U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

FEDERAL ENERGY MANAGEMENT PROGRAM

Effective White Light Options for Parking Area Lighting

New lighting technologies provide low maintenance alternatives to high-pressure sodium

August 2010

Photo courtesy of PNNL

While both providing white light, LED (foreground) provides improved uniformity and energy efficiency compared to induction (background upper right) but at a higher installed cost.

High-pressure sodium (HPS) lights are common for outdoor lighting because of their 24,000-hour rated life and high efficiency. However, high-pressure sodium technology is not without its drawbacks, such as low color rendition, a result of its narrow spectral distribution and low color temperature—sometimes described as amber or yellowish light source. While metal halide lamps provide a whiter light and better color rendition, they are not as efficient, experience longer strike and restrike times, and frequently have a shorter rated lamp life (as low as 10,000 hours average lamp life).

Today, there are effective white light alternatives that can compete with high-pressure sodium for outdoor parking areas. Induction lamps, also known as electrodeless lamps, are an established technology that operates using the same principle as fluorescent lamp technology. Induction lamps offer good color rendition, long lamp life, and instant-on capability. Light-emitting diodes (LEDs, a type of solid-state lighting) are an emerging technology that offers potential energy savings, improved directionality, better cold-weather performance, good color rendition, long life, multi-level switching, and instant-on capabilities. While more expensive that the alternatives, the cost of LED luminaires is expected to decrease as the technology matures.

In this Issue:

Introduction

Investigating ways to reduce energy consumption and costs, the Navy Technology Validation (Techval) Program, with support from the Department of Energy, Federal Energy Management Program, sought to demonstrate and compare induction and LED lighting technologies as alternatives for parking area applications.

Naval Base Ventura County

The Navy Exchange and Commissary at Naval Base Ventura County (NBVC) share a large common parking area. The lighting pole layout is fairly regular along the store front but irregular throughout the rest of the parking area. From the Commissary, power is supplied to 17, 400-Watt high-pressure sodium lights atop 13, 33½-foot light poles. An electronic timer is used to control the 7.77-kW lighting load. From the Navy Exchange, power is supplied to 14, 400-Watt high-pressure sodium lights atop 9, 33½-foot light poles. Another electronic timer is used to control the additional 5.81-kW lighting load.

To establish a baseline for the high-pressure sodium lighting system, a uniform grid of measurement points was developed and marked across the parking areas. New lamps were installed and allowed to properly burn in before illumination levels and color temperatures were measured and recorded.

Around the Commissary, the average measured illumination for the original lighting system was 21.9 lux, but ranged from a high of 120.9 lux to a low of 5.8 lux. Around the Navy Exchange, the average measured illumination for the original lighting system was 28.6 lux, but ranged from a high of 121.9 lux to a low of 2.9 lux. This high variation in illumination is not unusual for outdoor lighting systems.

In a unique demonstration project, the Navy Techval Program replaced the Commissary lights with new induction luminaires while replacing the Navy Exchange lights with new LED luminaires. The new lighting systems were designed around the existing light pole layout, using the same number of luminaires, and with the design intent to meet the Illuminating Engineering Society of North America (IESNA) standard for parking lot illumination.

After the new luminaires were installed and allowed to properly burn in, illumination levels and color temperature were measured and recorded using the same grid points as the baseline measurements. Table 1 and Table 2 show the comparison of photopic and scotopic illuminance measurements for the Commissary parking area. Table 3 and Table 4 show the comparison of photopic and scotopic illuminance measurements for the Navy Exchange parking area. Care was taken to disregard measurements points with

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significant influence from both lighting technologies.

As a result of the luminaire selected at the Commissary, the induction lighting system provides a less preferable uniformity ratio than the original high-pressure sodium lighting system. The induction luminaire focuses too much light down, resulting in hot spots directly beneath the fixture and dark spots between the wide-spread light poles. Further, the induction lamps are under sized resulting in illumination lower than the high-pressure sodium baseline, in addition to being below the IESNA recommended standard. While scotopic illumination results in a better comparison, IESNA does not have standards or recommended practices based on scotopic measurements.

Photo courtesy of PNNL

Figure 1: Commissary baseline with 400-Watt high-pressure sodium lighting system. Photo taken with a Canon PowerShot S500, 1/8 second exposure, F2.8, February, 2009.

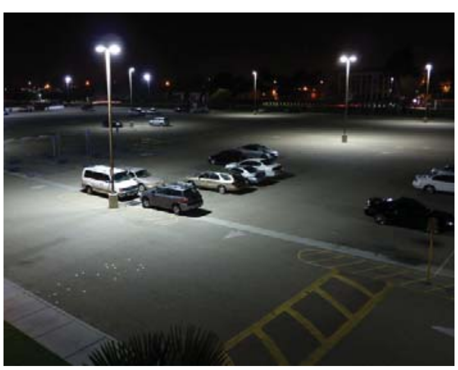

Photo courtesy of PNNL

Figure 2: Commissary with new 250-Watt induction lighting system. Photo taken with a Panasonic DMC-ZS1, 1.6 second exposure, F3.3, June 9, 2010.

Table 1: Comparison of Photopic Illumination Measurements at the NBVC Commissary

Light Type	Average Photopic Light Level (lux)	Maximum Photopic Light Level (lux)	Minimum Photopic Light Level (lux)	Uniformity Ratio (Avg to Min)	Uniformity Ratio (Max to Min)
HPS Baseline—new lamps	21.9	120.9	5.8	3.8:1	20.8:1
Induction—new lamps	14.3	115.4	1.7	8.4:1	67.9:1
IESNA Standard* Basic † Enhanced Security ‡			 2 5		 20:1 15:1

Notes (for all Tables)

* Source: 2000 IESNA Lighting Handbook, 9th Edition, figure 22-21. IESNA standard is based on maintained horizontal illumination, which should include all light-loss factors including lamp lumen depreciation. This condition occurs just prior to lamp replacement and luminaire cleaning.

† For typical conditions. Based on minimum maintained horizontal illumination on parking surface without any shadowing effect from parked vehicles or trees at point of measurement.

‡ If personal security or vandalism is likely and/or a severe concern, a significant increase of the Basic level may be appropriate.

** While IESNA does recognize scotopic and mesopic illumination, there are currently no standards or recommended practices based on scotopic measurements.

Table 2: Comparison of Scotopic Illumination Measurements at the NBVC Commissary **

Light Type	Average Scotopic Light Level (lux)	Maximum Scotopic Light Level (lux)	Minimum Scotopic Light Level (lux)	Uniformity Ratio (Avg to Min)	Uniformity Ratio (Max to Min)
HPS Baseline—new lamps	16.0	73	4.0	4.0:1	18.3:1
Induction—new lamps	26.3	204	5.0	5.3:1	40.8:1

Table 3: Comparison of Photopic Illumination Measurements at the NBVC Navy Exchange

Light Type	Average Photopic Light Level (lux)	Maximum Photopic Light Level (lux)	Minimum Photopic Light Level (lux)	Uniformity Ratio (Avg to Min)	Uniformity Ratio (Max to Min)
HPS Baseline—new lamps	28.6	121.9	2.9	9.9:1	42.0:1
LED—new luminaire	13.3	25.1	3.5	3.8:1	7.2:1
IESNA Standard* Basic † Enhanced Security ‡			 2 5		 20:1 15:1

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Table 4: Comparison of Scotopic Illumination Measurements at the NBVC Navy Exchange **

Light Type	Average Scotopic Light Level (lux)	Maximum Scotopic Light Level (lux)	Minimum Scotopic Light Level (lux)	Uniformity Ratio (Avg to Min)	Uniformity Ratio (Max to Min)
HPS Baseline—new lamps	17.9	77	3.0	6.0:1	25.7:1
LED—new luminaire	23.6	47	6.5	3.6:1	7.2:1

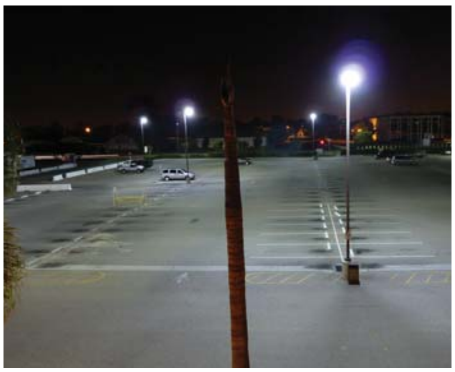

Photo courtesy of PNNL

Figure 3: Navy Exchange with new 207-Watt LED lighting system. Note uniformity of LED. Photo taken with a Panasonic DMC-ZS1, 3.2 second exposure, F3.3, June 10, 2010.

The LED lighting system installed at the Navy Exchange provides improved illumination in the low lit areas compared to the original high-pressure sodium lighting system. Minimum measured illumination, the basis for the IESNA standard, was increased. As a result of the directionality of LEDs combined with the luminaire design, the average and peak illumination are reduced, providing an improved uniformity ratio. The areas directly under the light poles are not overlit compared to the rest of the parking area. The whiter light of the LEDs, compared to the high-pressure sodium lamps, also provides improvement to the scotopic measurements.

Naval Station Pearl Harbor

Naval Station Pearl Harbor (NSPH) also participated in demonstration projects to compare induction and LED to high-pressure sodium. A significant portion of street lighting has already been converted to induction lamps but the installation was interested in assessing the potential for LED in outdoor lighting applications.

Two different parking areas were selected for comparison. Parking lot A, located in an industrial area, was lit with 20, 400-Watt high-pressure sodium luminaires atop 13, 25-foot light poles mounted on 3-foot elevated concrete pedestals. A timer was used to control the 8.54-kW lighting load. The parking area is not used much after dark and was determined to be over illuminated.

The parking area by the 1300 dormitory complex was lit with 34, 150-Watt high-pressure sodium luminaires atop 24, 22-foot light poles mounted on 3-foot elevated concrete pedestals. Timers are also used to control the 5.01-kW lighting load. Traffic in the parking area is moderate after dark and was determined to be under illuminated.

To establish a baseline for the two lighting systems, a uniform grid of measurement points for each parking area was developed and marked. Measurement grid points blocked by cars or car shadows were eliminated from comparative analysis.

New high-pressure sodium lamps were not installed to establish a proper baseline. Therefore, direct comparison of illumination between the old and new lighting systems is not possible. The intent of the demonstration was comparison to the design standard and between the two new light sources.

At parking lot A, the average measured illumination with the existing high-pressure sodium was 66.2 lux, but ranged from a high of 195.2 lux to a low of 7.9 lux. At the dormitory complex parking area, the average measured illumination with the existing high-pressure sodium was 10.8 lux, but ranged from a high of 40.1 lux to a low of 1.2 lux.

The Navy Techval Program replaced the lights in parking lot A with new 250-Watt induction light fixtures and replaced the lights in the dormitory complex with new 104-Watt LED luminaires. The new lighting systems were designed around the existing light pole layout, using the same number of luminaires, and with the design intent to meet the IESNA standard for parking lot illumination.

After the new luminaires were installed and allowed to properly burn in, illumination levels and color temperature were measured and recorded using the same grid points as the baseline measurements. Table 5 and Table 6 show the comparison of photopic and scotopic illuminance measurements for parking lot A. Table 7 and Table 8 show the comparison of photopic and scotopic illuminance measurements for the dormitory complex parking area.

The induction lighting system installed in parking lot A provides a similar uniformity ratio as the original high-pressure sodium lighting system. As intended, the induction lighting system provides lower illumination than the high-pressure sodium baseline but will still meet the maintained IESNA basic illumination standard even after the expected light loss depreciation factors. The scotopic measurements results in a notable increase in illumination; although, IESNA does not have standards based on scotopic measurements.

The LED lighting system installed at the dormitory complex provides improved illumination compared to the original high-pressure sodium lighting system. Minimum measured illumination is notably increased. Also, the uniformity ratio shows significant improvement with the new LED luminaires. The whiter light of the LEDs, compared to the high-pressure sodium lamps, provides similar improvement to the scotopic measurements.

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Photo courtesy of PNNL

Figure 4: Parking lot A baseline with 400-Watt high-pressure sodium lighting system. Photo taken with a Canon PowerShot S500, 1/8 second exposure, F2.8, May 21, 2009.

Photo courtesy of PNNL

Figure 5: Parking Lot A with new 250-Watt induction lighting system. Photo taken with a Panasonic DMC-ZS1, 4 second exposure, F3.3, June 24, 2010.

Photo courtesy of PNNL

Figure 6: Dormitory Parking Area with new 104-Watt LED lighting system. Photo taken with a Panasonic DMC-ZS1, 4 second exposure, F3.3, June 24, 2010.

Table 5: Comparison of Photopic Illumination Measurements at NSPH Parking Lot A

Light Type	Average Photopic Light Level (lux)	Maximum Photopic Light Level (lux)	Minimum Photopic Light Level (lux)	Uniformity Ratio (Avg to Min)	Uniformity Ratio (Max to Min)
HPS Baseline—old lamps	66.2	195.2	7.9	8.4:1	24.7:1
Induction—new lamps	37.5	136.4	5.4	7.0:1	25.5:1
IESNA Standard* Basic † Enhanced Security ‡			 2 5		 20:1 15:1

Table 6: Comparison of Scotopic Illumination Measurements at NSPH Parking Lot A **

Light Type	Average Scotopic Light Level (lux)	Maximum Scotopic Light Level (lux)	Minimum Scotopic Light Level (lux)	Uniformity Ratio (Avg to Min)	Uniformity Ratio (Max to Min)
HPS Baseline—old lamps	45.5	197	8.0	5.7	24.6:1
Induction—new lamps	62.7	235	7.5	8.4	31.3:1

Table 7: Comparison of Photopic Illumination Measurements at the NSPH 1300 Dormitory Complex Parking Area

Light Type	Average Photopic Light Level (lux)	Maximum Photopic Light Level (lux)	Minimum Photopic Light Level (lux)	Uniformity Ratio (Avg to Min)	Uniformity Ratio (Max to Min)
HPS Baseline—old lamps	10.8	40.1	1.2	9.0:1	33.4:1
LED—new lamps	12.4	18.8	3.9	3.2:1	4.9:1
IESNA Standard* Basic † Enhanced Security ‡			 2 5		 20:1 15:1

Table 8: Comparison of Scotopic Illumination Measurements at the NSPH 1300 Dormitory Complex Parking Area **

Light Type	Average Scotopic Light Level (lux)	Maximum Scotopic Light Level (lux)	Minimum Scotopic Light Level (lux)	Uniformity Ratio (Avg to Min)	Uniformity Ratio (Max to Min)
HPS Baseline—old lamps	9.1	27	3	3.0:1	9.0:1
LED—new lamps	20.6	33	6	3.4:1	5.5:1

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Conclusions

Table 9 summarizes the energy performance and economic analysis of the lighting systems. The new lighting systems provide notable reductions in power and energy. However, the costs are high, especially for the LED luminaires. The simple payback for each of the demonstration projects was beyond 10 years.

Overall, the induction lighting system offers some advantages over high-pressure sodium lighting systems.

- Longer lamp life, which will result in maintenance savings
- Higher correlated color temperature, which results in a white light appearance
- Instant on with no strike or restrike delay

The LED lighting system offers additional advantages but at a higher cost.

- Improved energy performance, reduction in power without sacrificing minimum illumination
- Longer lamp life, which will result in maintenance savings, but possibly not as long as induction
- Higher correlated color temperature, which results in a white light appearance
- Instant on with no strike or restrike delay
- Improved uniformity of lighting, which contributes to the potential for energy savings by not overlighting some areas

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Table 9: Energy and Economic Performance Comparison

	NSPH Parking Lot A		NSPH 1300 Complex Dormitory Parking		NBVC Commissary Parking		NBVC NEX Parking	
Lighting Technology	HPS	Induction	HPS	LED	HPS	Induction	HPS	LED
Total number of luminaires	20	20	34	34	17	17	14	14
Number of light poles	20	20	34	34	17	17	14	14
Rated lamp power, Watts	400	250	150	104	400	250	400	207
Total measured power, kW	8.54	5.44	5.01	3.42	7.77	4.74	5.81	2.88
Reduction in measured power, %		36.3%		31.7%		39.0%		50.4%
Operation, hours per year *	4380	4380	3832	3832	4015	4015	4015	4015
Annual energy consumed, kWh/yr	37,405	23,827	19,198	13,105	31,197	19,031	23,327	11,563
Annual energy reduction, kWh/yr		13,578		6,093		12,166		11,764
Annual energy cost reduction, $/yr †		$2,851		$1,280		$1,560		$1,412
CO_2 reduced per year, tons/yr ‡		12.3		5.5		4.4		4.3
Installed cost		$30,343		$88,072		$18,939		$36,746
Simple payback, years		10.6		68.8		12.1		26.0

* Operating hours based on timer control set points
† Electric energy cost = $0.21/kWh (NSPH) and = $0.12/kWh (NBVC). Reference: FY2007 Energy Management Reports
‡ Source: eGRID2007, version 1.1, United States Environmental Protection Agency, http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html

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