources. It can be accurately assumed that the BF for a metal halide ballast will not significantly impact the light output to a distinguishable difference, so it was determined that a factor of 1.0 should be used.

The LPF depends on the angular position of the metal halide lamp within the fixture and only affects HID lamp sources such as metal halide. The position is most commonly horizontal or vertical, but if desired can be set to an angle. If the lamp selected is not positioned according to the manufacturer's specifications, being horizontal or vertical, the over all lumen output will decreased and the lamp life will also be affected. Phillips lighting and most other manufactures produce metal halide lamps specifically for either horizontal or vertical applications to avoid this problem. In the case of the Cresthill sphere, the lamp will be mounted vertically and a vertical metal halide lamp is used in each fixture. Therefore, it can be determined that the LPF is equal to 1.0 and has no effect on the total light loss factor.

To finish the equation, the LSD factor is used to account for the degradation of the luminaire's reflective surfaces over a period of time. For outdoor purposes, typically this is caused by corroding paint and corrosive atmospheric conditions. As the Manhattan area sees very little of these conditions, and the acrylic globe is rated for outdoor conditions it can be assumed that this factor is equal to 1.0. (Bosela, 2003)

With all of these factors determined, a total light loss factor can be determined as follows:

$$LLF = (0.82\ LDD) \times (0.59\ LLD) \times (1.0\ VF) \times (1.0\ BF) \times (1.0\ LSD) \times (1.0\ LPF)$$

(Equation No. 1)

LLF = 0.48

This total light loss factor can now be used to accurately calculate the system's design capabilities. Using the Visual Professional (v2.06.0142) program the photometrics and photometric web are calculated as shown in Figure 1.6 on the following page using IES files. Visual Professional is a lighting calculation software used to calculate illumination levels. The IES files are photometric files created by the lighting manufacture through the testing of each fixture. The Advance Lighting Company did not create an IES file for the Cresthill Sphere so an equal fixture with an IES file had to be determined. Dynamic Lighting Incorporated manufactures a G-20 series luminaire with the same characteristics as the Cresthill Sphere, its IES file was used. (www.dynamiclighting.com, 2008) The contour lines show the 1, 0.75, 0.5, 0.25, and 0.1 footcandle readings. The data points are spaced 5ft apart in this 90 feet(ft) by 90 ft grid. The photometric web shows that the fixture disburses light in all directions. This data will be used for comparison throughout this report.

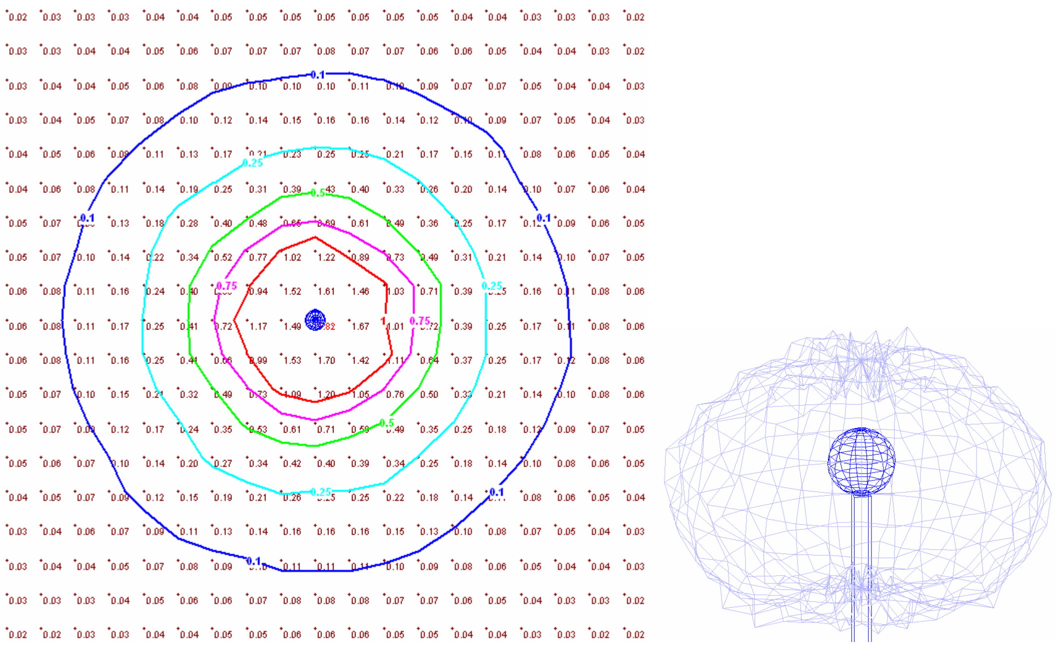


Figure 1.6 Walkway Fixture Design Photometrics Using a LLF = 0.48

(Program Inputs: Dynamic Lighting G-20 WH.IES file used with 12,800 lamp lumens)

(calculated and displayed using Visual Professional v2.06.0142)

1.2.2 Design Efficiency

The efficiency of the fixture can be determined with two separate values, efficacy and power density. Efficacy is typically defined as output lumens divided by the wattage of the lamp source. For the purposes of this report efficacy will be the initial lumens output from the fixture compared to the input wattage of the ballast and is given by Equation No. 2 on the next page. The more lumens produced per watt, the more efficient the fixture. For outdoor walkway applications only, the power density is the total wattage of all the lamps in the area being analyzed compared to the total linear feet of walkway; see Equation No. 3 on the next page. Here, the lower the ratio of watts per linear feet, the more efficient the lighting system. input

$$\text{Efficacy} = \frac{\text{output lumens}}{\text{fixture input watts}} \qquad \text{(Equation No. 2)}$$

$$\text{Power Density} = \frac{\text{total wattage}}{\text{linear feet of walkway}} \qquad \text{(Equation No. 3)}$$

Neither the efficacy nor the power density is regulated by code. However, the power density recommendations are set by industry standards, the most common being the American Society of Heating and Air-Conditioning (ASHRAE) Design Standard 90.1–2004. The U.S. Green Building Council (USGBC) has also established the Leadership in Energy and Environmental Design (LEED) program, which further lowers the standard density values set by ASHRAE. The LEED program is a point system where designers can meet a set of requirements in various design areas to acquire points for going above and beyond the design standards minimum requirements and designing the building to be more environmentally conscious. The more points that can be achieved, the higher LEED rating will be given to the building. Both the LEED program and the ASHRAE Design Standard will be discussed more in-depth and compared to the design in later sections.

When this system was originally designed there were no codes or design standards used or were designed to codes and standards that are less stringent than today's. Theses codes and standards are continually evolving based on the needs and safety of building and site occupants. The ASHRAE 90.1-2004 Design Standard now states that each linear foot of walkway less than 10 ft wide must have a maximum power density of 1.0 watts per linear foot (w/lf) and any walkway of over 10 feet wide must have a maximum power density of 0.2 watts per square foot (w/sf). (ASHRAE 90.1-2004, 2004)

The total initial lumens for the fixture was said to be 12,800 lm with an input wattage from the ballast of 208 W according to the manufacturer specifications. Using Equation No. 2, the fixture is calculated to have an efficacy of 61.5 lumens per watt (lm/w). This is somewhat typical for a metal halide fixture and will be used as a comparison for different lamp sources later in this report.

To determine the power density of the existing system the total number of fixtures must be counted and multiplied by the input wattages of each fixture. The Quad area has a total of 30 fixtures, all being the Cresthill Sphere, consuming 208 W each. This yields an overall value of 6,240 W. The total linear feet of walkway in the Quad is approximately 2,625 linear feet (lf). Using Equation No. 3, the area is calculated to have a power density of 2.38 w/lf. This is very high, and extremely inefficient. It would not meet today's design standards as it exceeds the requirements set by ASHRAE 90.1-2004 by more than 80% as calculated using the ComCheck v3.6 program. This report can be seen in Appendix C.1.

1.4 Actual Illumination Readings vs. Design

Actual illumination readings were taken for two fixtures in the quad area. These fixtures are labeled as W-1 and W-2 on the map of the Quad in Appendix A.2. These readings will be compared to the assumed design conditions to determine their accuracy and later compare to new proposed designs. With these actual readings, a true LLF can also be established as field conditions are rarely the same as the calculated conditions.

This data can be compared to the design calculations, but will show some differences due to the light from other fixtures in the surrounding area that contribute to the illumination at each point to a certain degree, depending on their spacing. Different types of landscaping, the moon, and clouds can also reflect light to the surface and affect the illumination readings at any given point on the surface. To gain a better means of comparison, the Quad area was modeled using the AGI32 (v. 2.03) program as a whole using the same LLF of 0.48 as calculated above. The AGI32 program is very similar to the Visual Professional program. The AGI32 program will be used due to its ability to more accurately represent the as built conditions due to new technology and program features. AGI32 is becoming a more widely accepted program among engineers today. These results can be seen in Figure 1.7 on the following page which shows the footcandle readings at the ground level. These results still do not account for the landscaping of the area. Many trees, shrubs, small berms for site drainage, and other landscaping features block, reflect or otherwise prevent the light from reaching the grade. The specific landscaping features that affect the overall lighting have been noted and will be discussed later in this section. There are a total of five fixtures creating additional light in the space as seen below; only four are shown as the other is an exterior wall mounted fixture to a buildings facade.

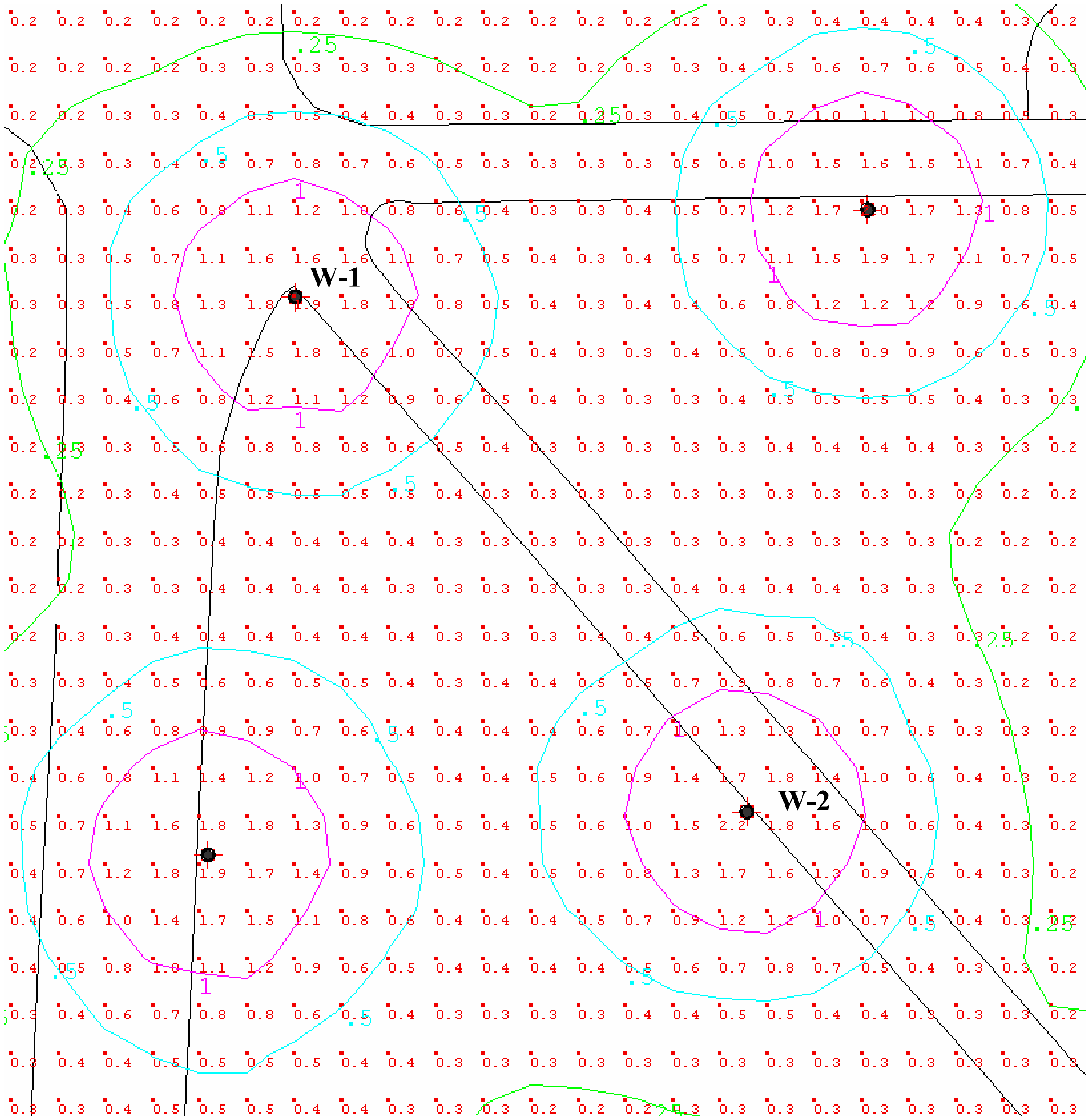


Figure 1.7 Walkway Fixture Design Photomentrics at Ground Level with a LLF = 0.48

(Program Inputs: Dynamic Lighting G-20 WH.IES file used with 12,800 lamp lumens)

(calculated and displayed using AGI32 v2.03)

Some illumination statistics with this design, calculated by the AGI32 (v 2.03) program for the entire Quad area using a LLF of 0.48 are as follows:

Max: 3.3 footcandles	Max/Min = 33:1
Min: 0.1 footcandles	Max/Avg = 6.11:1
Average: 0.54 footcandles	Avg/Min = 5.4:1

To verify that the actual readings are within reason compared to the AGI32, Figure 1.8 below shows what the calculated light levels would be with a light loss factor of 1.0. This will give a margin of maximum to minimum calculated light levels to which the actual light levels should fall within. After looking and comparing the two photometric graphs, it can be determined that the actual readings should fall between 3.8 and 1.8 footcandles (fc) under the fixtures at the most illuminated points and 0.6 and 0.3 fc between the fixtures at the darkest points of the walkway.

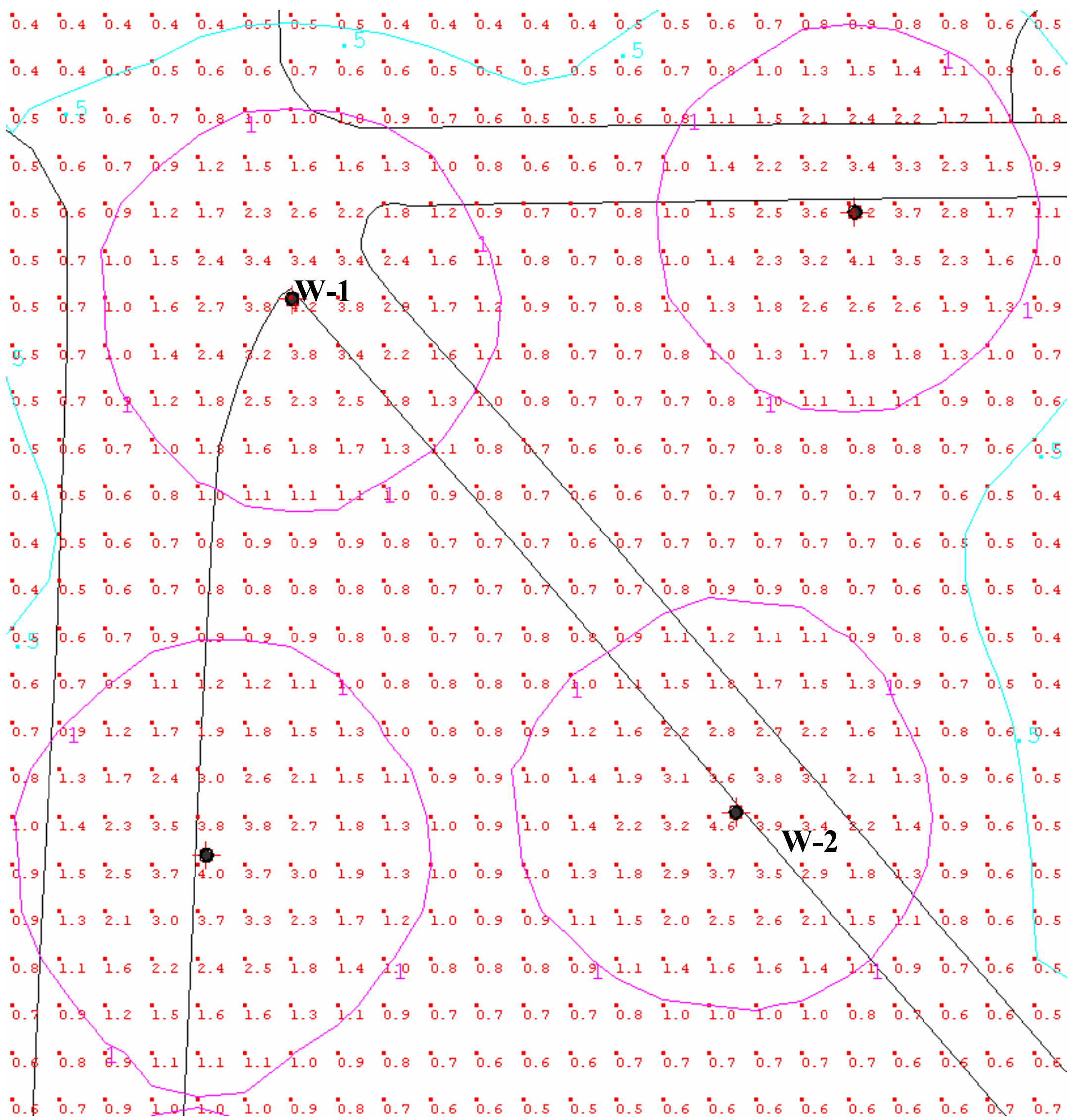


Figure 1.8 Walkway Fixture Design Photomentrics at Ground Level with of LLF = 1.0

(Program Inputs: Dynamic Lighting G-20 WH.IES file used with 12,800 lamp lumens)

(calculated and displayed using AGI32 v2.03)

This data can now be compared to the actual readings taken. The following pages show the actual illumination readings in Tables 1.1 and 1.2. One area, marked with ‘x’, could not be determined as it was blocked by landscaping. The green numbers indicate readings taken on landscape whereas blue numbers indicate readings taken on the walkway. This data was taken using the same 5ft spacing as used above in the design calculations. Strings of yarn were used to form the grid in each of the four quadrants (NE, NW, SE, SW) and a Minolta Illuminance Meter Model T-1M, Serial No. 908582, was used to take the horizontal readings at the grade level. Photos of these two fixtures (right) and the walkway being analyzed (left) can also be seen in Figure 1.9.

W-1 **W-2**

Figure 1.9 Walkway Fixtures W-1 and W-2 in the KSU Quad

Table 1.1 Measured Walkway Fixture Footcandle Readings of Fixture W-1

Walkway Fixture W-1 Footcandle Readings

Fixture Location: This fixture was located at the intersection of 3 walkways in the NW corner of the Quad. This is just south of the Waters Hall SW entrance.

Date: September 3, 2008

Reading Height: 0ft - grade level

Fixture Description: Round Post top with 20" white acrylic globe and Metal Halide lamping. Lamp and fixture are bright white in color and appear to have no lumen or color depreciation. The fixture was labeled by a piece of duct tape on its concrete base by 'GW9'.

Fixture Height: 12ft

Photo #: Figure 1.7
Figure 1.8
Figure 1.9
Appendix A.2

	30ft	25ft	20ft	15ft	10ft	5ft	0ft (N)	5ft	10ft	15ft	20ft	25ft	30ft
30ft	0.25	0.31	0.30	0.37	0.37	0.41	0.29	x	x	x	x	x	x
25ft	0.26	0.31	0.37	0.50	0.50	0.55	0.89	x	x	x	x	x	x
20ft	0.26	0.35	0.45	0.48	0.48	0.99	1.10	x	0.55	0.42	x	0.38	0.30
15ft	0.18	0.20	0.53	0.98	0.98	1.10	1.25	1.15	0.91	0.70	0.50	0.49	0.57
10ft	0.25	0.41	0.50	1.20	1.20	1.40	1.90	1.45	1.11	0.94	0.59	0.53	0.57
5ft	0.46	0.51	0.63	0.83	1.30	1.82	2.21	1.85	1.32	1.03	0.86	0.61	0.40
0ft (W)	0.49	0.82	0.68	1.01	1.49	1.87	**W-1**	2.12	1.80	1.21	0.81	0.59	0.56
5ft	0.29	0.58	0.65	1.07	1.46	1.84	2.00	1.85	1.45	1.16	0.65	0.57	0.42
10ft	0.36	0.41	0.65	0.92	1.10	1.25	1.80	1.53	1.12	0.83	0.64	0.53	0.48
15ft	0.39	0.40	0.57	0.57	0.80	1.00	1.28	0.32	0.15	0.58	0.53	0.44	0.30
20ft	0.28	0.31	0.50	0.50	0.56	0.22	0.75	0.32	0.09	0.18	0.20	0.37	0.33
25ft	0.24	0.25	0.28	0.35	0.09	0.10	0.36	0.30	0.22	0.24	0.11	0.28	0.24
30ft	0.22	0.19	0.22	0.17	0.15	0.05	0.10	0.29	0.15	0.25	0.14	0.22	0.28

Green = Surrounding Space or Landscaping
Blue = Campus Walkway
***See Drawings for fixture references and naming**

Area Landscaping Notes:
There is a tree located just SE of the fixture that has an effect on the South and SE footcandle readings, in the NE quadrant at 25ft + there is landscaping that nearly blocks all of the light from this fixture and no data was taken.

Weather Conditions:
Cloudy skies with very light sprinkles, only portons of the walkway appeared wet, grass was damp. The clouds were high in the sky and reflected no light back to the ground.

Table 1.2 Measured Walkway Fixture Footcandle Readings of Fixture W-2

Walkway Fixture W-2 Footcandle Readings

Fixture Location: This fixture was located in the NW area of the quad, just SE of fixture W-1. It illuminates a single walkway that extends from the Waters Hall entrance to the center of the quad.

Date: September 5, 2008

Reading Height: 0ft - grade level

Fixture Description: Round Post top with 20" white acrylic globe and Metal Halide lamping. Lamp and fixture are yellow in color and appear to have extensive color depreciation. The acrylic glove seems to be dirty in many places. The fixture was labeled by a piece of duct tape on its concrete base by 'GW10'.

Fixture Height: 12ft

Photo #: Figure 1.7, Figure 1.8, Figure 1.9, Appendix A.2

	30ft	25ft	20ft	15ft	10ft	5ft	0ft (N)	5ft	10ft	15ft	20ft	25ft	30ft
30ft	0.14	0.18	0.18	0.27	0.25	0.34	0.30	0.22	0.27	0.23	0.18	0.17	0.26
25ft	0.29	0.18	0.22	0.27	0.24	0.33	0.32	0.30	0.24	0.26	0.17	0.24	0.18
20ft	0.29	0.29	0.24	0.30	0.33	0.33	0.36	0.33	0.34	0.26	0.21	0.20	0.19
15ft	0.20	0.26	0.32	0.36	0.34	0.50	0.49	0.51	0.38	0.31	0.25	0.23	0.16
10ft	0.42	0.33	0.35	0.31	0.46	0.61	0.73	0.63	0.51	0.37	0.28	0.23	0.20
5ft	0.40	0.37	0.35	0.52	0.66	0.83	0.89	0.82	0.69	0.47	0.33	0.26	0.20
0ft (W)	0.55	0.46	0.51	0.63	0.85	1.05	**W-2**	0.83	0.65	0.44	0.29	0.24	0.19
5ft	0.52	0.43	0.46	0.57	0.71	0.87	0.97	0.83	0.67	0.49	0.30	0.24	0.16
10ft	0.60	0.43	0.44	0.48	0.58	0.64	0.78	0.58	0.46	0.40	0.30	0.21	0.19
15ft	0.60	0.46	0.42	0.40	0.48	0.58	0.57	0.43	0.33	0.29	0.22	0.20	0.18
20ft	0.58	0.40	0.37	0.33	0.35	0.37	0.41	0.29	0.24	0.25	0.21	0.20	0.14
25ft	0.27	0.23	0.34	0.31	0.26	0.26	0.28	0.26	0.22	0.20	0.17	0.17	0.16
30ft	0.11	0.09	0.13	0.17	0.23	0.26	0.21	0.15	0.15	0.20	0.13	0.17	0.19

Green = Surrounding Space or Landscaping
Blue = Campus Walkway
***See Drawings for fixture references and naming**

Area Landscaping Notes:
There is a tree located just NW of the fixture that has an effect on the North and NW footcandle readings. All other quadrants were only grass and walkway.

Weather Conditions:
Clear skies with no visible moon as it was blocked by the surrounding buildings.

Some initial observations can be made. First the actual footcandle readings are similar to the calculated readings where the LLF was equal to 0.48. With the actual readings and calculated readings within reason of each other, it can be determined that the calculated values by the Visual Program are accurate and will continue to be accurate to use in the lighting design.

The calculations above show that the walkway between the fixtures W-1 and W-2 reach a maximum and minimum of approximately 1.8 and 0.3 fc, respectively. The actual maximum readings range from 2.1 fc for W-1 and 0.9 fc for W-2. Also, the actual minimum readings between the fixtures are approximately 0.3 fc. The maximum to minimum uniformity is calculated to be 7 to 1 on the walkway in this area. The most probable cause for this difference is the landscaping issues; a tree is located just southwest of fixture W-1 which blocks the light from reaching the walkway in the area between the two fixtures. The AGI32 program has limitations, as landscaping cannot be modeled in the space. Therefore, it is up to the engineer's judgment on whether to add additional lighting due to obstructions outside the capabilities of the programs calculations. Also the plant growth and seasons can change the landscaping over time causing problems that could not be predicted.

In each of the tables, the data at certain points seems to vary greatly. As was discussed earlier, dirt and insect build-up inside the fixture can cause blockages that result in decreased light levels. When looking at the fixture, the human eye cannot always see many of these build-ups.

Comparing the two existing fixtures to each other also yields many differences, even though they are the same fixture and lamp. This can be caused by a number of different events that have been discussed already. These include the timeframe from when the fixture was last serviced and cleaned, the age of the lamp, and surrounding light fixture contributions. Some of these differences can be seen in Figure 1.9 shown earlier. Metal halide lamps can turn either yellow or green throughout its life; many times this is a random occurrence. Also notice the contrast of light reaching the ground on the walkway created by the differences between these two fixtures in this figure. The Facilities Planning Department does not practice group re-lamping so these problems are frequent throughout the campus. All of these issues will be discussed in more detail later in Chapter 2 of this report.

Looking strictly at the photometric curves, both the calculated and actual readings yield the same circular patterns. However, the curves for the actual readings decrease at a slightly higher rate than the calculated values. This again would be the result of dirt and debris build-up within the fixture housing. Overall, given the illumination of the space and ignoring the landscaping issues, it can be determined that our total LLF approximation was accurate.

One final observation can be made about the overall light levels reaching the walkway surface. Of the 12,800 lm emitted by the lamp, a maximum of approximately 2 fc are found at the base of the fixture. This is a result of the photometrics for this fixture having no optical reflectors and emitting light in all directions, both to the ground and up in the sky creating light pollution and inefficient illumination.

CHAPTER 2 - Issues with the Current Lighting Design

This chapter will analyze the current lighting system by looking at the maintenance, illumination, efficiency, aesthetics, and other miscellaneous issues. Included in this will be issues that are becoming more of a concern as more stringent energy codes and standards are changing the lighting industry by decreasing light pollution, light spill, lowering light level standards, and increasing efficiency standards. Each of these concerns must be evaluated in order to provide reasoning for upgrading the existing system and to help determine design strategies for a new system to be installed.

Expenses for energy, labor, and general maintenance for the fixtures will also be evaluated where it applies. This will also help to determine where improvements can be made to the system and how they can be used to compare with a new system by doing an economic analysis and feasibility study that will be performed in Chapter 5 of this report.

2.1 Fixture Maintenance

As previously described, the KSU Facilities Planning Department supervises all of the maintenance for the walkway fixtures. This includes changing out lamps and ballasts as well as replacing, cleaning, and repairing the fixtures – the most common of those being lamp replacements.

Replacing lamps for every fixture on campus can be difficult as the ranges of lamp wattages varies throughout the campus. With no master plan, the procedure, according to the Facilities Planning Department, for changing the lamps is by visual inspection. When a lamp burns out, an employee must look inside the fixture to verify its wattage and then retrieve a new lamp of the same wattage. This can be very time consuming so each employee must carry multiple lamps to replace only a few fixtures. It is at this time that they also clean the globe of the fixture as stated earlier. (Milton, Larry) Lamp outages are difficult to spot as it must be done at night. They can easily go unnoticed by the staff for a period of time because a majority of their work time is during the day.

The fixtures are powered for an average of 13 hrs each night. Based on the rated 11,500 hrs of life for the metal halide lamps, each lamp will last 2.4 yrs. (Milton, Larry) With more than 336 walkway fixtures on campus, and adding an additional 15% for multiple fixtures on a single pole (based on visual inspection), there could be an estimated 160 lamps replaced on average each year. In the Quad area alone, there would be close to 14 lamps replaced each year.

Another issue facing lamp changes and any other repair to the fixture is its accessibility. The Cresthill Sphere has an acrylic globe that contains four screws, which hold the fixture securely to the post or arm. To change the lamp requires an employee to remove these screws and then take the globe off of the fixture and set it gently on the ground as there is no hinge that can attach it to its mounting. This is very hazardous as the acrylic globe is fragile. The employee must take special consideration of passing students and the area terrain while removing it from its 12 ft high mounting. This is also a concern when replacing the ballasts. This will occur on a much more infrequent basis than a lamp change, but still poses a risk of damaging the fixture.

The maintenance costs to re-lamp these fixtures can also be substantial when including the costs of the lamps, ballasts, and labor. The Facilities Planning Department purchases the 175 W metal halide lamps from a store room, owned and operated by KSU, individually on an as needed basis. The store room purchases the lamps from Phillips Lighting and adds 20% to the total cost charged to the facilities department of the lamp, to account for its business operations. By this system each lamp bought by the university, including the 20% surcharge, is $11.87. It takes one General Maintenance Repair Technician (GMRT) employee (with a pay rate of approximately $13.00 per hour) 1 hour to replace a single lamp. Approximately 37% increase to the pay will be used to calculate the approximate cost to the university by accounting for employee benefits, insurance, retirement, worker's compensation, unemployment, and state leave reserve fees. (Mcvey, Karen, 2009) This would bring the total compensation to $17.81 per hour for each GMRT employee. Therefore, each fixture needing a lamp replaced will cost a total of $29.68. (Milton, Larry)

In addition to this cost, the ballast must also be replaced on occasion. The Advance ballast used in the Cresthill Sphere lasts approximately 50,000 hrs according to its manufacturer, or 10.5 yrs. This would require that approximately 37 be replaced throughout the campus, 4 in the Quad, on average each year using the same information stated in the lamp replacement calculations. The ballasts are purchased by the Facilities Planning Department in the same manner as the lamps, costing $72.35 per ballast. It would take the same employee 1.5 hrs to replace the ballast. Therefore, each ballast replacement will cost a total of $99.07. (Milton, Larry)

The Facilities Planning Department also purchases approximately 15 new acrylic globes each year to replace the older fixtures throughout campus that have been damaged. Each of these globes is approximately $234 from the store room who purchases them from the American Electric Lighting Company. The labor required for replacing a fixture is approximately 2 hrs, using two GMRT employees, totaling 4 hours of paid work per fixture. (Milton, Larry)

The cost data stated above is summarized in Table 2.1, on the following page, and used to calculate the estimated yearly maintenance expenses for lamp and ballast replacements for the university.

Table 2.1 Fixture Maintenance Charges per Year for the KSU Campus and Quad

Item	KSU Quad	KSU Campus
Lamp Cost	$11.87	$11.87
Lamps Replaced Each Year	14	160
Labor Cost Per Lamp Replaced Per Hour	$17.81	$17.81
Labor Hours Per Lamp Replaced	1	1
Sub-Total Lamp Repair Cost Per Year	**$415.52**	**$4,748.80**
Ballast Cost	$72.35	$72.35
Ballasts Replaced Each Year	4	37
Labor Cost Per Ballast Replaced Per Hour	$17.81	$17.81
Labor Hours Per Ballast Replaced	1.5	1.5
Sub-Total Ballast Repair Cost Per Year	**$396.26**	**$3,665.41**
Fixture Cost	$234	$234
Fixtures Replaced Each Year	0	15
Labor Cost Per Fixture Replaced	$17.81	$17.81
Labor Hours Per Fixture Replaced	4	4
Sub-Total Fixture Cost Per Year	$0.00	**$4,578.60**
Total Cost Per Year	**$811.78**	**$12,992.81**
1. All cost and labor information was provided by Larry Milton, Physical Plant Supervisor, KSU Facilities Planning Department.		

To gain an accurate maintenance cost for the Quad, it can be assumed that none of the fixtures would need replacing in a given year. This would just leave the lamp and ballast replacements and yield a total maintenance cost of $811.78 per year as calculated above. The campus calculations are lower as many of the walkway fixtures are 250 W throughout the campus, therefore more expensive to maintain. However these values will continue to be used throughout this report in order to not over price this analysis in any way.

Other maintenance issues include the fixture's fragility, lack of protection, and weathering. As stated above, the acrylic globe is very fragile and can easily be broken by flying debris or mishandling during maintenance. Fixtures on campus can develop holes or cracks because of reasons as varied as lawn equipment kicking up rocks, wind picking up debris, and vandalism. Each fixture has no protection against any of these occurrences. Weathering also creates yellowing within the globe, decreasing the aesthetics of the fixture, decreasing the light output, and making cleaning the fixture difficult. Keeping all of the fixtures on campus clean can be a very tedious and time-consuming task due to its vast size and number of fixtures; visible insect and dirt accumulation is easy to see throughout the campus. Pictures of these impacts on fixtures can be seen in Figure 2.1 below. The first picture (left) shows a lamp that needs replacing while the second (right) is a typical fixture where dirt has collected at the bottom and partially stained the globe.

Figure 2.1 Maintenance Issues for the Existing Light Fixtures

Weathering also affects the paint on each pole. Rust can easily spread if the coat of paint protecting the metal pole is worn or scratched. This requires each pole to be repainted if such an incident occurs.

2.2 Illumination Levels

IES recommendations state that a walkway should be illuminated by a minimum of 0.5 fc at the ground level for pedestrian walkways that are distant from roadways to create a safe atmosphere. IES further recommends that a minimum of 0.6 fc at the ground level is adequate for security lighting. The difference between safety and security according to the Illuminating Engineering Society of North America (IESNA) is that safety is the freedom from danger while security is freedom from worry. Security is considered the psychological version of safety. Security lighting must pay attention to both horizontal and vertical illumination. Security lighting is designed to protect occupants, protect property, deter criminals, and make occupants aware of their surroundings. It also states that there should be an average-to-min ratio of 4:1 along the length of the walkway and out a distance of 30 ft. An average-to-min ratio is the ratio of the average footcandle level over a given surface to the minimum footcandle level on that same surface. This is important because it determines that there will be no shadows and high differences in contrast, making it hard for the occupant to clearly focus on their surroundings. The vertical illumination must also be equal to that of the horizontal illumination, including the footcandle levels and ratios, at least 5 ft above the ground. (IESNA Lighting Handbook Reference Volume, 2000)

By looking back to Table 1.1 and Table 1.2 and the calculations shown in Figure 1.7, it can be determined that the current lighting system does not entirely meet the IES recommended footcandle reading or the average-to-min ratio for walkway being illuminated by these two fixtures. The minimum footcandle reading is 0.17 fc. It does not meet the 0.5 fc for typical pedestrian walkways, but is 0.43 fc below the 0.6 fc recommendation for security purposes. Also, the average-to-min ratio is 5.4:1 on the walkways in this area, measuring 30 ft perpendicular to the walkway; also below the needed 4:1 ratio.

This could be corrected by directing light downward to the walkway area, increasing the fixture's effectiveness. With the current system serving as the walkway lighting, landscaping lighting, and, in some cases, the building facade lighting, it is serving too large of area to be efficient. This can also be tied to light pollution, which will be discussed later in this chapter.

As stated earlier, bugs, debris, lamp life, and yellowing have also dramatically changed the light levels reaching the ground and have created more inconsistency. Tables 1.1 and 1.2 show many areas where the readings increase and decrease dramatically within a span of 5 ft. Also, Figure 1.9, shown earlier, reveals a great difference in the illumination under each fixture.

2.3 Lighting System Efficiency

Lighting efficiency is measured by efficacy and power density, as it was defined earlier in Equation 2 and Equation 3. The Cresthill Sphere was calculated to have an efficacy equal to 61.5 lm/w and yield a power density of 2.18 w/lf in the Quad area. By today's standards these values are extremely inefficient. The ASHRAE 90.1-2004 standard requires 1.0 w/lf or less for walkways up to 10 ft wide, and 0.2 w/sf for walkways over 10 ft wide. Currently the Quad area is 80% above this standard, the only solution to this problem is to replace the entire lighting system, as the current lamps cannot decrease in wattage without severely impacting the illumination. See the existing energy standard compliance report in Appendix C.1 for more details on this calculation. The design industry is moving quickly towards high-efficiency, and sustainable design. The KSU campus is currently far behind this trend and the installation of a new system would be required to bring them up-to-date as the codes and standards are becoming more stringent.

Another issue that is directly affected by the efficiency of this system is the energy costs. Thousands of dollars a year can potentially be saved in energy by installing a high-efficiency system as covered later in this report. The KSU campus is currently served by Westar Energy and, according to the Westar webpage, has a rate that is applied under the 'High Load Factor' service plan. (Westar Energy, 2007) The 'High Load Factor' service plan will be used as KSU cannot release actual utility bills. Even with the actual utility bills, there are multiple services and meters that serve different areas of campus and an accurate number would be difficult to determine.

For the purposes of this research, an accurate number, in cents per kilo-watt hour (¢/kWh), can be determined by looking at the sample bill for a 'High Load Factor' service plan, refer to Appendix D, and compare it to national and state averages. Using this, yearly energy costs can be calculated for the Quad area knowing that the lamps and ballast combination has an input wattage of 208 W. The entire campus can also be estimated, but not accurately calculated as the wattages of the lamps vary. However, an under estimated value will be utilized to compare with that of a new system for the purposes of this research by assuming that all of the campus walkway lighting has an input wattage of 208 W.

KSU is a state university and is tax exempt, therefore the total from the sample bill that can be used for this analysis is $18,569.44 and the overall consumption is equal to 300,000 kilo-watt hour (kWh). With this data, a rate of approximately 6.32 ¢/kWh is calculated. The average electricity rate in the state of Kansas is significantly higher at 7.87 ¢/kWh for commercial buildings, and the national average is still a higher 9.47 ¢/kWh. (Energy Information Administration, 2009) (D&R International, Ltd., 2008) It can be assumed that this difference is partially due to the tax exemptions. Using this data, Table 2.2 on the next page summarizes the energy costs calculated per year for the KSU Quad.

Table 2.2 Energy Cost Data per Year for the KSU Quad

Item	KSU Quad	KSU Campus
Energy Rate in ¢/kWh[2]	6.32	6.32
Input Wattage of Each Fixture	208	208
Hours of Operation for Each Fixture per Day[1]	13	13
Days of Operation for Each Fixture per Year[1]	365	365
Total kWh of Energy Consumed per Year per Fixture	987	987
Total Cost of Energy Consumed per Year per Fixture	**$62.38**	**$62.38**
Number of Fixtures[1]	30	387
Total kWh of Energy Consumed per year	29,610	381,954
Total Cost of Energy Consumed per Year	**$1,871.35**	**$24,139.46**

1. All cost and labor information was provided by Larry Milton, Physical Plant Supervisor, KSU Facilities Planning Department
2. Westar Energy 'High Load Factor' energy rate (Westar Energy, 2007). See Appendix D.

2.4 Aesthetics

Aesthetics is an issue that comes in a variety of forms. It can be the external appearance and architectural characteristics of the fixture, the position of the lamp within the fixture, the type and color of lamp within the fixture, the uniformity of lighting between different fixtures of the same type, and most importantly the illumination of the space where it is located. For the KSU campus, aesthetics can be especially important to create a pleasing and comfortable atmosphere to attract students to the university. The Cresthill Sphere is a very elegant fixture with a simplistic and historic look that suits the purposes of the campus from the appearance standpoint. However, it has also developed some issues over time that affect its overall aesthetic appeal.

The current light fixtures are showing signs of aging that are decreasing the overall aesthetics of the campus in many of the areas listed above. As mentioned earlier regarding the maintenance, some fixtures have yellowing due to corrosion and rust within the acrylic globe. This causes some fixtures to appear white and others to appear a shade of yellow or green, making the photometrics and appearance non-uniform. Also, the lamp itself appears to be different in color from fixture to fixture in many instances. This was discussed earlier as a result of the color shifting over the life of the lamp. When a lamp is replaced near a lamp that is near the middle of its 11,500-hour life, the difference can easily be seen in the lamp's color, refer back to Figure 1.9 and Figure 2.1. Both the yellowing and the age of the lamp contribute to non-uniform light levels reaching the walkway, creating dark spots. This is a unique characteristic to metal halide lamps. The color can change differently throughout its life from one lamp to the next, for example, one will change to blue while another to green. Figure 2.2 below shows more examples of the issues stated above. The fixtures shown are consistent throughout the campus; it is very difficult to find two fixtures with the same color. Only the fixture in the lower right corner of the figure could be considered aesthetically pleasing and is properly illuminated.

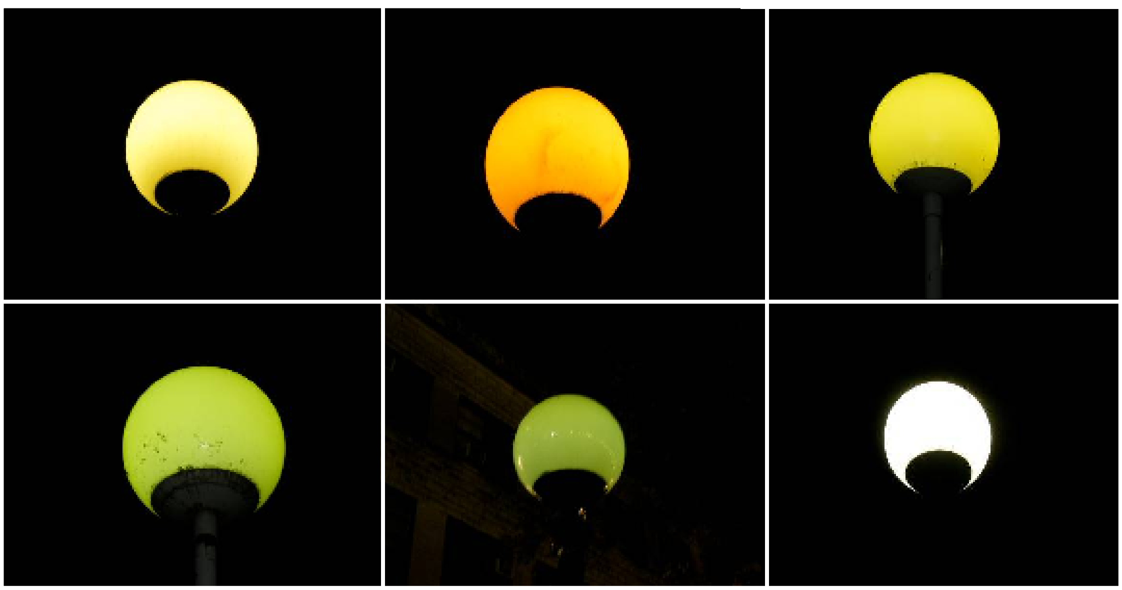


Figure 2.2 Aesthetic Issues for the Existing Light Fixtures

Dirt can also disturb the aesthetics of the area. The photo shown previously in Figure 2.1 is typical of many fixtures on campus where bugs and other debris have accumulated in the bottom of the fixture. Although the fixture shown is a pendent mounted fixture, it can be assumed that many of the post top fixtures have the same debris, only less visible. Having a more weather resistant and less fragile fixture would decrease all of these problems significantly.

2.5 Miscellaneous Issues

Other issues regarding the existing lighting system include light pollution, landscape lighting, and plant growth.

Light pollution, also called atmospheric or astronomical light pollution, is caused by light being emitted into the sky from the fixture illumination itself or from reflections of light off of dust, water vapor, and other particles in the air or on the ground. The result is a sky glow effect that can easily be seen on a cloudy day above most cities. (IESNA Lighting Reference Volume, 2000) The recommended engineering practice today is to use full cut-off luminaries where possible to prevent wasting light into the atmosphere. A full cutoff fixture produces a maximum initial luminance value no greater than 0.1 horizontal and vertical footcandles 90 degrees above nadir, or more than 90 degrees from the aiming direction of the fixture; in this case it is straight down. The Cresthill Sphere is considered to have an unrestricted distribution of light. It is considered the most inefficient use of light by today's standard practices. Other types of cutoff are semi cutoff and cutoff, Figure 2.3 below shows examples of these distribution types.

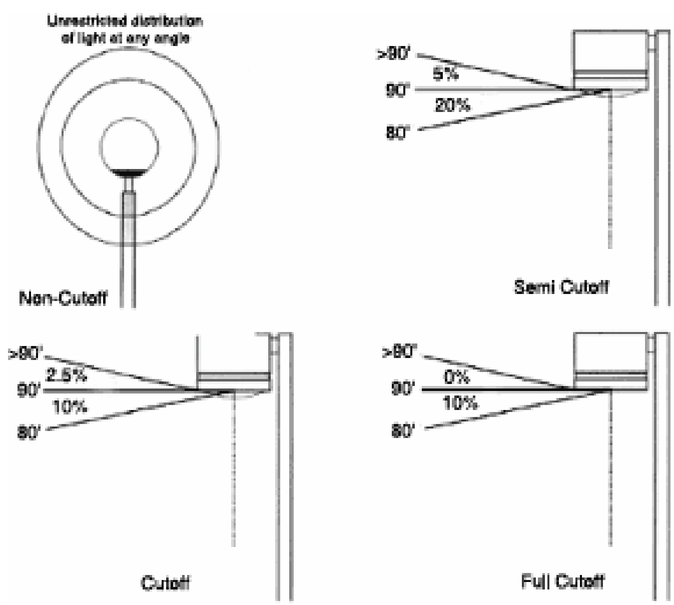


Figure 2.3 Examples of Fixture Light Cutoff

(City of Plymouth, Indiana, http://www.plymouthin.com)

A full cutoff fixture prevents light from being wasted by using the proper housings and reflectors to direct light downward to the ground only. The USGBC's LEED program, city ordinances, and IESNA Recommendations are organizations that restrict light pollution levels, but unfortunately these restrictions are not included in any building codes. These limitations will be discussed in the next chapter. The Cresthill Sphere has no cut-off and no reflectors to direct the light down to the surface. The only reflection of light within the fixture is its post-top mounting which reflects light upward to the sky. The result is more light being sent into the sky than down to the ground. Figure 2.4 on the following page shows another AGI32 photometric calculation, only this time taking data from 24 ft above the ground level of the Quad, 12 ft above the fixture. This data can be compared to Figure 1.7 where the calculations were taken from the ground level, 12 ft below the fixture.

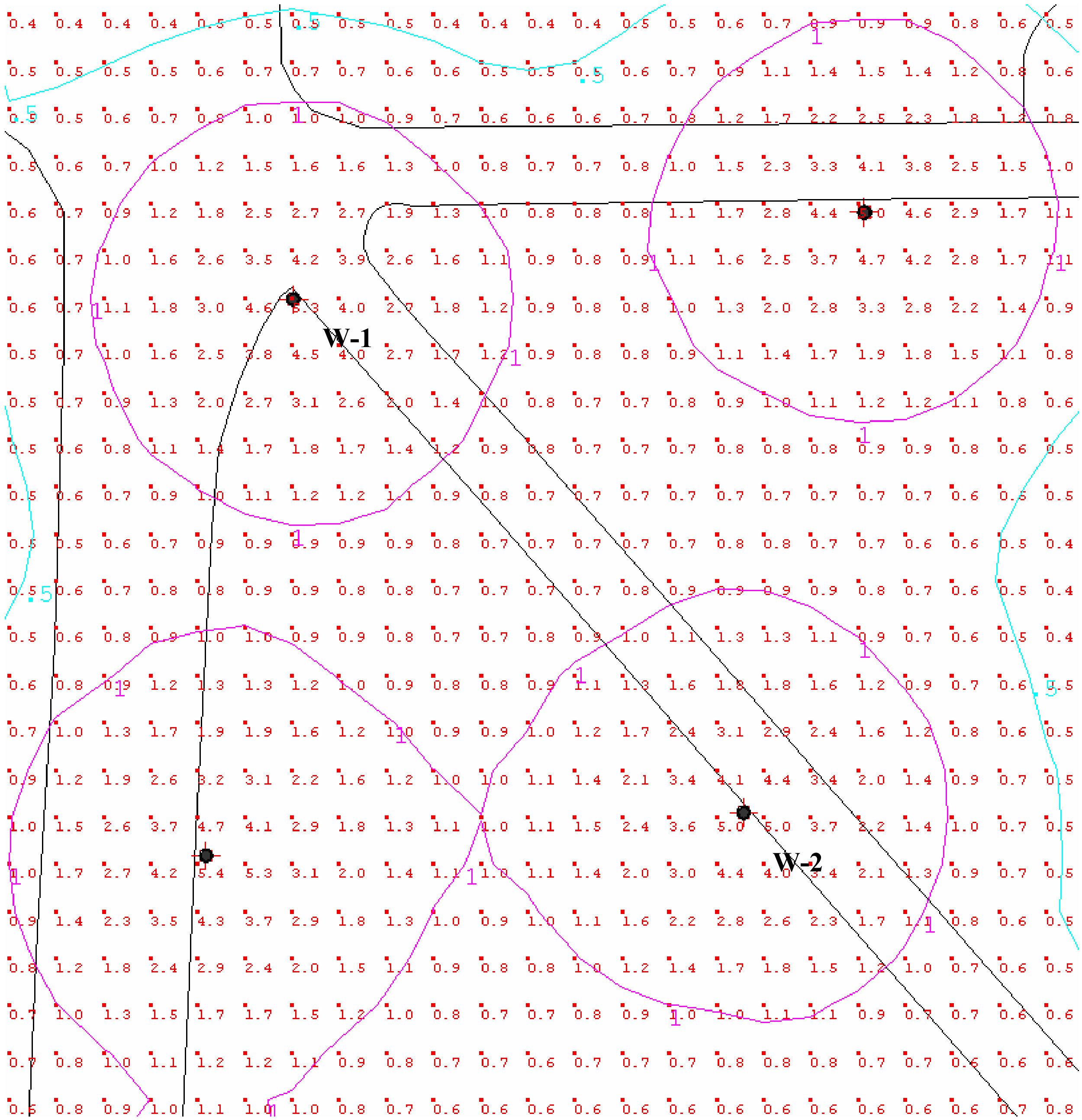


Figure 2.4 Walkway Fixture Design Photometrics at 12 ft Above the Fixture and LLF=0.48

(Program Inputs: Dynamic Lighting G-20 WH.IES file used with 12,800 lamp lumens)

(calculated and displayed using AGI32 v. 2.03)

From the figure above, it was determined that there is 5.3 fc directly above fixture W-1 compared to 1.9 fc directly below the fixture, a 3.4 fc increase. This means approximately 74% of the light is being sent into the sky rather than to the ground. Similar values can be seen at virtually every data point in the figure. This again proves the inefficient use of light for this fixture. If that light could be directed downward, it could result in more uniformity, control, and a substantial increase in illumination at the ground level.

Lastly, plant growth has surrounded many of the fixtures over the course of time. It has created a problem where the plants are blocking the light from reaching the ground and creating many shadows and more inconstant light levels. This particular problem cannot be fixed by simply replacing the fixture. One simple solution is for the campus officials to acknowledge the problem and perform the proper trimming. Figure 2.5 shows a few examples of where this problem exists on campus grounds.

Figure 2.5 Plant Growth Issues for the Existing Light Fixtures

CHAPTER 3 - New Design Criteria and Strategies

With the initial case study of the current lighting system completed, new design criteria and strategies can be established. The design criteria are particularly important as they will determine requirements for illumination, efficiency, and safety. These requirements are set by codes and standards that have been adopted by the City of Manhattan, KS, the State of Kansas, and KSU. City of Manhattan codes and regulations are not required as KSU property is owned by the state; however they are typically followed out of support for the city and communities. The design goals will include a discussion of the type of system that will be recommended, including the potential cost savings, and the opportunity to build a more efficient, greener campus while maintaining good aesthetics.

These goals must also meet the design standards of KSU officials. KSU publishes specification standards for all projects on campus grounds. These specifications are written by the Design and Construction Administration within the KSU Facilities Planning Department. An excerpt from the specifications relevant to exterior lighting is written below:

> *2.6 Policy #: 060*
>
> *Title: **BUILDING LIGHTING AND ELECTRICAL SYSTEMS***
>
> *2.6.1 Purpose:*
> *To provide criteria for design and equipment selection that will produce energy savings when applied to building electrical and lighting systems.*
>
> *2.6.2 Reference Codes and Standards:*
> *UBC Uniform Building Code*
> *IES Lighting Handbook*
> *ASHRAE Standard 90.1*
> *ASHRAE Standard 100*
>
> *2.6.3 General:*
> *Building electrical and lighting systems shall be selected and designated in a manner conducive to saving energy. Building electrical and lighting systems will be designed in accordance with Uniform Building Code, IES Lighting Handbook, ASHRAE Standard 90.1 or ASHRAE Standard 100. e compared to when it is analyzed.*
>
> *2.6.4 Interior Lighting*
> .
> .

.

2.6.5 Exterior Lighting:

2.6.5.1 General:

2.6.5.1.1 Exterior lighting systems will comply with the IES Lighting Handbook.

2.6.5.1.2 The lighting power budget limits specified in ASHRAE Standard 90.1, or ASHRAE Standard 100 will be used to establish the maximum building exterior lighting power that may be used for all permanently installed exterior lighting systems. The lighting power budget limit is expressed in watts per square foot and includes all power used by the lighting system including lamps, ballasts, current regulators and lighting controls.

2.6.5.2 Lamps, Ballasts and Fixtures:

2.6.5.2.1 High efficiency metal-halide lamps will be used for exterior lighting.

2.6.5.3 Controls:

2.6.5.3.1 Exterior lighting systems will use photocells as the primary control system. Time clocks will be provided when additional savings can be achieved by limiting the hours of use to less than the hours of darkness.

Source: KSU Facilities Planning Department, Design and Construction Administration

The specifications indicate that the ASHRAE 90.1-2004 Standard and IES Lighting Handbook must be followed in the design process. Beyond that, the standards list no other specific requirements.

3.1 Minimum Design Criteria

The design criteria will be built around the codes that have been adopted by the City of Manhattan, the State of Kansas, and KSU. The adopted related codes for this research include 2006 International Building Code (IBC) and the 2005 National Electrical Code (NEC). (City of Manhattan, Kansas, 2008) Other current standards being widely used by professionals that will be utilized in the design criteria include the IESNA Recommendations and the ASHRAE 90.1-2004 Design Standard that were discussed above.

The following sub-sections will describe the minimum criteria needed to create adequate lighting for the KSU campus.

3.1.1 Safety Considerations

Campus safety is vital to KSU, as students and faculty must be safe while walking on campus at night. The first and primary purpose of lighting the walkways is to provide safety to its occupants. Occupants must be able to clearly identify hazards in the area that could be on or near the walkways in order to take action to avoid them. These hazards can include non-level or sloped parts of the walkway, debris or objects on and around the walkway, and people on or near the walkway. Therefore horizontal and vertical illumination along with uniformity will be important. Poor uniformity creates shadows and high levels of contrast that make it difficult for the eye to focus and can contribute to glare.

Other safety considerations include security purposes, including protection of the property and deterring criminals from the property. Creating a safe and secure environment will play a key role in keeping students in the university and recruiting new students to the university.

3.1.2 Illumination Levels

To provide adequate safety and security, good illumination levels, uniformity, and color rendering must be established. As stated earlier, IESNA Recommendations state that the color rendering index (CRI) should be greater than 50, a 0.6 fc minimum at the ground level, and uniformity, with an average-to-min ratio of at least 4:1. It also states that the same information just stated must also apply to 5 ft above the ground level to create adequate vertical illumination. The calculation zone to which these levels must be measured shall extend 30 ft perpendicular to the walkway. (IESNA Lighting Reference Manual, 2000)

The City of Manhattan or KSU has not adopted or published any ordinances regulating the illumination levels in this kind of application.

3.1.3 Efficiency Levels

As discussed in the previous chapter, the ASHRAE 90.1-2004 Design Standard requires 1.0 w/lf or less for walkways up to 10 ft wide, and 0.2 w/sf for walkways over 10 ft wide. The Quad area has approximately 2,250 lf of walkway that is less than 10 ft wide and approximately 6,080 square feet (sf) of walkway that is greater than 10 ft wide. Using these values, it can be calculated that the total allowable wattage in the Quad area for lighting the walkways is approximately 3,466 W.

Using the current pole arrangement, the total allowable watts per fixture can now be determined. If each of the 30 poles were to be used in the Quad area, a maximum of 115 W could be drawn from each fixture to meet the ASHRAE 90.1-2004 Design Standard.

The efficacy of this new 115 W fixture must also be equal to or greater than the existing fixture to maintain the currently lighting levels and appearance. As previously calculated the Cresthill Sphere has an efficacy equal to 61.5 lm/w, using a 208 W input value. Changing this input value to the required 115 W can determine that the new fixture must have an efficacy equal to or greater than 111.3 lm/w.

Since there is no lamp source by itself on the market today that has an efficacy close to that range, it can be determined that optical reflectors must be used to redirect the light. This will result in more lumens reaching the ground and an increase in the efficacy.

3.1.4 Photometrics

The photometrics of a new fixture must be a full-cut off or semi cut-off in order to prevent light pollution, wasted light on building facades, and unnecessary landscape lighting (all issues discussed in the previous chapter). Light must be efficiently utilized by directing it downward on the walkway itself as much as possible. No code regulates the amount of cut-off a fixture must have, however it is a common engineering practice today to prevent sending unusable light into the sky.

A new fixture would also preferably have a Type II, Type III, Type IV, or Type V distribution to light the surrounding spaces of the walkway. This will help to provide the proper distribution based on the structure and paths of the walkway relative to their surroundings. Refer back to Figure 1.2 for examples of these distributions. This will ensure that the proper safety and security criteria are met, illuminating 30ft to either side of the walkway.

3.2 Design Goals

Now that a minimum basis of design has been established with the previously stated criteria, the design can be further refined by setting a few design goals to provide the most effective lighting system for the KSU campus. These goals will include looking at aesthetics, green design, the potential for cost and energy savings, and acknowledging some design limitations. All of these are outside the scope of any code or standard, but must be addressed in order to creating a working system for the KSU campus and its occupants.

3.2.1 Aesthetics

Aesthetics in lighting is characterized by visual appearance of the fixture, the light it produces, and the environment the light creates by illuminating objects and surfaces or simply, its uniformity. It is often different from individual to individual and difficult to define.

As it was determined in Chapter 2, the current aesthetics of the campus can be described as elegant, simplistic, and historic. However the fixtures have developed weathering and color issues. A new design should consider keeping this same appearance of the campus as much as possible. Only simplistic and modern fixture designs should be used to enhance the space and bring it up-to-date, preferably a round fixture can still be used. Lamps should also be selected that can maintain color and have less depreciation over time. This will give the campus a much more uniform, safe, and clean look.

3.2.2 Going Green

Going green simply means creating an energy efficient, environmentally safe, and sustainable design. It has been the new buzz word in engineering for the past few years and has taken off in the building sector with the new USGBC LEED New Construction and Existing Buildings programs. For this research the Existing Buildings v2.0 will be used due to the lighting renovations not being considered as new construction. Reasons for pursuing green design include saving energy, reducing greenhouse gas emissions, and reducing operating and maintenance costs. Also, in most cases, from the economic standpoint it will save money in the long run. The economic side of green design will be discussed in the next section.

Looking at some statistics, the importance and potential impact of green design can easily be identified. Buildings account for 38.9% of the total energy consumed in the United States, including 72.4% of all the electricity consumed. Educational facilities such as KSU currently consume 11% of this total energy, the third highest category next to office and mercantile facilities. Specifically, lighting accounts for 24.8% of the overall energy consumption by commercial buildings. This is approximately twice as much as space cooling, the next highest category, in overall end-use building consumption. Lighting accounts for 25.2% of all carbon dioxide emissions in the nation for commercial buildings, the highest contributor. In educational facilities, lighting accounts for 15.8% of the total energy consumption. (D&R International, Ltd., 2008) All of these statistics include building interior and exterior contributions, the majority being from building interiors. However, it still represents a great need for improving every aspect of building lighting systems.

Another reason to pursue sustainable design is the rising energy costs. The national average for electricity in 2006 was 9.47 ¢/kWh, up 0.92 ¢/kWh from 2000. It is projected to rise to 9.52 ¢/kWh this year. (D&R International, Ltd., 2008) As stated previously, the KSU campus estimated electricity costs are well below this average at 6.32 ¢/kWh, but will follow the rising national trend.

With less energy consumed, the university will support a better environment, more money will be saved as energy prices continue to increase, and less energy consumed leading to less green house gases being vented into the atmosphere.

As previously discussed, the USGBC has developed the LEED program as an incentive for owners and designers to pursue sustainable design. Specifically applying the LEED program to campus lighting, multiple points set design requirements. Exterior lighting systems alone cannot become LEED certified, but it will be required to allow for the individual campus buildings to become LEED certified. If LEED certification is not desired, these requirements will still set campus goals for a green design. The points affecting the design of this system are listed below:

1. Sustainable Sites Credit 7: Light Pollution Reduction – 1 point
2. Energy & Atmosphere (EA): Minimum Energy Performance – Prerequisite 2
3. Energy & Atmosphere (EA): Optimize Energy Performance – 1 to 10 points

(LEED for Existing Buildings Version 2.0, 2005)

To meet the Light Pollution Reduction credit, the lighting must meet light cut-off requirements. These requirements include having shields on all luminaries over 50 W or providing calculations to show that less than 5% of the light emitted by all outdoor lighting does not reach the night sky on an annual basis. This can be accomplished with the use of full cut-off optics as were described above. Another key component to this credit is that measurements must be taken along the perimeter of the property while the lights are both on and off. The light measurements cannot exceed a factor of 10 above the measured light levels when they are turned off. Using shields on the back of the fixtures at the property edges will easily accomplish this goal. (LEED for Existing Buildings Version 2.0, 2005)

To meet the criteria for the Minimum Energy Performance, the new design must obtain a Environmental Protection Agency (EPA) Energy Star rating of at least 60. The EPA Energy star rating system is based upon the amount of energy the new design saves verses the existing, or baseline, design. To receive a rating of 60, the energy reduction must be at least 10%, or 5,616 W. This is higher than the 3,466 W previously determined goal to meet ASHRAE 90.1-2004 standards, so this goal will already be greatly surpassed. (LEED for Existing Buildings Version 2.0, 2005)

To meet the criteria for Optimize Energy Performance, the EPA Energy Star ratings must improve more upon the Minimum Energy Performance credit. The higher rating the new design receives, the more credits it is awarded. These ratings can be seen on Table 3.1 below. (LEED for Existing Buildings Version 2.0, 2005)

Table 3.1 LEED E.C. 2.2: EA - Optimize Energy Performance Energy Savings Percentages

Energy Star Rating	Equivalent Energy Reduction	Renovations Points
63	13%	1
67	17%	2
71	21%	3
75	25%	4
79	29%	5
83	33%	6
87	37%	7
91	41%	8
95	45%	9
99	49%	10

Source: LEED for Existing Buildings Version 2.0, 2005

To meet the 3,466 W goal would result in a 55.54% decrease in energy usage, already achieving 10 points. Therefore the goal of having each fixture be less than 115 W still exists, with an efficacy of 111.3 lm/w. (LEED for Existing Buildings Version 2.0, 2005)

Another side of green design is looking at sustainability. For lighting systems, sustainability means installing longer life, lower wattage lamps and using design strategies for using more effective use of light. Using these lamps will save hundreds of man hours replacing and repairing the lamps. It will also cut down on the waste created by the shorter life lamps and fixtures. Therefore, a goal will be set to find a lamp that has a longer life than the current light fixture, which has an 11,500 hour metal halide lamp.

3.2.3 Potential Cost and Energy Savings

Creating a greener lighting system on the KSU campus will save potentially thousands of dollars a year in maintenance and operational costs. As previously discussed, installing a sustainable system will reduce the man hours needed to keep the system working. The energy savings will dramatically reduce the energy consumed and therefore significantly reduce the money spent on electricity each year.

Using the previous goal of 115 W per pole in the Quad area, the total electricity consumed would be approximately 16,370 kWh, 13,240 kWh less than the current system. Using the same energy rate of 6.32 ¢/kWh, this would save $836 per year in the Quad area alone. Applying the same principle to the entire KSU campus, the total electricity consumed would be approximately 211,176 kWh, 170,778 kWh less than the current system. This could save $10,793 per year in electricity bills.

Using savings from energy and maintenance costs, a simple payback (SP) and return on investment (ROI) can be calculated. For this research a SP goal of 15 yrs, 6.67% ROI, can be made. This comes from the assumption that KSU facilities have longer service lives than typical commercial applications. Typically commercial applications tend to want 10 years or less SP. Using engineering judgment, a goal of a 15 year SP can be established.

3.2.4 Design Limitations

Some design limitations must be determined before proceeding with the design of a new lighting system. These include, pole locations, site and landscaping modifications, and wiring limitations.

The existing fixtures are mounted on concrete bases with wiring already in place. To remove these bases and reroute wiring would be not be economical for KSU. The expenses for demolition, excavation, the purchase of new copper wiring, and installing new pole bases would prove to be to expensive. The existing bases and pole locations must be reused to make this project feasible.

Secondly, site and landscaping issues are outside the scope of this project. The trees and other landscaping issues that exist will not be corrected when replacing the lighting system. To create the optimum lighting scene, KSU should perform proper site maintenance by trimming overgrown trees and shrubs that negatively impact light fixture performance.

Lastly, the existing wiring is rated for a maximum amperage. Therefore the limitations of the wire cannot be exceeded. This should not be a problem as the previous design goals have stated that lower wattage fixtures be installed, therefore lowering the amperage loads seen by the wire. As stated earlier, the existing wiring and conduit cannot be easily replaced and should be reused. New conduit could be pulled if necessary, but will increase the overall cost of the project significantly.

3.3 Design Goal Summary

The criteria and goals stated above have been compiled into a table that will be used to determine if the new lighting design meets these standards. Refer to Table 3.1 on the following page. The Economic goals will be detailed as each design is discussed.

Table 3.2 Design Goal Summary

Goal	Minimum Design Goals
1.) Safety and Security	
a. Illumination (ground level)	0.6 fc
b. Uniformity – Average-to-Min	
i. Horizontal (ground level)	4:1
ii. Vertical (5ft above ground)	4:1
2.) Meet Current Design Standards	
a. ASHRAE 90.1-2004	
i. Power Density	
• >10ft wide	0.2 w/sf
• ≤10ft wide	1.0 w/lf
ii. Other	
b. IESNA Recommendations	
i. Illumination	0.6 fc
ii. Uniformity – Average-to-Min	
• Horizontal (ground level)	4:1
• Vertical (5ft above ground)	4:1
c. CRI	50
3.) Fixture Characteristics	
a. Input Wattage	115 W
b. Efficacy	111.3 lm/w
c. Cutoff	Full Cut-Off Optics
d. Photometric Distribution Type	Type II, III, IV, V
e. Lamp Life	11,500 hrs
f. CRI	50
4.) Green (LEED)	
a. LEED Credits	
i. Light Pollution Reduction	Full Cutoff
ii. Minimum Energy Performance	10% Reduction
iii. Optimize Energy Performance	49% Reduction
b. Sustainability	
i. Lamp Life	11,500 hrs
5.) Economic	
a. Simple Payback	15 yrs
b. Return on Investment	6.67%

CHAPTER 4 - Proposed Lighting Solution

This chapter will discuss a new design option for the walkways on the KSU campus. The design will revolve around a different type of light fixture that has the potential to meet all the design goals stated previously in Table 3.2. To determine the best design, the proper lamp source must be selected and analyzed. With the proper lamp source, fixtures can be found that meet the lumination requirements for the KSU campus. The following chapter discuses the lamp source, the new light fixture, and the new design compared to the goals that have already been established.

4.1 What Lamp Source Should Be Used?

Given the goals for high efficiency and sustainability, the lamp source becomes extremely important. It must consume less energy without sacrificing lumen output, meaning high efficacy. The graph in Figure 4.1 below gives an efficacy comparison of various light sources.

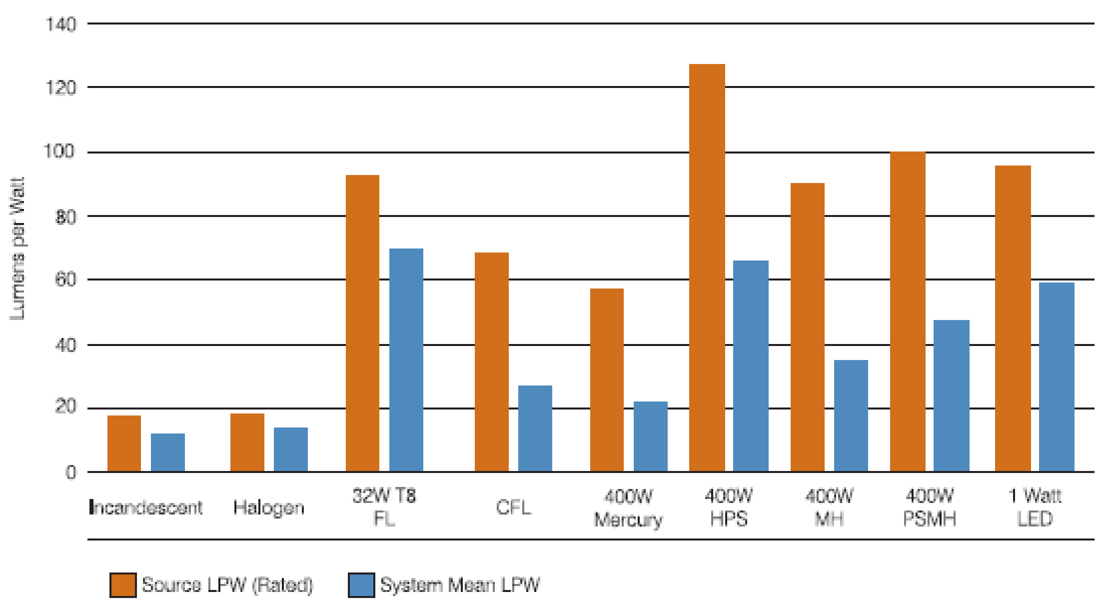


Figure 4.1 Comparison of Efficacies for LED and Traditional Lighting Technologies

(LED Lighting Systems in Sustainable Building Design, 2008)

From this graph, it can be determined that the efficacy of a 1 W LED source compares to a 400 W metal halide source. When multiple LED's are combined, this number can become greater. Its efficacy is only surpassed by high pressure sodium lamps, which have very poor CRI, unlike LEDs. LED technology has grown rapidly in the past year and is the most efficient light source in the market today.

To further verify LEDs as a quality light source, a comparison of lamp life and light loss over time can also be performed. Figure 4.2 below shows the efficacy of LEDs versus metal halide over a period of time.

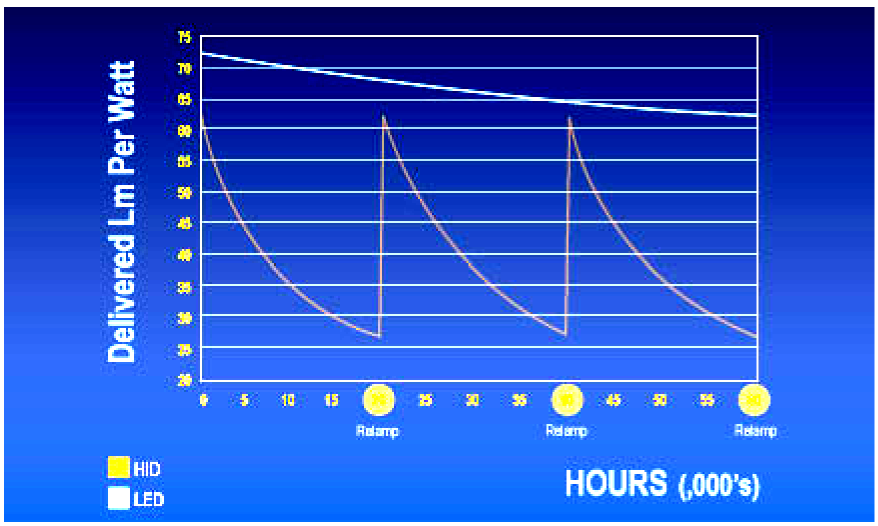


Figure 4.2 Efficacy Over a Period of Time For LED and Metal Halide Lamps

(Beta LED: Delivered Lumens per Watt, 2008)

The graph shows a comparison over a span of 60,000 hrs, using a 20,000 hr metal halide lamp. Using the information on this graph it can be calculated that the metal halide loses 57% (LLF = 0.57) of its lumens over the course of its life compared to the LED only losing 15% (LLF=0.15). However, these values can vary based upon the manufacture and development of new technology. Newer LED lamps have been found to have an even lower LLF.

The average rated life of an LED source is 150,000 hrs, 138,500 hrs longer than metal halide. However, typically the LED lamp will need replacing after 50,000 hrs to maintain an adequate light output. This issue will be discussed later in this report.

From these figures, a LED light source is a clear choice for the KSU campus. It will produce a more consistent illumination output and solve the current aesthetic issues where the lamps produce different colors of light. It will also be a very efficient and sustainable source that has the potential to dramatically decrease energy consumption and costs. The next step to complete a new lighting design must be to find a LED fixture that can meet the design goals.

4.1 LED Walkway Fixture Information and Photometrics

During a conversation with Ryan Diediker with Smith and Boucher Engineers, about his work on another KSU campus project, he recommended looking at Beta LED fixtures. He was using these fixtures for site lighting in his current project. After review of their product line, a fixture was selected that had the potential to meet all the design requirements and strategies stated previously.

The fixture to be analyzed will use the Beta LED: The Edge Round luminaire. This is a LED source, round, spider-mount fixture that is wet listed and has full-cut off optics. The housing is die-cast steel and made of extruded-aluminum, making it very durable. It is available in type II, III, IV, and V photometric distributions and connects to a 4 or 5 in round steel pole. A photo and dimensions of this fixture can be seen in Figure 4.3 below. Fixture specifications can be found in Appendix B.4, B.5, B.6, B.7, and B.8.

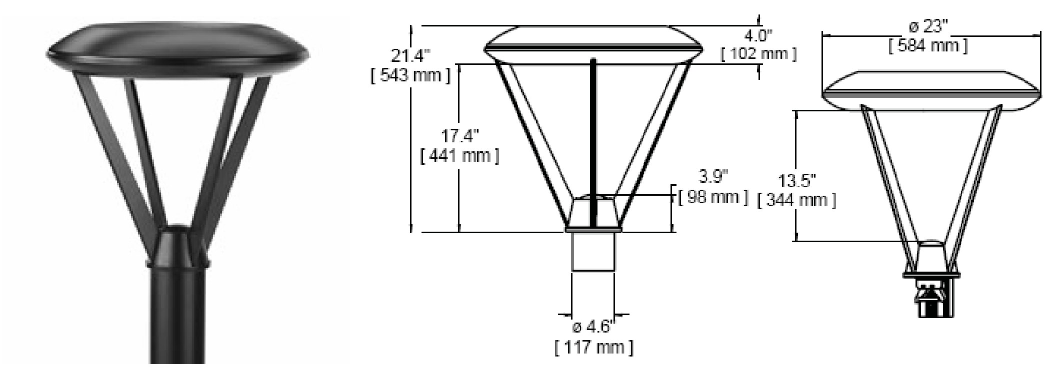


Figure 4.3 Beta LED: The Edge Round

(http://www.betaled.com, 2008)

The Beta LED Round has LEDs placed in what are called light bars, or 2 rows of 10 LED bulbs. The fixture can house 2 to 6 light bars in a single fixture, giving it anywhere from 20 to 120 LEDs. Each LED has a lamp life of 150,000 hrs, a 6000 Kelvin (K) color temperature, and a

CRI of approximately 75. To power the LEDs, an LED driver is required. This driver serves the same purpose of a ballast, it requires 350 milliamps (mA) of current to power the fixture.

Unlike the Cresthill sphere being currently used, this fixture has light optics that provides the various photometric distribution types. Since the light is reflected in a different manner in each instance, each type will have a different lumen output. However, this does not cause the input wattage to change due to the same light bars being installed. Table 4.1 below lists the lumen values for each distribution type and light bar combination along with their respective input wattages. Using this data, we can use the AGI32 program to determine the best distribution type and light bar combination for the KSU Quad area.

Table 4.1 Beta LED: The Edge Round Initial Delivered Lumens and Input Wattages

Light Bars	Type II		Type III		Type IV		Type V	
	System Wattage	Initial Output Lumens	System Wattage	Initial Output Lumens	System Wattage	Initial Output Lumens	System Wattage	Initial Output Lumens
2	55	3,120	55	3,500	55	3,240	55	3,400
3	79	4,680	79	5,250	79	4,860	79	5,100
4	104	6,240	104	7,000	104	6,480	104	6,800
5	128	7,800	128	8,750	128	8,100	128	8,500
6	153	9,360	153	10,500	153	9,720	153	10,200

Source: Beta LED The Edge Round Fixture, http://www.betaled.com

4.1.2 Illumination and Efficiency Calculations

Before any design can be completed, the total LLF must be determined using the same procedure from Chapter 1. Looking back to Equation No. 1, it can be determined that only the LLD and the LDD factors will change. The VF, BF, LSD, and LPF factors will remain at 1.0 as there have been no changes to the design environment that would affect these values.

The LLD factor for an LED lamp depends primarily on the average temperature of the space in which it is operating. Since this is an exterior case and the lamps are only operational during the night time hours, only the average night temperature needs to be determined. Beta LED has published information regarding LLD, this information can be found in Appendix F.

Looking at the given charts, it can be determined that central Kansas has an average night temperature of 50 ^{o}F, therefore having a 0.95 LLD after 50,000 hours and a 0.88 LLD after 100,000 hours. (http://www.betaled.com, 2008)

If the fixtures were to be re-lamped after 100,000 hours, each lamp would be operational for approximately 21 years. Due to the extreme time frame from when the fixture will need to be serviced, other factors such as fixture weathering must be considered. After 21 years, depending on the quality of construction, the fixture may experience moderate to severe weathering or damage from flying debris despite its outdoor rating. Given this information it will be recommended that the KSU Facilities Planning Department re-lamp the fixtures every 50,000 hours, or approximately every 10.5 years, assuming that the fixtures would be on 13 hours each night and 365 days per year. Therefore a LLD of 0.95 will be used for the new design.

As stated in Chapter 1, the LDD factor is based upon the dirt and insect build-up in or on the fixture and is determined by the amount of time between cleaning. In this case, the Beta LED Round has no spaces where dirt and insects could collect in or on the fixture. It can be assumed that the KSU Facilities Planning Department will keep the same cleaning schedule, every 30 months, and have a very clean environment. Looking back to Figure 1.4, it can be determined that the LDD will be equal to 0.93.

LLF = (0.93 LDD) x (0.95 LLD) x (1.0 VF) x (1.0 BF) x (1.0 LSD) x (1.0 LPF)

(Equation No. 1)

LLF = 0.88

With the LLF determined, the design capabilities of this fixture can be determined in the same manner as done in Chapter 1. Again using the Visual Professional (v. 2.06.0142) program the photometrics and photometric webs can be calculated for each distribution type. The IES files for the Beta LED: The Edge Round fixtures were downloaded from the manufactures web page. (http://www.betaled.com, 2008). The resulting photometric webs are shown on the following page in Figure 4.4

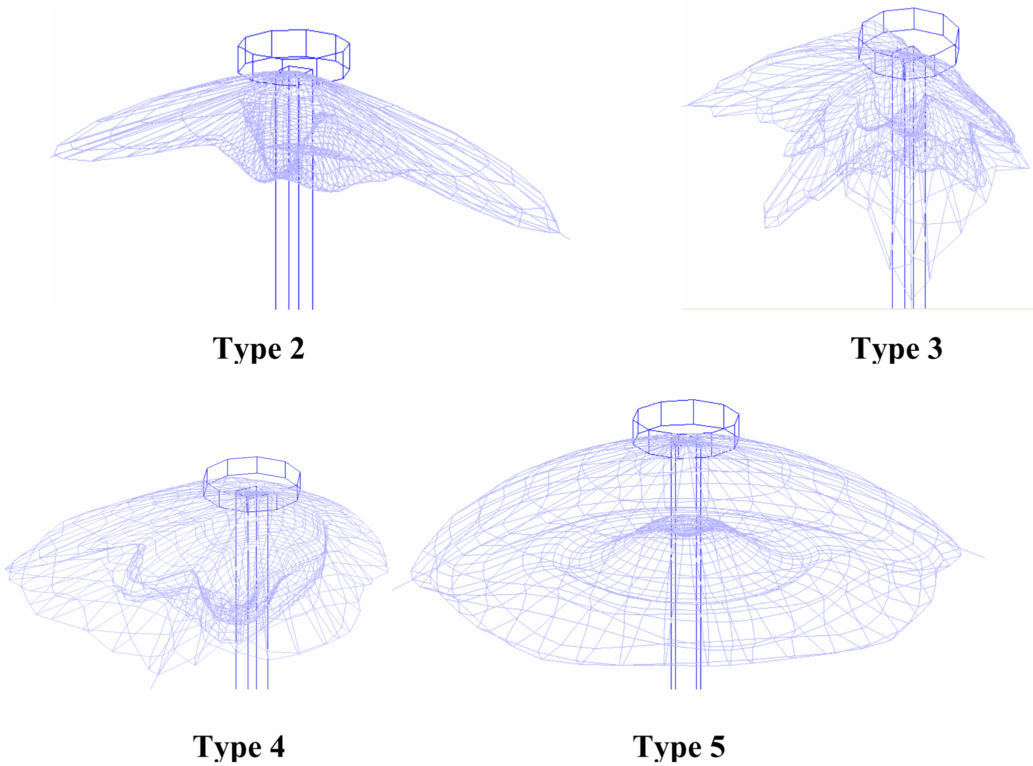


Figure 4.4 New Walkway Fixture Design Photometrics Using a LLF = 0.88

(Program Inputs: Beta LED Area Round IES files and lamp lumens from Figure 4.7)

(calculated and displayed using Visual Professional v2.06.0142)

With these distribution types, the fixtures can be located where the photometrics best match the walkway layout in that area. However, one more issue must be considered before completing a design. New research has been performed by Dr. Sam Berman and Dr. Don Jewett at the Lawrence Berkeley Laboratory that concludes that light levels may be lower than previously thought when high temperature lamps are used. This research revolves around the study of how the human eye uses light receptors called rods and cones to send visual signals to the brain. The rods, commonly called ‘scotopic vision,’ handle night vision, while the cones, called ‘photopic vision,’ handle day vision. Both are photoreceptors in our eye. This research is especially important to LED lighting design as LED lamps typically have a very high color temperature with lower light outputs. The following section describes the effects it can have on this design. (What is Scotopic and Photopic Vision?, 2008)

4.1.3 Photopic and Scotopic Vision

The number of scotopic rods in a typical retina is about 10 to 1 compared to the photopic cones. This is the primary reason scientists have thought that rods are used during the night, allowing more light to enter the eye. (What is Scotopic and Photopic Vision?, 2008) Research done in the 1990's reexamined this theory. This new theory studied the effects of pupil size relative to light level, or photopic, changes and then compared it to different types of luminance based on the sensitivity of the rods to different wavelengths of light. These different wavelengths are called the rod spectral sensitivity functions, or scotopic response functions. Experiments to test this theory were preformed in a 9 ft by 12 ft room with a television. The subjects were exposed to different wall colorings with common fluorescent lamps to change light levels and scotopic light contributions. The results of the test revealed that the pupil size had no correlation with simple changes in light levels, but had an almost perfect correlation with scotopic response functions. In other words, the pupil size follows the scotopic spectrum rather than the photopic spectrum, opposite of what was originally thought. (Berman, 2000)

These results greatly impact the lighting industry as all current light meters and lumen calculation programs on the market today only measure photopic light, leaving out the scotopic contributions. Other experiments were done to back up this theory that proved the rods primarily control the open and closing of the pupil and significantly influence the brightness of a room. However, even with this new information available, most engineering practices today do not apply these findings to standard design practices. Next, experiments were done where subjects had to choose the room that appears to be brighter on a repeated basis. Indirect lighting, all being the same color, was used to create a photopically enhanced and scotopically enhanced scenes in the room. Most subjects chose the scotopically enhanced room as brighter, when the light levels as measured by a standard light meter actually were 30% less. A final experiment was preformed at a national IES meeting where 100 lighting professionals were tested in the same conditions as stated earlier. Only observers with some color blindness did not select the scotopically enhanced room as being brighter. (Berman, 2000)

Scotopically enhanced spaces are spaces that use higher color temperature lamps. A lamp's color temperature can directly correlate to the amount of scotopic enhancement in a space, therefore making it appear brighter even when less footcandles are read at the working plane by activating more rods in the eye. To apply this to current lighting design depends on the light source being used and it's color temperature, each affecting the ratio of scotopic light output to photopic light output, called the S/P factor. Most lamps range from an S/P value of 1 to 2.3 except for high and low pressure sodium that is 0.6 and 0.4 respectively. The S/P factor can be applied in the following formula that estimates the total light output, or Effective Lumens (EL), considering both photopic and scotopic light contributions, see Equation No. 4 below. (Berman, 2000) The 0.78 exponent was determined in various laboratory experiments.

$$EL = P * (S/P)^{0.78} \qquad \text{(Equation No. 4)}$$

where

EL = Effective Lumens

P = Initial rated (photopic) lumens

S/P = Scotopic to Photopic Light Ratio

An S/P factor of 1 would mean the light output is the same as read from a conventional light meter whereas a 2.3 S/P factor would mean the light output is $2.3^{0.78}$ times the reading from the same light meter. Figure 4.5 below shows the S/P values for common light sources.

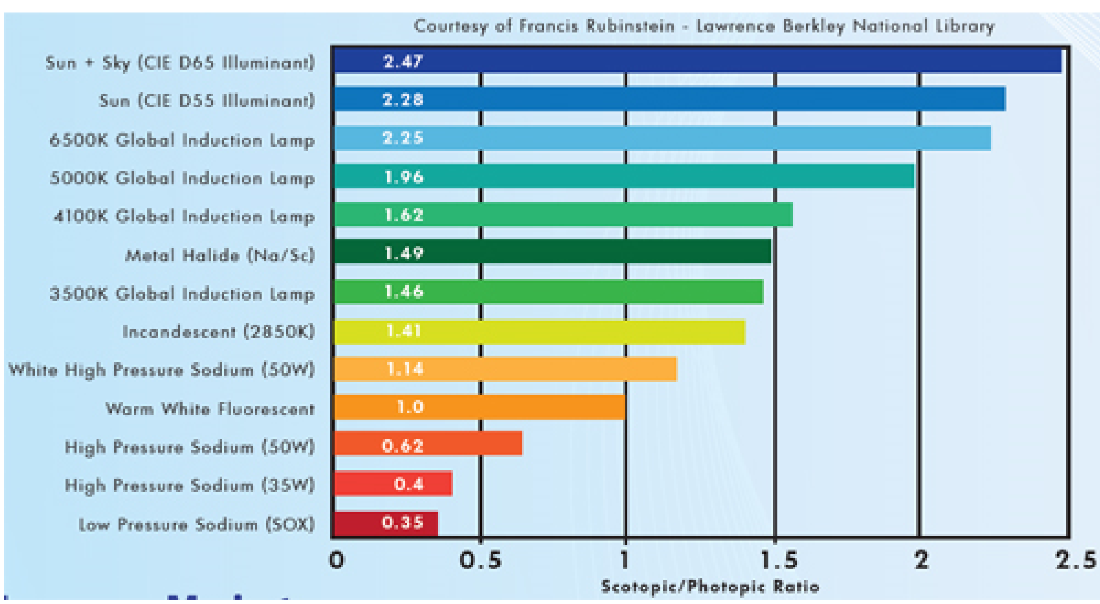


Figure 4.5 S/P Values for Common Light Sources

(Visually Effective Lighting, 2009)

To apply this formula to the selected LED light fixture, the S/P value must first be determined. The color temperature is approximately 6000K, white in color. By looking at Figure 4.5 above, it can be assumed that the S/P value should be between 1.96 and 2.25 based upon color temperature alone. Currently, Beta LED does not release any S/P value information for this fixture so a conservative value of 2.0 will be used for the purposes of this report.

Using the S/P value, the photometrics can be adjusted in two ways. The first is to lower the recommended footcandle levels at the task plane, or walkway surface. As the IES guidelines are only recommendations, not code requirements, it can be done with the proper calculations and supporting data. Lowering the levels however can become a very difficult task as each point must be individually adjusted as the lumen output will be different for each angle and distance from the light source. There is no set formula for every point of calculation. The second is to adjust the lumen output at the fixture using Equation No. 4. This calculation will adjust the light contributions at the source rather than at each individual point and is much simpler. Therefore using the second adjustment method and applying it to the given illumination values from Table 4.1 shown previously, an EL for each distribution type and number of light bars can be determined using Equation No. 4. The results of this calculation are shown below in Table 4.2. These values will be used when designing the new lighting scheme.

Table 4.2 Beta LED: Photopic Output Lumens and Effective Lumens Comparison

Light Bars	**Type II**		**Type III**		**Type IV**		**Type V**	
	Photopic Output Lumens	Effective Output Lumens	Photopic Output Lumens	Effective Output Lumens	Photopic Output Lumens	Effective Output Lumens	Photopic Output Lumens	Effective Output Lumens
2	3,120	5,357	3,500	6,010	3,240	5,564	3,400	5,838
3	4,680	8,036	5,250	9,015	4,860	8,345	5,100	8,757
4	6,240	10,715	7,000	12,020	6,480	11,127	6,800	11,676
5	7,800	13,394	8,750	15,025	8,100	13,909	8,500	14,596
6	9,360	16,072	10,500	18,030	9,720	16,691	10,200	17,515

This great difference between effective lumens and photopic output lumens can be easily seen in a case study provided by the BetaLED company. Figure 4.6 on the next page shows a before and after picture of a gas station. The photo on the left is the gas station with metal halide fixtures while the photo on the right is the gas station renovated with LED fixtures. Each photo has approximately the same photopic footcandle level as read by a conventional light meter or as calculated by program like Visual Professional or AGI32. However the photo on the right is much brighter and appears to have a higher footcandle level. This is due to the high color temperature of the LED lamps as described above and the associated scotopic footcandles that add to is luminous appearance.

Figure 4.6 Case Study Comparing Metal Halide to LED Lamping

(http://www.betaled.com, 2009)

To compare this to the current metal halide lamps on campus, Figure 4.5 shows that its S/P factor is equal to 1.49. Given the 12,800 initial lumens for the 175 W lamp used in the Cresthill Sphere, it can be calculated using Equation No. 4 that the EL would be equal to 17,470 lumens. The EL for metal halide however would be inaccurate if put into a lighting calculation program such as Visual Professional or AGI32 due to its color shift over time. As previously discussed, the color of a metal halide lamp can shift from white to blue or green. The result is also a change in color temperature of the lamp. Therefore, the S/P value would change throughout the life of the lamp, and be closer to 1.0 at the end of its life. Unless the maintenance personnel changed the lamp when the color shift was beginning, the design calculations cannot include any scotopic contributions. The design calculations must be performed at a near worst case scenario. Therefore it is accurate to compare the EL of an LED light source to the photopic lumens of a metal halide source.

4.2 Redesigning the Quad Area

After inputting the effective output lumens for each of the Beta LED fixture types as shown in Table 4.2 above into the AGI32 (v.2.03) just as previously done in Chapter 1 of this report, a new design was established. This design was performed using all of the design criteria and strategies described in Chapter 3 and the Beta LED Area Round fixture. The following sections describe and analyze this solution's illumination, efficiency, aesthetics, and economic characteristics.

4.2.1 Analyzing Illumination and Efficiency Calculations

Refer to Table 4.3 below for a light fixture schedule and Figure 4.7 for an overall view of the new design. The circled areas in Figure 4.7 will be further used as key plan to show areas that will be further discussed and enlarged to be shown in more detail. Also note the calculation points only extend 30ft beyond the walkway, as recommended by IES and previously described. This was done in order to provide accurate uniformity calculations.

Table 4.3 Light Fixture Schedule

LIGHT FIXTURE SCHEDULE				
Qty.	**Label**	**Model Number**	**Lumens**	**Watts**
2	T5-6	BLD-ARR-T5-R5-102-LED-B-UL-BK (Pole: PS5R15C)	17,515	153
1	T5-3	BLD-ARR-T5-R5-051-LED-B-UL-BK (Pole: PS5R15C)	8,757	79
4	T5-2	BLD-ARR-T5-R5-034-LED-B-UL-BK (Pole: PS5R15C)	5,838	55
2	T4-4	BLD-ARR-T4-R5-068-LED-B-UL-BK (Pole: PS5R15C)	11,127	104
1	T3-5	BLD-ARR-T3-R5-085-LED-B-UL-BK (Pole: PS5R15C)	15,025	128
2	T3-4	BLD-ARR-T3-R5-068-LED-B-UL-BK (Pole: PS5R15C)	12,020	104
10	T3-2	BLD-ARR-T3-R5-034-LED-B-UL-BK (Pole: PS5R15C)	6,010	55
1	T2-4	BLD-ARR-T2-R5-068-LED-B-UL-BK (Pole: PS5R15C)	10,715	104
1	T2-3	BLD-ARR-T2-R5-051-LED-B-UL-BK (Pole: PS5R15C)	8,036	79
4	T2-2	BLD-ARR-T2-R5-034-LED-B-UL-BK (Pole: PS5R15C)	5,357	55

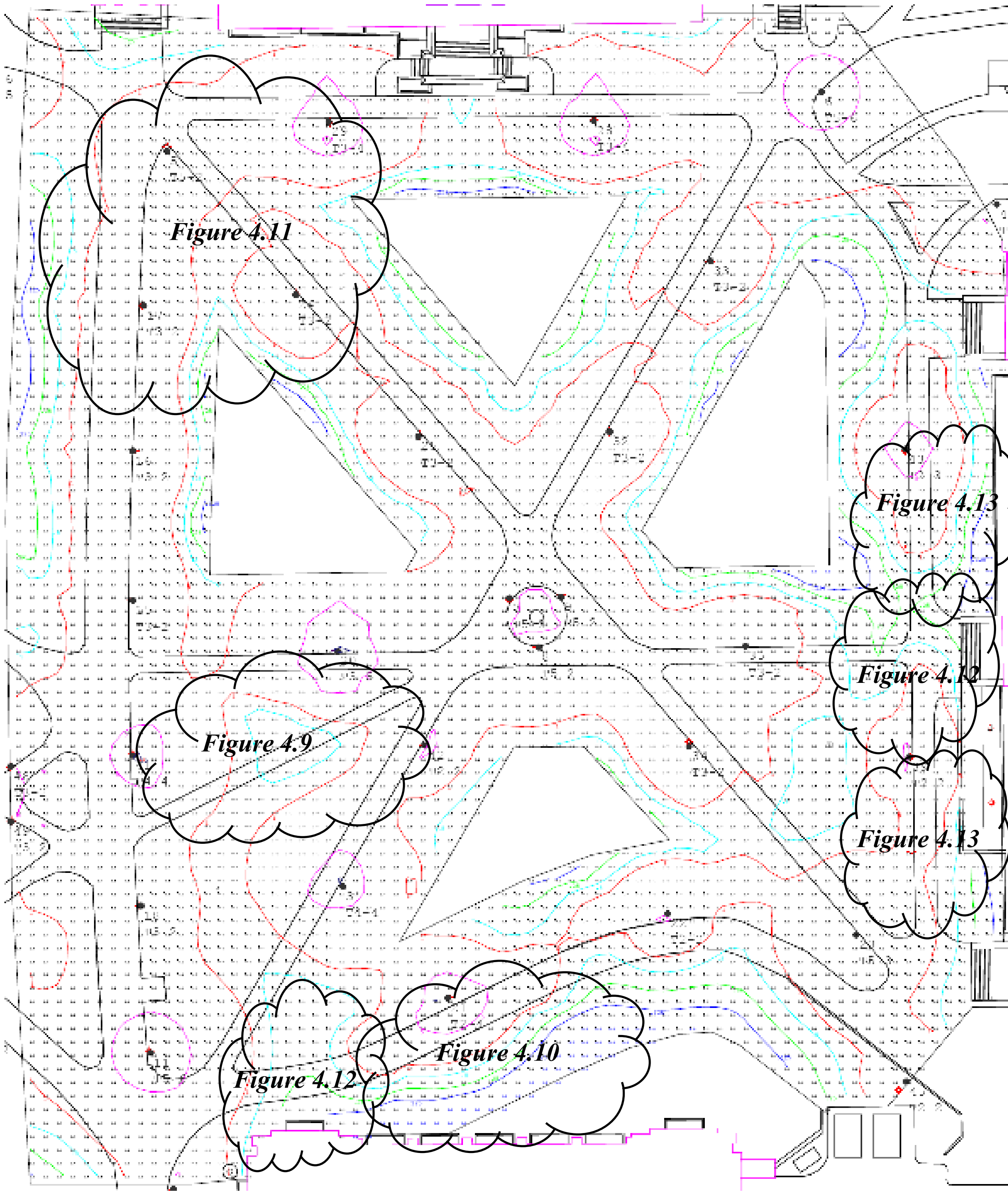


Figure 4.7 KSU Quad New Lighting Design and Illumination Levels

(Program Inputs: Beta LED Area Round IES files and lamp lumens from Figure 4.7)

(calculated and displayed using AGI32 v2.03)

Some illumination statistics with this design, calculated by the AGI32 (v. 2.03) program are as follows:

Max: 11 footcandles	Max/Min = n/a
Min: 0 footcandles	Max/Avg = 6.79
Average: 1.62 footcandles	Avg/Min = n/a

Starting the analysis, the primary disadvantage to this design is the hot spots created by higher wattage LED fixtures. Each figure shown previously indicates the amount of footcandles directly under the fixture to be much higher than the original design, approximately 11 footcandles. Looking at the overall plan in Figure 4.7 also shows isocontour lines that support the same conclusion. The pole heights have been increased from the original 12 ft to 15 ft to help reduce this problem; however given the limitations of this project they are unavoidable. With the pole locations being non-movable, higher output fixtures had to be placed in certain locations. An example of this is shown below in Figure 4.8 where high intensity fixtures must be used to reach a portion of distant walkway with no pole location.

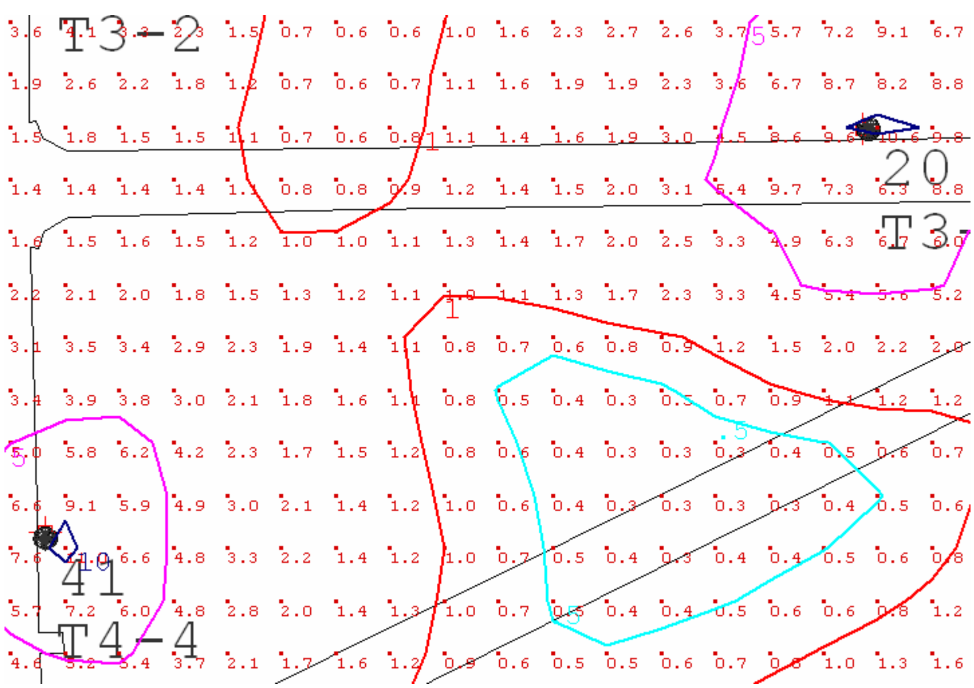


Figure 4.8 High Contrast Created by Beta LED Fixtures

(Program Inputs: Beta LED Area Round IES files and lamp lumens from Table 4.3)

(calculated and displayed using AGI32 v2.03)

Notice directly under pole number 20, there are 10.6 footcandles reaching the ground while the lowest readings on the far walkway are only 0.3 footcandles. These contrasts create a very poor min to max uniformity ratio of 35 to 1. With this design the lowest reading on any portion of the walkway is 0.2, yielding a max to min ratio of 55 to 1 for the entire area. Uniformity was not able to be calculated due to the minimum reading of 0 fc in a few areas as well. These areas are located 20ft off of the walkway, primarily on the south east side in front of a building with large windows that allow enough light to pass through and cover this area. Refer to Figure 4.9 below.

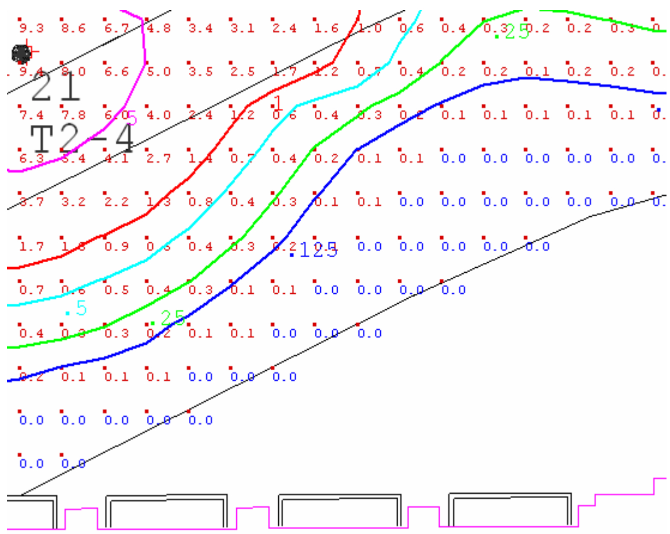


Figure 4.9 Low Light Level Calculations in the KSU Quad off the Walkway

(Program Inputs: Beta LED Area Round IES files and lamp lumens from Table 4.3)

(calculated and displayed using AGI32 v2.03)

Looking back to the maximum to minimum uniformity calculations from the current design, is equal to 7 to 1, the new uniformity of 55 to 1 is significantly worse. However, in contrast, the illumination goal of 0.6 fc min on the walkway itself was met a vast majority of the time. By looking back to the original design calculations in Figure 1.7 and comparing it to the new design calculations in Figure 4.10, shown on the next page, it can be determined that uniformity and overall illumination has improved significantly in this area. Since the overall illumination levels have exceeded the original design and are greater than 0.6 fc over a vast majority of the walkway, it should be determined that this design meets the overall illumination design goal for life safety and security. This is proven with the average illumination level of 1.62 fc throughout the entire calculated area, 30ft off the walkways.

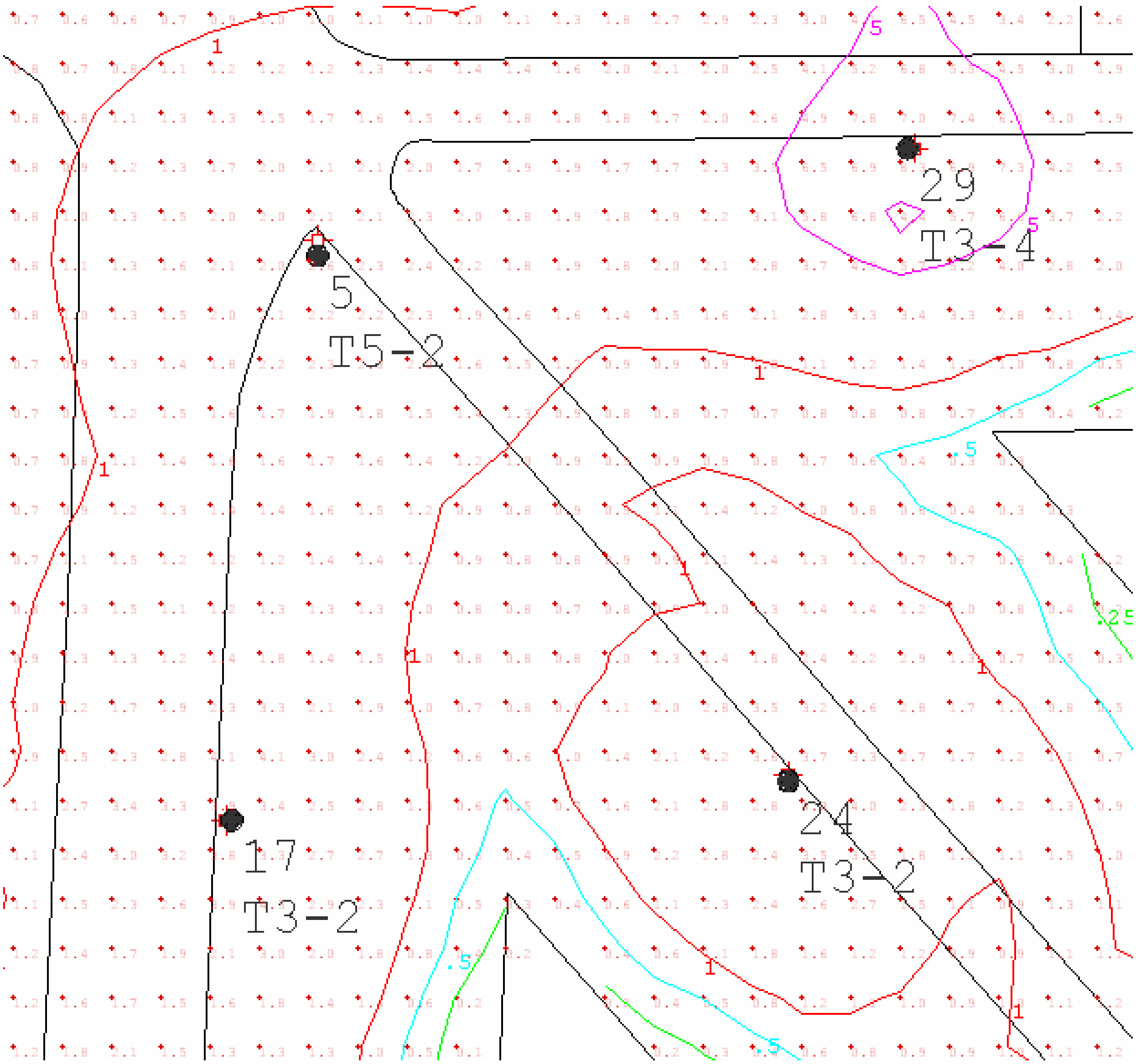


Figure 4.10 Fixtures to be removed from KSU Quad

(Program Inputs: Beta LED Area Round IES files and lamp lumens from Table 4.3)

(calculated and displayed using AGI32 v2.03)

There are only 2 areas where this goal was not met, and they are close to buildings where façade lighting is also applied. The façade lighting will improve these light levels in these areas. These key areas are shown in Figure 4.11 on the next page.

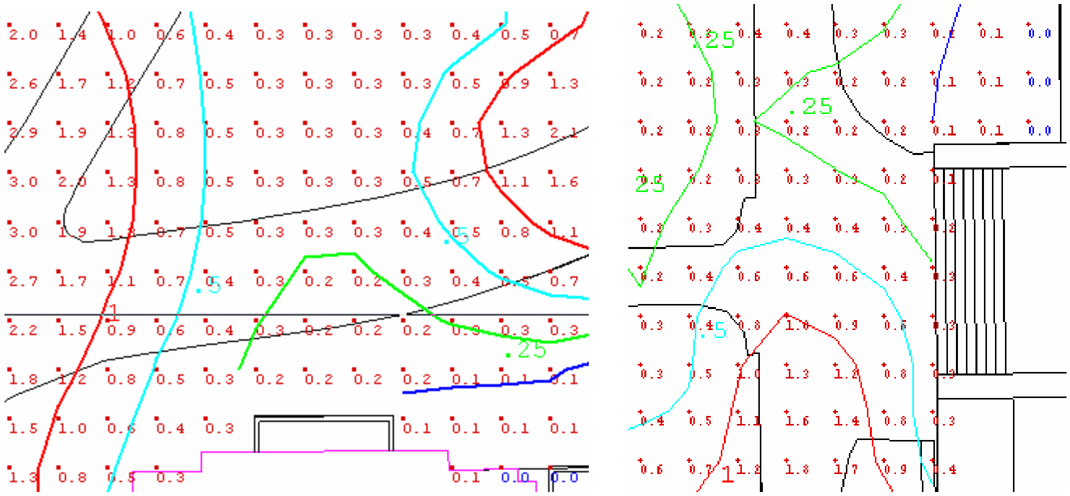


Figure 4.11 Low Light Level Calculations in the KSU Quad on the Walkway

(Program Inputs: Beta LED Area Round IES files and lamp lumens from Table 4.3)

(calculated and displayed using AGI32 v2.03)

There is a minimum reading of 0.2 fc on the walkway. Using a maximum of 11 fc, the average to maximum uniformity is 8 to 1 overall. The illumination readings are much greater than the original design readings. The design has sacrificed poor uniformity to have a much improved illumination. When the same calculations are taken 5ft above the ground to determine vertical illumination and uniformity, the average to minimum ratio becomes 16 to 1. This is due to an average illumination level of 1.64 and a minimum walkway calculation of 0.1 fc. Neither the ground uniformity nor vertical uniformity readings meet the original design goals and IES recommendations.

This new layout utilizes a wide range of light distribution patterns and fixture wattages. It uses the same pole locations as the previous design, where the fixtures have been selected for their particular location based upon the patterns of the surrounding walkway and the distance to the next light fixture. By doing this, the most cost effective design was also achieved using this type of fixture. This proposed layout will also require two less fixtures than the original design, making 28 fixtures instead of 30 in the Quad area. It was determined that with the proper fixture distributions on the east walkway, these fixtures were not needed to provide acceptable illumination levels. Figure 4.12 on the following page shows this area and the calculated footcandle levels. The building to the east of these fixtures also has some perimeter lighting that will further improve the illumination levels in these areas that could not be accounted for in the calculations.

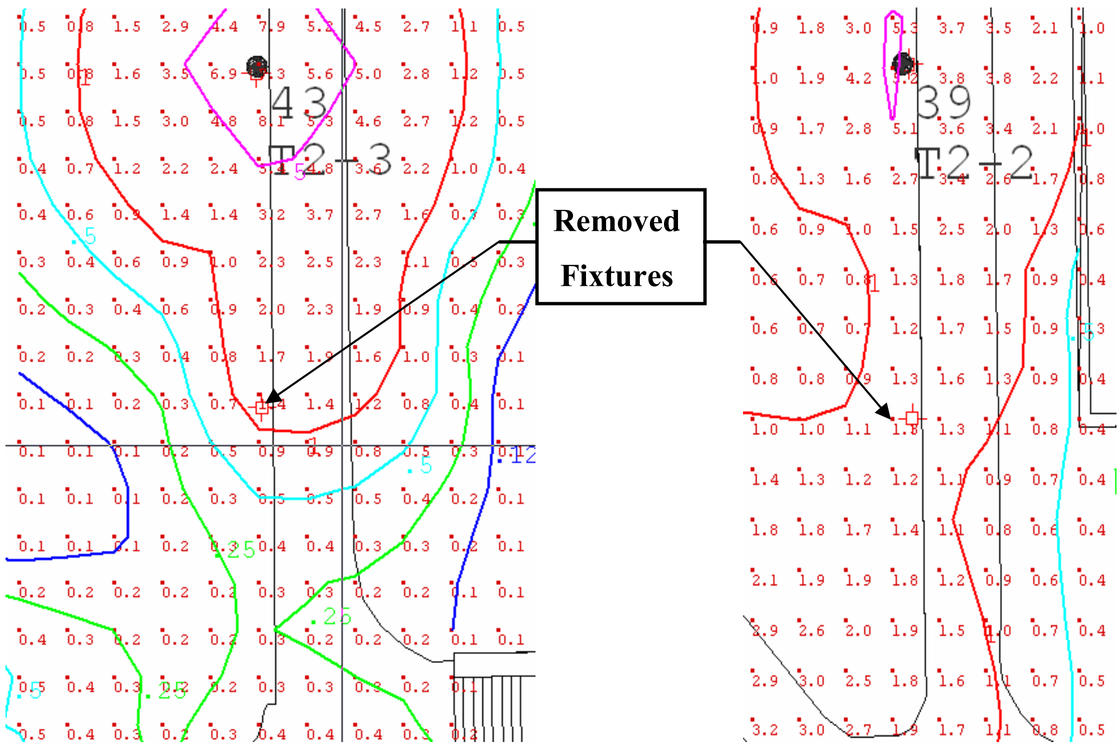


Figure 4.12 Fixtures to be removed from KSU Quad

(Program Inputs: Beta LED Area Round IES files and lamp lumens from Table 4.3)

(calculated and displayed using AGI32 v2.03)

Another advantage to this design is the average wattage for this area has dropped significantly. With the Cresthill Sphere the wattage was 208 W per fixture, with the Beta LED Area Round it is now approximately 75 W per fixture. With this drop in wattage, the overall footcandle levels reaching the ground have improved significantly as well.

Looking more closely at the wattage of these fixtures a new power density can be calculated using Equation No. 3. Using the same 2,625 lf of walkway the new power density will be 0.80 w/lf. A more detailed comparison using the COMcheck (v. 3.6) program can be found in Appendix C.2. This report shows that the new design surpasses the ASHRAE 90.1-2004 requirements by 39% in the Quad area. This would dramatically improve energy savings if this system would be installed throughout the entire campus as more light fixtures could be reduced in the same manner as the Quad. Energy consumption has been reduced to 2,102 W in the Quad area. Equaling an energy reduction of 66.3%, this exceeds the original 55.54% goal to meet the ASHRAE 90.1-2004 design standard and the 49% goal required to gain 10 Optimize Energy Performance LEED E.C. credits. That would be equivalent to an EPA Energy Star Rating of 99, the highest rating possible.

The efficacy of these fixtures has also been improved from the existing 61.5 lm/w. Using Equation No. 2 with the current light fixtures shown in Table 4.3, the efficacies were determined and summarized in Table 4.4 below.

Table 4.4 KSU Quad Beta LED Fixture Efficacy Values

Fixture	Effective Lumens	Watts	Efficacy (lm/w)
T5-6	17,515	153	114.5
T5-3	8,757	79	110.9
T5-2	5,838	55	106.1
T4-4	11,127	104	107.0
T3-5	15,025	128	117.4
T3-4	12,020	104	115.6
T3-2	6,010	55	109.3
T2-4	10,715	104	103.1
T2-3	8,036	79	101.7
T2-2	5,357	55	97.4

Using the given quantities of each fixture and their representative efficacy values, the average efficacy for the KSU Quad is 107.6 lm/w, a 75% increase in light production efficiency.

One final advantage is the reduction of light pollution. As previously described, this fixtures has full-cut off optics, therefore no lumens are being emitted 90 degrees above nadir. More advantages to the overall appearance of this design will be disused in later sections.

4.2.2 Aesthetics Analysis

The overall aesthetics of this lighting design will vary greatly from the existing design. The largest difference will be seen in the lamp color of each fixture. Rather than turning green, yellow, or blue like metal halide lamps, LED lamps will be almost identical in color. The only color swing will occur when the lamp is in its 50,000 plus hour of life and, as previously said, the recommendation to the KSU Facilities Planning Department will be to replace the lamps at this time. The lamp color itself, having a color temperature of 6000 K, will be a very cool white light and appear brighter than the current metal halide fixtures.

As figure 4.7 illustrates, the uniformity will appear very different as well. Many of the fixtures will have hot spots directly underneath them, however there will much fewer dark spots between the fixtures.

The fixture design itself is elegant and simplistic with a sleek finish. The spider mounting has no rough edges in its round shape and directs all light down to the walkway. The LED lamps will only be visible when the occupant is standing in close proximity to the fixture, unlike the current design where every lamp can be seen when the fixture is in view from all sides. Not only will this fixture make a difference in the appearance of the campus, it has the opportunity to impact the city of Manhattan as well. The amount of light pollution will be reduced, decreasing the sky glow effect contributions from the campus. Only the reflected light will be cast into the sky.

4.2.3 Economic Analysis

In this economic analysis, the demolition and installation costs will be approximated along with the maintenance and energy costs as previously performed for the existing design. This analysis will allow the university to determine if this design and lighting system is economically feasible.

Premier Lighting located in Lenexa, KS, a lighting manufacturer representative for Beta LED in this region, provided a contractor's cost quote for the Beta LED Area Round Fixtures. This quote has been summarized in Table 4.5 on the following page. This data is also used to calculate the installation costs later shown in this report. The contractor's cost includes the cost of the fixture and all its accessories required to create a working unit as well as the shipping costs to the site.

Table 4.5 Light Fixtures Contractor Cost Quote[1]

Fixture Type	No.	Cost Per Fixture	Total Cost
T5-6	2	$2,075	$4,150
T5-3	1	$1,535	$1,535
T5-2	4	$1,375	$5,500
T4-4	2	$1,720	$3,440
T3-5	1	$1,920	$1,920
T3-4	2	$1,720	$3,440
T3-2	10	$1,375	$13,750
T2-4	1	$1,720	$1,720
T2-3	1	$1,535	$1,535
T2-2	4	$1,375	$5,500
Total Cost:	**28**	**$1,517.50[2]**	**$42,490**

1. All cost information used in this table was provide by Dan Sanders, Premier Lighting and Controls, Lenexa, KS
2. Average cost of all fixtures.

To calculate the total cost to perform this renovation, the demolition and installation costs must now be determined. Using the information in Table 4.5 above, the total cost for the KSU Quad as entered into Table 4.6 on the next page, with an estimated electrical labor cost. Table 4.5 also includes the demolition costs of the Cresthill Sphere, including removal and disposal. All of the installation labor costs associated with this project uses the 2008 MEANS Estimating Guide. Each cost estimate includes all profit and overhead and can be considered a reasonable estimate for the total cost to KSU if the fixtures and work is performed in the month this report was published. The cost of each fixture for the entire KSU campus was calculated using the average cost per fixture for the KSU Quad. This method of estimating was used because the layout and number of each fixture type is unknown.

The number of fixtures to be installed on campus will also be assumed to decrease, proportionally to the Quad Area. Two fixtures removed from the Quad, is equal to approximately 7% of the fixtures. Applying this to the entire campus, with an originally estimated 387 fixtures, is reduced to 360 fixtures to be installed.

Table 4.6 Demolition and Installation Costs[1]

Item	KSU Quad			KSU Campus		
	No.	Cost/Unit[2]	Total	No.	Cost/Unit[2]	Total
Demolition						
Cresthill Sphere[3]	30	$44.32	$1,329.60	387	$44.32	$17,151.84
Sub-Total:			**$1,329.60**			**$17,151.84**
Installation						
Beta LED Area Round[4]	1	$42,490.00	$42,490.00	360	$1,517.50	$546,300.00
Electrical Labor[6]	28	$235.29	$6,588.12	360	$235.29	$84,704.40
Sub-Total:			**$49,078.12**			**$631,004.40**
Total Up-Front Cost:			**$50,407.72**			**$648,156.24**

1. All cost data will be taken from the 2008 RSMeans Building Construction Costs Data estimating guide.
2. A 101.4 multiplier and a 0.742 multiplier will be used for the cost of material and labor respectively based on the City Cost Index for Topeka, KS.
3. Cost taken from the 2006 RSMeans Electrical Cost Data estimating guide with an inflation factor of 1.068 according to the 2008 RSMeans Building Construction Cost Data estimating guide.
4. See Table 4.4 for quote by Premier Lighting. All material will be included or already on site.
5. Cost was determined by taking the average cost 28 of the fixtures in the Quad Area.
6. Based on interpolation between an 8 ft pole height and a 20' pole height, using 1 bracket arm. Add 10% for overhead and profit.

Maintenance costs to these new fixtures consist of replacing the LED light bars, or lamps, after their 50,000 hrs of life and repairing damaged fixtures. LED fixtures do not require ballasts therefore no costs need to be accounted for. After speaking with Beta LED representatives, it was determined that there is currently no replacement LED light bars available. This is due to the warranty of the fixture being 5 years or approximately 23,725 hrs of use, where Beta LED would replace the fixture completely, not including labor, if it fails within that time. Therefore there is no need for any manufacture, including Beta LED to produce a device or means to replace the LED's in this fixture. This can cause any cost data to become inaccurate due to the price variance after 5 years, and there is no device currently on the market similar to what is needed for this application. For the purposes of this research, the cost of the lamp will be considered to be $75 based on engineering judgment, while considering the replacement LED's will be significantly cheaper when they are purchased 5 years from the time of installation. Given the 50,000 hour life and same 365 days, 13 hours each night usage, it can be estimated that only three lamps will need replaced each year on average for the Quad area. The entire campus would require approximately 32 new lamps each year. However, it is likely that group re-lamping would occur after the 10.5 year suggested life span; this yearly quantity was calculated for comparison purposes. For this calculation, the same employees performing this maintenance at the same hourly rate as described in Chapter 2 will be used.

To estimate the number of fixtures that will be replaced is very difficult and could prove to be inaccurate. This number should be minimal considering the level of protection this fixture has from vandalism and weathering. For this research, using engineering judgment, it will be estimated that no fixtures will need replacing in the KSU Quad and five fixtures will need replacing each year throughout the campus on average. To total all the maintenance costs per year, see Table 4.7 on the next page.

Before the campus can be accurately estimated economically, the same principles must be applied as the design of the Quad area. Specifically the number of fixtures being reduced from 30 to 28. Assuming the same pattern can be used, for every original 15 fixtures, only 12 would be necessary, or roughly 93%. This would bring the original 387 fixtures currently on campus down to 360 fixtures. This data will be important in the maintenance and energy calculations in the following sections of this report.

Table 4.7 New Design Fixture Maintenance Costs per Year for the KSU Campus and Quad

Item	New Beta LED Area Round	
	KSU Quad	KSU Campus
Lamp Cost	$75.00	$75.00
Lamps Replaced Each Year	3	32
Labor Cost Per Lamp Replaced Per Hour	$17.81	$17.81
Labor Hours Per Lamp Replaced	1	1
Sub-Total Lamp Repair Cost Per Year	**$278.43**	**$2,962.92**
Ballast Cost	0	0
Ballasts Replaced Each Year	0	0
Labor Cost Per Ballast Replaced Per Hour	$17.81	$17.81
Labor Hours Per Ballast Replaced	0	0
Sub-Total Ballast Repair Cost Per Year	**$0.00**	**$0.00**
Fixture Cost	$1,517.50[1]	$1,517.50[1]
Fixtures Replaced Each Year	0	5
Labor Cost Per Fixture Replaced	$17.81	$17.81
Labor Hours Per Fixture Replaced	2	2
Sub-Total Fixture Cost Per Year	**$0.00**	**$7,765.61**
Total Cost Per Year	**$278.43**	**$10,735.53**

1. Average cost of all the fixtures from Table 4.4.

Now looking at the energy consumed by the new fixtures, the same 6.32 ¢/kWh energy rate will be used. Table 4.8 on the following page summarizes the energy cost data.

Table 4.8 New Design Energy Cost Data per Year for the KSU Quad

Item	New BetaLED Area Round	
	KSU Quad	KSU Campus
Energy Rate in ¢/kWh[2]	6.32	6.32
Input Wattage of Each Fixture	75[3]	75[3]
Hours of Operation for Each Fixture per Day[1]	13	13
Days of Operation for Each Fixture per Year[1]	365	365
Total kWh of Energy Consumed per Year per Fixture	356[3]	356[3]
Total Cost of Energy Consumed per Year per Fixture	**$22.49**	**$22.49**
Number of Fixtures[1]	28	360
Total kWh of Energy Consumed per year	9,974[4]	128,115[3]
Total Cost of Energy Consumed per Year	**$630.36**	**$8,096.87**

1. All cost and labor information was provided by Larry Milton, Physical Plant Supervisor, KSU Facilities Planning Department
2. Westar Energy 'High Load Factor' energy rate (Westar Energy, 2007). See Appendix D.
3. This value was calculated using the average of all the fixtures designed to be installed in the KSU Quad area due to their varying input wattages.
4. This is the actual wattage consumed by all the fixtures proposed to be installed in the KSU Quad per year.

In summary, the total cost to the university, for general maintenance and energy costs per year are calculated to be a total of $908.19 for the Quad area and $18,832.39 for the entire campus. This is significantly less than original $2,683.06 for the Quad area and $37,132.27 for the entire campus. All of the economic and design calculations will be further compared and discussed in the next chapter, including simple payback and return on investment.

CHAPTER 5 - Is the New Design Feasible and Practical?

This chapter will discuss the results of the new design and compare them to the existing conditions to determine some advantages and disadvantages to the new lighting system being proposed. The economic study will be concluded by looking at the savings, simple payback, and return on investment calculations. It will also make conclusions about the feasibility of this new system being installed on the KSU campus in the near future and provide some recommendations to KSU on how to proceed. The design goals introduced in Chapter 3 will also be reevaluated in this process.

5.1 Economic Feasibility

To determine whether or not this new lighting design is feasible, a simple payback of approximately 15 years or less would be desirable as stated in the design goals. Table 5.1 below summarizes the maintenance and energy cost findings for the existing system which uses the Cresthill Sphere, metal halide fixture and compares it to the proposed new system which uses the BetaLED Area Round, LED fixture to determine the savings. The table also multiplies these costs to determine the savings after 15 years in order to illustrate the cost and savings accumulated at the SP design goal.

Table 5.1 Total Cost Comparisons and Savings for the KSU Quad

Item		Existing Cresthill Sphere	BetaLED Area Round	Savings
1 - Year	Fixture Maintenance Cost	$811.78	$278.43	$533.35
	Fixture Energy Cost	$1,871.28	$629.76	$1,241.52
	Total	**$2,683.06**	**$908.19**	**$1,774.87**
15 - Year	Fixture Maintenance Cost	$12,176.70	$4,176.45	$8,000.25
	Fixture Energy Cost	$28,069.14	$9,446.35	$18,622.80
	Total	**$40,245.84**	**$13,622.80**	**$26,623.05**

Based upon these calculations, the Quad area would save KSU approximately $1,774.87 each year, and approximately $26,623.05 over a span of 15 years. These are significant savings, however considering the calculated initial costs shown in Table 4.5 of $50,407.72, they are relatively small. The SP is calculated to be 28.4 yrs, with a ROI of 3.52%, not meeting the design goals. Only 52% of the required savings to meet the design goal have been accumulated. Table 5.2 below shows the same data for the entire KSU campus.

Table 5.2 Total Cost Comparisons and Savings for the KSU Campus

Item		Existing Cresthill Sphere	BetaLED Area Round	Savings
1 - Year	Fixture Maintenance Cost	$12,992.81	$10,735.53	$2,257.28
	Fixture Energy Cost	$24,139.46	$8,096.67	$16,042.59
	Total	**$37,132.27**	**$18,832.89**	**$18,299.87**
15 - Year	Fixture Maintenance Cost	$194,892.08	$161,032.88	$33,859.20
	Fixture Energy Cost	$362,091.94	$121,453.02	$240,638.92
	Total	**$556,948.01**	**$282,485.90**	**$274,498.12**

These calculations show that the total savings for the KSU campus with this new lighting system would be approximately $18,299.87 each year. Again, this is a large amount of savings, but does not outweigh the high initial cost. As calculated in Table 4.5, the total initial cost would be approximately $648,156.24. The SP is calculated to be 35.4 yrs, with a ROI of 2.82%, also not meeting the design goals. In this case, only 42% of the required savings to meet the design goal have been accumulated

The conclusions from these calculations show that economically, this renovation is not feasible without capital funding, or a decrease in the initial cost of the fixtures. Later sections in this report will discuss options to decrease the initial costs.

5.2 Does it meet the design goals?

Now that all the data has been analyzed from the new design, it can be compiled and compared to the original design goals set in Chapter 3 of this report. Table 5.3 on the next page shows which of the design goals were met, or passed, and which ones were not met, or failed.

Table 5.3 Design Goal Summary

Goal	Minimum Design	New Design	Pass/Fail
1.) Safety and Security			
a. Illumination (ground level)	0.6 fc	1.62 fc	X
b. Uniformity – Average-to-Min			
i. Horizontal (ground level)	4:1	8:1	X
ii. Vertical (5ft above ground)	4:1	16:1	X
2.) Meet Current Design Standards			
a. ASHRAE 90.1-2004			
i. Power Density			
• >10ft wide	0.2 w/sf	0.088 w/sf	X
• ≤10ft wide	1.0 w/lf	0.70 w/lf	X
ii. Other			
b. IESNA Recommendations			
i. Illumination	0.6 fc	1.62 fc	X
ii. Uniformity – Average-to-Min			
• Horizontal (ground level)	4:1	8:1	X
• Vertical (5ft above ground)	4:1	16:1	X
c. CRI	50	75	X
3.) Fixture Characteristics			
a. Input Wattage	115 W	75 W	X
b. Efficacy	111.3 lm/w	107.6 lm/w	X
c. Cutoff Optics	Full Cutoff	Full Cutoff	X
d. Photometric Distribution Type	Type II or Type V	All Types	X
e. Lamp Life	11,500 hrs	50,000 hrs	X
f. CRI	50	75	X
4.) Green (LEED)			
a. LEED E.C. V2.0 Credits			
i. Light Pollution Reduction	Full Cutoff	Full Cutoff	X
ii. Minimum Energy Performance	10% Reduction	66.3%	X
iii. Optimize Energy Performance	49% Reduction	66.3%	X
b. Sustainability			
i. Lamp Life	11,500 hrs	50,000 hrs	X
5.) Economic			
a. Simple Payback	15 yrs	28.4	X
b. Return on Investment	6.67%	3.52%	X

Only the economic and uniformity design goals were not met with the new lighting design. The new design is efficient, provides better illumination, more sustainable, meets all current design codes and standards, and provides adequate safety and security illumination. It has greatly surpassed the existing design in all of these areas.

After completing the new lighting design and looking at the design goals, a few conclusions can be drawn. First, the new design will provide more illumination on the walkway and in the surrounding area. The average illumination level will increase from 0.54 fc to 1.62 fc over the Quad area, a 300% increase. However, even with more illumination, the uniformity will slightly decrease to an 8 to 1 average to minimum ratio, from the original 5.4 to 1.

Second, the new lighting design utilizes more sustainable, environmentally friendly products. Using LED lamps has a significant impact on energy consumption compared to the existing Metal Halide lamps. The new lighting system will decrease maintenance costs and energy consumption by 66%. These lamps will also reduce the light pollution created by the KSU campus by using full cutoff optics. The campus lighting system will then become ASHRAE 90.1 compliant, open opportunities to be LEED Certified, and meet IESNA recommendations. KSU will become one of the first universities in the nation to use LED technology. It may become an advertising tool for the university as well.

Lastly, the aesthesis of the KSU campus will be improved. The LED lamps will appear to produce a cleaner, clearer white light. Unlike the metal halide fixtures, the LED will stay very consistent in the lamp temperature and color. The students will feel safer with the higher quality of light and illumination levels. Closed Circuit Television (CCTV) cameras could be placed due to the higher illumination levels to also improve the campus security.

5.3 Future Options for KSU

Despite the economic difficulties with installing this new lighting system, KSU should strongly consider completing this renovation due to its high efficiency and sustainability as well as its ability to greatly improve the lighting quality on campus. As described previously in Chapter 2, there are many issues that need immediate attention regarding the existing system. Only the landscaping issues would not be improved with this new system or any other system in the future. Another point to consider is that any new lighting system installed on campus will have a long life, more than 30 years. This means that KSU would see a payback throughout the life of the system. The payback is likely to decrease over time due to the increase in energy and maintenance costs as well.

A second option that should be considered is to use the exiting poles rather than replacing them with new poles. The Beta LED Area Round fixture is capable of being mounted to any 5 in or 4 in round pole, such as the poles currently on the KSU campus. The installation would require a slip on flange and gasket for each fixture. Since only the luminaire itself is required, the price of each fixture is lowered substantially. Table 5.4 below shows the costs of each fixture without the pole according to a quote provided by Dan Sanders of Premier Lighting.

Table 5.4 Light Fixtures Contractor Cost Quote With No Poles[1]

Fixture Type	No.	Cost Per Fixture	Total Cost
T5-6	2	$1,530	$3,060
T5-3	1	$1,050	$1,050
T5-2	4	$875	$3,500
T4-4	2	$1,200	$2,400
T3-5	1	$1,385	$1,385
T3-4	2	$1,200	$2,400
T3-2	10	$875	$8,750
T2-4	1	$1,200	$1,200
T2-3	1	$1,050	$1,050
T2-2	4	$875	$3,500
Total Cost:	**28**	**$1,138.13[2]**	**$28,295**

1. All cost information used in this table was provide by Dan Sanders, Premier Lighting and Controls, Lenexa, KS
2. Average cost of all fixtures.

The total contractors cost of $28,295 saves $14,195 in the Quad area, and $182,507 for the whole campus. It reduces the average fixture cost by $379.38. As the exiting poles will also not be demolished and the installation is much simpler, the initial costs will also decrease significantly. As the labor costs for a project such as this are difficult to determine, it can be assumed that the labor costs will decrease by 50%. Table 5.5 below summarizes this data.

Table 5.5 Demolition and Installation Costs With No Poles[1]

Item	KSU Quad			KSU Campus		
	No.	Cost/Unit[2]	Total	No.	Cost/Unit[2]	Total
Demolition						
Cresthill Sphere[3]	30	$22.16	$664.80	387	$22.16	$8,575.92
Sub-Total:			**$664.80**			**$8,575.92**
Installation						
Beta LED Area Round[4]	1	$28,295.00	$28,295.00	360	$1,010.54	$363,792.86
Electrical Labor[6]	28	$117.65	$3,294.06	360	$117.65	$42,252.20
Sub-Total:			**$31,589.06**			**$406,145.06**
Total Up-Front Cost:			**$32,253.86**			**$414,720.98**

1. All cost data will be taken from the 2008 RSMeans Building Construction Costs Data estimating guide. A 0.50 multiplier for demolition and installation labor costs has been applied to account for the reuse of the existing poles.
2. A 101.4 multiplier and a 0.742 multiplier will be used for the cost of material and labor respectively based on the City Cost Index for Topeka, KS.
3. Cost taken from the 2006 RSMeans Electrical Cost Data estimating guide with an inflation factor of 1.068 according to the 2008 RSMeans Building Construction Cost Data estimating guide.
4. See Table 4.4 for quote by Premier Lighting. All material will be included or already on site.
5. Cost was determined by taking the average cost 28 of the fixtures in the Quad Area.
6. Based on interpolation between an 8 ft pole height and a 20' pole height, using 1 bracket arm. Add 10% for overhead and profit.

Having accumulated these projected costs, the SP and ROI can be recalculated for this situation. Using the same savings data calculated in Table 5.2, a SP of 18.2 yrs and a ROI of 5.5% is determined. This is much closer to the original design goal and could prove to be economically feasible if energy costs were to rise and/or the fixture prices to fall as LED technology is further developed and manufactured. Only one problem exists with reusing the existing poles, and that is the 12 ft mounting height, 3 ft lower than the design. The only implication would be a decrease in the calculated uniformity with more hot spots underneath each fixture. However, KSU should still consider this as a valid alternative option.

Another option can be to performing an economic study revolving around the tax, grant, and low interest loan incentives that come with renovating to a more sustainable, environmentally friendly design. There is currently an online database to help owners find such incentives called the Database of State Incentives for Renewables and Efficiency (DSIRE). A complete description of the available incentives, listed on the DSIRE web page that may apply to a lighting renovation project such as the one proposed in this report has been compiled and shown in Appendix F.

A fourth option would be to find a light fixture equivalent to the Beta LED Area Round that can be manufactured at a lower cost. The outdoor LED fixture market is currently very small; however it is projected to increase rapidly in the next few years, most likely making the fixtures more cost competitive. Other known manufactures that produce fixtures with similar capabilities include LSI Industries and General Electric (GE).

A final recommendation would include purchasing three or four trial poles and installing them on a less used walkway on campus using any of the previous options described above. This would allow KSU to see the capabilities of the fixture and determine how much of an improvement it would make when installed on the campus.

CHAPTER 6 - Conclusion

The KSU walkway network is extensive and must be adequately lit to provide the proper safety and security to the students, faculty, and visitors during the night time hours. The current lighting system primarily uses a 22 in, metal halide, white acrylic globe light fixture to illuminate the walkways. The fixture has unrestricted light distribution, 65 CRI lamp with a 4000K color temperature, and is mounted on a 12ft aluminum pole.

The Quad area on the KSU was specifically studied due to its long unobstructed walkways and high traffic. Using the AGI32 lighting calculation program, the photometrics were calculated and compared to actual data taken on the site around two fixtures (W-1 and W-2). With this data and visuals, it was determined that the current lighting scheme was inadequate for the KSU campus. Considering the 208 W input for each fixture, the power density is 80% above the ASHRAE 90.1-2004 standard and very inefficient. Other physical issues create more problems for the KSU Facilities Planning Department in maintaining these fixtures. This is due to various maintenance issues such as frequent lamp and ballast changes, the fixture's fragility, the significant weathering that has developed, lamp color discoloration, and debris and insect buildup in the fixture. These issues have caused poor illumination and uniformity in many areas, with light levels falling well below the IES recommendations. Maintenance costs in the Quad area are equal to approximately $811.78 each year, approximately $12,993 for the entire campus. The energy costs each year are higher at approximately $1,871 per year in the Quad and approximately $24,139 for the entire campus. There is a huge potential to save money in each of these areas by renovating the campus to use a more efficient and reliable fixtures.

Using new design criteria, goals can be established to bring the campus up-to-date with the current codes and standard practices regarding site lighting design. The first and primary goal of any lighting design must be safety and security of the occupants. For KSU, this means bringing the illumination on the walkways up to 0.6fc and the uniformity up to 4 to 1 according to IES recommendations. The next goal should be to meet the ASHRAE 90.1-2004 standards by lowering the power density by using a more efficient light source and fixture. A new fixture should have a longer life, consume less energy, and provide better light distribution using optic reflectors. A third goal would be achieve LEED credits and apply for Energy Star acknowledgement in order for KSU to become a leader in environmental design among U.S. universities. The final goal would be to create a system that is economically feasible for the university, meaning have a payback of approximately 15 years or less.

New technology has been developed for outdoor light fixtures using LED technology. LEDs are currently the most efficient light source on the market and would fit well with the design goals that were established. Beta LED is one of the current leading manufacturers of outdoor LED light fixtures. The new lighting design will use the Beta LED The Edge Round fixture. This fixture can have input wattages that range from 55 W to 153 W. When designing areas using LEDs, scotopic and photopic light must be considered. New research has suggested that scotopic light plays more of a role in the light perceived by the human eye than originally thought. Current light calculation programs and light meters only ready photopic light output. Therefore, to determine the actual illumination on the ground, the scotopic light contributions must be added.

After establishing a new lighting layout it was determined that the LED light fixture will meet a majority of the design goals. The campus can expect to see higher illumination levels, less maintenance costs, and less energy costs. The design surpasses the ASHRAE 90.1-2004 standard and could receive the highest Energy Star rating. The only disadvantage is a slightly poorer uniformity. This is due to the original pole locations being reused and the 15ft pole height limitations.

When the economic analysis is performed, it is determined that this design will save a combined $1,774.87 in maintenance and energy costs each year. Over a span of 15 years, it could save the university $26,623.05 per year in the Quad area. However, it has an initial cost including demolition and installation of approximately $50,407.72 which yields a 28.4 year payback period. The entire campus also has the same results, saving $18,299.87 each year in energy and maintenance costs, while having a $648,156.24 up-front cost. This yields a 35.4 year payback period. Both of these calculations are significantly over the original design goal of 15 years.

Knowing that the economic analysis proves the new design to be inadequate, the university may still be able to provide reason for replacing the current system. One option would be to reuse the existing poles, lowering the cost of each new fixture. This could result in a payback as low as 18.5 years. Another option would be to consider the impacts this project could have on the aesthetics, safety, and marketability of the campus. The campus would become an even stronger leader, being one of the most efficient campuses in the nation. LED light also provides a significantly clearer, more aesthetically pleasing light compared to metal halide. A third option could be to find an equivalent light fixture to the Beta LED The Edge Round that is less expensive. There also financial programs, or incentives, from the government that may help the university by providing grants, low interest loans, and other tax incentives to help cover the initial costs of the project, further lowering the payback period.

With all the information given in this report, the need for an updated lighting system for the KSU campus in the near future is apparent. University officials should closely monitor the situation as the current fixtures continue to deteriorate and LED technology becomes less expensive as the industry continues to grow. The opportunity for KSU to become a front runner in this technology, and high efficient campus lighting will continue to close each year, however the economic impacts must be carefully considered before it is pursued.

References

IESNA Lighting Handbook Reference and Application. Ed. Mark S. Ph D. Rae. 9th Edition ed.Illuminating Engineering Society of North America, 2000.

Acuity Brands. Visual Professional. Vol. 2.06.0142., 2008. <http://www.visual-3d.com>.

"Advance." Koninklijke Philips Electronics. 2008. <http://www.advancetransformer.com/>.

"American Electric Lighting." Acuity Brands Lighting, Inc. 2009. <http://www.americanelectriclighting.com/>.

ANSI/ASHRAE/IESNA Standard 90.1-2004 Energy Standard for Buildings Except Low-Rise Residential Buildings. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 2004.

Auto Desk. AutoCAD 2009. Vol. C.56.0., 2009.

Berman, Sam. The Coming Revolution in Lighting Practice., 2000.

"Beta LED: Delivered Lumens Per Watt." 2008. <http://www.betaled.com>.

"Beta LED: Uncompromising Brilliance." Beta LED. 2009. <http://www.betaled.com/>.

"Beta LED: Uncompromising Brilliance." Beta LED. 2008. <http://www.betaled.com/>.

Bosela, Theodore R. "Lighting Fundimentals." Electrical Systems Design.Prentice Hall, 2003. 295-341.

"Campus Maps." 2008. October 27, 2008 <http://www.ksu.edu/maps/index.html>.

Campus Master Plan. Weber Hall, Kansas State University: Facilities Planning Department, 2008.

City of Manhattan, Kansas. Code of Ordinances. No. 19. Update 2 ed. City of Manhattan, Kansas, 2008.

City of Plymouth, Indiana. "City of Plymouth Zoning Ordinance." 1986. <http://www.plymouthin.com>.

D&R International, Ltd. Building Energy Data Book. United States Department of Energy office of Energy Efficiency and Renewable Energy, 2008.

"Drill Spot: Online Hardware Store." Drill Spot. 2008. <http://www.drillspot.com/>.

"Dynamic Lighting Solutions." Netsential Website Developers. 2008. <http://dynamiclighting.com/index.cfm/MenuItemID/66/MenuGroup/Home.htm>.

"Dynamic Lighting Solutions." Netsential Website Developers. 2008. <http://dynamiclighting.com/index.cfm/MenuItemID/66/MenuGroup/Home.htm>.

"The Edge Round Luminarie." Beta LED. 2009. <http://www.betaled.com/specsheets-areamd.aspx>.

Energy Information Administration. "Kansas: State Energy Profiles." 2009. <http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=KS>.

"Enrollment Statistics." Kansas State University. 2008. <http://www.k-state.edu/registrar/a_r/>.

"LED Lighting Systems in Sustainable Building Design." (2008).

LEED for Existing Buildings. U.S. Green Building Cousel, 2005.

Light Guides. "Light Guide: Light Loss Factors." Lightseach.com. 2008. <http://www.lightsearch.com/resources/lightguides/lightloss.html>.

Lighting Analysts - Illumination Engineering Software. AGI32. Vol. 2.03., 2008.

"Location and History." 1999. <http://www.k-state.edu/welcome/background.html>.

"LSI Industries." LSI Industries Inc. 2009. <http://www.lsi-industries.com/>.

Lubinski, Richard G. "Demand-Side Management: Now More than Ever." .

"Lumination." Lumination, LLC. 2009. <http://www.lumination.com/>.

McVey, Karen. Benefits Eligible Classified Ee Making $12.04/hr - Total Cost the University. Ed. Daniel Matlack. Kansas State University: Havenstein, Patsy, 2009.

Milton, Larry. . Ed. Daniel Matlack. Vol. Interview. KSU Facilities Planning Department:, 2008.

National Lighting Bureau. "Lighting: Light Output Declines with Time." <http://www.reliant.com>.

NC State University. "DSIRE: Database of State Incentives for Renewables & Efficiency." 2009. <http://www.dsireusa.org/>.

"Philips Lighting." Koninklijke Philips Electronics. 2008. <http://www.lighting.philips.com/gl_en/index.php?main=global&parent=global&id=global&lang=en>.

PSEG. "Light Distribution Patterns." 2008. <http://www.pseg.com/customer/business/small/outdoorlighting/terms.jsp>.

Rahman, H. A. Economic Study on the Effectiveness of Photovoltaic Street Lighting in Universiti Teknologi Malaysia., 2008.

Recommended Lighting for Walkways and Class 1 Bikeways. IESNA DG-5-94 ed. United States: Illuminating Engineering Society of North America, 1994.

Sanders, Dan. Premier Lighting., 2009.

U.S. Department of Energy. COMcheck., 2009.

"Visually Effective Lighting." 2009. <http://www.globalinductionlighting.com/visuallyeffectivelighting.php?osCsid=b105db32c850131310b4aec794b35f42>.

Westar Energy. "Definition of Items Used to Calculate Your Monthly Bill." 2007. <www.westarenergy.com>.

"What is Scotopic and Photopic Vision." 2008. <www.betaled.com/whatisscotopic.aspx>.

Bibliography

IESNA Lighting Handbook Reference and Application. Ed. Mark S. Ph D. Rae. 9th Edition ed.Illuminating Engineering Society of North America, 2000.

Acuity Brands. Visual Professional. Vol. 2.06.0142., 2008. <http://www.visual-3d.com>.

"American Electric Lighting." Acuity Brands Lighting, Inc. 2009. <http://www.americanelectriclighting.com/>.

Berman, Sam. The Coming Revolution in Lighting Practice., 2000.

"Beta LED: Delivered Lumens Per Watt." 2008. <http://www.betaled.com>.

"Beta LED: Uncompromising Brilliance." Beta LED. 2009. <http://www.betaled.com/>.

"Beta LED: Uncompromising Brilliance." Beta LED. 2008. <http://www.betaled.com/>.

Bosela, Theodore R. "Lighting Fundimentals." Electrical Systems Design.Prentice Hall, 2003. 295-341.

"Campus Maps." 2008. October 27, 2008 <http://www.ksu.edu/maps/index.html>.

Campus Master Plan. Weber Hall, Kansas State University: Facilities Planning Department, 2008.

City of Manhattan, Kansas. Code of Ordinances. No. 19. Update 2 ed. City of Manhattan, Kansas, 2008.

City of Plymouth, Indiana. "City of Plymouth Zoning Ordinance." 1986. <http://www.plymouthin.com>.

D&R International, Ltd. Building Energy Data Book. United States Department of Energy office of Energy Efficiency and Renewable Energy, 2008.

"Drill Spot: Online Hardware Store." Drill Spot. 2008. <http://www.drillspot.com/>.

"Dynamic Lighting Solutions." Netsential Website Developers. 2008. <http://dynamiclighting.com/index.cfm/MenuItemID/66/MenuGroup/Home.htm>.

"The Edge Round Luminarie." Beta LED. 2009. <http://www.betaled.com/specsheets-areamd.aspx>.

Energy Information Administration. "Kansas: State Energy Profiles." 2009. <http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=KS>.

LEED for Existing Buildings. U.S. Green Building Cousel, 2005.

Lighting Analysts - Illumination Engineering Software. AGI32. Vol. 2.03., 2008.

"Location and History." 1999. <http://www.k-state.edu/welcome/background.html>.

"LSI Industries." LSI Industries Inc. 2009. <http://www.lsi-industries.com/>.

"Lumination." Lumination, LLC. 2009. <http://www.lumination.com/>.

McVey, Karen. Benefits Eligible Classified Ee Making $12.04/hr - Total Cost the University. Ed. Daniel Matlack. Kansas State University: Havenstein, Patsy, 2009.

Milton, Larry. . Ed. Daniel Matlack. Vol. Interview. KSU Facilities Planning Department:, 2008.

National Lighting Bureau. "Lighting: Light Output Declines with Time." <http://www.reliant.com>.

NC State University. "DSIRE: Database of State Incentives for Renewables & Efficiency." 2009. <http://www.dsireusa.org/>.

"Philips Lighting." Koninklijke Philips Electronics. 2008. <http://www.lighting.philips.com/gl_en/index.php?main=global&parent=global&id=global&lang=en>.

PSEG. "Light Distribution Patterns." 2008. <http://www.pseg.com/customer/business/small/outdoorlighting/terms.jsp>.

Sanders, Dan. Premier Lighting., 2009.

U.S. Department of Energy. COMcheck., 2009.

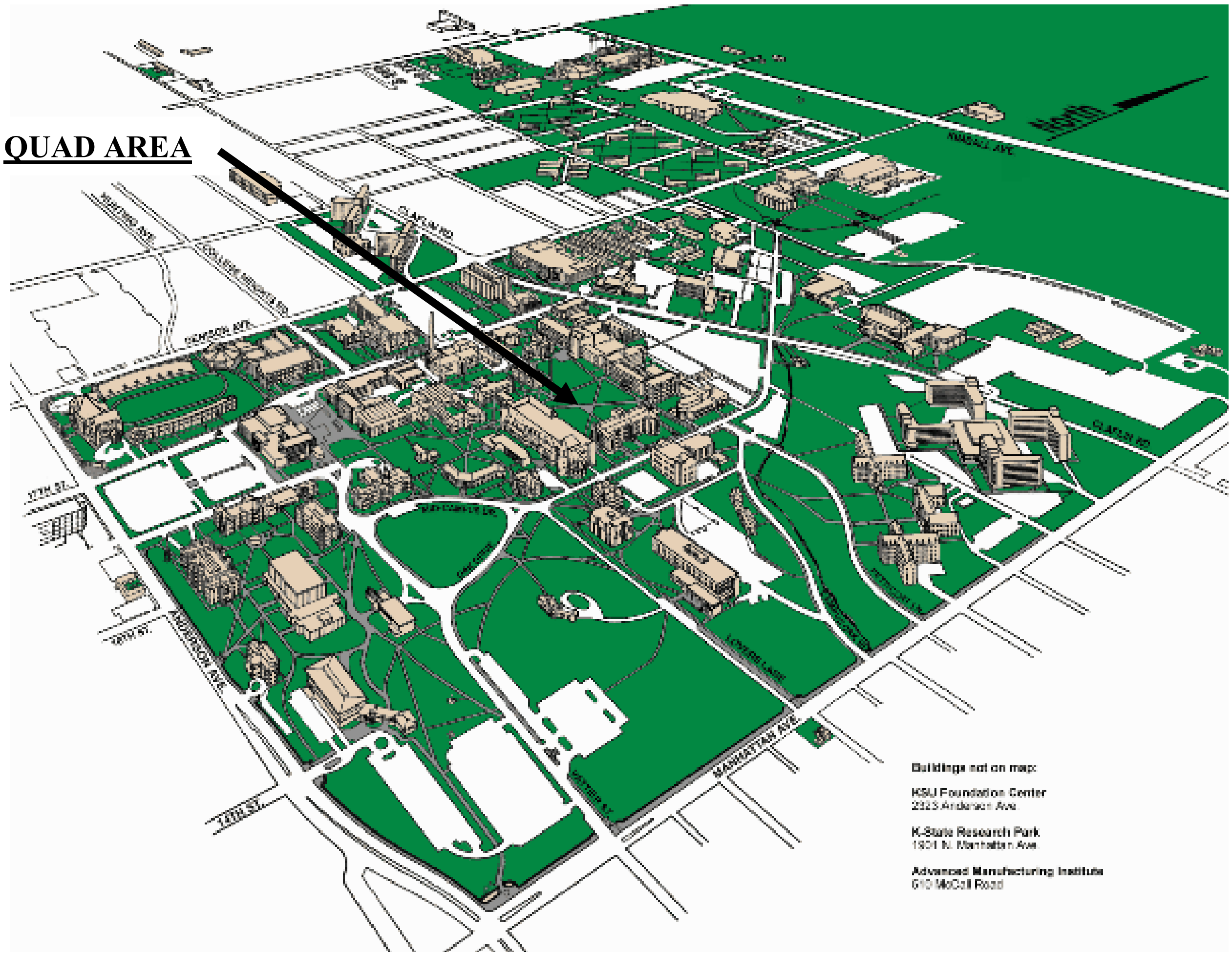
"Visually Effective Lighting." 2009. <http://www.globalinductionlighting.com/visuallyeffectivelighting.php?osCsid=b105db32c850131310b4aec794b35f42>.

Westar Energy. "Definition of Items Used to Calculate Your Monthly Bill." 2007. <www.westarenergy.com>.

"What is Scotopic and Photopic Vision." 2008. <www.betaled.com/whatisscotopic.aspx>.

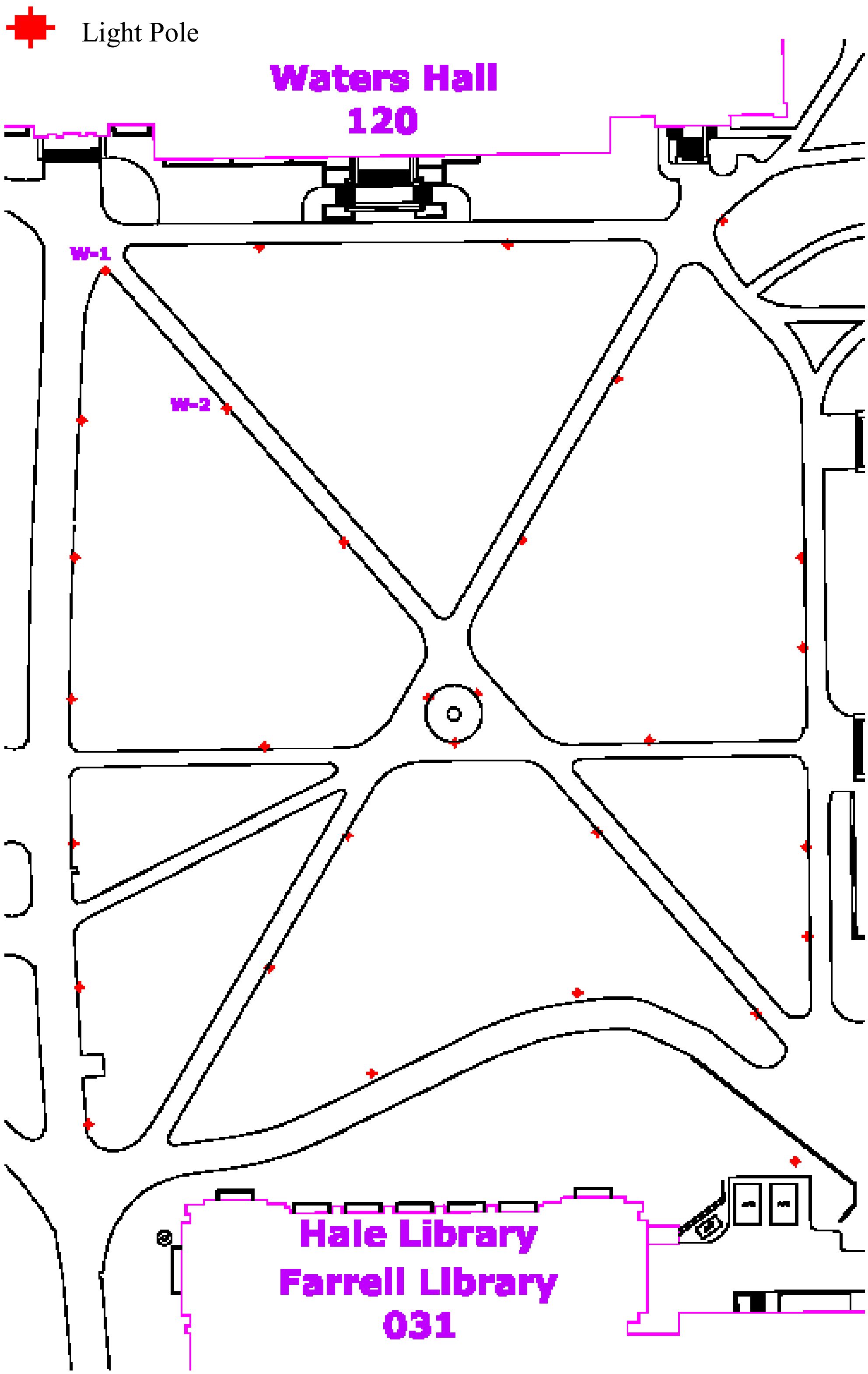
Appendix A - Kansas State University Maps

A.1 Kansas State University Campus Map – Manhattan, KS



Source: www.ksu.edu/maps/index.html

A.2 Kansas State University Quad Area Map



Source: KSU Facilities Planning Department

Appendix B - Light Fixture Specifications

B.1 American Electric Lighting Cresthill Sphere Exterior Light Fixture

B.2 Cresthill Sphere: Phillips Lighting 175W Pulse-Start Metal Halide Lamp

B.3 Cresthill Sphere: Advance 175W Metal Halide Pulse Start Ballast

B.4 Beta LED The Edge Round LED Area Light – Type V

B.5 Beta LED The Edge Round LED Area Light – Type IV

B.6 Beta LED The Edge Round LED Area Light – Type III

B.7 Beta LED The Edge Round LED Area Light – Type II

B.8 Beta LED Round Steel Pole – 5 in

B.1 American Electric Lighting Cresthill Sphere Exterior Light Fixture

Cresthill Sphere

Series LCR

50-150W HPS, 50-175W MH

PRODUCT OVERVIEW

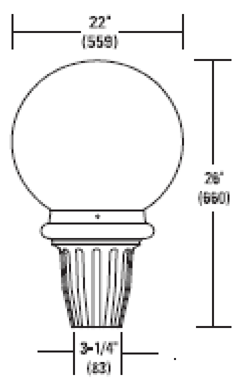
Applications:

Streetscapes
Walkways
Pathways
Parks

Features:

- Interchangeable base with a wide variety of globes
- Symmetric or Asymmetric distribution
- Globe 22" white acrylic or clear polycarbonate
- Base and optical ship separately
- HPS units standard with encapsulated starter that is located at the socket for quick access
- Quick disconnect plug for easy maintenance
- Easy access component door
- Photocontrol and terminal block available and located with easy access from component door
- E39 mogul base socket standard
- Mounts to 3" x 3" pole top tenons
- Powdercoat finish
- All electrical components warranted by American Electric Lighting's 6-year guarantee
- Complies with ANSI: C136.2, C136.10, C136.15, C136.31
- Suitable for -30°C MH / -40°C HPS

DIMENSIONS



Effective Projected Area (EPA)
The EPA for the Cresthill Sphere is 2.5 sq. ft.
Approx. Wt. = 22lbs.

Decorative Sheet # DL-LCR-B

B.2 Cresthill Sphere: Phillips Lighting 175W Pulse Start Metal Halide Lamp

Pulse Start MH Std 175W Mog ED28

Product family description
Range of Pulse Start quartz metal halide lamps for greater efficiency and lumen maintenance vs Switch Start metal halide.

Features/Benefits

- Up to 25% increase in maintained light output over standard metal halide.
- Increased efficacy (up to 120 lumens per watt) equals low total cost of ownership.
- Up to 50% faster warm-up and restrike time.
- Up to 50% increase in life when compared to switch start metal halide.

Applications

- Ideal for industrial and retail high/low bays, and parking lots.

Notes

- Color characteristics may vary somewhat from one lamp type to another. Time should be allowed for the lamp to stabilize in color when it is turned on for the first time or if for any reason its operating position is changed. This may require several hours' operation, with more than one start. Lamp color and output may change temporarily if the lamp is subjected to excess vibration or shock. Lamp color characteristics may change after long accumulate operating time. (372)
- Performance may not be satisfactory unless operated within specified operating positions. (374)
- Requires a ballast specified or approved for Philips Metal Halide lamp or one designed to the indicated ANSI Standard. A pulse ignitor is required. Sockets and wiring must withstand starting pulse. (391)
- Rated average life is the life obtained, on the average, from large representative groups of lamps in laboratory tests under controlled conditions at 10 or more operating hours per start. It is based on survival of at least 50% of the lamps and allows for individual lamps or groups of lamps to vary considerably from the average. For lamps with a rated average life of 24,000 hours, life is based on survival of 67% of the lamps. (351)
- Rated average life hours for universal lamps is based on vertical operating position. Operating these lamps in other position will reduce the life by approximately 25% of the rated average life hours.
- Approximate lumen values listed are for vertical operation of the lamp. (352)
- Means Lumens is the approximate lumen output at 40% of lamp rated average life. (353)
- Heat resisting glass bulb.

Product data	
Product Number	207514
Full product name	Pulse Start MH Std 175W Mog ED28

PHILIPS

Product data	
Ordering Code	MS175/HOR/PS
Pack type	1 Sleeve Open End
Pieces per Sku	1
Skus/Case	12
Pack UPC	046677207519
EAN2US	
Case Bar Code	50046677207514
Successor Product number	
System Description	Pulse Start
Base	Mogul [Single Contact Mogul Screw]
Base Information	Nic/Brass [Nickel/Brass Base]
Bulb	ED28
Bulb Material	Hard Glass
Bulb Finish	Clear
Operating Position	Horizontal +/-15D [Parallel +/-15D or Horizontal(HOR)]
Packing Type	1SL [1 Sleeve Open End]
Packing Configuration	12
RatedAvgLife(See Family Notes)	11500 hr
Ordering Code	MS175/HOR/PS
Pack UPC	046677207519
Case Bar Code	50046677207514
ANSI Code HID	M152/M137/E
Watts	175W
Lamp Voltage	132 V
Mercury (Hg) Content	30.6 mg
Color Code	640 [CCT of 4000K]
Color Rendering Index	60 Ra8
Color Designation	Cool White
Color Temperature	4200 K
Initial Lumens	12800 Lm
Design Mean Lumens	8960 Lm
Light Center Length L	5 in
Max Overall Length (MOL) - C	8.313 in
Diameter D	3.5 in
Product Number	207514

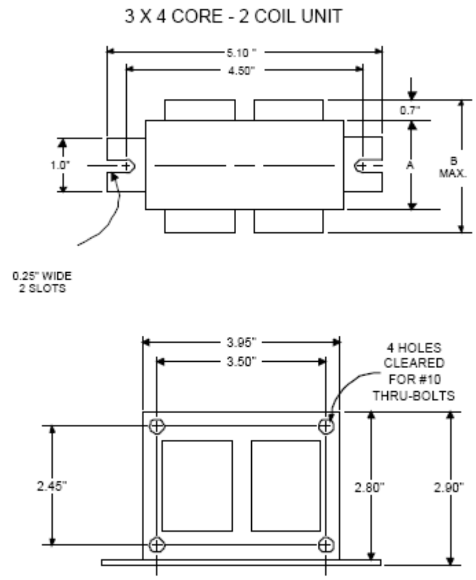
PHILIPS

B.3 Cresthill Sphere: Advance 175W Pulse Start Metal Halide Ballast

ADVANCE	Metal Halide Lamp Ballast	Catalog Number 71A5592 For 175W M137 (Pulse Start) 60 Hz SUPER-CWA Status: Active

DIMENSIONS AND DATA

3 X 4 CORE - 2 COIL UNIT



INPUT VOLTS		120	208	240	277	
CIRCUIT TYPE	SUPER-CWA					
POWER FACTOR (min)	90%					
REGULATION						
Line Volts	±10%					
Lamp Watts	±10%					
LINE CURRENT (Amps)						
Operating		1.80	1.05	0.90	0.80	
Open Circuit		1.80	1.05	0.90	0.80	
Starting		0.95	0.55	0.45	0.40	
UL TEMPERATURE RATINGS						
Insulation Class	H(180°C)					
Coil Temperature Code	1029	C	C	B	B	
MIN. AMBIENT STARTING TEMP.	-20°F or -30°C					
NOM. OPEN CIRCUIT VOLTAGE	270					
INPUT VOLTAGE AT LAMP DROPOUT		60	104	120	140	
INPUT WATTS	208					
RECOMMENDED FUSE (Amps)		5	3	3	2	
CORE and COIL						
Dimension (A)	2.08					
Dimension (B)	3.35					
Weight (lbs.)	7					
Lead Lengths	12"					
CAPACITOR REQUIREMENT						
Microfarads	11.5					
Volts (min.)	345					
Fault Current Withstand (amps)						
60 Hz TEST PROCEDURES (Refer to Advance Test Procedure for HID Ballasts - Form 1270)						
High Potential Test (Volts)						
1 minute	2000					
2 seconds	2500					
Open Circuit Voltage Test (Volts)	240-300					
Short-Circuit Current Test (Amps)						
Secondary Current	1.55-1.95					
Input Current		0.65	0.35	0.30	0.28	-
		0.95	0.55	0.50	0.40	

Capacitor: 7C115M34

Capacitance: 11.5
Dia/Oval Dim: 1.5
Height: 3.75
Temp Rating: 105°C

Ignitor: LI533-H4

Ballast to Lamp Distance
(BTL) = 2 feet
Temp Rating: 105°C

Wiring Diagram:

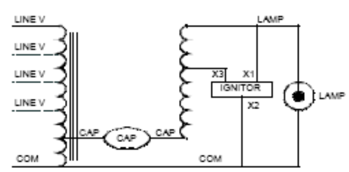


Fig. M

U.L. RECOGNIZED

Typical Ordering Information

(please call Advance for suffix availability)

Order Suffix	Description
500D.	Ballast With Ignitor and Dry Film Capacitor
510D.	Ballast w/Welded Bracket, Ignitor, & Dry Film Capacitor
600.	Ballast and Ignitor, No Capacitor
610.	Ballast with Welded Bracket and Ignitor, No Capacitor

Data is based upon tests performed by Advance Transformer in a controlled environment and representitive of relative performance. Actual performance can vary depending on operating conditions. Specifications are subject to change without notice.

ADVANCE

O'HARE INTERNATIONAL CENTER · 10275 WEST HIGGINS ROAD · ROSEMONT, IL 60018

Customer Support/Technical Service: Phone: 800-372-3331 · Fax: 630-307-3071

Corporate Offices: Phone: 800-322-2086

05/24/99

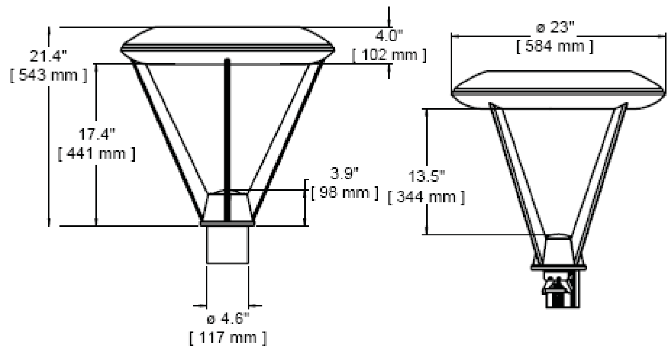
B.4 Beta LED The Edge Round LED Area Light – Type V

BLD-ARR-T5-R5 The Edge™ Round LED Area Light – Type V Rev. Date: 12/15/08

Beta Catalog Number: ***BLD - ARR - T5 - DA - - LED-B - - -***

Reset

Notes:



Product Family	*Housing Indicator*	*Optics*	*Mounting*	*Initial Delivered Lumens (00's)*	*LED Performance*	*Voltage*	*Color Options*	*Factory-Installed Options* If choosing more than one option, please type in manually on the lines provided above.
BLD	ARR	T5[1]	R5[2]	☐034 ☐051 ☐068 ☐085 ☐102	LED-B	☐UL (120–277V Universal) ☐UH (347–480V Universal)[3] ☐12 ☐27 ☐34	☐SV ☐BZ ☐BK ☐WH ☐PB	☐EM–Emergency[4] ☐F–Fuse ☐HL–Hi/Low (175/350/525, dual circuit input)[5-8] ☐P–Photocell[6] ☐35K–3500k Color Temperature[9] ☐43K–4300k Color Temperatur[9] ☐525–525mA Drive Current[10]

Footnotes

1-IESNA Type V distribution
2-Spider mount, center direct mount for 5" round pole
3-Consult factory
4-Emergency mode delivers 1 light bar 350mA lumen output, consult LED Emergency Spec Sheet for further details
5-Available for 2-6 light bar fixtures
6-Must specify voltage other than UL or UH
7-Refer to multi level spec sheet for more information
8-Sensor not included
9-Color temperature per fixture
10-Driver operates at 525mA instead of the standard 350mA providing a higher lumen output and a shorter life

Output Multipliers

Color Temperature	Lumen Multiplier
6000K (Standard)	1.00
4300K	0.80
3500K	0.75

Ambient Temperature (°C)	Lumen Multiplier
-20	1.11
10	1.04
25	1.00
40	0.96

Drive Current	Lumen Multiplier	Power Multiplier	L_{70} Life* (hours)
175mA	0.6	0.5	> 150,000
350mA (Standard)	1.0	1.0	> 150,000
525mA	1.3	1.5	70,000

* *Based on fixture operating at 15° C. Refer to LED Ambient spec sheet.*

LED Performance Generation B Specs*

Light Bars	Initial Delivered Lumens – Type V Optic	System Watts 120-277V	System Watts 347-480V
2	3,400 (034)	55	59
3	5,100 (051)	79	84
4	6,800 (068)	104	109
5	8,500 (085)	128	133
6	10,200 (102)	153	156

* *Based on 6000k color temperature fixture operating at 350mA and 25C Ambient.*

Beta LED • 1200 92nd Street • Sturtevant, WI 53177 • 800-236-6800 • www.BetaLED.com

beta LED

BLD-ARR-T5-R5 The Edge™ Round LED Area Light – Type V Rev. Date: 12/15/08

General Description
Slim, low profile design minimizes wind load requirements. Fixture housing is rugged cast aluminum with integral, weather-tight LED driver compartments, spun aluminum vented cover and high performance aluminum heatsinks. Post top mounting consists of precision machined, extruded aluminum arms (4) mounted to weather tight cast lower hub with center bolt direct mount system for 5" round poles. Direct mount system provides clean hardware-less outer appearance.

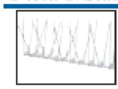
Electrical
Modular design accommodates varied lighting output from high brightness, white, 6000K (+/- 500k per full fixture), minimum 75 CRI, long life LED sources. 120-277V 50/60 Hz, Class 1 LED drivers are standard. 347-480V 50/60 Hz driver is optional. LED drivers have power factor >90% and THD <20% of full load. Integral weather-tight electrical box with terminal strip for easy power hook-up.

Finish
Exclusive Colorfast DeltaGuard® finish features an E-Coat epoxy primer with an ultra-durable silver powder topcoat, providing excellent resistance to corrosion, ultraviolet degradation and abrasion. Bronze, black, white and platinum bronze powder topcoats are also available. The finish is covered by our 10 year limited warranty.

Labels
UL listed in the U.S. and Canada for wet locations. RoHS compliant.

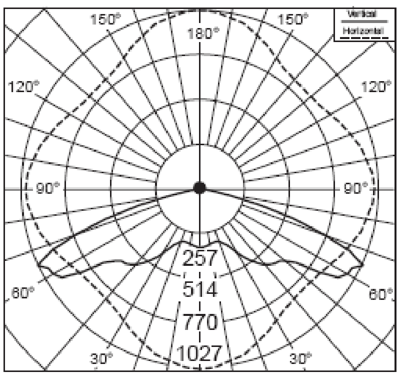
Patents
US Pat D577,847, Patents Pending; AU Des. 853122; EC000906482; NZ410610; International Patents Pending

Field-Installed Accessories

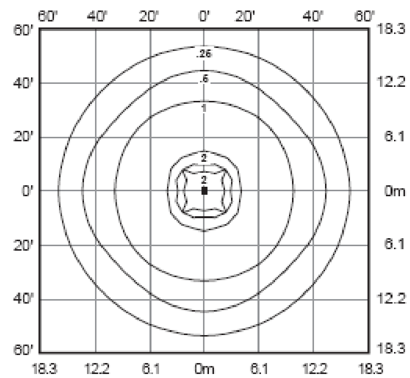


Bird Spikes
☐XA-BRDSPK

Output gains using Generation B LEDs can be achieved by multiplying footcandle levels by 1.06.



Independent Testing Laboratories certified test. Report No. ITL 59237. Candlepower distribution curve of 2 light bar luminaire with 3138 initial delivered lumens.



Isofootcandle plot of 6 light bar Type V LED luminaire at 20' A.F.G. Initial delivered lumens at 9414. Initial FC at grade.

LED Area Light EPA Calculations

	2 – 6 LIGHT BARS
Post Top	
Post top fixture	0.95

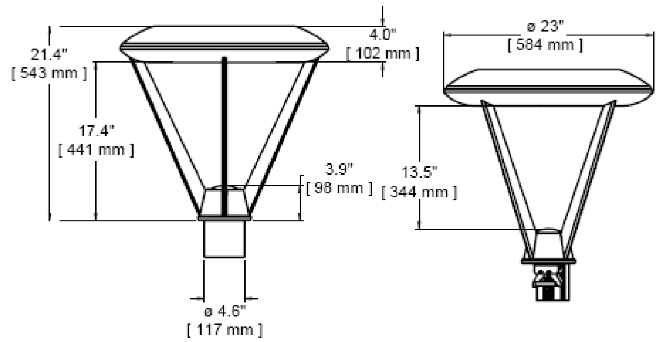
B.5 Beta LED The Edge Round LED Area Light – Type IV

BLD-ARR-T4-R5 The Edge™ Round LED Area Light – Type IV Rev. Date: 12/15/08

Beta Catalog Number: BLD - ARR - - R5 - - LED-B - - -

Reset

Notes:



Product Family	*Housing Indicator*	*Optics*	*Mounting*	*Initial Delivered Lumens (00's)*	*LED Performance*	*Voltage*	*Color Options*	*Factory-Installed Options*
								If choosing more than one option, please type in manually on the lines provided above.
BLD	ARR	☐ T4[1]	R5[3]	☐ 034	LED-B	☐ UL (120–277V Universal)	☐ SV	☐ EM–Emergency[5]
		☐ 4B[2]		☐ 051		☐ UH (347–480V Universal)[4]	☐ BZ	☐ F–Fuse
				☐ 068		☐ 12	☐ BK	☐ HL–Hi/Low (175/350/525, dual circuit input)[6-9]
				☐ 085		☐ 27	☐ WH	☐ P–Photocell[7]
				☐ 102		☐ 34	☐ PB	☐ 35K–3500k Color Temperature[10]
								☐ 43K–4300k Color Temperature[10]
								☐ 525–525mA Drive Current[11]

Footnotes

1-IESNA Type IV distribution
2-IESNA Type IV distribution with backlight shield
3-Spider mount, center direct mount for 5" round pole
4-Consult factory
5-Emergency mode delivers 1 light bar 350mA lumen output, consult LED Emergency Spec Sheet for further details
6-Available for 2-6 light bar fixtures
7-Must specify voltage other than UL or UH
8-Refer to multi level spec sheet for more information
9-Sensor not included
10-Color temperature per fixture
11-Driver operates at 525mA instead of the standard 350mA providing a higher lumen output and a shorter life

Output Multipliers

Color Temperature	Lumen Multiplier
6000K (Standard)	1.00
4300K	0.80
3500K	0.75

Ambient Temperature (°C)	Lumen Multiplier
-20	1.11
10	1.04
25	1.00
40	0.96

Drive Current	Lumen Multiplier	Power Multiplier	L_{70} Life* (hours)
175mA	0.6	0.5	> 150,000
350mA (Standard)	1.0	1.0	> 150,000
525mA	1.3	1.5	70,000

* *Based on fixture operating at 15° C. Refer to LED Ambient spec sheet.*

LED Performance Generation B Specs*

Light Bars	Initial Delivered Lumens – Type IV Optic	Initial Delivered Lumens – Type IV Optic w/ Backlight Shield	System Watts 120-277V	System Watts 347-480V
2	3,240 (034)	2,360 (034)	55	59
3	4,860 (051)	3,540 (051)	79	84
4	6,480 (068)	4,720 (068)	104	109
5	8,100 (085)	5,900 (085)	128	133
6	9,720 (102)	7,080 (102)	153	156

* *Based on 6000k color temperature fixture operating at 350mA and 25C Ambient.*

Beta LED • 1200 92nd Street • Sturtevant, WI 53177 • 800-236-6800 • www.BetaLED.com

BLD-ARR-T4-R5 The Edge™ Round LED Area Light – Type IV

Rev. Date: 12/15/08

General Description

Slim, low profile design minimizes wind load requirements. Fixture housing is rugged cast aluminum with integral, weather-tight LED driver compartments, spun aluminum vented cover and high performance aluminum heatsinks. Post top mounting consists of precision machined, extruded aluminum arms (4) mounted to weather tight cast lower hub with center bolt direct mount system for 5" round poles. Direct mount system provides clean hardware-less outer appearance.

Electrical

Modular design accommodates varied lighting output from high brightness, white, 6000K (+/- 500k per full fixture), minimum 75 CRI, long life LED sources. 120-277V 50/60 Hz, Class 1 LED drivers are standard. 347-480V 50/60 Hz driver is optional. LED drivers have power factor >90% and THD <20% of full load. Integral weather-tight electrical box with terminal strip for easy power hook-up.

Finish

Exclusive Colorfast DeltaGuard® finish features an E-Coat epoxy primer with an ultra-durable silver powder topcoat, providing excellent resistance to corrosion, ultraviolet degradation and abrasion. Bronze, black, white and platinum bronze powder topcoats are also available. The finish is covered by our 10 year limited warranty.

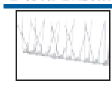
Labels

UL listed in the U.S. and Canada for wet locations. RoHS compliant.

Patents

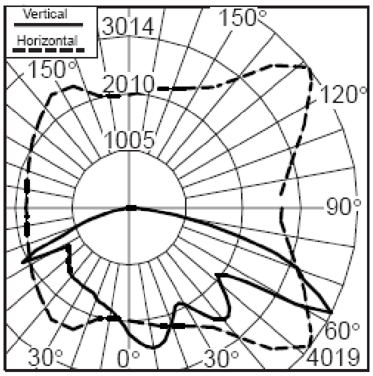
US Pat D577,847, Patents Pending; AU Des. 853122; EC000906482; NZ410610; International Patents Pending

Field-Installed Accessories

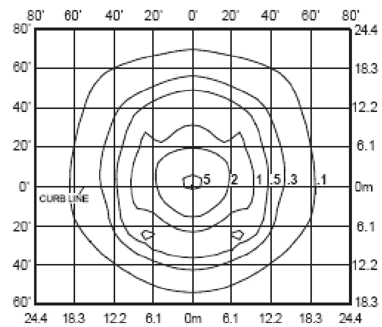


Bird Spikes

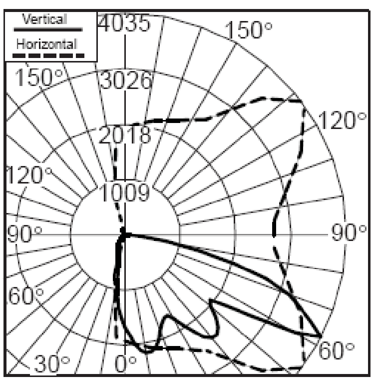
☐ XA-BRDSPK



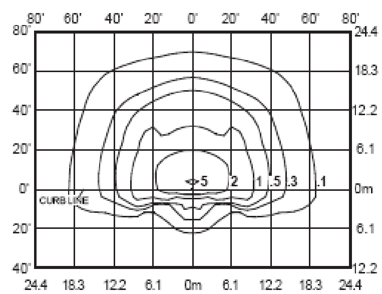
Independent Testing Laboratories certified test. Report No. ITL 60823. Candlepower distribution curve of 6 light bar luminaire with 9,720 initial delivered lumens operating at 350mA.



Isofootcandle plot of 6 light bar Type IV LED luminaire at 20' A.F.G. Luminaire with 9,720 initial delivered lumens operating at 350mA. Initial FC at grade.



Independent Testing Laboratories certified test. Report No. ITL 60824. Candlepower distribution curve of 6 light bar luminaire with 7,080 initial delivered lumens operating at 350mA.



Isofootcandle plot of 6 light bar Type IV LED luminaire with backlight shield at 20' A.F.G. Luminaire with 7,080 initial delivered lumens operating at 350mA. Initial FC at grade.

LED Area Light EPA Calculations

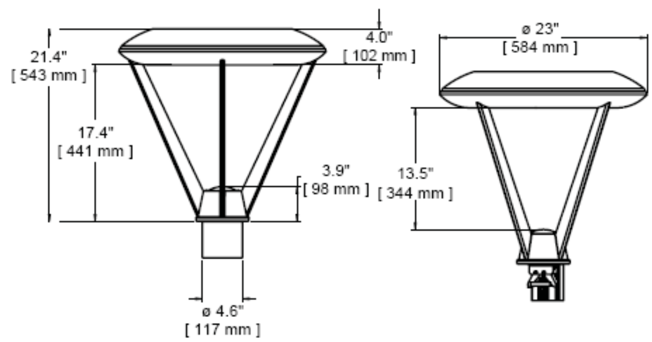
	2 – 6 LIGHT BARS
Post Top	
Post top fixture	0.95

B.6 Beta LED The Edge Round LED Area Light – Type III

BLD-ARR-T3-R5 The Edge™ Round LED Area Light – Type III Rev. Date: 12/15/08

Beta Catalog Number: BLD - ARR - - R5 - - LED-B - - -

Reset



Notes:

Product Family	Housing Indicator	Optics	Mounting	Initial Delivered Lumens (00's)	LED Performance	Voltage	Color Options	Factory-Installed Options
BLD	ARR	☐T3[1] ☐3B[2]	R5[3]	☐034 ☐051 ☐068 ☐085 ☐102	LED-B	☐UL (120–277V Universal) ☐UH (347–480V Universal)[4] ☐12 ☐27 ☐34	☐SV ☐BZ ☐BK ☐WH ☐PB	If choosing more than one option, please type in manually on the lines provided above. ☐EM–Emergency[5] ☐F–Fuse ☐HL–Hi/Low (175/350/525, dual circuit input)[6-9] ☐P–Photocell[7] ☐35K–3500k Color Temperature[10] ☐43K–4300k Color Temperature[10] ☐525–525mA Drive Current[11]

Footnotes

1-IESNA Type III distribution
2-IESNA Type III distribution with backlight shield
3-Spider mount, center direct mount for 5" round pole
4-Consult factory
5-Emergency mode delivers 1 light bar 350mA lumen output, consult LED Emergency Spec Sheet for further details
6-Available for 2-6 light bar fixtures
7-Must specify voltage other than UL or UH
8-Refer to multi level spec sheet for more information
9-Sensor not included
10-Color temperature per fixture
11-Driver operates at 525mA instead of the standard 350mA providing a higher lumen output and a shorter life

Output Multipliers

Color Temperature	Lumen Multiplier
6000K (Standard)	1.00
4300K	0.80
3500K	0.75

Ambient Temperature (°C)	Lumen Multiplier
-20	1.11
10	1.04
25	1.00
40	0.96

Drive Current	Lumen Multiplier	Power Multiplier	L_{70} Life* (hours)
175mA	0.6	0.5	> 150,000
350mA (Standard)	1.0	1.0	> 150,000
525mA	1.3	1.5	70,000

** Based on fixture operating at 15° C. Refer to LED Ambient spec sheet.*

LED Performance Generation B Specs*

Light Bars	Initial Delivered Lumens – Type III Optic	Initial Delivered Lumens – Type III Optic w/ Backlight Shield	System Watts 120-277V	System Watts 347-480V
2	3,500 (034)	2,320 (034)	55	59
3	5,250 (051)	3,480 (051)	79	84
4	7,000 (068)	4,640 (068)	104	109
5	8,750 (085)	5,800 (085)	128	133
6	10,500 (102)	6,960 (102)	153	156

** Based on 6000k color temperature fixture operating at 350mA and 25C Ambient.*

Beta LED • 1200 92nd Street • Sturtevant, WI 53177 • 800-236-6800 • www.BetaLED.com

BLD-ARR-T3-R5 The Edge™ Round LED Area Light – Type III **Rev. Date: 12/15/08**

General Description
Slim, low profile design minimizes wind load requirements. Fixture housing is rugged cast aluminum with integral, weather-tight LED driver compartments, spun aluminum vented cover and high performance aluminum heatsinks. Post top mounting consists of precision machined, extruded aluminum arms (4) mounted to weather tight cast lower hub with center bolt direct mount system for 5" round poles. Direct mount system provides clean hardware-less outer appearance.

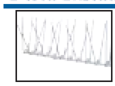
Electrical
Modular design accommodates varied lighting output from high brightness, white, 6000K (+/- 500k per full fixture), minimum 75 CRI, long life LED sources. 120-277V 50/60 Hz, Class 1 LED drivers are standard. 347-480V 50/60 Hz driver is optional. LED drivers have power factor >90% and THD <20% of full load. Integral weather-tight electrical box with terminal strip for easy power hook-up.

Finish
Exclusive Colorfast DeltaGuard® finish features an E-Coat epoxy primer with an ultra-durable silver powder topcoat, providing excellent resistance to corrosion, ultraviolet degradation and abrasion. Bronze, black, white and platinum bronze powder topcoats are also available. The finish is covered by our 10 year limited warranty.

Labels
UL listed in the U.S. and Canada for wet locations. RoHS compliant.

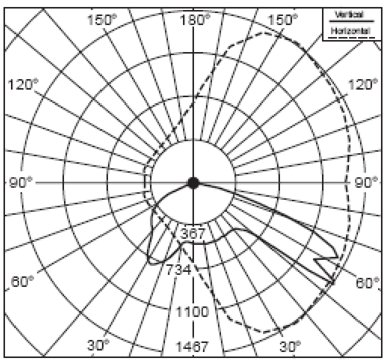
Patents
US Pat D577,847, Patents Pending; AU Des. 853122; EC000906482; NZ410610; International Patents Pending

Field-Installed Accessories

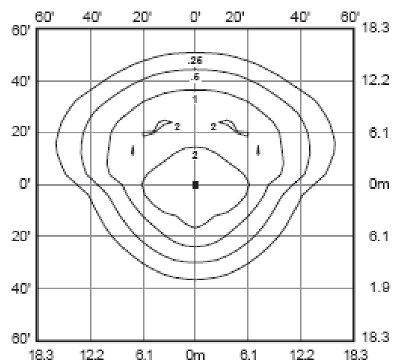


Bird Spikes
☐ XA-BRDSPK

Output gains using Generation B LEDs can be achieved by multiplying footcandle levels by 1.1.



Independent Testing Laboratories certified test. Report No. ITL 59234. Candlepower distribution curve of 2 light bar luminaire with 2863 initial delivered lumens.



Isofootcandle plot of 6 light bar Type III LED luminaire at 20' A.F.G. Initial delivered lumens at 8589. Initial FC at grade.

LED Area Light EPA Calculations

	2 – 6 LIGHT BARS
Post Top	
Post top fixture	0.95

Beta LED • 1200 92nd Street • Sturtevant, WI 53177 • 800-236-6800 • www.BetaLED.com

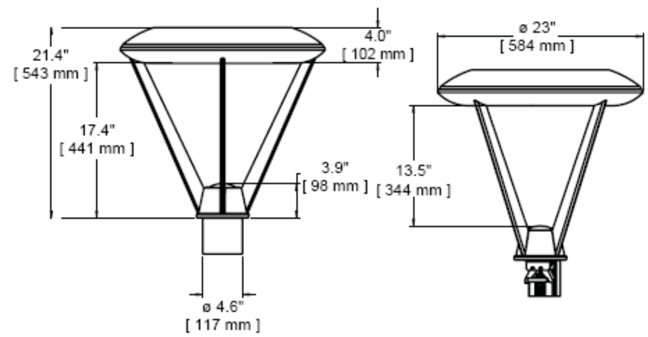
B.7 Beta LED The Edge Round LED Area Light – Type II

BLD-ARR-T2-R5 The Edge™ Round LED Area Light – Type II **Rev. Date: 12/15/08**

Beta Catalog Number: ***BLD - ARR - - R5 - - LED-B - - -***

Reset

Notes:



Product Family	*Housing Indicator*	*Optics*	*Mounting*	*Initial Delivered Lumens (00's)*	*LED Performance*	*Voltage*	*Color Options*	*Factory-Installed Options* If choosing more than one option, please type in manually on the lines provided above.
BLD	**ARR**	☐**T2**[1]	**R5**[3]	☐034	LED-B	☐UL (120–277V Universal)	☐SV	☐EM–Emergency[5]
		☐**2B**[2]		☐051		☐UH (347–480V Universal)[4]	☐BZ	☐F–Fuse
				☐068		☐12	☐BK	☐HL–Hi/Low (175/350/525, dual circuit input)[6-9]
				☐085		☐27	☐WH	☐P–Photocell[7]
				☐102		☐34	☐PB	☐35K–3500k Color Temperature[10]
								☐43K–4300k Color Temperature[10]
								☐525–525mA Drive Current[11]

Footnotes

1-IESNA Type II Short distribution
2-IESNA Type II Short distribution w/ backlight shield
3-Spider mount, center direct mount for 5" round pole
4-Consult factory
5-Emergency mode delivers 1 light bar 350mA lumen output, consult LED Emergency Spec Sheet for further details
6-Available for 2-6 light bar fixtures
7-Must specify voltage other than UL or UH
8-Refer to multi level spec sheet for more information
9-Sensor not included
10-Color temperature per fixture
11-Driver operates at 525mA instead of the standard 350mA providing a higher lumen output and a shorter life

Output Multipliers

Color Temperature	Lumen Multiplier
6000K (Standard)	1.00
4300K	0.80
3500K	0.75

Ambient Temperature (°C)	Lumen Multiplier
-20	1.11
10	1.04
25	1.00
40	0.96

Drive Current	Lumen Multiplier	Power Multiplier	L_{70} Life* (hours)
175mA	0.6	0.5	> 150,000
350mA (Standard)	1.0	1.0	> 150,000
525mA	1.3	1.5	70,000

** Based on fixture operating at 15° C. Refer to LED Ambient spec sheet.*

LED Performance Generation B Specs*

Light Bars	Initial Delivered Lumens – Type II Optic	Initial Delivered Lumens – Type II Optic w/ Back-light Shield	System Watts 120-277V	System Watts 347-480V
2	3,120 (034)	2,320 (034)	55	59
3	4,680 (051)	3,480 (051)	79	84
4	6,240 (068)	4,640 (068)	104	109
5	7,800 (085)	5,800 (085)	128	133
6	9,360 (102)	6,960 (102)	153	156

** Based on 6000k color temperature fixture operating at 350mA and 25C Ambient.*

Beta LED • 1200 92nd Street • Sturtevant, WI 53177 • 800-236-6800 • www.BetaLED.com

BLD-ARR-T2-R5 The Edge™ Round LED Area Light – Type II

Rev. Date: 12/15/08

General Description

Slim, low profile design minimizes wind load requirements. Fixture housing is rugged cast aluminum with integral, weather-tight LED driver compartments, spun aluminum vented cover and high performance aluminum heatsinks. Post top mounting consists of precision machined, extruded aluminum arms (4) mounted to weather tight cast lower hub with center bolt direct mount system for 5" round poles. Direct mount system provides clean hardware-less outer appearance.

Electrical

Modular design accommodates varied lighting output from high brightness, white, 6000K (+/- 500k per full fixture), minimum 75 CRI, long life LED sources. 120-277V 50/60 Hz, Class 1 LED drivers are standard. 347-480V 50/60 Hz driver is optional. LED drivers have power factor >90% and THD <20% of full load. Integral weather-tight electrical box with terminal strip for easy power hook-up.

Finish

Exclusive Colorfast DeltaGuard® finish features an E-Coat epoxy primer with an ultra-durable silver powder topcoat, providing excellent resistance to corrosion, ultraviolet degradation and abrasion. Bronze, black, white and platinum bronze powder topcoats are also available. The finish is covered by our 10 year limited warranty.

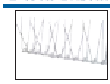
Labels

UL listed in the U.S. and Canada for wet locations. RoHS compliant.

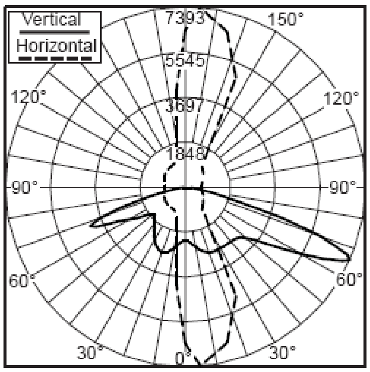
Patents

US Pat D577,847, Patents Pending; AU Des. 853122; EC000906482; NZ410610; International Patents Pending

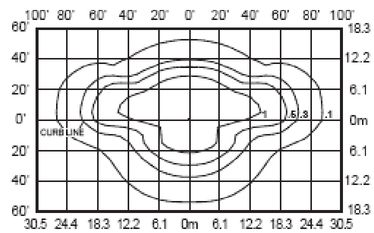
Field-Installed Accessories



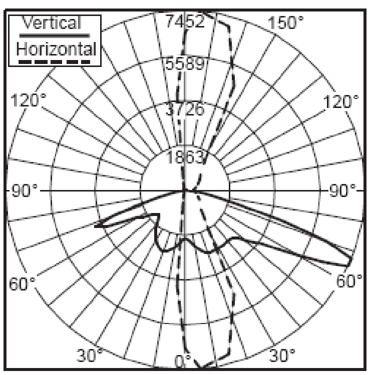
Bird Spikes
☐XA-BRDSPK



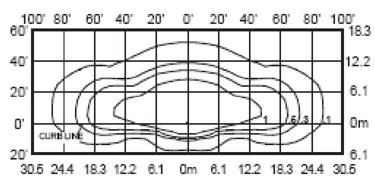
Independent Testing Laboratories certified test. Report No. ITL 60640. Candlepower distribution curve of 6 light bar luminaire with 9,360 initial delivered lumens operating at 350mA.



Isofootcandle plot of 6 light bar Type II LED luminaire at 25' A.F.G. Luminaire with 9,360 initial delivered lumens operating at 350mA. Initial FC at grade.



Independent Testing Laboratories certified test. Report No. ITL 60641. Candlepower distribution curve of 6 light bar luminaire with backlight shield and 6,960 initial delivered lumens operating at 350mA.



Isofootcandle plot of 6 light bar Type II LED luminaire with backlight shield at 25' A.F.G. Luminaire with 6,960 initial delivered lumens operating at 350mA. Initial FC at grade.

LED Area Light EPA Calculations

	2 – 6 LIGHT BARS
Post Top	
Post top fixture	0.95

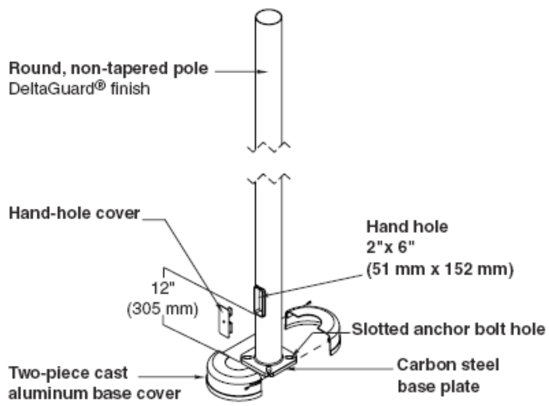
B.8 Beta LED Round Steel Pole – 5 in

PS5R Round Steel Poles

Beta Catalog Number: - -

Reset

Notes:



Catalog Number	*Height (feet) x Dia. (inches) x Wall (inches)*	*Height (m) x Dia. (mm) x Wall (mm)*	*Pole Configuration*	*Finish Color*
☐PS5R12C	12 x 5 x 0.120	3.7 x 127 x 3	☐0 Single Post Top Mount	☐BZ
☐PS5R15C	15 x 5 x 0.120	4.6 x 127 x 3		☐BK
☐PS5R17C	17 x 5 x 0.120	5.2 x 127 x 3		☐WH
☐PS5R20C	20 x 5 x 0.120	6.1 x 127 x 3		☐PB
☐PS5R22C	22 x 5 x 0.120	6.7 x 127 x 3		☐SV
☐PS5R25C	25 x 5 x 0.120	7.6 x 127 x 3		
☐PS5R27C	27 x 5 x 0.120	8.2 x 127 x 3		
☐PS5R30C	30 x 5 x 0.120	9.1 x 127 x 3		

Field-Installed Accessories

GFI Outlet Accessory - 120V

☐REC-GFI5&6BZ ☐REC-GFI5&6PB
☐REC-GFI5&6BK ☐REC-GFI5&6SV
☐REC-GFI5&6WH

General Description

Non-tapered round steel poles are supplied with welded base with cover, four galvanized anchor bolts, masonite mounting template. Each anchor bolt is provided with two washers and two nuts. Steel pole base has slotted holes. Per National Electrical Code requirements, pole is standard with a 2" x 6" (51 x 152 mm) hand hole, located 12" (305 mm) above bottom of pole base. A #10-32 stainless-steel weld stud with grounding lug is located inside pole, opposite hand hole; a hand hole cover is supplied but shipped separately. For EPA ratings, see "Windloading" sheet.

Materials

Round, non-tapered pole of structural steel tubing (ASTM A 500); with a minimum yield strength of 42,000 p.s.i. Welded to a formed carbon steel base plate with a minimum yield strength of 36,000 p.s.i.

Finish

Exclusive Colorfast DeltaGuard® finish features an E-Coat epoxy primer with an ultra-durable powder topcoat, providing excellent resistance to corrosion, ultraviolet degradation and abrasion. The finish is covered by our 7 year limited warranty.

Labels

In the US, Beta square poles are classified by Underwriters Laboratories Inc. for electrical ground bonding.

Appendix C - Energy Standard Compliance Reports

C.1 Existing Lighting Energy Standard Compliance Report

C.2 New Lighting Design Energy Standard Compliance Report

C.1 Existing Lighting Energy Standard Compliance Report

COMcheck Software Version 3.6.0

Exterior Lighting Compliance Certificate

90.1 (2004) Standard

Section 1: Project Information

Project Type: **New Construction**
Project Title : Kansas State University Quad

Construction Site:
Manhattan, KS 66506

Owner/Agent:
Kansas State University
Manhattan, KS 66506

Designer/Contractor:
Daniel Matlack
Architectural Engineering
Kansas State University
Manhattan, KS 66506
785 462 1039
dwm4474@ksu.edu

Section 2: Exterior Lighting Area/Surface Power Calculation

A Exterior Area/Surface	B Quantity	C Allowed Watts / Unit	D Tradable Wattage	E Allowed Watts (C x B)	F Proposed Watts
Walkway < 10 feet wide	2250 ft of walkway length	1	Yes	2250	4784
Walkway >= 10 feet wide	6080 ft2	0.2	Yes	1216	1456
			Total Tradable Watts* =	3466	6240
			Total Allowed Watts =	3466	
			Total Allowed Supplemental Watts** =	173	

* Wattage tradeoffs are only allowed between tradable areas/surfaces

** A supplemental allowance equal to 5% of total allowed wattage may be applied toward compliance of both non-tradable and tradable areas/surfaces

Section 3: Exterior Lighting Fixture Schedule

A Fixture ID : Description / Lamp / Wattage Per Lamp / Ballast	B Lamps/ Fixture	C # of Fixtures	D Fixture Watt.	E (C X D)
Walkway < 10 feet wide (2250 ft of walkway length): Tradable Wattage				
HID 1: Metal Halide 175W / Electronic	1	23	208	4784
Walkway >= 10 feet wide (6080 ft2): Tradable Wattage				
HID 2: Metal Halide 175W / Electronic	1	7	208	1456
			Total Tradable Proposed Watts =	6240

Section 4: Requirements Checklist

Lighting Wattage:

☐ 1. Within each non-tradable area/surface, total proposed watts must be less than or equal to total allowed watts. Across all tradable areas/surfaces, total proposed watts must be less than or equal to total allowed watts.
Compliance: Fails

Controls, Switching, and Wiring:

☐ 2. All exemption claims are associated with fixtures that have a control device independent of the control of the nonexempt lighting.

☐ 3. All lighting fixtures are controlled by a photosensor or astronomical time switch that is capable of automatically turning off the fixture when sufficient daylight is available or the lighting is not required.

Exceptions:

Covered vehicle entrance/exit areas requiring lighting for safety, security and eye adaptation.

Exterior Lighting Efficacy:

❑ 4. All exterior building grounds luminaires that operate at greater than 100W have minimum efficacy of 60 lumen/watt.

Exceptions:

Lighting that has been claimed as exempt and is identified as such in Section 3 table above.

Lighting that is specifically designated as required by a health or life safety statue, ordinance, or regulation.

Emergency lighting that is automatically off during normal building operation.

Lighting that is controlled by motion sensor.

Exterior Lighting FAILS: Design 80% worse than code.

C.2 New Lighting Design Energy Standard Compliance Report

COM*check* Software Version 3.6.0

Exterior Lighting Compliance Certificate

90.1 (2004) Standard

Section 1: Project Information

Project Type: **Alteration**
Project Title : Kansas State University Quad

Construction Site:
Manhattan, KS 66506

Owner/Agent:
Kansas State University
Manhattan, KS 66506

Designer/Contractor:
Daniel Matlack
Architectural Engineering
Kansas State University
Manhattan, KS 66506
785-452-1839
dwm4474@ksu.edu

Section 2: Exterior Lighting Area/Surface Power Calculation

A Exterior Area/Surface	B Quantity	C Allowed Watts / Unit	D Tradable Wattage	E Allowed Watts (C x D)	F Proposed Watts
Walkway < 10 feet wide	2250 ft of walkway length	1	Yes	2250	532
Walkway >= 10 feet wide	6080 ft2	0.2	Yes	1216	1570
			Total Tradable Watts* =	3466	2102
			Total Allowed Watts =	3466	
			Total Allowed Supplemental Watts** =	173	

* Wattage tradeoffs are only allowed between tradable areas/surfaces.

** A supplemental allowance equal to 5% of total allowed wattage may be applied toward compliance of both non-tradable and tradable areas/surfaces.

Section 3: Exterior Lighting Fixture Schedule

A Fixture ID : Description / Lamp / Wattage Per Lamp / Ballast	B Lamps/ Fixture	C # of Fixtures	D Fixture Watt.	E (C X D)
Walkway < 10 feet wide (2250 ft of walkway length): Tradable Wattage				
Incandescent 1: T5-2: Other	1	1	55	55
Incandescent 1 copy 1: T3-2: Other	1	4	55	220
Incandescent 1 copy 2: T4-4: Other	1	1	104	104
Incandescent 1 copy 3: T5-6: Other	1	1	153	153
Walkway >= 10 feet wide (6080 ft2): Tradable Wattage				
Incandescent 5: T3-4: Other	1	2	104	208
Incandescent 5 copy 1: T3-2: Other	1	6	55	330
Incandescent 5 copy 2: T5-2: Other	1	3	55	165
Incandescent 5 copy 3: T5-6: Other	1	1	153	153
Incandescent 5 copy 4: T2-3: Other	1	1	79	79
Incandescent 5 copy 5: T2-4: Other	1	1	104	104
Incandescent 5 copy 6: T2-2: Other	1	4	55	220
Incandescent 5 copy 7: T5-3: Other	1	1	79	79
Incandescent 5 copy 8: T3-5: Other	1	1	128	128
Incandescent 5 copy 9: T4-4: Other	1	1	104	104
			Total Tradable Proposed Watts =	2102

Section 4: Requirements Checklist

Lighting Wattage:

- [ ] 1. Within each non-tradable area/surface, total proposed watts must be less than or equal to total allowed watts. Across all tradable areas/surfaces, total proposed watts must be less than or equal to total allowed watts.

  Compliance: Passes.

Controls, Switching, and Wiring:

- [ ] 2. All exemption claims are associated with fixtures that have a control device independent of the control of the nonexempt lighting.
- [ ] 3. All lighting fixtures are controlled by a photosensor or astronomical time switch that is capable of automatically turning off the fixture when sufficient daylight is available or the lighting is not required.

  Exceptions:

  Covered vehicle entrance/exit areas requiring lighting for safety, security and eye adaptation.

Exterior Lighting Efficacy:

- [ ] 4. All exterior building grounds luminaires that operate at greater than 100W have minimum efficacy of 60 lumen/watt.

  Exceptions:

  Lighting that has been claimed as exempt and is identified as such in Section 3 table above.

  Lighting that is specifically designated as required by a health or life safety statue, ordinance, or regulation.

  Emergency lighting that is automatically off during normal building operation.

  Lighting that is controlled by motion sensor.

Exterior Lighting PASSES: Design 39% better than code.

Section 5: Compliance Statement

Compliance Statement: The proposed exterior lighting design represented in this document is consistent with the building plans, specifications and other calculations submitted with this permit application. The proposed lighting system has been designed to meet the 90.1 (2004) Standard requirements in COM*check* Version 3.6.0 and to comply with the mandatory requirements in the Requirements Checklist.

Name - Title	Signature	Date

Appendix D - Westar Energy Service Rates for KSU

High Load Factor

This rate applies to customers with electrical demand of 1,000 kW or more.

Demand Charge
$7.54 per kW for service taken at primary voltage.

Energy Charge
$0.013136 per kWh for all kWh

Plus all applicable adjustments and surcharges.

Sample Bill Calculation

This example is based on a customer using 300,000 kWh and a 1,000 kW demand at primary voltage.

Energy Charge	
300,000 kWh x $0.013136	**$3,940.80**
Demand Charge	
1,000 kW x $7.54	**$7,540.00**
Fuel Charge**	
300,000 kWh x $0.017720 (using estimated annual fuel costs)	**$5,316.00**
Transmission Charge**	
1,000 kW x $1.25	**$1,250.00**
Environmental Cost Recovery Rider**	
1,000 kW x $0.098182	**$98.18**
Property Tax Surcharge**	
300,000 kWh x ($0.000388)	**($116.40)**
SUBTOTAL	**$18,028,58**
Franchise Fee*	
$18,028.58 x 3%	**$540.86**
SUBTOTAL	**$18,569.44**
Sales Tax*	
State $18,569.44 x 5.3%	**$984.18**
Local $18,569.44 x 1%	**$185.69**
TOTAL Sales Tax	**$1,169.87**
TOTAL BILL	**$19,739.31**

Westar Energy will provide more information about specific rates or how to use electricity efficiently and economically.

We also will help you determine which rate will best match your needs at the lowest cost. Contact us at the Customer Contact Center at 1-800-383-1183.

Estimated Energy Rate Calculation**:**

Total Cost without tax:

$19,739.31-$1,169.87

= $18,569.44

Total Energy Consumed: 300,000kWh

Energy Cost:

$$\frac{\$18,569.44}{300,000\text{kWh}}$$

= $0.0632/kWh

* Amounts vary by Location

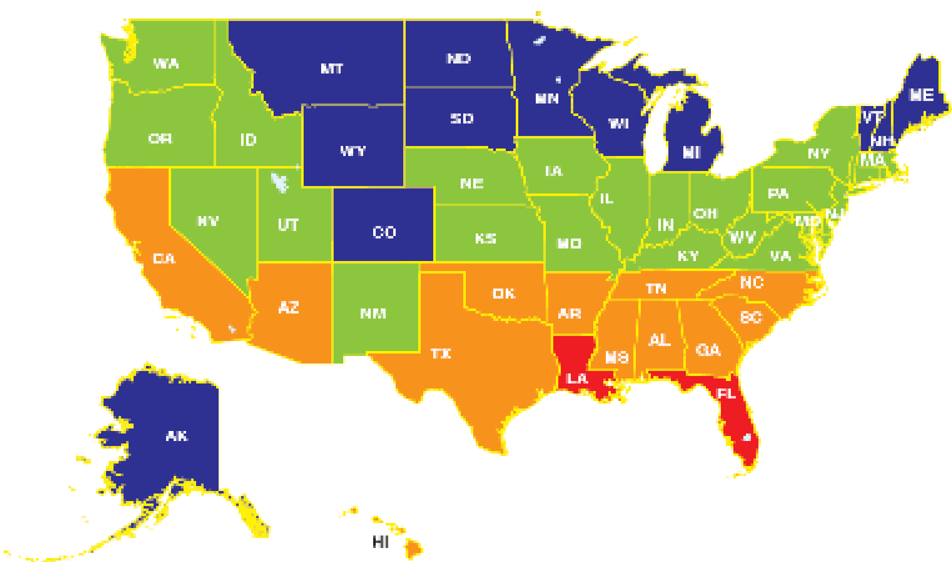
** Rates may vary monthly or annually

Source: Westar Energy, 2007

Appendix E - BetaLED LLF Recommendations

Rev A   Expires 7/09

BetaLED™ LLF RECOMMENDATIONS



Zone*	Drive Current (mA)	25K hr LLF	50K hr LLF	100K hr LLF
5°C (41°F)	350mA	1.02	0.98	0.92
	525mA	0.97	0.89	0.76
	700mA	0.91	0.77	0.57
10°C (50°F)	350mA	1.00	0.95	0.86
	525mA	0.95	0.86	0.71
	700mA	0.88	0.74	0.52
15°C (59°F)	350mA	0.98	0.93	0.83
	525mA	0.92	0.82	0.65
	700mA	0.85	0.70	0.48
20°C (68°F)	350mA	0.95	0.90	0.78
	525mA	0.89	0.78	0.60
	700mA	0.83	0.66	0.43
25°C (77°F)	350mA	0.95	0.86	0.73
	525mA	0.86	0.74	0.54
	700mA	0.79	0.63	0.39

*Average Nighttime Temperature

Use the LLF values in this chart when performing lighting calculations for Beta LED products ONLY.

For additional information on the derivation of these LLF chart values, see LD-13

Appendix F - Federal Incentives for Renewable Energy

F.1 Energy Efficient Commercial Buildings Tax Deduction

F.2 Qualifying Advanced Energy Project Investment Tax Credit

F.3 Department of Energy – Loan Guarantee Program

F.1 Energy Efficient Commercial Buildings Tax Deduction

Last DSIRE Review: 10/07/2008

Incentive Type: Corporate Deduction
Eligible Efficiency Technologies: Equipment Insulation, Water Heaters, Lighting, Lighting Controls/Sensors, Chillers, Furnaces, Boilers, Heat pumps, Air conditioners, CHP/Cogeneration, Caulking/Weatherstripping, Duct/Air sealing, Building Insulation, Windows, Doors, Siding, Roofs, Comprehensive Measures/Whole Building
Applicable Sectors: Commercial, Construction, State Government, Fed. Government, (Deductions associated with government buildings are transfered to the designer)
Amount: $0.30-$1.80 per square foot, depending on technology and amount of energy reduction
Maximum Incentive: $1.80 per square foot
Equipment Requirements: Must meet certification requirements
Website: http://www.efficientbuildings.org
Authority 1: 26 USC § 179D
Date Enacted: 8/8/2005 (Amended 2008)
Effective Date: 1/1/2006
Expiration Date: 12/31/2013
Authority 2: H.R. 1424: Div. B, Sec. 303 (The Energy Improvement and Extension Act of 2008)
Date Enacted: 10/3/2008
Expiration Date: 12/31/2013

Summary:
The federal Energy Policy Act of 2005 established a tax deduction for energy-efficient commercial buildings applicable to qualifying systems and buildings placed in service from January 1, 2006, through December 31, 2007. This deduction was subsequently extended through 2008, and then again through 2013 by Section 303 of the federal Energy Improvement and Extension Act of 2008 (H.R. 1424, Division B), enacted in October 2008.

A tax deduction of $1.80 per square foot is available to owners of new or existing buildings who install (1) interior lighting; (2) building envelope, or (3) heating, cooling, ventilation, or hot water systems that reduce the building's total energy and power cost by 50% or more in comparison to a building meeting minimum requirements set by ASHRAE Standard 90.1-2001. Energy savings must be calculated using qualified computer software approved by the IRS. Click here for the list of approved software.

Note that the eligible technologies listed above are provided as examples and do not represent an official list specified in the statute.

Deductions of $0.60 per square foot are available to owners of buildings in which individual lighting, building envelope, or heating and cooling systems meet target levels that would reasonably contribute to an overall building savings of 50% if additional systems were installed.

The deductions are available primarily to building owners, although tenants may be eligible if they make construction expenditures. In the case of energy efficient systems installed on or in government property, tax deductions will be given to the person primarily responsible for the systems' design. Deductions are taken in the year when construction is completed.

The IRS released interim guidance (IRS Notice 2006-52) in June 2006 to establish a process to allow taxpayers to obtain a certification that the property satisfies the energy efficiency requirements contained in the statute. IRS Notice 2008-40 was issued in March of 2008 to further clarify the rules. NREL published a report (NREL/TP-550-40228) in February 2007 which provides guidelines for the modeling and inspection of energy savings required by the statute.

Click here for answers to frequently asked questions provided by the *Commercial Building Tax Deduction Coalition.*
For more information, visit the Energy Star Web site.

Contact:
Public Information - IRS
Internal Revenue Service
1111 Constitution Avenue, N.W.
Washington, DC 20224
Phone: (800) 829-1040
Web site: http://www.irs.gov

Source: NC State University, DSIRE

F.2 Qualifying Advanced Energy Project Investment Tax Credit

Last DSIRE Review: 02/19/2009

Incentive Type: Industry Recruitment/Support
Eligible Efficiency Technologies: Lighting, Lighting Controls/Sensors, Energy Conservation Technologies
Eligible Renewable/Other Technologies: Solar Water Heat, Solar Thermal Electric, Photovoltaics, Wind, Geothermal Electric, Fuel Cells, Geothermal Heat Pumps, Fuel Cells using Renewable Fuels, Microturbines
Applicable Sectors: Commercial, Industrial, Manufacturing
Amount: 30% of qualified investment
Max. Limit: Total amount of credits to be allocated shall not exceed $2.3 billion
Terms: Apply to the Internal Revenue Service for certification for credits
Website: http://www.ustreas.gov
Authority 1: H.R. 1: Div. B, Sec. 1302 (American Recovery and Reinvestment Act of 2009)
Date Enacted: 02/17/2009
Effective Date: 02/17/2009

Summary:
The American Recovery and Reinvestment Act of 2009 (H.R. 1), enacted in February 2009, established a new investment tax credit to encourage the development of a U.S.-based renewable energy manufacturing sector. In any taxable year, the investment tax credit is equal to 30% of the qualified investment required for an advanced energy project that establishes, re-equips or expands a
manufacturing facility that produces any of the following:

- Equipment and/or technologies used to produced energy from the sun, wind, geothermal or "other" renewable resources
- Fuel cells, microturbines or energy-storage systems for use with electric or hybrid-electric motor vehicles
- Equipment used to refine or blend renewable fuels
- Equipment and/or technologies to produce energy-conservation technologies (including energyconserving lighting technologies and smart grid technologies)*

Qualified investments generally include personal tangible property that is depreciable and required for the production process. Other tangible property may be considered a qualified investment only if it is an essential part of the facility, excluding buildings and structural components.

The U.S. Treasury Department will issue certifications for qualified investments eligible for credits to qualifying advanced energy project sponsors. In total, $2.3 billion worth of credits may be allocated under the program. After certification is granted, the taxpayer has one year to provide additional evidence that the requirements of the certification have been met and three years to put the project in service.

In determining which projects to certify, the U.S. Treasury Department must consider those which most likely will be commercially viable, provide the greatest domestic job creation, provide the greatest net reduction of air pollution and/or greenhouse gases, have great potential for technological innovation and commercial deployment, have the lowest levelized cost of generated (or stored) energy *or* the lowest levelized cost of reduction in energy consumption or greenhouse gas emissions, *and* have the shortest
project time. The U.S. Treasury Department, in consultation with the U.S. Department of Energy, must create additional specific program guidelines and the application process by August 16, 2009.

Any taxpayer receiving this credit may not also receive business energy investment tax credit.

**Note: This credit may be expanded in the future to include other energy technologies that reduce greenhouse gas emissions, as determined by the U.S. Treasury Department.*

Source: NC State University, DSIRE

F.3 U.S. Department of Energy - Loan Guarantee Program

Last DSIRE Review: 02/19/2009

Incentive Type: Federal Loan Program
Eligible Efficiency Technologies: Lighting, Windows, Roofs, Yes; specific technologies not identified
Eligible Renewable/Other Technologies: Solar Thermal Electric, Solar Thermal Process Heat, Photovoltaics, Wind, Hydroelectric, Renewable Transportation Fuels, Geothermal Electric, Fuel Cells, Manufacturing Facilites, Daylighting, Tidal Energy, Wave Energy, Ocean Thermal, Biodiesel
Applicable Sectors: Commercial, Industrial, Nonprofit, Schools, Local Government, State Government, Agricultural, Institutional, Any non-federal entity
Amount: Varies. Program focuses on projects with total project costs over $25 million.
Max. Limit: None stated
Terms: Full repayment is required over a period not to exceed the lesser of 30 years or 90% of the projected useful life of the physical asset to be financed
Website: http://www.lgprogram.energy.gov
Authority 1: 42 USC § 16511 et seq.
Authority 2: 10 CFR 609

Summary:

Innovative Technology Loan Guarantee Program:
Title XVII of the federal *Energy Policy Act of 2005* (EPAct 2005) authorized the U.S. Department of Energy (DOE) to issue loan guarantees for projects that "avoid, reduce or sequester air pollutants or anthropogenic emissions of greenhouse gases; and employ new or significantly improved technologies as compared to commercial technologies in service in the United States at the time the guarantee is issued." The loan guarantee program has been authorized to offer more than $10 billion in loan guarantees for energy efficiency, renewable energy and advanced transmission and distribution projects. The authority to issue loan guarantees granted by EPAct 2005 expires on September 30, 2009.

DOE actively promotes projects in three categories: (1) manufacturing projects, (2) stand-alone projects, and (3) large-scale integration projects that may combine multiple eligible renewable energy, energy efficiency and transmission technologies in accordance with a staged development scheme. Under the original authorization, loan guarantees were intended to encourage early commercial use of new or significantly improved technologies in energy projects. The loan guarantee program generally does not support research and development projects.

The most recent solicitation for this program was issued in July 2008. The application deadline for stand-alone and manufacturing projects, as well as the Part I applications for large-scale integration projects, was February 26, 2009.

Temporary Loan Guarantee Program:
The American Recovery and Reinvestment Act of 2009 (H.R. 1), enacted in February 2009, extended the authority of the DOE to issue loan guarantees and appropriated $6 billion for this program. Under this act, the DOE may enter into guarantees until September 30, 2011. The act amended EPAct 2005 by adding a new section defining eligible technologies for new loan guarantees. Eligible projects include renewable energy projects that generate electricity or thermal energy and facilities that manufacture related components, electric power transmission systems, and innovative biofuels projects. Funding for biofuels projects is limited to $500 million. Davis-Bacon wage requirements apply to any project receiving a loan guarantee.

Contact:

Director
DOE Loan Guarantee Program Office
1000 Independence Avenue, SW
Washington , DC 20585-0121
Phone: (202) 586-8336
E-Mail: LGProgram@hq.doe.gov
Web site: http://www.lgprogram.energy.gov

Source: NC State University, DSIRE