PG&E's Emerging Technologies Program

San José Washington United Youth Center High Bay LED Lighting Study

ET Project Number: ET11PGE1151

Project Manager: **Jeff Beresini**
Pacific Gas and Electric Company

Prepared By: **kW Engineering, Inc.**
287 17th Street, Suite 300
Oakland, CA 94612

Issued: **May 16, 2013**

Pacific Gas and Electric Company®

ACKNOWLEDGEMENTS

Pacific Gas and Electric Company's Emerging Technologies Program is responsible for this project. It was developed under internal project number ET11PGE1151. KW Engineering, Inc. conducted this technology evaluation for Pacific Gas and Electric Company with overall guidance and management from Jeff Beresini. For more information on this project, contact JLBd@pge.com.

Abbreviations and Acronyms

Acronym	Description
LED	Light Emitting Diode
HID	High Intensity Discharge
MH	Metal Halide
K	Kelvin
CCT	Correlated Color Temperature
PG&E	Pacific Gas and Electric Company
kW	Kilowatt
CT	Current Transducer
I	Current, Amperage
V	Voltage
μF	Microfarad
IOU	Investor Owned Utility

FIGURES

TABLES

EQUATIONS

CONTENTS

EXECUTIVE SUMMARY

This report summarizes an assessment project conducted to study the performance of light emitting diode (LED) high bay fixtures in a multi-purpose gymnasium. In collaborating with PG&E and the City of San José, kW Engineering performed a field study of a metal halide (MH) high bay to LED high bay fixture replacement project.

The field study evaluated the performance of the existing MH system and the new LED system. The collaboration included energy and light quality measurements as well as occupant surveys for both technologies.

The project included the replacement of 30 existing, 400-watt MH fixtures in a gymnasium with 30, 200-watt LED fixtures. An evaluation of energy savings and light quality improvements between the pre- and post-retrofit fixtures was also conducted. In order to determine energy savings, the baseline MH fixtures and the new LED fixtures' energy usage was monitored. During the study, it was discovered that the MH fixtures had not been wired properly during the original installation. They were producing less light and consuming less energy than expected.

In comparing the new LED lighting to the in-situ, baseline (incorrectly wired MH fixtures), there was a 34% reduction in input power. Extrapolated to one year of use, the project saves 9,941 kWh or $1,650 with a simple payback period of 16.0 years. The potential energy savings that would be expected with the fixtures wired correctly was also calculated. There would have been a 60% potential reduction in input power. This represents 29,488 kWh and $4,895 in potential annual savings with a simple payback period of 5.4 years.

TABLE 1: ANNUAL ENERGY & COST SAVINGS COMPARISON BETWEEN MEASURED BASELINE AND LED HIGH BAY

	ANNUAL ENERGY USE (KWH/YR)	ANNUAL ENERGY SAVED (KWH/YR)	ENERGY SAVED AS PERCENT OF BASELINE	ANNUAL ENERGY COST	ANNUAL ENERGY COST SAVINGS (@$0.166/KWH)	LED INSTALLED COST	PAYBACK PERIOD (YEARS)
MH - LOGGED	29,270	-	-	$4,859	-	-	-
LED HIGH BAY	19,329	9,941	34%	$3,209	$1,650	$26,420	16.0

TABLE 2: ANNUAL ENERGY & COST SAVINGS COMPARISON BETWEEN CORRECTLY WIRED BASELINE AND LED HIGH BAY

	ANNUAL ENERGY USE (KWH/YR)	ANNUAL ENERGY SAVED (KWH/YR)	ENERGY SAVED AS PERCENT OF BASELINE	ANNUAL ENERGY COST	ANNUAL ENERGY COST SAVINGS (@$0.166/KWH)	LED INSTALLED COST	PAYBACK PERIOD (YEARS)
MH – WIRED CORRECTLY	48,817	-	-	$4,859	-	-	-
LED HIGH BAY	19,329	29,488	60%	$3,209	$4,895	$26,420	5.4

To evaluate the quality of light provided by the baseline MH fixtures and replacement LED fixtures, the illuminance (foot-candles) and correlated color temperature (CCT, in Kelvin) were measured.

The LED fixtures improved the lighting quality in the space over the baseline MH system by increasing the uniformity of the lighting in the space, primarily through better photometric performance. The more precise tolerance of LED fixture components offered better color temperature uniformity than the metal halides. The light levels rose significantly, due to a faulty baseline installation. With properly installed fixtures one would expect the average illuminance to increase by 12.6% as compared to the in-situ MH installation.

While the BritePointe LED high bay fixtures performed well overall, there are key issues that need to be addressed in order to encourage the adoption of LED high bay fixtures in gymnasiums. It is recommended that fixture selection criteria include the capability to withstand significant ball-shock damage and specifications with minimum warranty requirements (e.g. 5 years) that state manufacturer response time when a fixture fails within the first year. Due to the significant differences in light output and aesthetics between MH and LED fixtures, it is important to view the specific LED fixtures being considered in place at an existing site or as part of a mock-up/demo at project site. This step provides an essential opportunity to assess potential glare and light distribution issues before a final LED fixture is selected.

Based on the data collected in this study, LED high bay lighting for gymnasiums is ready for adoption into the energy efficiency portfolio of the California IOUs. The increased performance and control capabilities along with potential maintenance and energy savings build a case for promoting the use of LED high bay fixtures in gymnasiums.

Figure 1: Baseline MH Lighting in the Gymnasium - Photo Taken At 4000K Exposure Setting

Figure 2: Installed LED Lighting in the Gymnasium - Photo Taken At 4000K Exposure Setting

INTRODUCTION

As a lighting technology that continues to be one of the fastest-evolving emerging technologies, LED has displaced several legacy lighting technologies and applications. One example of the continuous improvement in LED fixture designs is in the high bay gymnasium environment. The benefits of LED technology include long life, lower facility maintenance costs, and, in the case of gymnasiums, the elimination of glass components that may be vulnerable to vibration or breakage. Combined with the superior performance and new control capabilities, LED technologies can build a persuasive case to replace older high intensity discharge (HID) fixtures.

For this project, PG&E teamed with the City of San José and kW Engineering to conduct a study on the lighting at the San José Washington United Youth Center gymnasium at 921 S 1st Street in San José, California. The goal of the study was to evaluate the impact of an LED lighting system in a gymnasium setting.

PG&E collaborated with the City of San José to select and install BritePointe high-bay LED fixtures at the gymnasium. BritePointe worked with the client, the City of San José, to complete the initial upgrade in January 2013. Field measurements were conducted through February 2013, measuring baseline and installed lighting conditions and power consumption.

This study was initiated to better understand the high-bay LED fixture technology as it becomes more prevalent in multi-purpose gymnasiums, in particular, and the commercial sector, in general.

BACKGROUND

High-bay lighting is common in gymnasiums where fixtures must illuminate the large area of play without interfering in game-play. Most gymnasiums use metal halide fixtures with enclosed diffusers, ball-cages, or both. Metal halide lamps operate in a similar fashion to other HID lamps, with some technology-specific differences. HID lamps provide light via an electric arc discharge contained in an arc tube, surrounded by an outer bulb. Inside the arc tube, there are electrodes for terminating the arc, an easily-ionized gas, and selected metals that will absorb energy from the ionized gas and emit light.

METAL HALIDE LAMPS

Metal halide lamps can have two or three electrodes, depending on the starting mechanism.

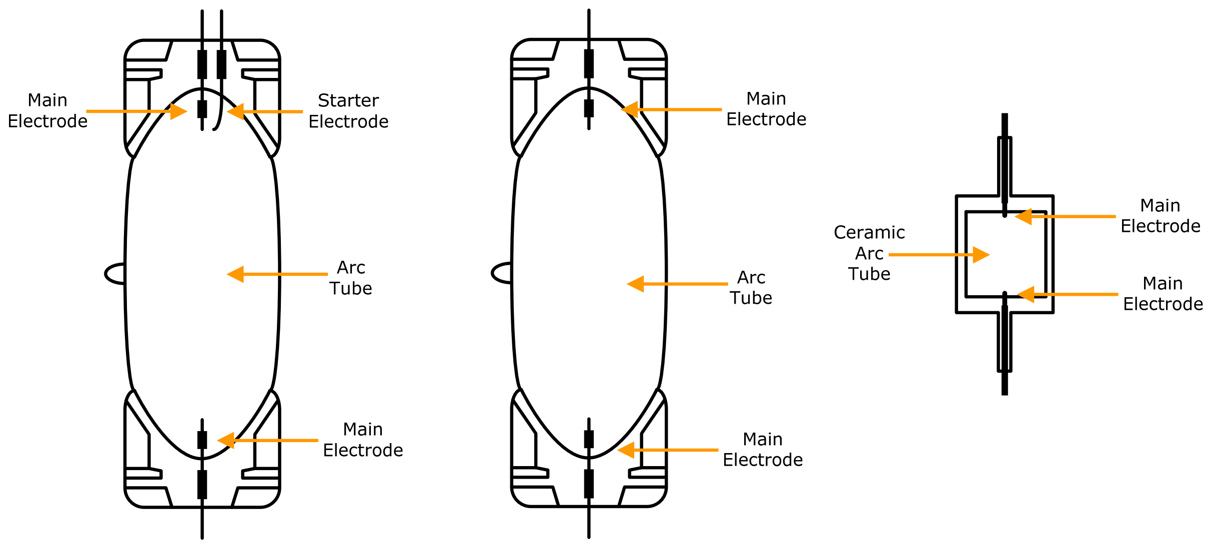


FIGURE 3: METAL HALIDE LAMP TECHNOLOGIES (FROM LEFT TO RIGHT, PROBE-START, PULSE-START, AND CERAMIC)[1]

PROBE-START METAL HALIDES

Conventional metal halide lamps use a probe-start mechanism and have three electrodes – two main electrodes placed at the opposite ends of the arc tube and a starter electrode located near the base of the arc tube. At start-up, a small arc forms between the starter electrode and the nearest main electrode. This small arc ionizes the gas in the arc tube, making it easier to strike an arc between the two main electrodes. Once the two main electrodes arc, a bi-metal switch severs the connection to the starter electrode. Probe-start metal halides use quartz arc tubes.

PULSE-START METAL HALIDES

Pulse-start metal halide lamps do not have a starting electrode and compensate with a high-voltage igniter component in the ballast. The high-voltage igniter provides a high-

[1] Based on graphic contained in "The Lighting Handbook: 10th Edition", IES, 2011

voltage pulse during start-up to facilitate arc formation inside the lamp. With the absence of the starting electrode, the seal areas of the lamps are reduced, allowing for better bulb shaping. Compared to the probe-start metal halides, pulse start metal halides offer reduced warm-up and re-strike times, longer lamps life, improved lumen maintenance, and better startup behavior at cold temperatures. Standard pulse-start metal halide lamps use quartz arc tubes, which limits the lamp life due to seal quality.

CERAMIC METAL HALIDES

Newer metal halide lamps are available using ceramic arc tubes. Ceramic tubes are more thermally robust and allow for higher arc-tube temperatures. The high temperature results in better luminous efficacy (lu/W), color rendering (CRI), and color stability (shift in color temperature over time). Ceramic metal halide lamps are almost entirely marketed for pulse-start metal ballasts.

TABLE 3: RELATIVE PERFORMANCE OF 400W PROBE START METAL HALIDE EQUIVALENT HID TECHNOLOGIES[2]

LAMP & BALLAST	BALLAST TYPE	SYSTEM POWER (W)	LAMP LIFE (HRS)	INITIAL SYSTEM LUMINOUS EFFICACY (LU/W)	DESIGN SYSTEM LUMINOUS EFFICACY (LU/W)
Quartz Probe-Start	Magnetic	454	20,000	85.9	56.2
	Electronic	Not Applicable		Not Applicable	Not Applicable
Quartz Pulse-Start	Magnetic	360	20,000	88.3	62.1
	Electronic	342		93.1	65.4
Ceramic Pulse-Start	Magnetic	360	28,000	94.8	71.1
	Electronic	341		100.1	75.5

[2] Based on tables included in Appendix I

LIGHT EMITTING DIODES/HIGH BAY LIGHTING FIXTURE

The BritePointe HyBeem fixture, pictured in Figure 4, is a 200-watt LED high bay fixture intended to replace a 400-watt HID high bay fixture. LED fixtures differ from the incumbent technology in significant ways. LED fixtures are composed of a protective housing containing an electronic driver that converts line current to direct-current and an array or panel of individual LED chips. Most LED fixtures incorporate a heat sink of some type to remove heat from the junction of the LED chip rapidly. In the case of the HyBeem fixture, the heat sink is a finned copper heat pipe forming a ring around the fixture protected by an open plastic covering.

FIGURE 4: A CLOSE UP OF THE BRITEPOINTE HYBEEM FIXTURE

Due to the differences between HID fixtures and LED fixtures, the same test methods for evaluating photometric behavior and lamp life cannot be used. The standard test methods for LED fixtures are LM-79 and LM-80. These methods, used in conjunction with technical memorandum TM-21 (developed by the Illuminated Engineering Society (IES)), provide a testing and data interpretation methodology used for comparing different technologies. LM-79, *Electrical and Photometric Testing of Solid State Lighting Devices*, provides insight into efficacy (lu/W), correlated color temperature (CCT, in Kelvin), total luminous flux (lumens), power consumption (W), and power factor. LM-79 also measures the spatial distribution of light from an LED fixture, which is useful in modeling a fixture's performance in the illuminated environment during the design stage.

As they age, barring an LED driver failure, LED fixtures dim over time. Because LED fixtures do not experience lamp mortality like conventional light sources, there is not a definitive failure point to mark the end of life of an LED panel or fixtures. To account for the gradual reduction in light output of LED fixtures, lighting designers use an arbitrary percentage of the initial light output after which the fixture is said to have reached its end of life and the LED panel or fixture is replaced. Current industry practice assumes fixtures need to be replaced after the light output reaches 70% of the initial light output, or the L70 point (measured in hours).

The LM-80 test, *Measuring Lumen Depreciation of LED Light Sources*, measures the lumen depreciation of solid-state light sources, including LED chips, arrays, and modules. LM-80 alone does not provide a framework for predicting the long-term lumen maintenance of the LEDs in a manufactured fixture.

To interpret the LM-80 results, manufacturers use an experimentally derived mathematical method called TM-21, *Projecting Longer Term Lumen Maintenance of LED Light Sources*. TM-21 requires LM-80 test data and an in situ temperature measurement test (ISTMT) to measure the LED operating temperature. The junction temperature of an LED light source is the leading variable that affects the speed at which an LED fixture's light output depreciates. While the junction temperature is impossible to measure in a manufactured fixture, it is possible to measure the solder joint temperature of an LED within the fixture and then use empirical relationships to closely approximate the junction temperature. Using the LM-80 and the ISTMT test results data, a manufacturer can extrapolate the lumen depreciation curve as far as six times the LM-80 test period.[i]

ASSESSMENT OBJECTIVES

The objectives of this project were to:

- Test the reliability and functionality of LED systems in a high-bay lighting application;
- Test the lighting quality of LED systems in a high-bay lighting application;
- Collect operational information and data to determine energy use and savings for such projects;

To this end, the project team selected a multi-purpose gymnasium to measure the performance characteristics of the MH fixtures and new LED fixtures. Instantaneous light measurements were collected and measurement and verification (M&V) was conducted at the site before and after the LED installation. The light measurements were used to determine the acceptability of the LED in a high bay gymnasium application. The M&V data was used to develop calculations and quantify the energy savings. The methodology is discussed further in the Technical Approach section of this report.

In addition, surveys with site staff were conducted to determine perceived light quality and collect information regarding the installation process. Two surveys (occurring pre- and post-installation of LED fixtures) asked the occupants of the gymnasium to provide feedback on perceived lighting quality. A third survey asked the lighting installers about the ease of installation and perceived LED lighting quality.

TECHNOLOGY/PRODUCT EVALUATION

The BritePointe Hybeem high bay product was evaluated through a field installation located at a community youth center multi-purpose gymnasium in San José. This LED product was compared to a Genlyte MH high bay product on a one-for-one fixture replacement basis. In addition to on-site measurements, a component of this study was a customer feedback and satisfaction survey completed by site staff and the public who used the gymnasium. This qualitative feedback, as well as details of the product installation and testing under real-life gymnasium conditions, would not have been available through a laboratory evaluation of the technology.

Pacific Gas and Electric Company (PG&E), in collaboration with the City of San José, selected the Washington Youth Center gymnasium because it was a good example of a multi-purpose gymnasium with common high bay, metal halide HID fixtures. The City provided staff and equipment to re-lamp existing MH lamps for the baseline study and install new LED high bay fixtures. The onsite staff associated with the Catholic Charities of Santa Clara County also assisted with coordinating the field measurements, photography visits, and surveys. Having a multi-use facility that served the greater community and a pre-existing working relationship between maintenance and on-site staff made this site an excellent choice for a LED high bay evaluation project.

The product selection research (including RFQ) was conducted by Mary Matteson Bryan, P.E., a consultant for PG&E. The assessment was completed by kW Engineering with assistance from City of San José staff, Catholic Charities of Santa Clara County staff, and BritePointe sales representatives.

FIXTURE SELECTION PROCESS

For this study, PG&E solicited performance specifications and pricing information from six manufacturers of LED high-bay products.

- BritePointe
- Dialight
- LSI
- Lithonia
- Lusio
- Xeralux

All the proposed products met the minimum performance criteria. However, each had unique aspects that made them more or less suitable for the multi-purpose youth center gymnasium in this study. The study team (composed of PG&E, City of San José staff, Mary Matteson Bryan, and kW Engineering) conducted an initial review of the performance specifications of each product and eliminated three products based on high cost, potential glare issues, and lack of LM-79 performance testing data. The team selected three products for further examination and potential evaluation:

- BritePointe HyBeem
- LSI Crossover
- Lusio Essentials Bay

The key deciding factor against the selection of the LSI fixture was the lens options. While LSI's standard, clear tempered glass lens was rated for ball shock, there was limited glare control. The plastic lens with glare control had reduced light output. The Lusio product may have been an appropriate application for a site that had pre-existing wiring/circuitry that allowed dimming capability. (The location for this study did not have this capability.) In addition, the wide fixture surface area raised concern over being knocked out of alignment – especially at this particular gymnasium where fixtures are pendant mounted to an electrical conduit.

After further review and discussions between project team members, the City of San Jose selected the BritePointe HyBeem fixture for the study. The main criteria that lead to the selection were good photometric performance, acceptable efficacy, relatively low price, and perceived durability (based on manufacturer's assurance of fixture's capability to withstand ball-shock in gym environments).

All 30 Genlyte 400-watt metal halide fixtures would be replaced with 30 BritePointe HyBeem 200-watt LED fixtures.

TECHNICAL APPROACH/TEST METHODOLOGY

FIELD TESTING OF TECHNOLOGY

PG&E and the City of San José selected the site for the LED study based on the following criteria:

- The site is a gymnasium with 30 high-bay light fixtures to serve one open area.
- The baseline lighting fixtures were high-bay, 400-watt metal halides.
- The lighting fixtures are manually controlled to meet occupant needs.
- Input power to the light fixtures could be isolated and monitored at the panel in the electrical room.
- Light measurements could be taken after dark to minimize interference from outside light sources.

TEST PLAN

In order to accurately compare the lighting quality between the MH and LED fixtures, the existing MH lamps were replaced with new lamps to meet original specifications. The new MH lamps went through a burn-in period of 100 hours. The LED fixtures also went through a 100 hour burn-in period. Lighting measurements on both types of fixtures were conducted after their respective burn-in periods. In addition, lighting measurements were taken at night to avoid interference from natural light coming in through the windows.

kW Engineering used Option B (Retrofit Isolation) from the International Performance Measurement and Verification Protocol (IPMVP) to quantify the energy savings from the new LED system.

The lighting energy usage was isolated by measuring the current draw at dedicated circuits in the electrical panel. The same equipment was used to log amperage for a period of at least two weeks for the pre- and post-retrofit light fixtures. Data from the logger was downloaded once for each technology (MH and LED), at the end of the logging period.

Spot power measurements were taken during the LED fixture installation, including voltage, amperage, kW, and power factor. These parameters were then used to calculate the kW input power and energy consumption of the fixtures from the logged amperage data using Equation 1.

kW Engineering recorded instantaneous measurements of light levels (in foot-candles) and CCT (in Kelvin) for each fixture type. The initial M&V Plan was to select measurement positions that met IESNA Standard LM-5-04, *IESNA Guide for Photometric Measurements of Area and Sports Lighting Installations*. In practice, however, there were nine measurement positions (rather than 35) due to the short window of opportunity to conduct the measurements. (Activities ended at 9:30 PM and staff had to close the facility at 11:00 PM.)

EQUATION 1: INPUT POWER CALCULATION

$$P = \frac{I_H V_{PS}(cos\varphi)}{\frac{I_H}{I_{PS}}}$$

Where:

P: Input Power, watts

I_H: Average Current from Hobo Data Logger, A

I_{PS}: Current from PowerSight, A

V_{PS}: Voltage from PowerSight, V

$cos\varphi$: Power Factor from PowerSight, unitless

The IESNA Standard requires measurements to be taken at 15 feet intervals, which equates to 35 measurement positions at this gymnasium. In order to set up the measurements positions and take the measurements, it would have taken two hours after the photographers were done taking their photos. Because site staff needed to lock up the gymnasium and could not stay beyond 11:00 PM, light level and CCT measurements were taken at nine measurement positions. These nine positions (noted in Figure 8) were a satisfactory representation of the gymnasium lighting.

Instrumentation Plan

To collect the necessary data to verify energy savings, standalone data loggers and spot measurement equipment were used.

Table 4 provides a summary of the standalone devices used to measure each parameter. For the electrical current data collection, a 5-minute sample rate was used over several weeks.

Table 4: Measurement Parameters, Devices, and Accuracy

Parameter	Units	Measurement Device	Range of Parameters	Accuracy
Illuminance	Lux	Solar Light SL-3101	0 – 150,000 lux	± 0.2% of full scale ± 30 lux
Correlated Color Temperature	Kelvin	Konica Minolta CL-200	2,300 – 20,000 K	± 20 Kelvin
Power, Power Quality	Watts, PF, THD	PowerSight PS250 Power Meter	None given	± 3.0% for kW
Current	Amps	PowerSight PS250 Power Meter – 100Amp CT	0.1 – 100 Amps	± 2.5% for current
Current	Amps	Onset HOBO U12 Data Logger with split-core AC current transducers	0 – 100 Amps	± 4.5% of full scale ± 4.5 Amps
Capacitance	μF	Fluke 375 Clamp Meter	0 – 1000 μF	± 0.1 μF (≤100 μF) ± 1 μF (≤1000 μF)

RESULTS

POWER MEASUREMENTS

The Monitoring Plan included a spot power measurement and logged power for both the MH and LED fixtures. Spot power measurements of the MH system were not taken due to a lack of safe access to the electrical panel. Safe access to the panel was subsequently provided for a spot power measurement of the LED system. A spot power measurement of the MH fixture was taken during a post-monitoring site visit to test the input power to the MH fixture at various capacitance settings.

Two-and-a-half weeks of power monitoring (amps) for the MH fixtures and four weeks of monitoring for the LED fixtures was conducted. The MH fixtures were monitored from October 13 to October 30, 2012 and the LED fixtures were monitored from February 14 to March 14, 2013. The LED fixtures were delivered to the site at the end of December 2012. They were installed by City staff in January of 2013. The LED fixtures were monitored for a longer period of time because one LED fixture was broken during the first three weeks of monitoring. One full week of monitoring was obtained that included all 30 functioning LED fixtures.

A PowerSight PS250 was used to measure the instantaneous input power to the LED fixtures. The reading of 5.7 kW for 30 fixtures, or 190 watts per fixture, was within 10% of the nominal fixture wattage (200 W). The power factor was 0.93, which is within a reasonable range.

Input power in watts was calculated from the monitored current data by multiplying the average current from the monitoring period by the voltage and power factor measured using the PowerSight. The amperage readings between the PowerSight and HOBO measurements were compared and found to be reasonably close. (HOBO amperage readings were 97% of PowerSight amperage readings.) This difference was applied to the input power calculation because the PowerSight measurement for the voltage and power factor were also being used. The difference was applied by taking the ratio of amperage readings between the two pieces of equipment. The average power measurements for the MH and LED fixtures are illustrated in Table 5.

Figure 5 illustrates the input power difference between the MH and LED fixtures on a typical day. The MH fixture reading was taken on Tuesday, October 23, 2012 and the LED fixture reading was taken on Tuesday, March 12, 2013. The full monitoring and spot measurement results can be found in Appendix A.

TABLE 5: INITIAL POWER MEASUREMENTS (AVERAGE OVER MONITORING PERIOD)

POWER MEASUREMENTS	MH	LED
NOMINAL WATTS/FIXTURE (WATTS)	400	200
AVERAGE POWER/FIXTURE (WATTS)	290.9	192.1
AVERAGE CURRENT/FIXTURE (AMPS)	1.03	0.68
POWER FACTOR[3]	0.91	0.93
NUMBER OF FIXTURES	30	30
TOTAL POWER (KW)	8.55	5.76

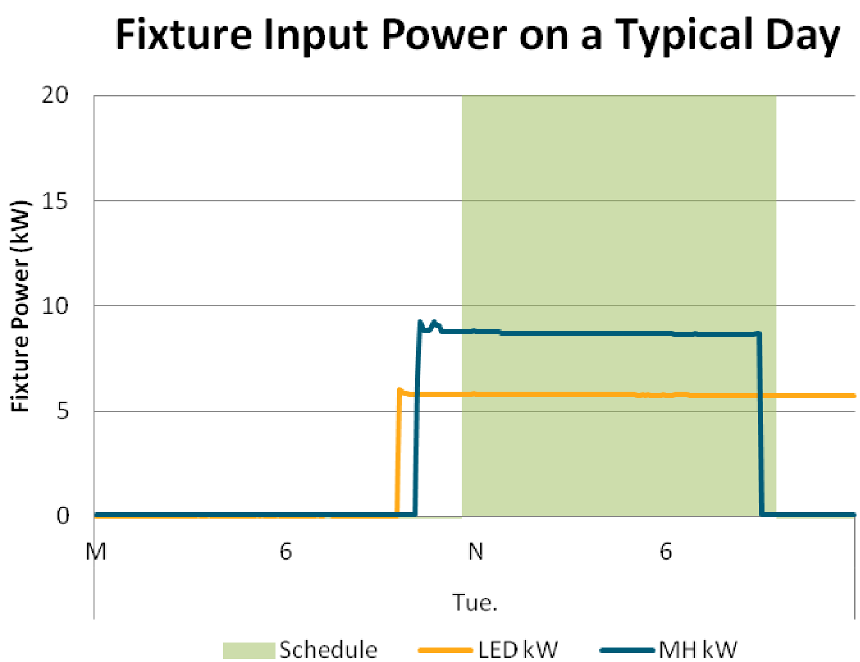


FIGURE 5: COMPARISON OF FIXTURE INPUT POWER ON A TYPICAL DAY

During the review of the baseline logged data, it was discovered that the baseline fixtures were not consuming the wattage expected from a 400-watt MH fixture. A probe-start 400-watt MH fixture typically consumes 458 watts per fixture (see Appendix D) while the logged data indicated that the average MH fixture in this study was consuming 291 watts.

City of San José maintenance staff determined that incorrect wiring between the MH ballast and capacitor in the fixtures caused the low power and light level readings. This situation

[3] Power factor is from the spot power measurement

had been in place since the original installation of the MH fixtures (mid 1990s). The ballast specifies a 24 microfarad (µF) capacitance. The capacitor in the fixture was a multi-tap capacitor with a common tap, a tap to 24 µF, and a tap to 42 µF. When wired from the common to the 24 µF or 42 µF taps, the capacitor produces 24 µF or 42 µF, respectively. When wired from the 24 µF to 42mF taps, the capacitor produces 15 µF. City of San José staff tested the fixtures at the 15 µF and 24 µF capacitance settings and found that with the correct capacitance, the amperage reading and light output was higher.

Another site visit was conducted by kW Engineering to spot check the wiring on the fixtures and found that all fixtures were wired to produce 15 µF. The capacitance, input power, and power factor on the MH fixtures were measured using a Fluke 375 meter (for capacitance) and PowerSight PS250 power meter (for input power and power factor) at the three capacitance settings. Table 6 illustrates the measured values of the MH fixture at each capacitance. The input power to the MH fixture with the correct capacitance is 485 watts per fixture. See Figure 6 and Figure 7 for the capacitance wiring.

FIGURE 6: MULTI-TAP CAPACITOR – BASELINE MH AS FOUND: INCORRECTLY WIRED FOR 15 µF

FIGURE 7: MULTI-TAP CAPACITOR – CORRECTLY WIRED FOR 24 µF DURING TESTING

TABLE 6: SHORT TERM MONITORING OF METAL HALIDE FIXTURES IN MULTIPLE CAPACITANCE CONFIGURATIONS

POWER MEASUREMENTS	MH - 15 µF	MH - 24 µF	MH - 42 µF
NOMINAL WATTS/FIXTURE (WATTS)	400	400	400
MEASURED CAPACITANCE (µF)	16.3	25.1	45.2
AVERAGE POWER/FIXTURE (WATTS)	228.6	488.6	1212
AVERAGE CURRENT/FIXTURE (AMPS)	0.88	1.79	4.44
POWER FACTOR	0.90	0.96	0.96
NUMBER OF FIXTURES	30	30	30
TOTAL POWER (KW)	6.86	14.66	36.36

ILLUMINANCE MEASUREMENTS

Lighting measurements were conducted in nine positions across the gymnasium using the basketball court as a reference. Figure 8 notes the basketball court dimensions and orientation.

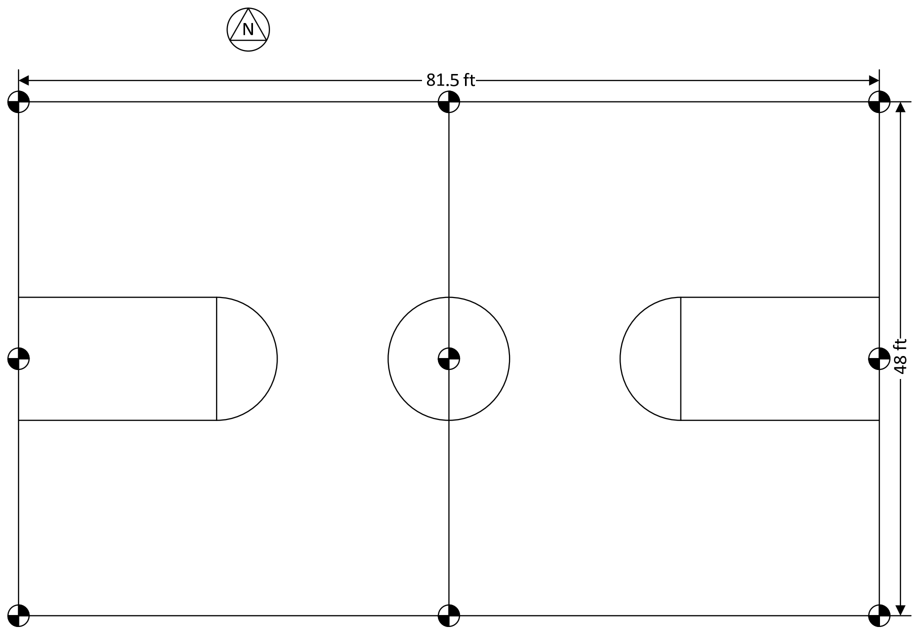


FIGURE 8: BASKETBALL COURT MEASUREMENT LAYOUT

Table 7 and Table 8 record the illuminance measurements at various locations on the basketball court inside the gymnasium. The mid-court light levels are generally higher than the north and south light levels because the fixtures in the gymnasium align with the basketball court. The west and east illuminance readings tend to be lower than the other light readings due to the proximity to the walls and relatively poor surface reflectance.

TABLE 7: PROBE-START METAL HALIDE ILLUMINANCE MEASUREMENTS (FC)

	WEST BASKET	MID-COURT	EAST BASKET
NORTH (WINDOWS)	9.20	14.3	10.1
MID-COURT	22.0	38.9	24.6
SOUTH (OFFICES)	9.94	25.5	22.0

TABLE 8: BRITEPOINTE LED HIGH-BAY ILLUMINANCE MEASUREMENTS (FC)

	WEST BASKET	MID-COURT	EAST BASKET
NORTH (WINDOWS)	24.1	34.0	23.8
MID-COURT	37.7	56.7	40.7
SOUTH (OFFICES)	24.9	35.8	23.8

Figure 9 and Figure 10 illustrate the difference in light levels and uniformity between the MH and LED fixtures. Both photos were taken with a 4000K CCT setting on the camera. The smaller capacitance, due to the faulty MH capacitor installation, shifted the color temperature of the MH fixtures toward the blue-end of the spectrum.

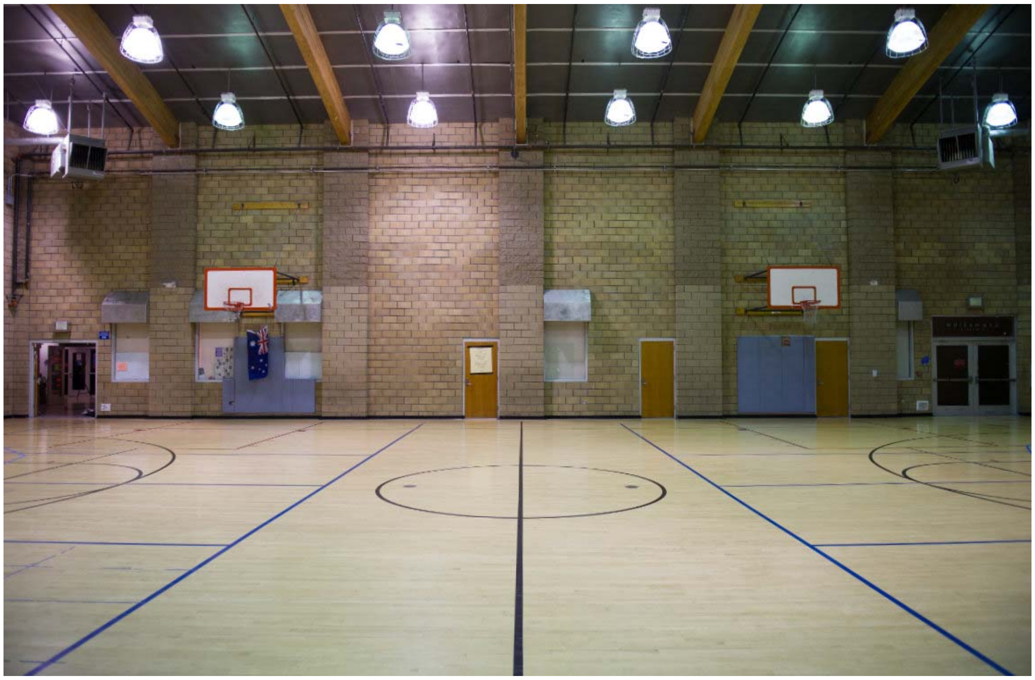


FIGURE 9: BASELINE MH FIXTURE LIGHT LEVEL AND COLOR UNIFORMITY

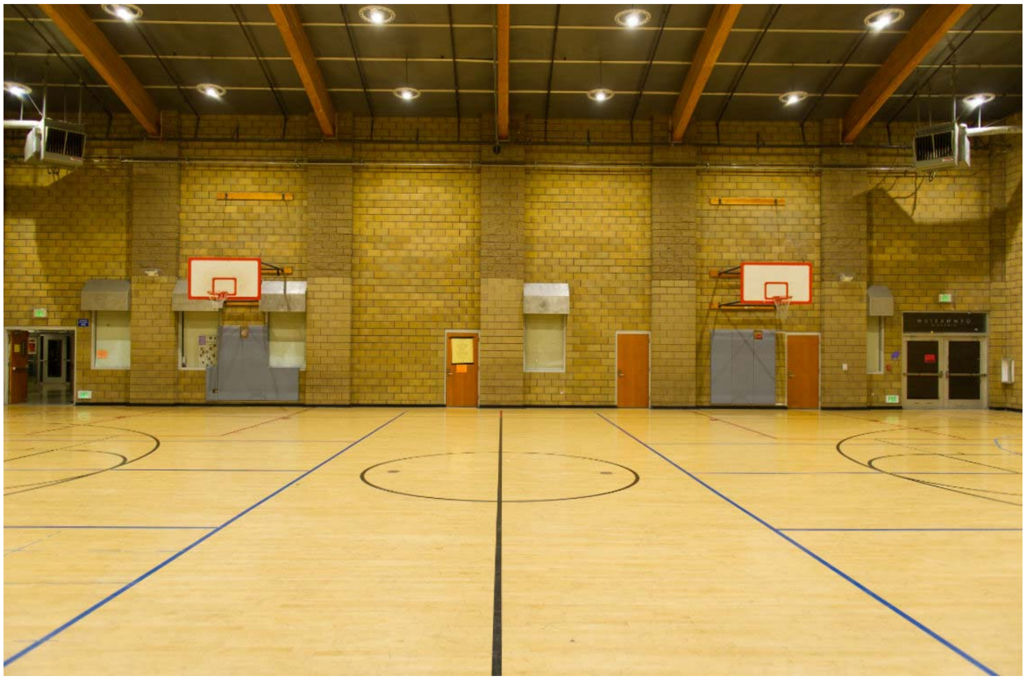


FIGURE 10: INSTALLED LED FIXTURE LIGHT LEVEL AND COLOR UNIFORMITY

CORRELATED COLOR TEMPERATURE MEASUREMENTS

Table 9 and Table 10 list the correlated color temperature measurements in the gymnasium. These measurements were recorded at the same nine reference points indicated in Figure 8. The metal halide fixtures averaged 4,900K while the BritePointe LED averaged closer to 4,000K. The metal halide lamps (Sylvania M400/U) and BritePointe LED fixtures are nominally 4,000K.

TABLE 9: PROBE-START METAL HALIDE CORRELATED COLOR TEMPERATURE (K)

	WEST BASKET	MID-COURT	EAST BASKET
NORTH (WINDOWS)	5,007	5,219	5,050
MID-COURT	4,830	4,902	4,843
SOUTH (OFFICES)	5,088	4,843	4,408

TABLE 10: BRITEPOINTE LED HIGH-BAY CORRELATED COLOR TEMPERATURE (K)

	WEST BASKET	MID-COURT	EAST BASKET
NORTH (WINDOWS)	3,920	4,001	3,937
MID-COURT	3,984	4,003	3,994
SOUTH (OFFICES)	3,949	3,956	3,886

SURVEY RESULTS

kW Engineering worked with site staff to conduct three surveys as a part of this study. Two surveys regarding the lighting quality were sent to the site maintenance staff and occupants – one before and one after the LEDs were installed. Another survey was conducted with the lighting installers regarding the installation process.

PRE-RETROFIT SURVEY

A pre-retrofit survey was conducted to establish the perception of lighting quality associated with the baseline MH fixtures. A survey was sent out mid-January, 2013, after the holiday season to maximize participation before the installation of the LED fixtures. A total of fourteen surveys were sent to the occupants of the space along with several frequent users of the gymnasium. In order to attempt to obtain a statistically significant sample, several follow up communications with the tenant of the gymnasium were necessary. Responses, however, indicated reference to the new LED fixtures, which at that point had already been installed. Additional follow-up with the respondents of the survey found that only one of the respondents referenced the baseline MH fixtures while taking the survey. Therefore, the team concluded that the pre-retrofit (baseline MH) survey did not yield significant results.

POST-RETROFIT SURVEY

According to the results from the post-retrofit (LED) user survey, 63% of respondents spend less than two hours in the gymnasium performing athletics, maintenance, or casual face-to-face conversations. The space is most often (63% of the time) used with the curtain drawn across mid-court, and all of the lights on. All occupants agreed or strongly agreed that the space is evenly lit without bright or dim spots and that the lighting appears uniform in the space. In addition, all occupants agreed or strongly agreed that the LED lighting fixtures were nice-looking and help create a good image for the organization. There were fourteen surveys that were sent out. Of these, nine respondents initiated the survey; however, one respondent did not complete the survey and is not included in the results below. A total of eight survey responses were tallied for the report.

The following tables provide survey results regarding lighting quality. The full survey question and responses are included in Appendices F, G, and H.

In reference to the LED lighting quality, all participants agreed or strongly agreed that the quality of light is pleasant and uniform throughout the gymnasium.

Table 11: LED Lighting Quality Survey Results

Light Quality:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Does Not Apply
Space is evenly lit	0.0%	0.0%	0.0%	25.0%	75.0%	0.0%
Light color appears uniform	0.0%	0.0%	0.0%	50.0%	50.0%	0.0%
Fixtures are nice-looking	0.0%	0.0%	0.0%	37.5%	62.5%	0.0%
Fixtures create good image for organization	0.0%	0.0%	0.0%	50.0%	50.0%	0.0%
Environment of gym is pleasant	0.0%	0.0%	0.0%	50.0%	50.0%	0.0%

In reference to glare from the fixtures, most respondents reported rare instances of glare from the fixtures.

Table 12: LED Lighting Glare Survey Results

Glare From:	Never	Rarely	Sometimes	Often	Always
Fixtures (fixtures too bright)	0.0%	62.5%	37.5%	0.0%	0.0%
Floor and walls	25.0%	50.0%	25.0%	0.0%	0.0%
Equipment in the room	37.5%	62.5%	0.0%	0.0%	0.0%
Natural light (windows)	25.0%	62.5%	12.5%	0.0%	0.0%

In reference to the light level in performing various tasks most respondents reported the light levels as just right.

Table 13: LED Lighting Task Survey Results

Task:	Much too bright	Too bright	Just right	Too dim	Much too dim	Does not apply
Athletics	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%
Facility maintenance	0.0%	0.0%	87.5%	12.5%	0.0%	0.0%
Paper tasks (read/write)	0.0%	12.5%	50.0%	12.5%	0.0%	0.0%
Using a computer	0.0%	12.5%	37.5%	0.0%	0.0%	50.0%
Multi-media presentations	0.0%	0.0%	50.0%	0.0%	0.0%	50.0%
Face-to-face conversations	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%

Regarding the perception of color temperature, the responses were varied with not one category receiving the majority vote.

TABLE 14: LED LIGHTING COLOR SURVEY RESULTS

COLOR TEMPERATURE:	VERY WARM	SOMEWHAT WARM	NEUTRAL	SOMEWHAT COOL	VERY COOL	DO NOT KNOW
HOW DO THE FIXTURES APPEAR?	0.0%	37.5%	25.0%	25.0%	12.5%	0.0%
WHAT IS YOUR PREFERENCE?	0.0%	25.0%	50.0%	0.0%	25.0%	0.0%

INSTALLER SURVEY

The installer survey was sent to the City maintenance staff who installed the LED fixtures. The questions focused on the equipment installation process and staff's experiences with previous and current lighting installations. All five installers completed surveys. All but one respondent has performed over 15 LED installations (highest possible response). All installers have had experience with several types of lighting equipment applications (e.g., high bay, offices, exterior) and lighting technologies (linear fluorescent, LED, metal halide, high pressures sodium, halogen, CFL).

The installers were asked if there were any difficulties with the installation of the fixtures. The most common difficulty reported by the installers was the wiring/rewiring of the new LED fixtures. Installers reported that the BritePointe fixtures, unlike other fixtures they've worked with, have "no accessible wiring compartment". Since they were concerned about voiding the warranty (per statement on fixture) if they unscrewed the plate to access wiring, they had to make connections and then "stuff the wires through a small opening in connector". The installers also encountered complications when removing the LED fixtures. Due to a lack of access to wiring, "you have to wedge out the plastic adapter and try to work the wires through the small opening while the fixture is suspended in a high bay position."

There was no consensus on whether the LED fixtures were easier or more difficult to install when compared to HID fixtures. Most respondents, however, did not feel that any problems encountered were easily remedied. In addition, one of the fixtures was non-operational at the time of installation and had to be replaced by BritePointe. Some results from the installer survey are displayed in the following tables.

TABLE 15: INSTALLATION PROCESS SURVEY RESULTS

ANSWER CHOICES:	STRONGLY DISAGREE	DISAGREE	NEUTRAL	AGREE	STRONGLY AGREE	DOES NOT APPLY
THE INSTALLATION WAS SIMPLE AND STRAIGHTFORWARD	0.0%	20.0%	40.0%	40.0%	0.0%	0.0%
THE INSTALLATION WAS THE SAME LEVEL OF DIFFICULTY AS INSTALLING HID FIXTURES	20.0%	20.0%	20.0%	0.0%	20.0%	20.0%
ANY PROBLEMS ENCOUNTERED DURING THE INSTALLATION WERE EASILY REMEDIED	25.0%	50.0%	25.0%	0.0%	0.0%	0.0%

TABLE 16: INSTALLER DIFFICULTY SURVEY RESULTS

DIFFICULTIES ENCOUNTERED IN:	REPLY: YES
REMOVAL OF MH FIXTURE	20.0%
DISPOSAL OF MH FIXTURE	0.0%
REWIRING FOR NEW FIXTURE	20.0%
NOT ENOUGH SPACE FOR LED FIXTURE	0.0%
WIRING OF LED FIXTURE	60.0%
MOUNTING OF LED FIXTURE	40.0%
WEIGHT OF LED FIXTURE	0.0%
LED FIXTURE(S) HAD LOOSE PARTS	0.0%
LED FIXTURE(S) HAD BROKEN/MISSING PARTS	0.0%
LED FIXTURE(S) WAS NON-OPERATIONAL	80.0%
LED FIXTURE(S) WAS NOT DELIVERED	0.0%
N/A (NO PROBLEMS)	0.0%

DATA ANALYSIS

ANALYSIS OF POWER MEASUREMENTS

The power measurements collected from the probe start metal halide and the LED high-bay installations demonstrate that the LED fixtures consume less power than the MH fixtures.

As stated in the Results section, it was discovered that the baseline fixtures were not consuming the wattage expected from a 400-watt MH fixture. A probe-start 400-watt MH fixture typically draws 458 watts per fixture while in situ measurement indicated that the fixture was drawing 291 watts.

LED fixtures provided power savings even though the baseline MH fixtures were wired incorrectly and were consuming less power than expected. The in-situ MH to LED fixture wattage decreased 99 watts or 34%, from 291 watts to 192 watts per fixture. If the MH fixtures had been wired correctly, the expected per-fixture wattage decrease would have been 293 watts or 60% (from 485 watts to 192 watts per fixture). When extrapolated out to the entire gymnasium (30 fixtures), the total power savings are 2.79 kW for the in-situ fixtures and could potentially be 8.80 kW for the correctly wired fixtures. Table 17 summarizes the comparative differences of measurements between the in-situ (Logged) MH, properly-wired MH, and LED fixtures.

TABLE 17: MH AND LED FIXTURE MEASUREMENTS

PARAMETER	MH - LOGGED	MH - 24µF	LED
NOMINAL WATTS/FIXTURE (WATTS)	400	400	200
CAPACITANCE (µF)	15.1	25.1	n/a
POWER/FIXTURE (WATTS)	291	489	192
MEASURED VOLTAGE (VOLTS)	283	285	283
CORRECTED POWER (KW)	291	485	192
INPUT POWER DIFFERENCE TO LED FIXTURE (WATTS)	99	293	N/A
NUMBER OF FIXTURES	30	30	30
TOTAL POWER (KW)	8.73	14.56	5.76
TOTAL POWER DIFFERENCE COMPARED TO LED FIXTURE (KW)	2.79	8.80	N/A

Analysis of Illuminance Measurements

Using the illuminance data sets collected from the probe start metal halide and the LED high-bay installations, one can draw conclusions with regard to the distribution and uniformity of the light fixtures. This comparison uses the ratio of the maximum illuminance value versus the minimum illuminance value to compare the relative distribution of the light in the space. A smaller ratio means that the monitored illuminance values are closer together and that light levels are more even. As shown in Table 18 the LED fixture installation has a much lower maximum-to-minimum ratio, and thus more evenly distributed light.

Table 18: Illuminance Max/Min Ratios

Lighting Technology	Probe-Start Metal Halide	BritePointe LED High-bay
Maximum Illuminance (FC)	38.9	56.7
Average Illuminance (FC)	19.6	35.5
Minimum Illuminance (FC)	9.20	23.8
Max/Min Ratio	4.23	2.38

Averaging these illuminance data sets provides valuable insight into the overall illuminance of the gymnasium. The BritePointe fixture provides 81% more light than the base case probe-start metal halide fixture with the smaller capacitor. Adjusting for the faulty capacitor wiring, we expect the probe-start metal halide fixtures would have produced approximately 60% more luminous flux (lumens), raising the average baseline level to approximately 31.5 (instead of 19.6) footcandles. Thus, the average illuminance for the LED installation (35.5 FC) would only be 12.6% brighter than the metal halide fixtures (31.5 FC) wired for an appropriately sized capacitor.

Analysis of Correlated Color Temperature (CCT)

The CCT data sets collected from the probe start metal halide and the LED high-bay installations indicate the LED fixtures had much closer color temperature according to the specifications provided by the manufacturer. Again, the faulty capacitor installation affected this measurement, as the smaller capacitance shifted the color temperature toward the blue-end of the spectrum. The typical CCT skew of for dimming metal halide lamps to the level observed in this study is approximately 25% (equivalent to 5,125K), which approximately lines up with the data we saw in our study.[ii]

EVALUATIONS

Based on the results of this LED high bay fixture retrofit, the selected 200-watt BritePointe fixture proved that LED replacements of 400W MH fixtures are effective in creating a desired lighting effect while reducing power demands and creating energy savings.

The BritePointe fixture achieved 34% savings in demand and energy use as compared to the in-situ, incorrectly-wired MH fixtures. Because the gym usage is not consistent, annual energy savings was evaluated based on the operating schedule provided by the tenant at the gymnasium. Based on the stated operating hours, the annual operating hours for the gymnasium lighting are 3,354 hours per year. Using these hours, the annual energy savings are 9,941 kWh per year for the in-situ MH fixtures as compared to the LED fixtures. When the total costs of the installation are included, the simple payback for the in-situ scenario is 16.0 years.

Taking into account the scenario where the correct capacitance was used, the LED fixtures are estimated to have achieved 60% savings in demand and energy use. Using the same operating hours described above and correcting for a slight difference in input voltage from the monitored fixture to the test fixture, the annual energy savings for correctly wired 400W MH fixtures to LED fixtures would have been 29,488 kWh per year. (Note: the Data Analysis section describes how we calculated the potential baseline input power.) The simple payback in a correctly-wired MH baseline scenario is 5.4 years.

Table 19 and Table 20 summarize energy and cost comparisons between the LED high bay retrofit and the MH – Logged (or in-situ) fixtures and MH-24μF (proper capacitance) fixtures. Utility incentives are not included in the calculations of simple payback.

TABLE 19: ANNUAL ENERGY & COST SAVINGS COMPARISON BETWEEN MEASURED BASELINE AND LED HIGH BAY

	ANNUAL ENERGY USE (KWH/YR)	ANNUAL ENERGY SAVED (KWH/YR)	ENERGY SAVED AS PERCENT OF BASELINE	ANNUAL ENERGY COST	ANNUAL ENERGY COST SAVINGS (@$0.166/KWH)	LED INSTALLED COST	PAYBACK PERIOD (YEARS)
MH - LOGGED	29,270	-	-	$4,859	-	-	-
LED HIGH BAY	19,329	9,941	34%	$3,209	$1,650	$26,420	16.0

TABLE 20: ANNUAL ENERGY & COST SAVINGS COMPARISON BETWEEN CORRECTLY WIRED BASELINE AND LED HIGH BAY

	ANNUAL ENERGY USE (KWH/YR)	ANNUAL ENERGY SAVED (KWH/YR)	ENERGY SAVED AS PERCENT OF BASELINE	ANNUAL ENERGY COST	ANNUAL ENERGY COST SAVINGS (@$0.166/KWH)	LED INSTALLED COST	PAYBACK PERIOD (YEARS)
MH – WIRED CORRECTLY	48,817	-	-	$4,859	-	-	-
LED HIGH BAY	19,329	29,488	60%	$3,209	$4,895	$26,420	5.4

TABLE 21: GYM OPERATING HOURS (STATED)

DAY	ON TIME	OFF Time
SUN.	8:30 AM	9:00 PM
MON.	3:30 PM	10:00 PM
TUES.	11:30 AM	9:30 PM
WED.	3:30 PM	10:00 PM
THURS.	11:30 AM	9:30 PM
FRI.	3:30 PM	10:00 PM
SAT.	8:30 AM	9:00 PM

TABLE 22: TECHNICAL SUMMARY OF LED AND MH SCENARIOS (30 FIXTURES)

PARAMETER	MH - LOGGED	MH - 24µF	LED
NOMINAL WATTS/FIXTURE (WATTS)	400	400	200
POWER/FIXTURE (WATTS)	290.9	488.6	192.1
CAPACITANCE (MF)	15.1	25.1	n/a
MEASURED VOLTAGE (VOLTS)	283	285	283
CORRECTED POWER (KW)	290.9	485.2	192.1
TOTAL POWER (KW)	8.73	14.56	5.76
OPERATING HOURS	3,354	3,354	3,354
ANNUAL ENERGY USE (KWH)	29,270	48,817	19,329
ENERGY SAVINGS COMPARED TO LED FIXTURES (KWH)	9,941	29,488	N/A

Lighting Performance

The BritePointe LED fixture improved the lighting quality in the space over the baseline, probe-start MH system by increasing the uniformity of the lighting in the space, primarily through better photometric performance. The light levels rose significantly, due to the faulty baseline capacitor installation. With a properly installed capacitor we would expect an average illuminance to increase by approximately 12.6% as compared to the in-situ MH installation. The more precise tolerance of LED fixture components offered better color temperature uniformity than the MH fixtures.

However, of the 30 BritePointe LED fixtures that were installed, there were three instances of failed fixtures:

1. One fixture was non-operational at the time of the installation and was replaced with a new fixture from BritePointe. According to BritePointe, the non-operational fixture had a driver failure.
2. An additional fixture failed during normal use of the gym. Soon after the installation was complete, one fixture became dislodged from the conduit pendant mounting (Figure 11). It was not clear what caused the fixture to become dislodged. There was no noticeable, physical damage to the failed fixture. The fixture was repaired on site by a BritePointe employee and remounted. Additional testing of the mounting was considered by BritePointe, but no additional information was provided for this report.
3. The third failure occurred on the same fixture that had previously become dislodged during normal use. The cause for failure is unknown. PG&E requested details of the cause of failure from BritePointe, but did not receive a response. After several weeks of inactivity in addressing the City's request for assistance, BritePointe provided a replacement fixture. As of the completion of this report, the replacement fixture had not been installed.

FIGURE 11: FAILED LED FIXTURE

ADDITIONAL CUSTOMER FEEDBACK

Occupants of the space were satisfied with the lighting quality improvements in the space achieved by the BritePointe fixtures. In the three categories of gymnasium usage (athletics, maintenance, or casual face-to-face conversations), all but one response stated that the light levels were "just right." Survey questions regarding the lighting quality also had positive results as all respondents agreed or strongly agreed that the lighting was uniform in color, are nice-looking, and creates a good image for the organization.

During follow up site visits, additional feedback was offered by the occupants and City maintenance staff to kW Engineering. These comments originated as a result of additional fixture failures after the original survey was conducted. Concerns were expressed over the reliability of the fixtures as the project had then experienced three failures. In related comments, the client expressed dissatisfaction with the amount of time it took to receive replacement fixtures from the vendor.

RECOMMENDATIONS

Based on the data collected in this study, LED high bay lighting for gymnasiums is a strong candidate for adoption into the energy efficiency portfolio of the California IOUs. While the LED fixtures performed well overall, there are key issues that need to be addressed in order to encourage the adoption of LED fixtures in gymnasiums.

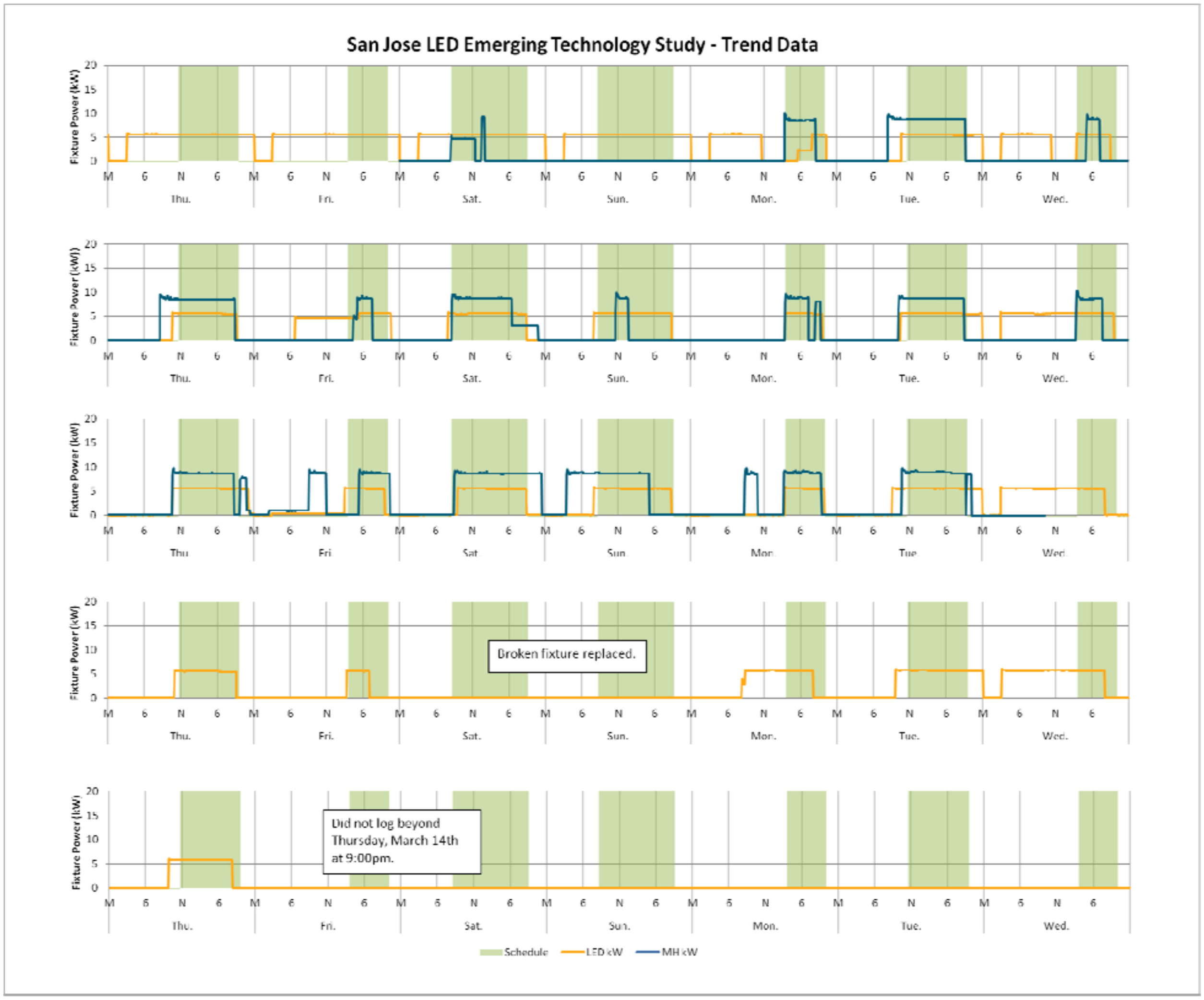
It is recommended that fixture selection criteria include the capability to withstand significant ball-shock damage. Special attention should be made regarding specifications with minimum warranty requirements (e.g. 5 years) that state manufacturer response time when a fixture fails within the first year. It is clear that any lighting installed in a gymnasium with sports activities must be robust enough to withstand significant ball-shock damage. During the fixture selection phase, BritePointe assured the Team that the fixtures were suitable for sports activities in a gymnasium. Even with this due diligence, fixtures are still prone to failure in an active gymnasium environment. Manufacturers should continue to be encouraged to design rugged, impact-resistant fixtures for gymnasiums.

Besides fixture durability, it is important to conduct a thorough assessment of installation best practices for a selected LED fixture in order to ensure the best possible installation. When possible, request that a manufacturer’s representative work with installation crew during the initial phase of installation.

Also, due to the significant differences in light output and aesthetics between MH and LED fixtures, it is important to view the specific LED fixtures being considered in place at an existing site or as part of a mock-up/demo at the project site. This step provides an essential opportunity to assess potential glare and light distribution issues before a final LED fixture is selected.

APPENDICES

APPENDIX A. POWER MONITORING DATA



Appendix B. Spot Power Measurements

LED - PowerSight PS250 Measurement on Site - 2/13/2013
One fixture not operational (29 of 30 LED fixtures)

Leg:	A	B	C	Total
Amps (A)	7.30	6.47	7.17	20.94
Volts (V)	280	282	281	281
Power (kW)	1.904	1.695	1.864	5.46
Power Factor (PF)	0.93	1.00	1.00	0.93

LED - PowerSight PS250 Measurement on Site – 3/12/2013
All 30 LED fixtures operational

Leg:	A	B	C	Total
Amps (A)	7.32	7.23	7.18	21.73
Volts (V)	283	282	284	283
Power (kW)	1.943	1.882	1.873	5.70
Power Factor (PF)	0.94	1.00	1.00	0.93

MH - PowerSight PS250 Measurement on Site – 4/24/2013
One MH fixture at 15 μF capacitance (fixture only on one leg of circuit)

Leg:	A	B	C	Total
Amps (A)	0.99	0	0	0.99
Volts (V)	284	282	284	283
Power (kW)	0.245	0	0	0.245
Power Factor (PF)	0.90	1.00	1.00	0.90

MH - PowerSight PS250 Measurement on Site – 4/24/2013
One MH fixture at 26 μF capacitance (fixture only on one leg of circuit)

Leg:	A	B	C	Total
Amps (A)	1.79	0	0	1.79
Volts (V)	285	283	285	284
Power (kW)	0.487	0	0	0.487
Power Factor (PF)	0.96	1.00	1.00	0.96

MH - PowerSight PS250 Measurement on Site – 4/24/2013
One MH fixture at 42 μF capacitance (fixture only on one leg of circuit)

Leg:	A	B	C	Total
Amps (A)	4.44	0	0	4.44
Volts (V)	285	283	285	284
Power (kW)	1.212	0	0	1.212
Power Factor (PF)	0.96	1.00	1.00	0.96

APPENDIX C. MANUFACTURER SPECIFICATIONS FOR BRITEPOINTE HYBEEM FIXTURE (LED FIXTURE)

CATALOG NO.
TYPE NO. JOB NAME.

BritePointe

HyBeem Fixture

BP400 High Bay Lighting

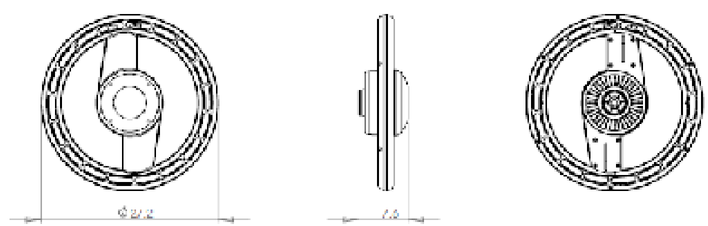
- Exchange existing HID or T5/T8 fixtures with HyBeem fixture
- Mounting: Hook & Plug or ¾" Conduit
- 55+% reduction in energy usage
- 200 Watt universal 100-277VAC input
- 15,880 lumen light output
- No drop in lumens over 50,000 hours
- Instant on/off
- 5 year warranty

ORDERING INFORMATION

Catalog Number: Example: BP400UNIGRY52HP6

BP400	UNI				
MODEL	VOLTAGE	TYPE	COLOR TEMPERATURE	MOUNTING OPTIONS	OPTIONS
400 watt equivalent	UNI-120-277VAC	GRY-down light CLR-up light	52-5000K 40-4000K	HP3-Hook & plug 3-foot CO cord HP6- Hook & plug 6-foot CO cord HP11- Hook & plug 11-foot CO cord ¾" conduit	NS- No Screen

TECHNICAL INFORMATION



ADAPTER	ADD X" HEIGHT
E39	14.5"
3/4" CONDUIT HUB	2"
HOOK AND PLUG	4"

BRITEPOINTE SPECIFICATION SHEET

APPENDIX D: MANUFACTURER SPECIFICATIONS FOR SYLVANIA M4000U LAMP (BASELINE MH LAMP)

| Return to search | | Print Page |

Product Number: 64490

Order Abbreviation: M400/U

General Description: 400W METALARC quartz metal halide lamp, E39 base, BT37 bulb, enclosed fixture rated, universal burn, clear, 4000K

Product Information	
Abbrev. With Packaging Info.	M400U 6/CS 1/SKU
ANSI Code	M59/S
Approx. Lumens (initial - horizontal)	32000
Approx. Lumens (initial - vertical)	36000
Approx. Lumens (mean - horizontal)	20500
Approx. Lumens (mean - vertical)	23500
Arc Length (in)	1.77
Arc Length (mm)	45
Average Rated Life - Horizontal (hr)	15000
Average Rated Life - (hr)	15000
Average Rated Life - Vertical (hr)	20000
Base	E39 Mogul
Bulb	BT37
Color Rendering Index (CRI)	65
Color Temperature/CCT (K)	4000
Diameter (in)	4.6
Diameter (mm)	117
Family Brand Name	Metalarc®
Fixture Requirement	S
Hot Restrike Time (min)	7-12
Lamp Finish	Clear
Light Center Length - LCL (in)	7
Light Center Length - LCL (mm)	178
Maximum Base Temperature - Fahrenheit	482
Maximum Base Temperature - Celsius	250
Maximum Bulb Temperature - Fahrenheit	752
Maximum Bulb Temperature - Celsius	400
Maximum Overall Length - MOL (in)	11.5
Maximum Overall Length - MOL (mm)	292
Nominal Voltage (V)	135.00

APPENDIX E: MANUFACTURER SPECIFICATIONS FOR ADVANCE 71A6091 BALLAST (BASELINE MH BALLAST)

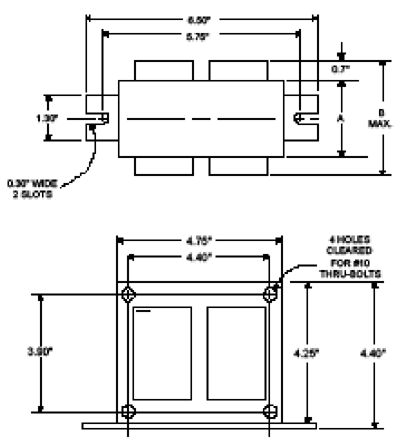
ADVANCE

Metal Halide Lamp Ballast

Catalog Number 71A6091
For 400W M59
60 Hz CWA
Status: Active

DIMENSIONS AND DATA

4 1/4 X 4 3/4 CORE - 2 COIL UNIT

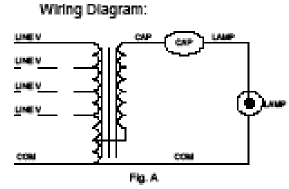


INPUT VOLTS		120	208	240	277	
CIRCUIT TYPE	CWA					
POWER FACTOR (min)	90%					
REGULATION						
Line Volts	±10%					
Lamp Watts	±10%					
LINE CURRENT (Amps)						
Operating		4.00	2.30	2.00	1.75	
Open Circuit		3.00	1.75	1.50	1.30	
Starting		3.50	2.00	1.75	1.50	
UL TEMPERATURE RATINGS						
Insulation Class	H(180°C)					
Coil Temperature Code	1029	D	E	D	E	
MIN. AMBIENT STARTING TEMP.	-20°F or -30°C					
NOM. OPEN CIRCUIT VOLTAGE	300					
INPUT VOLTAGE AT LAMP DROPOUT		60	104	120	138	
INPUT WATTS	458					
RECOMMENDED FUSE (Amps)		10	7	5	5	
CORE and COIL						
Dimension (A)	2.00					
Dimension (B)	3.90					
Weight (lbs.)	12					
Lead Lengths	12"					
CAPACITOR REQUIREMENT						
Microfarads	24.0					
Volts (min.)	400					
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)	270-330					
Short-Circuit Current Test (Amps)						
Secondary Current	3.50-4.30					
Input Current		2.70 4.20	1.55 2.40	1.35 2.10	1.10 1.80	-

Capacitor: 7C240P40-R

Capacitance: 24
Dia/Oval Dim: 1.75
Height: 5.125
Temp Rating: 105°C

Wiring Diagram:



Ignitor: NA

This ballast does not require the use of an ignitor.

Ordering Information

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

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

ADVANCE TRANSFORMER CO.
O'HARE INTERNATIONAL CENTER - 10275 WEST HIGGINS ROAD - ROSEMONT, IL 60018 07/12/04
Customer Support/Technical Service: Phone: 800-372-3331 - Fax: 630-307-3071
Corporate Offices: Phone: 800-322-2086

APPENDIX F: BASELINE (MH) SURVEY QUESTIONS AND RESPONSES

Q1: WHICH OF THESE BEST DESCRIBES THE TYPE OF WORK THAT YOU DO?

ANSWER CHOICES	RESPONSE
FACILITY MANAGEMENT	25.0%
COACHING, FITNESS INSTRUCTION	0.0%
YOUTH GROUP LEADERSHIP	37.5%
PROGRAM PARTICIPANT	0.0%
FACILITY MAINTENANCE/OPERATIONS	37.5%
OTHER	0.0%

Q2: WHAT IS YOUR AGE?

ANSWER CHOICES	RESPONSES
20 OR YOUNGER	12.5%
21-30	25.0%
31-40	37.5%
41-50	25.0%
50 OR OLDER	0.0%

Q3: WHAT IS YOUR GENDER?

ANSWER CHOICES	RESPONSES
FEMALE	50.0%
MALE	50.0%

A

B

C

Q4: BASED ON THE FIXTURES ABOVE, WHICH MOST CLOSELY RESEMBLES THE OLD OVERHEAD LIGHTING IN THE GYMNASIUM?

ANSWER CHOICES	RESPONSES
A	0.0%
B	50.0%
C	0.0%
I DON'T SEE THE GYMNASIUM FIXTURE HERE.	50.0%

Q5: On a typical day, how long are you in the gymnasium?

Answer Choices	Responses
More than 6 hours	0.0%
4-6 hours	0.0%
2-4 hours	37.5%
Less than 2 hours	62.5%

Q6: Which tasks do you (personally) perform in the this space? Please check all items that apply.

Answer Choices	Response
Athletics	50.0%
Maintenance	37.5%
Paper-based tasks (reading/writing)	25.0%
Computer use	25.0%
Multi-media presentations	0.0%
Casual, face to face conversations with other people	62.5%

Q7: When using one-half of the gym, what are the conditions?

Answer Choices	Responses
Curtain drawn across mid-court; all lights on	87.5%
Curtain drawn across mid-court; half the lights on	0.0%
Open court (no curtain); all lights on	12.5%
Open court (no curtain); half the lights on	0.0%
I only use the gym in its entirety	0.0%

Q8: To what extent do you agree or disagree with the following statements about the OLD lighting quality in the gym?

Light Quality:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Does Not Apply
The space is evenly lit without very bright or dim spots	0.0%	0.0%	14.3%	28.6%	57.1%	0.0%
The lighting flickers throught the day	42.9%	14.3%	42.9%	0.0%	0.0%	0.0%
The lighting color appears uniform in space	0.0%	0.0%	28.6%	57.1%	14.3%	0.0%
My skin is an unnatrual tone under the lighting	28.6%	14.3%	57.1%	0.0%	0.0%	0.0%

Q9: To what extent do you agree or disagree with the following statements about the OLD light's effects on the environment in the gym?

Lighting environment:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Does Not Apply
The lighting fixtures in the gym are nice-looking	0.00%	0.00%	28.57%	28.57%	42.86%	0.00%
The lighting helps create a good image for the organization	0.00%	0.00%	42.86%	28.57%	28.57%	0.00%
The room walls have a pleasant brightness	0.00%	14.29%	28.57%	42.86%	14.29%	0.00%
The room floor has a pleasant brightness	0.00%	14.29%	28.57%	42.86%	14.29%	0.00%
The room ceiling has a pleasant brightness	0.00%	0.00%	42.86%	42.86%	14.29%	0.00%
Overall, the environment in the gym is pleasant	0.00%	0.00%	42.86%	42.86%	14.29%	0.00%

Q10: How often do you experience any of the following condition in the gym durin an average day? For the purpose of answering these questions, consider the definition of glare to be unwanted light (i.e., loud noise is to sounds as glare is to light)

Glare from:	Never	Rarely	Sometimes	Often	Always
the lights (the light fixtures appear too bright)	42.86%	14.29%	28.57%	14.29%	0.00%
the light fixtures reflected on the floor and/or walls	42.86%	28.57%	28.57%	0.00%	0.00%
the light fixtures on the equipment in the room	85.71%	14.29%	0.00%	0.00%	0.00%
natural light	42.86%	57.14%	0.00%	0.00%	0.00%

Q11: How would you rate the OLD lighting in the gym for the following tasks?

Task:	Much Too Bright	Too Bright	Just Right	Too Dim	Much Too Dim	Does Not Apply
Athletics	0.00%	0.00%	85.71%	0.00%	0.00%	14.29%
Facility maintenance	0.00%	0.00%	85.71%	0.00%	0.00%	14.29%
Paper tasks (read/write)	0.00%	0.00%	42.86%	14.29%	0.00%	42.86%
Using a computer	0.00%	0.00%	57.14%	0.00%	0.00%	42.86%
Multi-media presentations	0.00%	42.86%	28.57%	0.00%	0.00%	28.57%
Face-to-face conversations	0.00%	0.00%	85.71%	0.00%	0.00%	14.29%

Q8: Lighting comes in a range of colors, from a "warm" white to a "cool" white. "Warm" light is often described as slightly yellow in appearance, and "cool" light is often described as slightly blue in appearance. Using the indicated color range, please indicate:

Color Temperature:	Very Warm	Somewhat Warm	Neutral	Somewhat Cool	Very Cool	Do Not Know
What is the color appearance of the lighting in your space?	14.29%	14.29%	28.57%	14.29%	14.29%	14.29%
What would you prefer the color appearance of the lighting in the space?	0.00%	14.29%	71.43%	0.00%	0.00%	14.29%

APPENDIX G: INSTALLED (LED) SURVEY QUESTIONS AND RESPONSES

Q1: WHICH OF THESE BEST DESCRIBES THE TYPE OF WORK THAT YOU DO?

ANSWER CHOICES:	RESPONSE
FACILITY MANAGEMENT	25.0%
COACHING, FITNESS INSTRUCTION	0.0%
YOUTH GROUP LEADERSHIP	37.5%
PROGRAM PARTICIPANT	0.0%
FACILITY MAINTENANCE/OPERATIONS	12.5%
OTHER	25.0%

Q2: WHAT IS YOUR AGE?

ANSWER CHOICES:	RESPONSES
20 OR YOUNGER	12.5%
21-30	25.0%
31-40	25.0%
41-50	37.5%
50 OR OLDER	0.0%

Q3: WHAT IS YOUR GENDER?

ANSWER CHOICES:	RESPONSES
FEMALE	37.5%
MALE	62.5%


A


B


C

Q4: BASED ON THE FIXTURES ABOVE, WHICH MOST CLOSELY RESEMBLES THE NEW OVERHEAD LIGHTING IN THE GYMNASIUM?

ANSWER CHOICES:	RESPONSES
A	0.0%
B	0.0%
C	87.5%
I DON'T SEE THE GYMNASIUM FIXTURE HERE.	12.5%

Q5: On a typical day, how long are you in the gymnasium?

Answer Choices:	Responses
More than 6 hours	0.0%
4-6 hours	12.5%
2-4 hours	25.0%
Less than 2 hours	62.5%

Q6: Which tasks do you (personally) perform in the this space? Please check all items that apply.

Answer Choices:	Responses
Athletics	50.0%
Maintenance	62.5%
Paper-based tasks (reading/writing)	0.0%
Computer use	0.0%
Multi-media presentations	0.0%
Casual, face to face conversations with other people	62.5%

Q7: When using one-half of the gym, what are the conditions?

Answer Choices:	Responses
Curtain drawn across mid-court; all lights on	62.5%
Curtain drawn across mid-court; half the lights on	0.0%
Open court (no curtain); all lights on	25.0%
Open court (no curtain); half the lights on	0.0%
I only use the gym in its entirety	12.5%

Q8: To what extent do you agree or disagree with the following statements about the NEW lighting quality in the gym?

Light Quality:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Does Not Apply
The space is evenly lit without very bright or dim spots	0.0%	0.0%	0.0%	25.0%	75.0%	0.0%
The lighting flickers throughout the day	62.5%	25.0%	12.5%	0.0%	0.0%	0.0%
The lighting color appears uniform in space	0.0%	0.0%	0.0%	50.0%	50.0%	0.0%
My skin is an unnatrual tone under the lighting	12.5%	37.5%	12.5%	25.0%	0.0%	12.5%

Q9: To what extent do you agree or disagree with the following statements about the NEW light's effects on the environment in the gym?

Lighting environment:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Does Not Apply
The lighting fixtures in the gym are nice-looking	0.0%	0.0%	0.0%	37.5%	62.5%	0.0%
The lighting helps create a good image for the organization	0.0%	0.0%	0.0%	50.0%	50.0%	0.0%
The room walls have a pleasant brightness	0.0%	0.0%	37.5%	37.5%	25.0%	0.0%
The room floor has a pleasant brightness	0.0%	12.5%	25.0%	62.5%	0.0%	0.0%
The room ceiling has a pleasant brightness	0.0%	0.0%	37.5%	25.0%	37.5%	0.0%
Overall, the environment in the gym is pleasant	0.0%	0.0%	0.0%	50.0%	50.0%	0.0%

Q10: How often do you experience any of the following condition in the gym during an average day? For the purpose of answering these questions, consider the definition of glare to be unwanted light (i.e., loud noise is to sounds as glare is to light)

Glare from:	Never	Rarely	Sometimes	Often	Always
the lights (the light fixtures appear too bright)	0.0%	62.5%	37.5%	0.0%	0.0%
the light fixtures reflected on the floor and/or walls	25.0%	50.0%	25.0%	0.0%	0.0%
the light fixtures on the Equipment in the room	37.5%	62.5%	0.0%	0.0%	0.0%
natural light	25.0%	62.5%	12.5%	0.0%	0.0%

Q11: How would you rate the NEW lighting in the gym for the following tasks?

Task:	Much Too Bright	Too Bright	Just Right	Too Dim	Much Too Dim	Does Not Apply
Athletics	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%
Facility maintenance	0.0%	0.0%	875.0%	12.4%	0.0%	0.0%
Paper tasks (read/write)	0.0%	12.5%	50.0%	12.5%	0.0%	25.0%
Using a computer	0.0%	12.5%	37.5%	0.0%	0.0%	50.0%
Multi-media presentations	0.0%	0.0%	50.0%	0.0%	0.0%	50.0%
Face-to-face conversations	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%

Q8: Lighting comes in a range of colors, from a "warm" white to a "cool" white. "Warm" light is often described as slightly yellow in appearance, and "cool" light is often described as slightly blue in appearance. Using the indicated color range, please indicate:

Color Temperature:	Very Warm	Somewhat Warm	Neutral	Somewhat Cool	Very Cool	Do Not Know
What is the color appearance of the lighting in your space?	0.0%	37.5%	25.0%	25.0%	12.5%	0.0%
What would you prefer the color appearance of the lighting in the space?	0.0%	25.0%	50.0%	0.0%	25.0%	0.0%

Appendix H: Installer Survey Questions and Responses

Q1: Which of these best describes the type of work that you do?

Answer choices:	Responses
Owner / management	20.0%
Equipment installer	60.0%
Other	20.0%

Q2: What is your age?

Answer choices:	Responses
30 or younger	0.0%
31-40	40.0%
41-50	20.0%
50 or older	40.0%

Q3: What is your gender?

Answer choices:	Responses
Female	0.0%
Male	100.0%

Q4: How many installations do you perform in a given year?

Answer choices:	Responses
1 to 5	20.0%
6 to 10	0.0%
11 to 15	0.0%
15+	80.0%

Q5: Have you ever installed LED fixtures?

Answer choices:	Responses
Yes	0.0%
No (go to question 7)	12.5%

Q6: If you answered yes on question 5, how many LED fixture installations have you completed?

Answer choices:	Responses
1 to 5	0.0%
6 to 15	0.0%
15+	80.0%

Q7: What types of lighting equipment do you typically install? (Select up to three)

Answer choices:	Responses	# Responses
High bay	60.0%	3
Commercial interior (troffers, downlights, etc.)	60.0%	3
Exterior (bollards, pole lighting, wallpacks, etc.)	60.0%	3
Decorative (track lighting, architectural soffit, etc.)	40.0%	2
Specialty or customized	40.0%	2
Other	40.0%	2

Other responses: N/A, All types above

Q8: What lighting technology do you typically use? (Check all that apply)

Answer choices:	Responses	# Responses
Linear fluorescent - T8	60.0%	5
Linear fluorescent - T5	60.0%	3
LED	60.0%	5
Induction	0.0%	0
Metal halide	60.0%	4
Ceramic metal halide	60.0%	2
High pressure sodium	60.0%	3
Halogen	40.0%	2
CFL	40.0%	4
Other (please specify)	40.0%	1

Other response: Low pressure sodium

Q9: Please rank the considerations when choosing a fixture type for an area with "1" being the most important a "9" being the least important.

Answer choices:	1	2	3	4	5	6	7	8	9	10
Specified by customer	0%	0%	20%	0%	0%	20%	0%	20%	40%	0%
Ease of installation	20%	0%	0%	0%	20%	0%	20%	20%	20%	0%
Energy use/energy efficiency	20%	20%	20%	0%	0%	20%	20%	0%	0%	0%
Quality of light output (CRI, color temperature)	0%	20%	0%	20%	0%	20%	0%	0%	0%	0%
Quality of technology (established technology, rated life of lamps)	20%	0%	40%	20%	20%	0%	0%	0%	0%	0%
Quality of product (reliability/track record of a particular brand)	20%	0%	40%	20%	20%	0%	0%	0%	0%	0%
Cost of product	0%	20%	0%	20%	40%	0%	0%	20%	0%	0%
Availability of product (delivery and lead time)	20%	0%	0%	0%	0%	20%	40%	0%	20%	0%
Availability of customer services or sales rep	0%	0%	0%	0%	20%	20%	0%	40%	20%	0%
Other	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%

Q10: Did you encounter any difficulties during the installation? (check all that apply)

Answer choices:	Responses	# Responses
There were no difficulties	0.0%	0
The old fixtures were difficult to remove	20.0%	1
The old fixtures were difficult to dispose	0.0%	0
The wiring was difficult to rewire for the new fixtures	20.0%	1
There was not enough space to mount the new fixtures	0.0%	0
Other (please specify)	60.0%	3

Other responses: N/A, failed new fixture, making up splice

Q11: Did you encounter any problems with the new fixtures? (check all that apply)

Answer choices:	Responses	# Responses
There were no problems	0.0%	0
The wiring of the fixtures made it difficult for installation	60.0%	3
The mounting of the fixtures made it difficult for installation	40.0%	2
The weight of the fixtures made it difficult for installation	0.0%	0
The fixtures had loose parts (e.g. screws, washers) that were easy to drop	0.0%	0
One or more fixtures had broken or missing parts	0.0%	0
One or more fixtures were non-operational	80.0%	4
One or more fixtures were not delivered	0.0%	0
Other (please specify)	20.0%	1

Other response: N/A

Q12: To what extent do you agree or disagree with the following statements about the lighting quality in the gym after the installation of the new fixtures?

Answer choices:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Does Not Apply
The installation was simple and straightforward	0.0%	20.0%	40.0%	40.0%	0.0%	0.0%
The installation was the same level of difficulty as installing HID fixtures	20.0%	20.0%	20.0%	0.0%	20.0%	20.0%
Any problems encountered during the installation were easily remedied	25.0%	50.0%	25.0%	0.0%	0.0%	0.0%

Q13: To what extent do you agree or disagree with the following statements about the lighting quality in the gym after the installation of the new fixtures?

Light Quality:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Does Not Apply
The space is evenly lit without very bright or dim spots	0.0%	20.0%	60.0%	0.0%	0.0%	20.0%
The lighting flickers throughout the day	20.0%	20.0%	20.0%	0.0%	0.0%	40.0%
The lighting color appears uniform in space	0.0%	0.0%	20.0%	60.0%	0.0%	20.0%
My skin is an unnatrual tone under the lighting	0.0%	20.0%	60.0%	30.0%	0.0%	0.0%

Q14: To what extent do you agree or disagree with the following statements about the lights' effects on the environment in the gym after the installation of the new fixtures?

Lighting environment:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Does Not Apply
The lighting fixtures in the gym are nice-looking	0.0%	20.0%	0.0%	40.0%	40.0%	0.0%
The lighting helps create a good image for the organization	0.0%	0.0%	40.0%	20.0%	40.0%	0.0%
The room walls have a pleasant brightness	0.0%	20.0%	60.0%	0.0%	20.0%	0.0%
The room floor has a pleasant brightness	0.0%	20.0%	40.0%	20.0%	20.0%	0.0%
The room ceiling has a pleasant brightness	0.0%	40.0%	40.0%	0.0%	20.0%	0.0%
Overall, the environment in the gym is pleasant	0.0%	20.0%	40.0%	40.0%	0.0%	0.0%

APPENDIX I: METAL HALIDE MANUFACTURER SURVEY

TABLE 23: 400-WATT METAL HALIDE BALLASTS

MANUFACTURER	MODEL	START TYPE	BALLAST TYPE	NOMINAL LAMP WATTAGE	INPUT WATTAGE	NOMINAL POWER FACTOR	DESIGN CAPACITOR SIZE (μF)
Sylvania	M400/Multi-Kit	Probe	Magnetic	400	458	90%	24
Sylvania	M400/Multi-PS-Kit	Pulse	Magnetic	400	452	90%	24
Sylvania	QHE MH	Pulse	Electronic	400	426	98%	None
Philips Advance	71A6051-001D	Probe	Magnetic	400	458	90%	24
Philips Advance	71A6052-001D	Pulse	Magnetic	400	454	90%	26
General Electric	GEM400TRIAC4-5	Probe	Magnetic	400	460	90%	24
General Electric	GEP400MLTAC4-5	Pulse	Magnetic	400	443	90%	24
General Electric	GEM400ML5AA4-5	Probe	Magnetic	400	436	90%	24
General Electric	GE-MH-250-400-MA	Pulse	Electronic	400	431	99%	None
Venture	V90D6414	Probe	Magnetic	400	458	90%	24
Venture	V90J6414	Probe	Magnetic	400	454	90%	24
Venture	V90AM6411	Probe	Magnetic	400	457	90%	24
Venture	V90AM6410	Probe	Magnetic	400	450	90%	24
Venture	V90D7613	Pulse	Magnetic	400	450	90%	26
Venture	V90J7612	Pulse	Magnetic	400	453	90%	26
Average Magnetic Pulse Start Metal Halide					450.4	90%	25.2
Average Electronic Pulse Start Metal Halide					428.5	98.5%	24
Average Magnetic Probe Start Metal Halide					453.9	90%	None
Average Electronic Probe Start Metal Halide					*Not Applicable, Not Available*		

TABLE 24: 320-WATT PULSE START METAL HALIDE BALLASTS

Manufacturer	Model	Start Type	Ballast Type	Nominal Lamp Wattage	Input Wattage	Nominal Power Factor	Design Capacitor Size (μF)
Sylvania	QHE1x320MH	Pulse	Electronic	320	342	98%	None
Sylvania	M320/MULTI-PS-KIT	Pulse	Magnetic	320	368	90%	21
Philips Advance	71A5837BPEE	Pulse	Magnetic	320	342	90%	17.5
Philips Advance	71A5842TAEE	Pulse	Magnetic	320	363	90%	21
Philips Advance	71A5852AEE	Pulse	Magnetic	320	363	90%	21
Philips Advance	71A5892AEE	Pulse	Magnetic	320	363	90%	21
Average Magnetic Pulse Start Metal Halide					359.8	90%	20.3
Average Electronic Pulse Start Metal Halide					342.0	98%	None
Average Magnetic Probe Start Metal Halide					*Not Applicable, Not Available*		
Average Electronic Probe Start Metal Halide					*Not Applicable, Not Available*		

TABLE 25: 315-WATT PULSE START METAL HALIDE BALLASTS

Manufacturer	Model	Start Type	Ballast Type	Nominal Lamp Wattage	Input Wattage	Nominal Power Factor	Design Capacitor Size (mF)
Venture	VEN6-315L-MRD5	Pulse	Electronic	315	341	98%	None
Philips Advance	IZTMH-210315-R-LF	Pulse	Electronic	315	342	98%	None
Average Magnetic Pulse Start Metal Halide					*Not Applicable, Not Available*		
Average Electronic Pulse Start Metal Halide					341.5	98%	None
Average Magnetic Probe Start Metal Halide					*Not Applicable, Not Available*		
Average Electronic Probe Start Metal Halide					*Not Applicable, Not Available*		

TABLE 26: 400-WATT PROBE START METAL HALIDE LAMPS

MANUFACTURER	MODEL	NOMINAL WATTAGE	LAMP LIFE (HOURS)	CRI	CCT	INITIAL LUMENS	DESIGN LUMENS
Philips	MH400/U	400	20,000	65	3900	39,000	25,350
Philips	MP400/BU	400	20,000	65	4000	38,000	26,600
Sylvania	MP400/BU-Only	400	20,000	65	3600	40,000	26,000
Sylvania	MS400/BU-Only	400	20,000	65	4000	42,000	26,000
Sylvania	M400/U	400	20,000	65	4000	36,000	23,500
Average Probe Start Metal Halide			20,000	65	3900	39,000	25,490

TABLE 27: 315-320 WATT CERAMIC PULSE START METAL HALIDE LAMPS

MANUFACTURER	MODEL	NOMINAL WATTAGE	LAMP LIFE (HOURS)	CRI	CCT	INITIAL LUMENS	DESIGN LUMENS
Philips	CDM330/V/O/4K/EA /LL	315	36,000	90	4000	33,000	23,100
Philips	CDMAllstar 330W/940 ED37 U EA AllStart	315	36,000	90	4000	33,000	24,750
Philips	CDM330/U/O/4K/ED 28 EA ALLSTART	315	20,000	90	3900	33,000	26,400
Sylvania	MCP320/PS/BU-Only/840PB	320	20,000	88	4000	37,500	28,125
Average Ceramic Pulse Start Metal Halide			28,000	90	3,975	34,125	25,594

TABLE 28: 320 WATT PULSE START METAL HALIDE LAMPS

Manufacturer	Model	Nominal Wattage	Lamp Life (Hours)	CRI	CCT	Initial Lumens	Design Lumens
Philips	Pulse Start MH Std 320W/640 Mog ED28 CL	320	20,000	62	4100	30,000	21,000
Philips	Pulse Start MH Pro 320W Excl Mog ED37 CL	320	20,000	65	3800	29,500	20,650
Sylvania	M400/PS/U	320	20,000	65	4000	36,000	25,500
Average Pulse Start Metal Halide			20,000	64	3,967	31,833	22,383

APPENDIX J: SOLAR LIGHT SL-3101 SPECIFICATIONS

SELECT LANGUAGE | ▼

Call Us (215) 517-8700 or Chat Live @ info@solarlight.com

SOLAR LIGHT

BROWSE BY CATEGORY | BROWSE BY APPLICATION | LEARN MORE ABOUT US

SOLARLIGHT.COM PRODUCTS

Search & Press Enter

SL-3101 SPMETER DUAL SCOTOPIC / PHOTOPIC METER

METERS
INDUSTRIAL LIGHT MEASUREMENT

Delivery on all products is Stock to 2 weeks.

Every product is calibrated to NIST traceable standards before shipment.

[GET A QUOTE NOW]

Question?

CALL US AT 1 (215) 517-8700 OR CHAT WITH LIVE SUPPORT

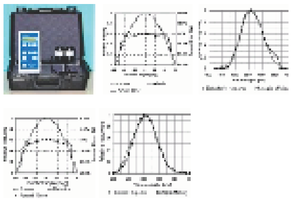
MODEL SL-3101 SPMETER FOR THE CREATION OF SPECTRALLY ENHANCED LIGHTING DESIGNS

The Solar Light Model SL-3101 SP-meter™ is a portable and innovative meter. It measures spectral response following the CIE scotopic and photopic action spectrum with on board calculations:
- S/P ratio
- Visually effective light level
- Perceived brightness

Uses

This meter is used by lighting design professionals, researchers, lamp and ballast manufacturers, and energy management consultants.

Alternate Views



TECHNICAL DETAILS VIDEO PRINT THIS PAGE

Applications

Architectural Lighting Design
Lighting Efficiency Measurements
Energy Efficiency Designing
Scotopic Lighting Research

Meter Specifications

Dynamic range:
2.6 x10^6 (6.5 digits)
Temperature coefficient:
50 PPM/°C
Batteries:
4xAA Alkaline batteries
Battery life:
>40 hours continuous use

Accuracy:
Within 0.2% FS
Max. Sampling rate:
3 per second
Screen refresh rate:
10 per sec.
Operating temperature:
0 to 50°C (non-condensing)
Program control:
9-button keypad

Non-linearity:
0.003% integral non-linearity
Weight:
18 oz (510 g)
Size:
4"W x 1.75"D x 7.6"H (10 x 4.35 x 19.3 cm)
LCD Size:
2.5" x 0.5" (6.4 x 1.3 cm)

LIVE CHAT OFFLINE

Photopic Detector Specifications

Spectral response:
Follows CIE photopic spectral luminous efficiency curve (400-700nm) Figure 1
Angular response:
5% for angles <60°

Range:
PMA2130SP - 150,000 Lux, 14,000 ft-cd
Display resolution:
PMA2130SP - 1 Lux, 0.1 ft-cd
Operating environment:
32 to 120 °F (0 to +50 °C) no precipitation

Diameter:
1.6" (40.6 mm)
Height:
1.8" (45.8 mm)
Weight:
7.1 oz (200 grams)

http://solarlight.com/product/spmeter/

APPENDIX K: KONICA MINOLTA CL-200 SPECIFICATIONS

CHROMA METER CL-200

Enables measurement of tristimulus values, chromaticity, color difference, correlated color temperature and illuminance of light sources.

MAIN FEATURES

Four types of calibration functions for correcting measurement values:

Normal Calibration : Corrects measurement values for Standard Illuminant A as the calibration light source

Normal User Calibration : Corrects measurement values for input calibration light source values

Multi Calibration : Corrects measurement values for the R/G/B/W values of ultra-high-pressure mercury lamps

Multi User Calibration : Corrects measurement values for input calibration light source values for R/G/B/W

- Input of R/G/B/W values for Multi User Calibration requires Data Processing Software CL-S1w,(sold separately)

Enables multi-point measurement

Allows simple and low-cost multi-point measurement. Up to 30 receptors can be connected to one main body.

Simple operation

- Turning on the meter will perform zero adjustment (no cap required), allowing immediate measurement.
- Keys that are not used frequently can be placed under a sliding cover, to prevent pressing a key in error and to give the operating panel a neat appearance.

Other features

- The receptor can be separated and then connected to the main body with a LAN cable. This allows the user to install the receptor up to 100m from the main body and control it remotely. (For this, optional adapters T-A20 (for main body) and T-A21 (for receptor) are required.
- Use of the built-in RS232C interface allows the meter to be connected to a personal computer.
  (For RS-232C interface, an optional cable (T-A11) is available.)
- Connecting to a commercially available thermal printer allows printout of measured data.
  (For connecting to a printer, an optional printer cable (T-A12) is available.)
- The LCD back-light turns on automatically when illuminance is low.
- Powered by AA-size batteries or optional AC adapter.
- This optional PC software offers several desirable features (e.g. easy operation, visual data display, and flexible data processing).
  This software provides multi-point graphical data.

MAIN APPLICATIONS

- R&D and color inspection of light sources in a variety of industries, eg. lamp manufacturers, building and interior design.
- Setting up projectors for presentation purposes.
- Color adjustment of CRTs, flat panel and other display devices.
- Color evaluation and control of light boxes and light booths.
- Evaluating color in an experimental environment for physchology.

SPECIFICATIONS

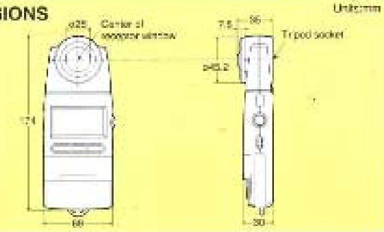
Relative Spectral Response*	Closely matches CIE Standard Observer curves $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, and $\bar{z}(\lambda)$ Within 8% (f1') of the CIE spectral luminous efficiency V(λ)
Receptor	Silicon photocell
Measuring function	Tristimulus values : XYZ Chromaticity : Ev xy, Ev u'v' Correlated color temperature : Ev, Tcp, Δuv Color difference : Δ(XYZ), Δ(Ev xy), Δ(Ev u'v'), ΔEv Δu'v'
Other function	User calibration function, Data hold function, Multi-point measurement (2 to 30 points)
Measuring range	0.1~99,990 lx, 0.01~9,999 fcd (Chromaticity : 5 lx, 0.5 fcd or above) in four automatically selected ranges (lx or fcd is switchable)
Accuracy	Ev : ±2% ±1digit of displayed value (based on Minolta Standard) xy : ±0.002 (800 lx, standard illuminant A measured)
Repeatability	Ev : 0.5% +1digit (2σ) xy : ±0.0005 (800 lx, standard illuminant A measured)
Temperature drift	Ev : ±3% ±1 digit of displayed value, xy : ±0.003
Humidity drift	Ev : ±3% ±1 digit of displayed value, xy : ±0.003
Response time	0.5 sec. (continuous measurement)
Digital output	RS-232C
Display	4 Significant digit LCD with back light illumination
Operating temperature /humidity range	-10 to 40°C, relative humidity 85% or less (at 35°C) with no condensation
Storage temperature /humidity range	-20 to 55°C, relative humidity 85% or less (at 35°C) with no condensation
Power source	2 AA-size batteries / AC adapter (optional)
Battery life	72 hours or longer (When alkaline batteries are used) in continuous measurement
Dimensions	69×174×35mm (2-6/16×6-14/16×1-7/16 in.)
Weight	215g (7.6 oz.) not including batteries

Specifications are subject to change without notice.

* Equivalent to 2% specified for T-1 series. 8% CIE(f1') (new JIS('993) 2% old JIS

DIMENSIONS

Unit: mm



8

http://www.svg-tech.com/catalog/manuals/CL-200%20catalog.pdf

APPENDIX L: POWERSIGHT PS250 AND 100A CT SPECIFICATIONS

PS250
Power Monitor
"The Premier Power Logger"

Order Number:
[PS250]

Complete power monitoring and analysis in a simple basic package.

- **SureStart™** *for getting great results*
  Uses artificial intelligence to verify that the wiring, connections, and setup parameters are correct. Information is available on the front panel display. This unique program (patent pending) reduces the time to hook up voltage and current probes and makes sure that all your measurements are correct.
- **SureSense™** *for accurate current*
  Uses automatic current probe identification to set the input of the PS250 to match each current probe in use. This makes sure that the current probe readings are correct.
- **SurePower™** *for reliable logging*
  The meter's operation is backed up by rechargeable batteries and has an option to power it directly from the voltage being monitored. Current probes that normally require batteries (flexible AC probes and DC probes) get their power from the PS250. This guarantees that the PS250 will log power as long as you need it to with no part failing you. The longest logging capacity in its class.
- **Measures 140 different parameters**
  Volts, amps, watts, power factor, frequency, THD, etc. Minimums, maximums, averages, and present values. Individual phases and total. The PS250 measures parameters every second, regardless of the recording rate. This guarantees that you will have a true view of all of the data when the job is done.

- **Four current and three voltage channels**
  This allows the PS250 to directly measure all phases and neutral in single, two-phase, three-phase, split delta, 2PT/2CT, DC, 45-66 Hz, 360-440 Hz, just about any situation you will ever encounter.
- **Clear display**
  View voltage, current, true power, apparent power and true power factor summaries without the use of a laptop
- **Compatible with our product line**
  Use the same software, current probes (AC/DC, 0.01 to 5000 amps), voltage probes (AC/DC, 1 to 15,000 volts), and accessories.

Pricing and Availability
The PS250 is priced at $1,245. To order, specify **PS250**. For a low cost entry system, order the **PK213,** priced at $1,980 which includes three HA1000 current probes. Harmonic analysis capability can be added for $195 [order **HAO**]. PS250 includes software, voltage leads, AC charging unit, and soft carrying case (everything except current probes).

PowerSight® products are manufactured in the USA and sold by Summit Technology, Inc.

For more information on our products contact:
Summit Technology Inc.
2717 N. Main St., Suite 15
Walnut Creek, CA 94597-2747

Voice: 1-925-944-1212
Fax: 1-925-944-7126
Email: sales@powersight.com

PowerSight®, SureStart™, SurePower™, and SureSense™ are trademarks of Summit Technology. Prices and specifications are subject to change without notice

http://powersight.com/HTML/DOWNLOADS/brochures.html

APPENDIX M: ONSET COMPUTERS HOBO U12-006 LOGGER

HOBO® U12 4-External Channel Data Logger (Part # U12-006)

Inside this package:

- HOBO U12 4-External Channel Data Logger
- Mounting kit with magnet, hook and loop tape, tie-wrap mount, tie wrap, and two screws.

Doc # 13125-B, MAN-U12006-web Onset Computer Corporation

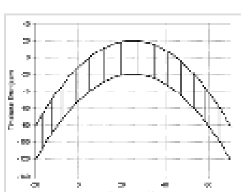
Thank you for purchasing a HOBO data logger. With proper care, it will give you years of accurate and reliable measurements.

The HOBO U12 4-External Channel data logger has a 12-bit resolution and can record up to 43,000 measurements or events. The four external channels accept a wide range of Onset and third-party sensors/transducers with a 0-2.5 VDC output, including external temperature, AC current, pressure, air velocity, and kW sensors. Specifications for Onset sensors can be found at www.onsetcomp.com or by contacting your Onset Authorized Dealer. For 0-5 VDC, 0-10 VDC, or 4-20mA output, use optional Onset Part No. CABLE-ADAP5, CABLE-ADAP10, or CABLE-4-20mA respectively.

The logger uses a direct USB interface for launching and data readout by a computer. Onset software is required for logger operation. Visit www.onsetcomp.com for details.

Specifications

Measurement range	External input channels (see sensor manual): 0 to 2.5 VDC; 0 to 5 VDC (with CABLE-ADAP5) and 0 to 10 VDC (with CABLE-ADAP10)
Accuracy (logger only)	± 2 mV ± 2.5% of absolute reading ± 2 mV ± 1% of reading for logger-powered sensors
Resolution	0.6 mV
Time accuracy	± 1 minute per month at 25°C (77°F), see Plot A
Operating range	-20 to 70°C (-4° to 158°F)
Operating temperature	Logging: -20° to 70°C (-4° to 158°F) Launch/readout: 0° to 50°C (32° to 122°F), per USB specification
Humidity range	0 to 95% RH, non-condensing
Battery life	1 year typical use (see "Battery" details on next page)
Memory	64K bytes (43,000 12-bit measurements)
Weight	46 g (1.6 oz)
Dimensions	58 x 74 x 22 mm (2.3 x 2.9 x 0.9 inches)
CE	The CE Marking identifies this product as complying with all relevant directives in the European Union (EU).



Plot A

4-20mA input cable

This cable (part number CABLE-4-20mA) measures current from 0 to 20.1 mA. Do not expose to current above 20 mA or to negative current. Do not cut off the end of the gray cable where it connects to the blue and yellow wires, as it contains the precision resistor required for current measurement.

Voltage input cable

The logger's external inputs can accept the voltage input cable (Onset part number CABLE-2.5-STEREO), which allows a voltage to be recorded. The input line must not be exposed to signals below 0 V or above 2.5 V.

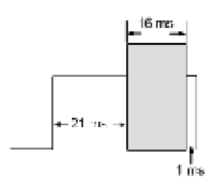
Voltage Input Cable Connections

Wire	Connection
Red	Switched 2.5 V output
White	Voltage input
Black	Ground

Switched 2.5 V output

The external input channels have a switched 2.5 V output. This signal can be used to power a sensor directly, or it can be used to trigger an external circuit. External sensors should draw no more than 4 mA total when powered.

The switched 2.5 V output turns on about 21 ms before the external channels are measured and stays powered for 1 ms after the external channels are measured, as shown in the diagram. The striped area shows the 16 ms period during



http://www.onsetcomp.com/products/data-loggers/u12-006

APPENDIX N: ONSET COMPUTERS 20A AND 50A CTS SPECIFICATIONS

Onset Computer Corporation
470 MacArthur Blvd., Bourne, MA 02532
Mailing: PO Box 3450, Pocasset, MA 02559-3450
Tel: 508-759-9500, 1-800-564-4377 Fax: 508-759-9100
loggerhelp@onsetcomp.com www.onsetcomp.com

6225-E MAN-CTV

4 Split-core AC Current Transformer (CTV)

Split-core AC Current Transformer (CTV)

(AC Amperage to DC Voltage Transducer)

Doc. #: 6225-E Part #: MAN-CTV

For use with HOBO® U12 series data loggers and HOBO data nodes

		Dimensions			
Part Number	Current Range	Window Size	Length	Width	Height
CTV-A	0-20 AMPS AC	28 x 20 mm (1.1 x 0.8 in.)	79 mm (3.1 in.)	71 mm (2.8 in.)	36 mm (1.4 in.)
CTV-B	0-50 AMPS AC	28 x 20 mm (1.1 x 0.8 in.)	79 mm (3.1 in.)	71 mm (2.8 in.)	36 mm (1.4 in.)
CTV-C	0-100 AMPS AC	28 x 20 mm (1.1 x 0.8 in.)	79 mm (3.1 in.)	71 mm (2.8 in.)	36 mm (1.4 in.)
CTV-D	0-200 AMPS AC	39 x 32 mm (1.54 x 1.26 in.)	100 mm (3.92 in.)	120 mm (4.72 in.)	29 mm (1.14 in.)
CTV-E	0-600 AMPS AC	74 x 62 mm (2.92 x 2.46 in.)	135 mm (5.3 in.)	150 mm (5.91 in.)	28 mm (1.12 in.)

Specifications:

- Accuracy with U12: ±4.5% of full scale (includes logger accuracy)
- Accuracy with ZW: +/-4.0% of full scale (includes data node accuracy)
- Response time (from 10% to 90% of amplitude):
  - CTV-A approx. 440 milliseconds
  - CTV-B approx. 200 milliseconds
  - CTV-C approx. 100 milliseconds
  - CTV-D approx. 450 milliseconds
  - CTV-E approx. 490 milliseconds
- Input Current: AC current, sine wave, single phase 50 Hz or 60 Hz, load power factor 0.5 to 1.0 lead or lag
- Output: 0-2.5 VDC
- Voltage rating: 600 VAC.
- Temperature rating
  - CTV-A, -B, -C: -15° to +60°C (+5° to +140°F),
  - CTV-D, -E: -15°: to +40°C (+5° to +104°F)
- Construction: Molded plastic housing for indoor use per UL508
- Cable: 1.8 m (6 ft.), compatible with U12 family external inputs
- CE The CE Marking identifies this product as complying with all relevant directives in the European Union (EU)

Split-core AC Current Transformer (CTV) 1

http://www.onsetcomp.com/products/sensors/ctv-a
http://www.onsetcomp.com/products/sensors/ctv-b

APPENDIX O: FLUKE 375 CLAMP METER SPECIFICATIONS

FLUKE.

374 and 375 True-rms AC/DC Clamp Meters

Work horse clamps with increased performance and flexibility

The new Fluke 374 and 375 clamp meters offer improved performance perfect for many current measurement situations. With true-rms ac voltage and current measurements, the Fluke 374 and 375 can read up to 600 V and 600 A in both ac and dc modes. Additionally, both are compatible with the new iFlex™ flexible current probe (sold separately) which expands the measurement range to 2500 A ac and provides increased display flexibility, ability to measure around awkward sized conductors and improved wire access.

Technical Data

Measurement capability

- 600 A ac and dc current measurement with fixed jaw
- 2500 A ac current measurement with iFlex™ flexible current probe (sold separately)
- 600 V ac and dc voltage measurement
- True-rms ac voltage and current for accurate measurements on non-linear signals
- Frequency measurement to 500 Hz with both jaw and iFlex™ (Fluke 375 only)
- Resistance measurement to 60 kΩ (Fluke 375) or 6000 Ω (Fluke 374) with continuity detection
- Min, max, average and inrush recording to capture variations automatically
- 500 mV dc measurement range to interface with other accessories (Fluke 375 only)
- 1000 μF capacitance measurement

Features

- iFlex™ flexible current probe expands the measurement range to 2500 A ac while providing increased display flexibility, ability to measure awkward sized conductors and improved wire access
- CAT IV 600V, CAT III 1000 V safety rating
- Integrated low pass filter (Fluke 375 only) and state of the art signal processing allows for use in noisy electrical environments while providing stable readings

http://support.fluke.com/find-sales/Download/Asset/3801511_0000_ENG_B_W.PDF

REFERENCES

[i] Green Creative (2013), "Learn more about the critical LED Standards", Website http://www.gc-lighting.com/leducation/lm-80/

[ii] NEMA (2010), "Guidelines on the Application of Dimming to High-Intensity Discharge Lamps". Rosslyn, Virginia: National Electrical Manufacturers Association