



# Traffic Engineering and Highway Safety Bulletin

## Exterior Lighting for Safety and Security

October 2010



### Did You Know?

Lighting for security purposes is very important on DoD installations, especially at entry control facilities (ECFs), at sensitive locations within the installation, and around the perimeter of the installation.

Most of the exterior lighting on DoD installations is currently high-pressure sodium (HPS). Although today's color-improved HPS lighting is more efficient than earlier types of lighting, pulse start metal halide (MH) lamps are the preferred lamp on military installations because they are more efficient, require less maintenance, and provide better visibility.<sup>1</sup>

There have been major advancements in lighting technology and the understanding of uniformity, contrast, glare and the color of the light and how they affect nighttime visibility. UFC 3-530-01, entitled Design: Interior and Exterior Lighting and Controls, incorporates current design concepts.

Sustainability is also an important design consideration. As a result, installations should:

- ✓ Use the most effective, energy-efficient light source available.
- ✓ Avoid over lighting, and ensure that lights are only on during the hours they are needed.
- ✓ Promote dark skies and reduce light trespass onto adjacent properties by using cutoff luminaires.
- ✓ Recycle lamps containing mercury.

### Basics

The proper design of the lighting system will increase safety and efficiency, aid security forces, and enhance appearance. Therefore, a qualified lighting engineer should develop a lighting plan that meets lighting requirements within site constraints.

<sup>1</sup>UFC 3-530-01, Section 2.5

Newer lighting technologies are rapidly evolving that should further reduce energy and maintenance costs. For example, light emitting diode (LED) street lighting is commercially available but there are reliability issues. However, when these issues are resolved, LED street lights could perhaps become the recommended lamp.

High efficiency lighting has many applications at entry control facilities and for general lighting on DoD installations.

**Illuminance** – Illuminance is a measure of the intensity of light on a surface. A footcandle is the U.S. customary unit of measure equal to one lumen per square foot and originally quantified as the amount of light from a typical candle burning at a distance of one foot from the surface. Exhibit 1 shows a range of some illumination levels.

Although illuminance is typically measured on a horizontal surface, the term “vertical illuminance” is used in the ID check areas, pedestrian areas, and perimeter lighting. This vertical illuminance is the density of light on upright objects, which is very important in identifying people.

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**Exhibit 1. Typical Illuminance Values**

| Lighting Source        | Level of Illuminance (footcandles) |
|------------------------|------------------------------------|
| Full moon              | 0.02                               |
| Gas station canopy     | 10-20                              |
| Office                 | 20-50                              |
| Overcast day           | 100                                |
| NFL football stadium   | 300                                |
| Direct bright sunlight | 10,000                             |

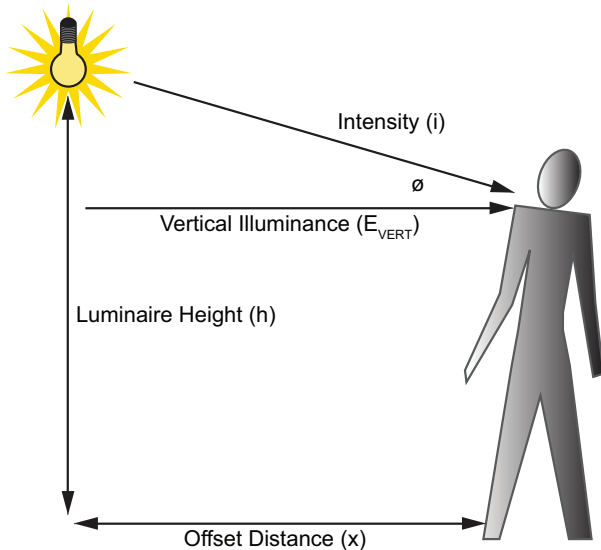


Exhibit 2 shows minimum illuminance levels at select locations within DoD installations.

**Types of Lamps** – There are currently several types of lamps:

- ✓ **High-pressure sodium (HPS) lamps** are currently the most common lamp but they do not have the best efficiency, longevity, or color.
- ✓ **Pulse-start metal halide (MH) lamps** are the current lamp of choice for most external lighting due to their excellent color and high efficiency. However, because of a long restrike and warm-up periods as discussed on the next page, when used for security purposes they always require backup lights. (Note, standard MH lamps are not as efficient or durable as the pulse-start types.)
- ✓ **Quartz-halogen lamps** are inefficient, but provide excellent color and a quick start, making them ideal for back-up lighting.
- ✓ **Incandescent lamps** have excellent color, but poor energy efficiency.
- ✓ **Fluorescent lamps** have excellent color and can be of a rapid start variety.

**Exhibit 2. Minimum Illuminance**

| Location                                                                                                | Minimum Illuminance (footcandles)                                                                                                                                 | Notes                                                                                                                                                                                   |
|---------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>ECFs Near the ID Check Area</b><br>✓ Approach & response zones<br>✓ Search area parking and roadways | ✓ 3 [4 for Air Force at primary gates]*                                                                                                                           | ✓ Illuminance on the pavement and sidewalks<br>✓ Average-to-minimum uniformity levels shall not exceed 4:1                                                                              |
| <b>ECFs at the ID Check Area</b><br>✓ Access control zones<br>✓ Search areas                            | ✓ 5 in general areas*<br>✓ 10 or twice the immediate surrounding areas at the ID checking area [Air Force is 20 under the canopy and 30 at the point of contact]* | ✓ Average-to-minimum uniformity levels shall not exceed 3:1<br>✓ In immediate area where ID and inspection occur, vertical illuminance is 25% of horizontal illuminance at driver level |
| <b>Parking Lots</b>                                                                                     | ✓ 1 – 2**                                                                                                                                                         | ✓ The maximum-to-minimum uniformity ratio should be not greater than 15                                                                                                                 |
| <b>Pedestrian Areas</b>                                                                                 | ✓ 0.5**                                                                                                                                                           | ✓ By using shorter poles with illuminance from multiple directions, adequate vertical illuminance should be provided to light individuals and their faces                               |
| <b>Perimeter Lighting</b>                                                                               | ✓ 0.2 – 0.4 vertical illuminance**                                                                                                                                | ✓ See Table 6-1 in UFC 3-530-01                                                                                                                                                         |

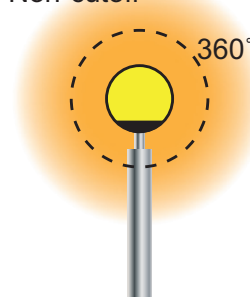
\* minimum illuminance at location 6 inches above the ground level

\*\* average illuminance

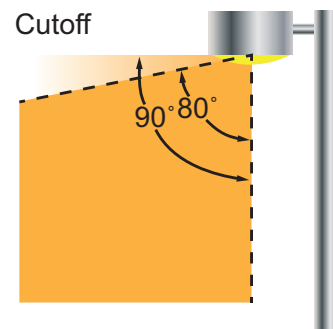
### Exhibit 3. Cutoff Classifications

| Classification | Maximum Intensity<br>(% Lamp Lumens) |                       |
|----------------|--------------------------------------|-----------------------|
|                | Above<br>Horizontal                  | 80° Above<br>Vertical |
| Full Cutoff    | 0                                    | 10                    |
| Cutoff         | 2.5                                  | 10                    |
| Semi-Cutoff    | 5                                    | 20                    |
| Non-Cutoff     | n/a                                  | n/a                   |

Non-cutoff



Cutoff



**Light Trespass** – To help promote dark skies and minimize light trespass, whenever possible, use full cutoff luminaires as addressed in Exhibit 3.

It is generally possible to classify the type of cutoff by visual observation. For example, if the lens is not visible when viewed from the side it is a full cutoff lamp, whereas a low hanging globe-like lens is a semi-cutoff lamp.



The primary issue with the full cutoff lamps is the fact that more poles and lamps may be required to provide proper illuminance.

A canopy over an ECF will also reduce light trespass. In addition, special shields can be used to further reduce light trespass.

Exhibit 4 shows a significant light trespass problem.

**Exhibit 4. A Light Trespass Problem**



**Color Rendering** – The color rendering index (CRI), ranges from 1 to 100 and indicates how accurately colors are rendered by a light source. The greater the number, the better the light source is at rendering colors. “White” light produces higher CRI than “yellow” lighting. A light source with a CRI greater than 65 should always be used.

When closed circuit television (CCTV) is used as part of the traffic and security operations, it is important to provide the correct lighting to support the CCTV system. It is also important to ensure that the camera is capable of automatically adjusting the white balance.

**Restrike and Warm-up Times** – Another important design consideration is the restart or restrike time for the lamps. Restart occurs when a lamp experiences a loss of power, which could be caused by a power outage or someone accidentally turning off a light switch. Once power is restored, the time it takes for the lamp to cool down and then begin to come back on is the lamp’s “restrike time.”

After the restrike time, many lamps still take several minutes for the lights to warm up and reach their full intensity. This warm-up time is generally measured from restrike to the time the light output is 60 percent of its maximum output. Exhibit 5 identifies three different lamps and their restrike and warm-up times. For example, a power outage of only a few seconds may require 6 minutes for the preferred MH lamp to cool down, restart, and warm up sufficiently to produce 60 percent of its normal illuminance.

It is important to note that MH lamps should be the pulse start lamps and not the standard MH lamps. The standard MH lamp is not as efficient and does not last as long, but the biggest problem is that they have even larger restrike and warm-up times.

**Exhibit 5. Types of Lamps**

| Lamp Type                   | Lumen Output (Initial) | Restrike Time (Minutes) | Warm-up Time to 60% Light Output (Minutes) | Light Color/CRI     | Notes                                                                           |
|-----------------------------|------------------------|-------------------------|--------------------------------------------|---------------------|---------------------------------------------------------------------------------|
| MH (Pulse Start)            | 44,000 (400W)          | 4                       | 2                                          | White/65 or greater | Preferred lamp due to high efficiency                                           |
| HPS (w/color improved lamp) | 37,400 (400W)          | 1                       | 3                                          | White/65 or greater | Acceptable, but has lower lumen and life expectancy than MH lamps               |
| Quartz-Halogen              | 5,000 (250W)           | n/a                     | n/a                                        | White/97-100        | Recommended back-up lighting. Typical designs provide 15% of normal illuminance |

## Entry Control Facilities

From a security standpoint, the importance of good lighting is the most critical on DoD installations at the entry control facilities (ECFs) where lighting is required for guards to perform their security functions. For safety reasons it is also important that motorists and guards can see each other. Therefore, ECFs should be designed with lighting features that support the operational requirements during dawn, dusk, and nighttime periods. Even if an ECF is intended to be used only during daylight hours, lighting should be included to accommodate the short winter days and in the event that in the future there is a change in usage.

ECF lighting should be complete and continuous, and in accordance with UFC 4-022-01, specific areas of the ECF have their own lighting requirements, as captured in Exhibit 2.

The level of illuminance required depends on the task being performed and the needed visibility to perform those tasks. Special consideration must be given to the ID check and inspection areas where the identification of vehicle occupants and contents occurs. As noted in Exhibit 2, the vertical illuminance is a minimum of 25 percent of the required horizontal illuminance.

This lighting should be directed across the vehicle's travel path, where it will illuminate the roadway in front of the gatehouse, the driver, and the guard. Lighting may also be mounted at or below pavement level to facilitate under vehicle inspection, but lighting should not be directed toward either the guards' or the drivers' eyes.

The ability to identify and distinguish colors accurately and confidently is very important, particularly in ECF areas. For example, at an ECF, the color of the driver's eyes and hair is very important for ID purposes. Further, the color of the car may be important in a description to a guard in an oversight position, especially since a green car under yellow lights will have a blue tint.

Within the ECF, it is essential that either back-up lamps are provided or that an uninterrupted power supply (UPS) is available. The recommended type of back-up lamps is the quartz-halogen lamp as referenced in Exhibit 5. Portable lamps operating off of a back-up power supply may also be used within ECF areas in the event of a power interruption.

## Approach Roadways

Transitional lighting is necessary on approaches and departures to the ECF to minimize blinding effects as drivers travel into and out of a brightly illuminated ECF. Therefore, transitional lighting should be used as drivers enter the ECF in the approach zone and leave the ECF in the response zone.

Standard conventional lighting is mounted at a height of 30 to 60 feet. When standard conventional lighting is used, transitional lighting should be provided to allow time for the driver's eyes to adjust to the change in lighting levels on arrival or departure. Departure lighting is more critical since the human eye has more trouble adjusting from light to dark than from dark to light. Therefore, designers should provide gradual change in lighting levels using three or more lighting poles.

The UFC recommends that illuminance levels should not be reduced more than 50 percent within 15 seconds.

For example, if the speed limit is 25 mph (i.e., 36.67 feet per second), the luminance should be a minimum of 5 footcandles (i.e., 50 percent of the minimum 10 footcandles required at the ID checking area) when vehicles are at a maximum distance of 550 feet (i.e., 15 seconds x 36.67 feet per second) after the ECF.

High mast lighting in the range of 60 to 120 feet high is practical because it provides broader and more natural light distribution. It also requires fewer poles than standard conventional lighting and may reduce the need for transitional lighting. However, high mast lighting may cast light on neighboring properties, herein referred to as “light trespass.”

The final determination of the lighting type selected should consider the life-cycle cost of each system. Although one high mast light can often replace six conventional lights, the construction cost of high mast lights are often five times more than the cost of standard light poles.

## Definitions

**High-pressure sodium (HPS) lamp** – A high intensity discharge (HID) lamp in which light is produced by radiation from sodium vapor.

**Horizontal illuminance** – The density of light that falls on a horizontal surface and measured at a location 6 inches above the ground.

**Light trespass** – Unwanted light that either illuminates adjacent properties or creates excess brightness in someone’s field of vision. Unwanted light can generally be reduced or eliminated by using cutoff or shielded luminaires.

**Metal halide (MH) lamp** – A high-intensity discharge (HID) lamp in which the major portion of the light is produced by radiation of metal halides and their products of dissociation, possibly in combination with metallic vapors such as mercury.

**Vertical illuminance** – This is the application of light on upright objects such as people, instead of horizontal surfaces like roadways and parking lots. For security purposes, the need to illuminate people, especially their face, for identification purposes is more important than illuminating horizontal surfaces. Vertical illuminance is generally measured at a height of 5 feet above the grade.

Light poles can be placed along the roadway or in the median. In some cases, light poles in the median may limit the number of poles needed. However, on wider roadways such as at ECFs with numerous lanes, the needed illuminance may not be achievable with median light poles; therefore, light poles may need to be placed on both sides of the road. When light poles are in uncurbed areas the pole should be located outside of the clear zone. In curbed areas, at least a 2-foot clearance from the curb face to the pole is required.

*The Roadway Lighting Design Guide* is an excellent resource for designing roadway lighting.

## Intersection and Crosswalk Lighting

Intersection lighting increases motorist and pedestrian visibility and reduces crash potential. Although no specific warrants have been established, the *MUTCD* suggests roadway lighting if a disproportionate number of crashes occur at night. Lighting should be installed at those locations where a qualified lighting engineer has determined that lighting will contribute to the efficiency, safety, and/or comfort of motorists and pedestrians. Similar lighting can also be used at midblock pedestrian crosswalks and would be especially beneficial at busier crosswalks.

Most state DOTs, as well as IESNA, have developed criteria to assist in determining lighting requirements. When designing lighting, the following factors should be considered; luminaire type, light source type, wattage, mounting height, and pole location. A qualified lighting engineer should evaluate intersection lighting.

In an effort to improve visibility of pedestrians, the preferred location of light standards for intersection and midblock crosswalks is as illustrated in Exhibit 6.

It is also permissible to use in-roadway warning lights in a line parallel to the edges of the crosswalk, either at or within 10 feet of the near edge of the crosswalk as illustrated in Exhibit 7. Additional design details are included in Chapter 4N of the *MUTCD*. However, DoD installations should be aware that these systems are expensive, and for installations with winter maintenance activities snowplowable light assemblies will be required. The lights are generally activated by a pedestrian pushbutton and the lights flash for a sufficient period of time to allow pedestrians to either reach the far side of the roadway or another pushbutton, for example, in a median.

## Exhibit 6. Recommended Location for Luminaires at Intersections and Midblock Crosswalks<sup>2</sup>

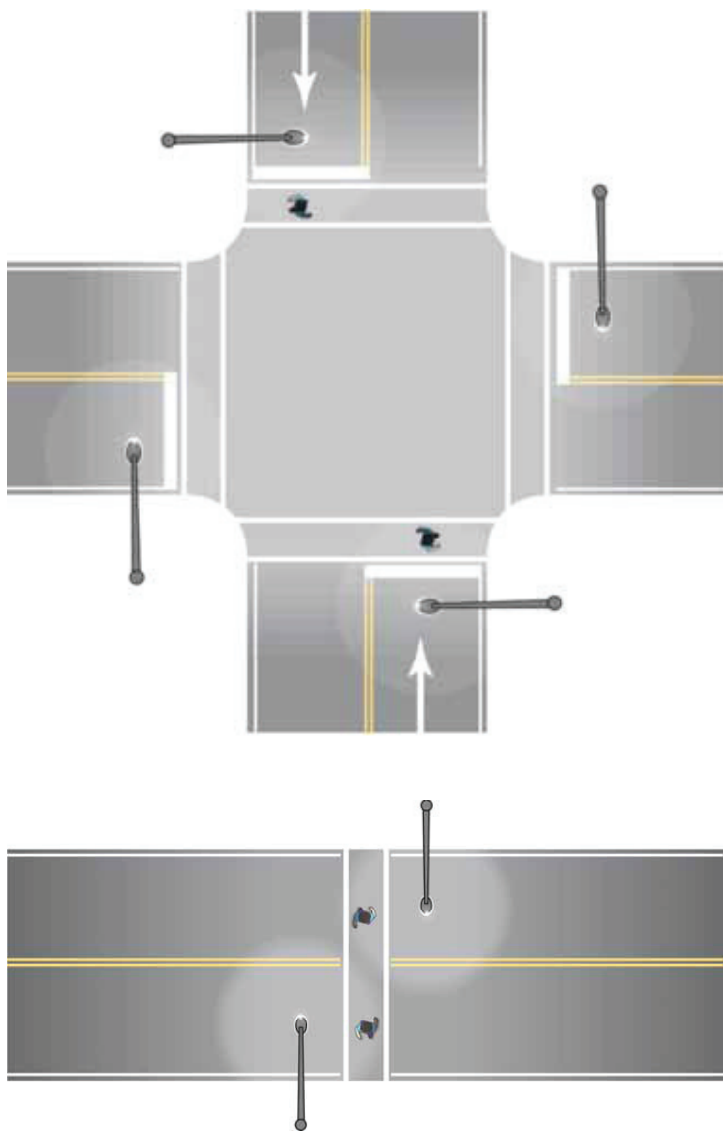


Exhibit 7. In-Roadway Warning Lights



## Parking Lot Lighting

In addition to security, lighting in parking lots also plays a critical role in maximizing visibility between motorists and pedestrians since pedestrians typically walk next to vehicle parking aisles. In large PX and commissary parking lots, lighting is also helpful as shoppers transfer goods from shopping carts to their vehicles.

Mounting height and spacing of luminaires should be sufficient to distribute the desired lighting intensity to the entire parking area. Pole heights range from 20 to 50 feet high or more. A normal lighting level is from 1 to 2 footcandles, and the maximum-to-minimum uniformity ratio should be not greater than 15.

Locate light fixtures away from traffic aisles and parking stalls wherever possible. Light poles are ideally located in islands, and protected by raised curbs. When light poles are within parking rows, locate the poles at the junctions of adjacent stalls, and install them on top of a 3-foot high concrete base to avoid accidental knockdowns. While this practice is acceptable in parking lots, high concrete bases should not be used on open roadways due to the need to provide breakaway designs in areas with higher travel speeds. Poles and fixtures should be in scale and accommodating to the setting and surrounding area, while providing adequate illuminance of the parking lot. As illustrated in Exhibit 8, luminaires should direct the light downward to promote dark skies.

Exhibit 8. Parking Lot Lighting using Full Cutoff Lamps



<sup>2</sup>FHWA, Report No. FHWA-HRT-08-053. *Informational Report on Lighting Design for Midblock Crosswalks*, Figures 12 and 14

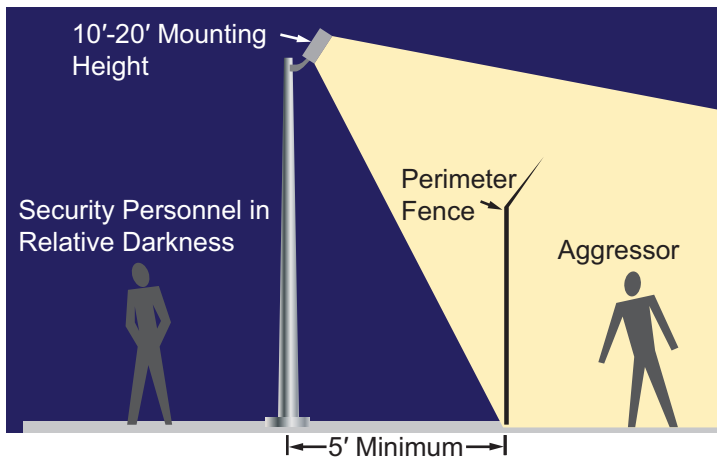
## Perimeter Security Lighting

Securing the perimeter around a military installation is important, but expensive. When used, perimeter lighting normally can be on standby except when there is a perceived threat. Activation can be done either manually by security personnel or automatically by an intrusion detection system. A standby system creates the impression of activity and may offer a deterrent value while also achieving energy conservation. Use lamps that do not have a restrike and warm-up period.

It would be very expensive to light the entire perimeter of a large base as they are often many miles around. Due to the cost, this practice could be reserved to areas that are adjacent to off-base roadways or nearby on-base attractions.

As illustrated in Exhibit 9, one suggestion is to place lights slightly inside a security perimeter and to direct the light outward. This method is useful when the glare of the lights across the surrounding territory will neither annoy nor interfere with operations outside of the security fence. The fact that the light illuminates the potential intruder makes it more difficult for them to see what is inside the fence. Therefore, this practice protects the security personnel by keeping them in relative darkness while enabling them to see a considerable distance beyond the fence.

**Exhibit 9. Suggested Perimeter Security Lighting**



## Miscellaneous Considerations

Good lighting does not eliminate the need to use retroreflective traffic signs. Lighting devices should be provided in temporary traffic control areas based on engineering judgment. When nighttime work is being

performed, floodlights should be used to illuminate the work area, equipment, crossings, and other areas. Except in emergency situations, flagger stations shall be illuminated at night, and provide vertical illuminance without producing disabling glare for approaching road users, flaggers, or workers.

## Future Technologies

Solar-powered lighting currently is not a viable lighting solution except as landscape lights to delineate walkways. These inexpensive lights do not adequately illuminate walking surfaces, but they are effective in defining the edges of pathways and sidewalks. Reliability of these inexpensive lights is an on-going problem.

With on-going improvements in solar collectors, batteries and energy-efficient lights, solar power will undoubtedly become a more viable option in the future.

As noted on Page 1, LEDs may ultimately replace other types of lighting. Some of the potential advantages of LEDs include:

- ✓ Reduce energy consumption
- ✓ Reduce maintenance costs
- ✓ Provide more uniform illuminance
- ✓ Eliminate the need for backup lamps
- ✓ Reduce the number of insects attracted to the lights

In all cases, it is important to use a qualified engineer to ensure that your lighting needs are satisfied. SDDCTEA is available to assist your installation.

Although solar powered lights are not currently good for illuminance, they can be used to energize large “flashing arrow” and “dynamic message” panels used on construction projects and for special events. These solar-powered devices have large solar panels and sufficient batteries to work for many cloudy days. They also have the added benefit of operating without the noise of a generator.

Solar power is also a cost effective power source to operate flashing lights such as pedestrian-activated lights attached to Pedestrian signs, or flashing lights attached to signs in remote areas that do not have readily-accessible commercial electricity.

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