UFC 3-530-01
22 August 2006
Including Change 2, 1 September 2012

UNIFIED FACILITIES CRITERIA (UFC)

Design: Interior, Exterior Lighting and Controls

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UNIFIED FACILITIES CRITERIA (UFC)

CRITERIA FORMAT STANDARD

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

U.S. ARMY CORPS OF ENGINEERS

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	Date	Location
1	10 Dec 2010	Updated all ASHRAE/IES 90.1 to 2007. Added EPACT 2005 requirements, Section 1-4, All design applications, Chapter 7 Updated sustainable policy, Chapters 1, 2, & 3. Expanded task lighting, Chapter 2. Expanded controls & occupancy sensor requirements, Chapters 2, 5, and 7. Added exterior HID lighting retrofit considerations. 3-10.9. Added Security Lighting, Chapter 6 & Chapter 8. Added emergency egress requirements, Chapter 7. Required proof of designs to meet EPACT/ASHRAE, Chapter 7. Expanded use of Solid State Lighting (SSL) technology, 5-3.7, Chapters 7 and 8. Changed Equipment Recommendations to Equipment Requirements and updated applications, Chapters 7 & 8. Added TVSS for exterior lighting circuits.
2	1 Sept 2012	Updated IES Lighting Handbook References to Apply to the 10th Edition. Updated to Include Advances in Technology Including Solid State Lighting (SSL), Controls, Dimming and Ballasts. Added Mesopic Multipliers. 2-5.2.4 Moved Lighting Control content from Chap 5 to Chap 2 and updated Lighting Control sections in both chapters Added SSL technology to 3-10 Retrofits Updated Exterior Luminaire Classification, 5-2.6.1 Added Lighting Zones, 5-2.6.6 Added CCT of fluorescent light sources, 5-3.4.4 Added Discussion of SSL CCTs 5-3.7.2 Expanded on Ballasts, Drivers, Generators, and Power Supplies, 5-4 Expanded on Temperature Effects, 5-4.10 Expanded on Lighting Controls, 5-5 Expanded use of SSL technology, Chapters 7 and 8 Updated lumen requirements for marinas and piers Added effects of dimming on light sources

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

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- Whole Building Design Guide web site http://dod.wbdg.org/.

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AUTHORIZED BY:

DONALD L. BASHAM, P.E.
Chief, Engineering and Construction
U.S. Army Corps of Engineers

D
Chief Engineer
Naval Facilities Engineering Command

The Deputy Civil Engineer
DCS/Installations & Logistics
Department of the Air Force

D P.E.
Director, Installations Requirements and Management
Office of the Deputy Under Secretary of Defense (Installations and Environment)

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CHAPTER 1: INTRODUCTION

1-1 PURPOSE AND SCOPE.

This UFC provides guidance for the design of interior and exterior lighting systems and controls based on the Illuminating Engineering Society of North America's (IES) *Lighting Handbook Reference and Application*, 10th Edition (hereafter called *Lighting Handbook*), Energy Policy Act of 2005, and current recommended practices. This UFC meets the current IES standard of practice and addresses general lighting requirements for Department of Defense (DoD) facilities. Specific requirements not outlined here may apply to facilities overseas.

1-1.1 Lighting Handbook.

In 2011, the IES published the 10th Edition of the *Lighting Handbook*, which changed the direction of lighting design criteria. In previous editions, horizontal illuminance values were given as the strongest basis for design. In the \2\ 10th Edition Handbook, presents both analytic and quantitative lighting criteria recommendations. Chapters 21-37 outline specific criteria for lighting applications. Now the emphasis is on quality based design. Chapter 26, "Lighting for Exteriors" provides lighting criteria for each lighting zone which addresses ambient lighting conditions. /2/

1-1.2 Lighting Design Criteria.

Lighting practitioners must evaluate the application and consider the important lighting design criteria, including direct glare, surface luminances, and uniformity. Also, the importance of daylight on human health and productivity is emphasized. In addition to this UFC, some service specific requirements are outlined in Interim Technical Guidance (ITG) documents and Engineering Technical Letters (ETL). In particular, Solid State Lighting (SSL) and network controls may have differing requirements depending on the service. Designers should refer to \2\ Navy ITG 2010-03 and Air Force ETL 12-15 /2/ for more information.

1-1.3 Exterior Lighting.

Exterior lighting design now addresses the role of glare in creating poor visibility. Over-lighting and discontinuity between areas is also addressed as this could cause adaptation delays when moving from one area to another. Also, the increased effectiveness of white light on enhanced peripheral detection for exterior and other low lighting level applications is addressed.

1-2 APPLICABILITY.

\2\This document applies /2/ to all service elements and contractors designing interior or exterior lighting systems for \2\ construction, repair, and maintenance projects./2/

1-3 REFERENCES.

Appendix A contains a list of references used in this document.

1-4 ENERGY POLICY ACT OF 2005.

In August 2005, the new Energy Policy Act was signed into law by the President. \1\

Refer to UFC 3-400-01 for the minimum standards and policy for energy conservation. /1/ Key sections of EPAct 2005 that affect DoD buildings include:

- Section 102, Energy Management Requirements, establishes new energy efficiency goals for all Federal agencies – annual two percent reduction in energy use per gross square foot of buildings, starting in 2006, culminating in a 20 percent reduction in fiscal year 2015 – from a new baseline of 2003.
- Section 103, Energy Use Measurement and Accountability, directs that all Federal buildings be metered by October 1, 2012.
- Section 109, Federal Building Performance Standards, requires buildings to be designed to be 30 percent below ASHRAE standard 90.1 \1\/1/ or the International Energy Code, if life cycle cost effective and the application of sustainable design principles. http://www.wbdg.org/pdfs/epact2005.pdf

\1\

1-5 SUSTAINABLE DESIGN.

Provide sustainable design to achieve the required LEED or other agency certification level in accordance with UFC 4-030-01, "Sustainable Development".

/1/

1-6 INTEGRATED DESIGN.

Utilize an integrated design process throughout the project's planning and delivery process to achieve high performance and sustainable buildings. See http://www.wbdg.org/references/mou.php.

CHAPTER 2: LIGHTING DESIGN CONSIDERATIONS

2-1 INTRODUCTION.

The IES Lighting Handbook defines visibility as, "the ability to extract information from the field of view."[1] Visibility is affected by glare, uniformity, illuminance, surface brightness, and lighting components. The consideration of these factors improves task performance, mood and atmosphere, visual comfort, aesthetic judgment, health, safety and well-being, and social communication. Additionally, sustainability concerns, lighting control, and maintenance issues all affect the amount of energy required to achieve, operate, and maintain this level of visibility. The IES \2\ 10th Edition Handbook, Chapters 21-37 discusses these aspects for each lighting application. /2/

2-1.1 The criteria outlined in this UFC describe the most relevant issues for DoD facility applications and it refers extensively to the IES. However, the IES criteria may at times be superseded by other UFC requirements.

2-1.2 This chapter describes the most important lighting design considerations. Each issue is discussed with the specific requirements that must be met as well as the items that should be considered during the design process. To use this document, review these requirements and considerations and refer to Chapters 3 – 5 to get more detailed information on sustainability issues, daylighting, and lighting equipment. Chapters \2\ 7 and 8 /2/ give specific examples of various lighting applications. If a designer has very little time, these examples provide immediate and specific equipment recommendations that can be used to meet the outlined criteria.

2-2 VISIBILITY.

2-2.1 Task visibility describes how size, brightness, and contrast of a particular activity affect the lighting required to view that activity. The ability to actually perform a task well includes other non-visual human factors such as skills and experience, independent of the task visibility.

2-2.1.1 Large tasks generally require less illuminance, brightness, and contrast to be performed. Small detailed tasks may require task lighting to increase the light level significantly. Knowing a description of the task is essential to designing the lighting for that task. The luminance or brightness of a task increases the task visibility. Brighter tasks are easier to see, so long as it is not so much brighter than its surroundings that it becomes uncomfortable or a source of direct glare. As task contrast decreases, the light level required to see it will increase. If the contrast is too low, it will be difficult to distinguish various components of the task, reducing visibility.

[1] "Perceptions and Performance", *The IES Lighting Handbook*, Chapter 4, Ninth Edition (New York: The Illuminating Engineering Society of North America, 2000), p. 4-19.

2-2.1.2 Way finding refers to the visual guidance provided by the lighting system and the visual elements illuminated. This guidance may be illuminated signage that directs occupants to various destinations, or it may be more subtle aids such as continuity and hierarchy of lighting equipment that reinforces areas of similar use. By using the same luminaires for areas of the same use, a consistent pattern is established that visually guides and orients building occupants. Accent lighting can also be used to draw attention to specific areas by increasing the brightness.

2-2.1.3 In exterior applications, the size and type of lighting equipment provides visual cues about the surroundings. Bollards and low pedestrian scale poles often signify pedestrian walkways or plazas. Roadway poles may alert pedestrians to intersections in the same way that pedestrian poles or bollards may alert motorists to crosswalks.

2-3 GLARE.

2-3.1 Direct glare is caused by excessive light entering the eye from a bright light source. The potential for direct glare exists anytime one can "see" a light source. With direct glare, the eye has a harder time seeing contrast and details. A system designed solely on lighting levels, tends to aim more light directly towards a task, thus producing more potential for glare. The effective use of indirect light minimizes the negative effects of direct glare. In some circumstances such as entries and checkpoints, glare can be used to increase vertical illuminance on approaching vehicles or individuals while increasing visibility for guards and patrols.

2-3.1.1 Causes of direct glare include an exposed bright light source, for example an HID high bay luminaire, or an exterior floodlight. Overhead T5HO fluorescent light sources in a downlight also can cause direct glare.

2-3.1.2 Direct glare can be minimized with careful equipment selection and placement. In interior applications, indirectly light the walls and ceiling. A limited amount of direct light can provide accent and task lighting. In exterior applications, use fully shielded luminaires that direct light downwards towards the ground or a building façade.

Figure 2-1. Examples of direct glare.

Figure 2-2. Minimize direct glare with IES \2\ fully shielded /2/ luminaire.

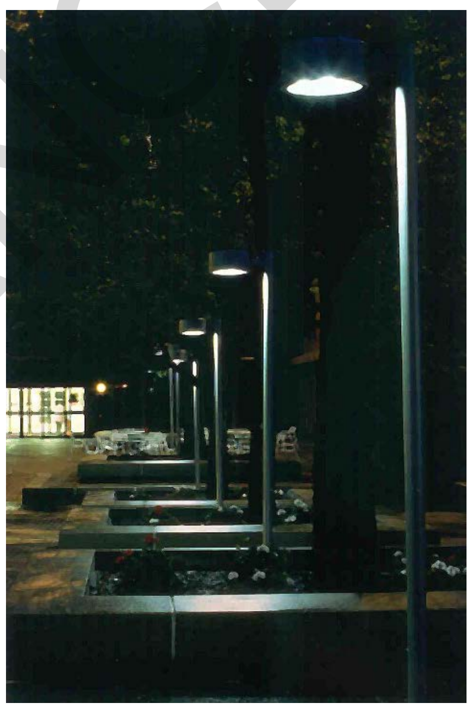


Figure 2-3. Minimize direct glare with indirect lighting.

2-3.2 Indirect or reflected glare is caused by light reflecting off the task or pavement in such a manner that the contrast is “washed out”. Many work situations position the light directly in front of the task, producing reflected glare. Unshielded streetlights can also produce reflected glare on wet pavement, washing out lines on the road. Reflected glare will limit one’s ability to “see” contrast.

2-3.2.1 Like direct glare, indirect glare can be minimized with the type and layout of lighting equipment. For interior applications, locate direct light to the side or behind a critical task. Use semi-indirect light to bounce light off of surfaces in order to provide uniform low glare light with less reflected glare. For exterior lighting, direct the light away from the observer with the use of low glare, fully shielded luminaires.

Figure 2-4. Semi-indirect lighting minimizes indirect glare.

2-3.3 Overhead glare.
Direct luminaires that are immediately over an individual can cause glare even though the light source is not in the field of view. This type of glare can produce the same negative effects as direct or reflected glare including eye strain and headaches.

2-3.3.1 To minimize overhead glare, use indirect luminaires to light the ceiling surface and avoid totally direct luminaires. Where direct luminaires are used, make sure that individuals are not working directly under them.

2-3.4 Requirements to minimize glare:

1. Follow IES recommendations for individual lighting application. Refer to \2\Chapter 7 and 8 of this UFC or to the IES 10th Edition Handbook, Chapters 21-37 for specific criteria./2/
2. For roadway applications, use fully shielded luminaires. Refer to "exterior luminaires" in Chapter 5 "Lighting Equipment" and Chapter \2\ 8 /2/ "Exterior Applications.

2-3.5 Considerations to minimize glare:

1. Indirectly light the ceiling and walls for interior ambient lighting systems. Refer to specific applications in Chapter \2\ 7 /2/, "Interior Applications".
2. Use direct light only in limited amounts for task and accent light. Refer to specific applications in Chapter \2\ 7 /2/, "Interior Applications".
3. For exterior applications, use fully shielded luminaires (see exterior luminaires in Chapter 5, "Lighting Equipment" and Chapter \2\ 8 /2/, "Exterior Applications".)

2-4 UNIFORMITY.

Lighting level or illuminance uniformity is important on work surfaces where sustained tasks are performed as well as on wall and ceiling surfaces that make up a significant portion of the field of view. Poor uniformity can cause adaptation problems. It is very important to prevent "spotty" lighting especially in interior areas where people are working, and exterior areas where safety and security are concerns.

2-4.1 Flicker or strobing of luminaires can cause annoyance as well as headaches and fatigue. This may be caused by fluorescent ballasts near the end of life or placement of luminaires in relation to ceiling fans. If ceiling fans are required in a space, position the luminaires so that they are suspended below the level of the fans.

Figure 2-5. Uniform ceiling brightness.

Figure 2-6. Uniform illuminance.

2-4.2 Requirements for appropriate uniformity:
Follow IES uniformity criteria for specific areas unless superseded by other UFC criteria. Refer to specific application requirements in \2\ Chapters 7 and 8, "Interior and Exterior Applications" and Chapters 21-37 of the IES 10th Edition Handbook. /2/

2-4.3 Considerations for appropriate uniformity:

1. In office areas, uniformity should not exceed 5:1 in immediate work surrounds, not including accent lighting. Also, refer to Chapter \2\ 7 /2/, "Interior Applications".
2. Exterior uniformity should not exceed 10:1 along areas of use including roadways, walkways, and parking areas. Refer to specific application in Chapter \2\ 8 /2/, "Exterior Applications".

2-5 ILLUMINANCE.

Illuminance refers to the light level, or amount of light falling on a surface. It is measured in lux or footcandles. Horizontal illuminance refers to the amount of light falling on a horizontal surface. This type of illuminance is often measured on a desk, work surface, or floor. Vertical illuminance refers to the amount of light falling on a vertical surface such as white boards, signs, and walls. Vertical illuminance on peoples' faces is also important for identification at entries and security checkpoints.

2-5.1 Traditionally, illuminance has been the basis of lighting design. However, we "see" brightness; we don't see lighting levels or lux. Since the revision of the IES guidelines, new standards regarding design must be followed. IES's \2\ 10th Edition Handbook, Chapters 21-37 /2/, have added other design factors besides illuminance. It is important to review all of the design criteria issues in order to prioritize issues. In many cases illuminance is no longer a top priority. Lighting wall and ceiling surfaces is usually more important than providing high levels of horizontal illuminance. In order to provide flexibility and interest in a space light ceiling and wall surfaces with lower ambient lighting levels. Provide higher illuminance levels with individualized task lighting.

There are three different types of visual responses: Photopic or our day vision (\2\ 10 /2/ cd/m^2 and higher), Scotopic or our night vision (0.001 cd/m^2 and below) and mesopic or a combination of night and day vision (0.001 cd/m^2 to \2\ 10 cd/m^2). (IES 10th Edition page 2.14)./2/ The majority of exterior lighting is designed in the mesopic range.

2-5.2 Photopic sensitivity peaks at 555 nm in the green-yellow range. Scotopic vision sensitivity peaks at 507 nm more in the blue light range. Mesopic vision varies between these values depending on the lighting level. As the lighting levels become lower, light sources with more blue or \2\ short wavelength /2/ light become more effective in nighttime vision.

2-5.2.1 Since light source lumen ratings are all based on photopic sensitivity, they need to be adjusted for nighttime applications. Per the IES, photopic and mesopic lumens must be determined from the spectral power distribution of the light source. In addition, photopic luminous efficiency function applies to visual fields of size 2 degrees or less. \2\ (IES 10th Edition page 5.7)./2/ This means that only tasks that are on-axis or one that is focusing straight ahead apply to the photopic light source lumen ratings. Any task that is in our peripheral vision does not. Peripheral vision shifts to shorter wavelength sensitivity. \2\ (IES 10th Edition, page 5.8). /2/

2-5.2.3 For all exterior lighting applications where peripheral vision is important such as detecting pedestrians and other potential off axis activity, white light as produced by a metal halide, fluorescent, \2\ Solid State Lighting (SSL) /2/, or induction light source is recommended.

2-5.2.4 \2\ Mesopic multipliers may be used to account for the improved visibility provided by white light. The process for calculating mesopic multipliers can be performed with luminance values or with illuminance values that are converted to luminance values as a function of the background reflectance. Table 26.6 in the IES 10th Edition Handbook provides an example for how mesopic multipliers can be applied to average illuminance values. Point by point mesopic multipliers, as outlined in CIE

191:2010 Recommended System for Mesopic Photometry Based on Visual Performance adjusts not only the average luminance, but also the uniformity. /2/

2-5.3 Requirements for adequate illuminance:

Follow IES recommendations by evaluating all QVE criteria including illuminance, paying particular attention not to overlight. Refer to specific applications in Chapters \2\ 7 and 8 /2/.

2-5.4 Considerations for adequate illuminance:

1. Design ambient lighting levels to 1/3 to 1/2 task lighting levels. Add task lighting to increase light level.
2. Use white light sources for exterior lighting. Refer to light source recommendations in Chapter 5, "Lighting Equipment".

2-6 SURFACE BRIGHTNESS.

We "see" brightness; we don't see lighting levels or lux. Our perception of spaces depends on how surfaces are lighted. \2\ The factors that lead to brightness as a response are: object luminance, surround luminance, state of adaptation, gradient, and spectral content[2]. /2/ It is important to light vertical surfaces such as walls and building facades as a first priority, then horizontal surfaces such as ceilings and canopies. The least effective surfaces to light are floors.

2-6.1 Traditional lighting design has emphasized lighting level as the only criteria, ignoring the importance of surface brightness. For a more effective design, light the walls and ceiling and use light colored surfaces.

2-6.2 When using fluorescent light sources to light surfaces, the color rendering index of the light sources determines how colors will appear. In spaces where color appearance is important, a higher color rendering index (CRI) will improve the appearance of colors.

[2] "Perceptions and Performance", *The IES Lighting Handbook*, Chapter 4, Tenth Edition (New York: The Illuminating Engineering Society of North America, 2011), p. 4.9.

Figure 2-7. Downlighting only results in spaces feeling dark and "cave-like". Lighting surfaces improves the feel of the space.

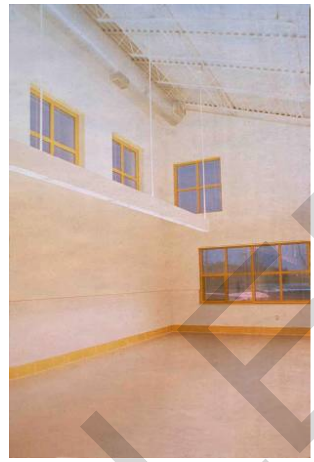
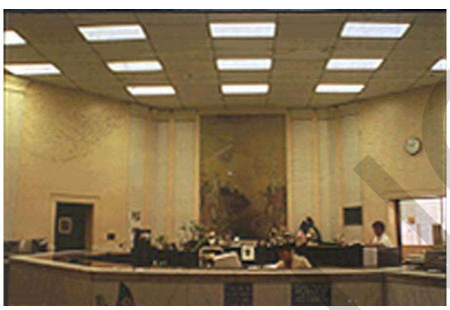
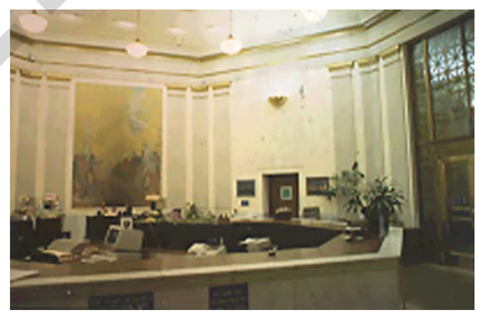


Figure 2-8. Example of the same space with downlighting only (left) and then with improved surface brightness (right).





2-6.3 Considerations for appropriate surface brightness:

1. Provide high surface reflectances for walls (60% minimum) and ceilings (85% minimum).
2. Light ceilings with semi-indirect wall or pendant mounted lighting. Refer to specific application in Chapter 7, "Interior Applications".
3. Light walls with wallwashers Refer to Chapter 5, "Lighting Equipment".
4. Direct daylight to ceiling and walls. Refer to Chapter 4, "Daylighting".
5. For exterior applications, light vertical surfaces that are in pedestrians' field of view. Refer to specific application in Chapter \2\ 8 /2/, "Exterior Applications".

2-7 AMBIENT/TASK/ACCENT SYSTEMS.

A lighting system made up of layers of ambient light, task light, and accent light improves the visual comfort in a space as well as reduces the amount of lighting energy used. Lighting with these three layers balances the contrast ratios between objects in an occupant's field of view, adds some visual interest, and provides flexibility in controlling what is lighted. This design strategy is crucial in lowering the amount of energy consumed for lighting. By providing task lighting only where required, the ambient light level can be much lower. For example, an entire open office does not need to have a light level suitable for reading detailed tasks, only the desktops. In such a case the ambient level may be low, with task lighting increasing the light to necessary levels at the necessary locations.

2-7.1 Additionally, when the system is designed with these "sub-systems", greater control flexibility results in greater opportunity for reducing energy use. Task lighting can be turned off at a workstation not in use. This control flexibility also results in greater user satisfaction. The LightRight Consortium (www.lightright.org) \2\ has research on how personally controlled and "ergonomic" lighting affects occupant comfort and satisfaction./2/

2-7.2 Ambient lighting provides general illuminance and surface brightness for wayfinding and transitional tasks. Lighting high reflectance surfaces will create the perception of brightness and provide enough ambient light for a space.

2-7.3 Task lighting increases the illuminance of a particular task at close range. The type of lighting and the light level vary with the task. General reading will require a lower light level than detailed accounting tasks. Computer use may require light on an adjacent written task, but not on the computer screen itself. \1\ When \2\ an illuminance criterion /2/ for a detailed task requires a high light level, it should not be provided with overhead, ceiling mounted lighting. Task lighting much closer to the task will meet the criteria with significantly lower energy use. /1/

2-7.4 Accent lighting highlights particular architectural features or artwork. If the ambient light level is too high, no amount of accent lighting will increase the brightness of a feature enough to make the contrast apparent. Selective use of accent lighting also increases its effect. Too much accent lighting will wash out the impact of any single feature.

2-7.5 Considerations to incorporate ambient/task/accent systems:

1. Design a lighting system to provide a minimal amount of ambient light. Add task lighting to increase light level at the point of use. Add accent lighting for visual interest. Refer to specific application in Chapter 7, "Interior Applications".
2. \1\Task lighting equipment may fall under another construction budget or

procurement time frame and needs to be coordinated with interior designers and construction managers. /1/

\1\

2-8 LIGHTING CONTROL.

Controlling the electric lighting \2\ in response /2/ to daylight availability and occupancy are some of the most effective methods of reducing lighting energy and cooling loads. \2\ Occupancy sensors can save between 20%-40% of the energy in appropriate spaces[3]. /2/ Devices also can provide for individual control over the indoor environment resulting in higher occupant satisfaction. \2\ Table 2-1 and Table 2-4 /2/ describe space types, control strategies which may be most appropriate, and potential energy savings. \1\ *ASHRAE/IES 90.1-2007* /1/ \2\ and *ANSI/ASHRAE/USGBC/IES 189.1-2009* lighting control requirements must be met in addition to the requirements outlined in this UFC. In many cases, UFC requirements may exceed those of ASHRAE /2/. A summary of these control requirements are listed below. Refer to \1\ *ASHRAE/IES 90.1 -2007* /1/ \2\ and *ANSI/ASHRAE/USGBC/IES 189.1-2009 /2/* for specific control implementation and exceptions. In all cases, implement the simplest and most cost effective strategy that will meet the occupants' needs and energy goals. Complex solutions are not required for every application.

/1/ \2\

If a networked control system is to be used for the lighting, then the system must be certified in accordance with the Department of Defense Assurance Certification and Accreditation Process (DIACAP) and the Service implimentaion policy. For additional information on the Certification and Accreditation process, see *DoDI 8510.01.*

/2/

2-8.1 \2\ Lighting Control Requirements**.** /2/

Lighting control requirements to meet \1\ ASHRAE/IES 90.1-2007 /1/ \2\ and *ANSI/ASHRAE/USGBC/IES 189.1-2009 /2/*:

1. Automatic Lighting Shutoff. Interior lighting in buildings larger than 5000 ft^2 must be controlled with an automatic control device to shut off building lighting in all spaces. This automatic device can be a timeclock, occupancy sensor, \2\ vacancy sensor, /2/ or signal from a building control system. The device can control up to 25,000 square feet but not more than one building floor.
2. Space Control. Each space enclosed by ceiling-height partitions must have at least one control device to independently control the general lighting within the space. This control must be located adjacent to the

[3] "Energy Management", *The IES Lighting Handbook*, Chapter 17, Tenth Edition (New York: The Illuminating Engineering Society of North America, 2011), p. 17.2.

entrance to the space. Each control device must be activated either manually by an occupant or automatically by sensing an occupant. For example, to meet this requirement and achieve maximum energy savings, a private office could be fitted with a \2\ vacancy sensor requiring /2/ manual-on, auto off, switch.

3. Exterior Lighting Control. Lighting for all exterior applications not exempted in \2\ ASHRAE 90.1 2007 Section /2/ 9.1 must be controlled by a photosensor, astronomical time switch or a combination of both. Controls must be configured to automatically turn on exterior lighting at dusk and turn off the exterior lighting when sufficient daylight is available or the lighting is not required.

4. \2\ Controls for outdoor lighting. All outdoor lighting controls shall comply with Section 9 of ANSI/ASHRAE/IES Standard 90.1 with the following modifications and additions. For lighting of building facades, parking lots, garages, canopies, (sales and non-sales), and all outdoor sales areas, automatic controls shall be installed to reduce the sum of all lighting power (in watts) by a minimum of 50% one hour after normal business closing and to turn off outdoor lighting within 30 minutes after sunrise./2/

Table 2-1. Required Control Devices for Different Building Applications.

SPACE TYPE	CONTROL DEVICE	
	VACANCY OR OCCUPANCY SENSOR	OCCUPANCY SENSOR WITH MULTI-LEVEL / BI-LEVEL SWITCHING OR DIMMING
Classroom	●	
Conference/Meeting Room	●	
File/Storage Closet/Room	●	
\2 \ Copy/Printer/Mail Room	●	/2/
Hallway		●
Janitor Closet/Room	●	
Lunch/Break Room	●	
Private Offices	●	
Restrooms	●	
Stairwell		●
Telecommunication (Telcom) Closet/Room	●	
Warehouse (stacks)		●

Note: Do not \2\ turn off /2/ lighting that provides illumination for working spaces about electrical service equipment such as switchboards, panelboards, or motor control centers with occupancy sensors, \2\ vacancy sensors /2/ or timers. \2\ To reduce energy consumption, equip spaces with bi-level or dimmable luminaires controlled by an integrated or separate vacancy sensor. Manually switch luminaires to operate at full light output. Upon sensing vacancy, switch or dim luminaires to 50% of full light output while maintaining the minimum life safety code requirement for egress. /2/

2-9 INTERIOR LIGHTING CONTROL STRATEGIES

2-9.1 Occupancy Based Controls.

\2\ Occupancy sensors automatically turn the lights on when an occupant enters a space and automatically turn the lights off after a predetermined period in which no human activity is sensed. Vacancy sensors automatically turn the lights off after a predetermined period in which no human activity is sensed. The occupant must manually turn on the lights when he or she enters the space. The operating technologies behind either an occupancy or vacancy sensor are: passive infrared (detecting heat), ultrasonic (detecting sound), or dual technology (which detects both heat and sound)./2/

Occupancy based controls are required for spaces such as storage rooms, janitor closets, classrooms, conference rooms, private offices and break rooms, see Table 2-1. These controls detect individuals with passive infrared, ultrasonic, or dual technology. They may be ceiling mounted to cover large spaces or they may be integrated with wall switches for smaller spaces. Occupancy \2\ based controls /2/ are ideal for areas of convenience such as storage rooms where individuals often have their hands full when entering or leaving. \2\ For private offices, it may be ideal to have an auto-on occupancy sensor that turns the lights on to a preset light level such as 50% with a manual 100% and then automatically turns the lights off. /2/ Manual override may be necessary in spaces where the lights occasionally need to be turned off with occupants such as classrooms and conference rooms. \2\ It may also be useful to group luminaires and control with a single occupancy or vacancy sensor./2/ Ballast selection must match control strategies. Instant start ballasts must not be used in areas where lighting is controlled with occupancy \2\ or vacancy /2/ sensors. Refer to Chapter 5 “Lighting Equipment” for more detail on \1\ application and /1/ types of occupancy-based controls. Controls must have a time delay that can be adjusted up to 30 minutes. \2\ If the sensor fails, local override control shall be available or the system shall revert /2/ to the ON position./1/\2\ Table 2-2 below summarizes strategies for selecting the appropriate occupancy based control sensor. /2/

2-9.2 Bi-Level and Multi-Level Switching.

Bi-level switching allows for step dimming or the lamps in a two lamp luminaires to be switched independantly. /2/ \1\Bi-level switching shall be used in stairwells and similar low occupancy spaces such as hallways to reduce energy consumption. Spaces should be equipped with bi-level \2\ luminaires /2/ controlled by an integrated or separate occupancy sensor. The \2\ luminaire /2/ operates at 50% full light output maintaining the minimum life safety code requirement for egress during vacancy and switches to full light output upon detecting occupancy in the space.

\2\ Multi-level switching allows multiple light sources within a luminaire to be switched independently. For example, a three lamp luminaire would offer four light output settings: 100%, 66%, 33%, and OFF.

2-9.3 Light Level Tuning.

Light level tuning is used to adjust the maximum light level to precisely set the lighting requirements based on the preference of the occupants in the space, the color of the carpets, office furniture, cubicles, walls, etc. Different spaces can have different maximum light levels and the ability to adjust the high-end output of the luminaire can offer typical lighting energy savings of 20% or more.

2-9.4 Scene Based Dimming.

One button touch allows multiple zones of light within a space to go to the appropriate light levels, known as a scene, for a specific task or use. Scene based control shall allow the integration of AV controls, shading, and lighting to work seamlessly with one button touch (i.e. lights dim, projection screen lowers, and shades go down).

2-9.5 Daylight Based Controls.

Daylight-based controls detect the amount of daylight in a space and dim luminaires to supplement the daylight. There are two types of daylight sensors: open loop and closed loop (Table 2-4). Sensors must be located according to manufacturer's recommendations. If daylighting is used, electric lighting must be integrated with daylight controls. Refer to Chapter 3, "Sustainability", Chapter 4, "Daylighting" and Chapter 5, "Lighting Equipment – Controls".

Harvesting daylight is best suited in spaces that are frequently occupied and a significant amount of daylight enters the space. During periods of peak daylight availability, daylight levels should be at least two to three times greater than the design criteria for electric lighting in the primary daylight control zone. Secondary zones \2\ typically /2/ have one half to one third of the design criteria for electric lighting. When selecting daylight zones, it is important to consider the exterior environment in addition to the proximity to glazing. As Figure 5-14 indicates, if exterior buildings or foliage are blocking some of the daylight contribution into the building, treat those zones as secondary. It is recommended that electric lighting be located parallel to the daylight zones for dimming control.

Figure 2-9. Daylight Control Zones

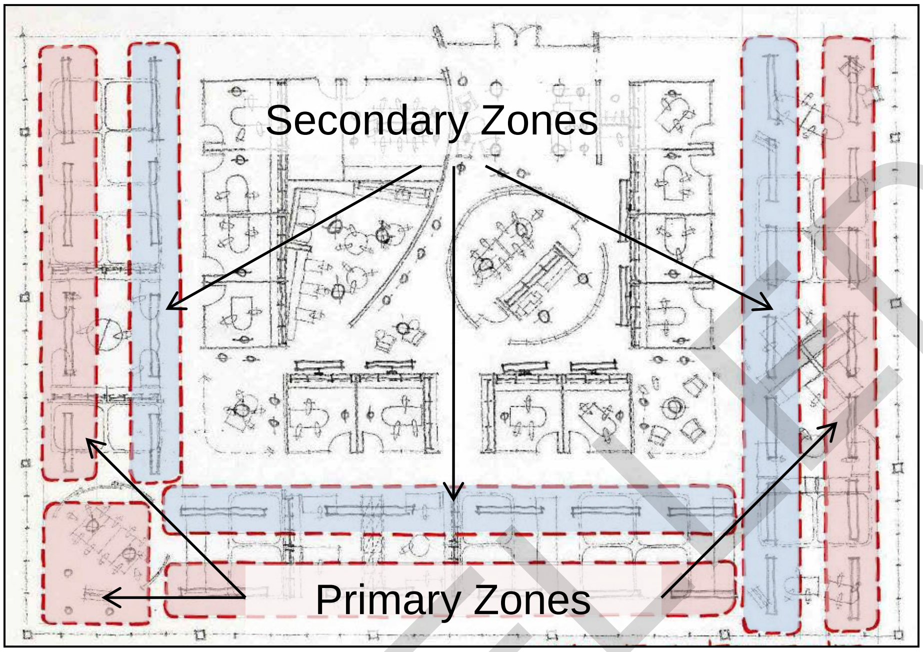


Figure 2-10. Daylight Control Zones with Obstructions (Upper Floors).

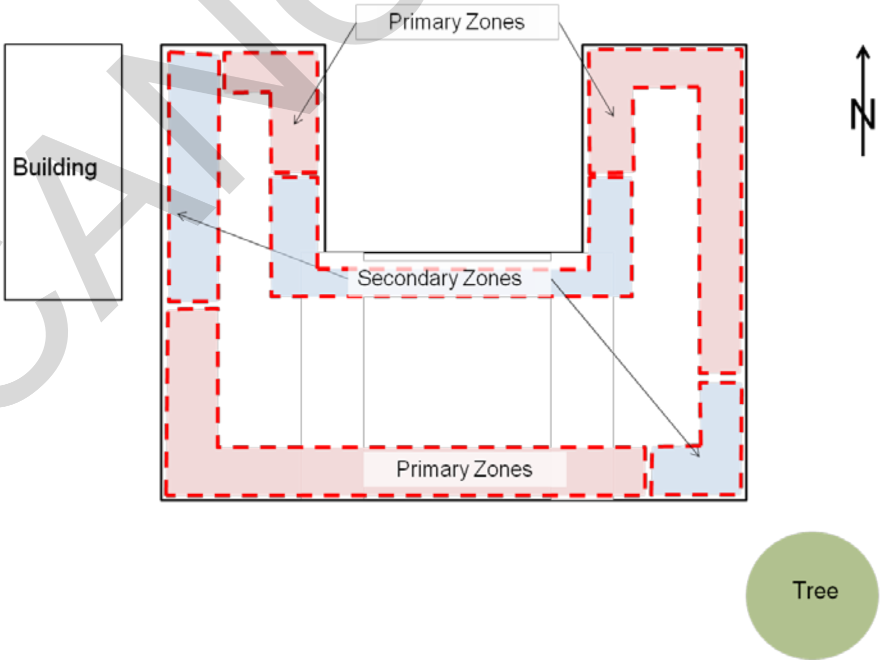
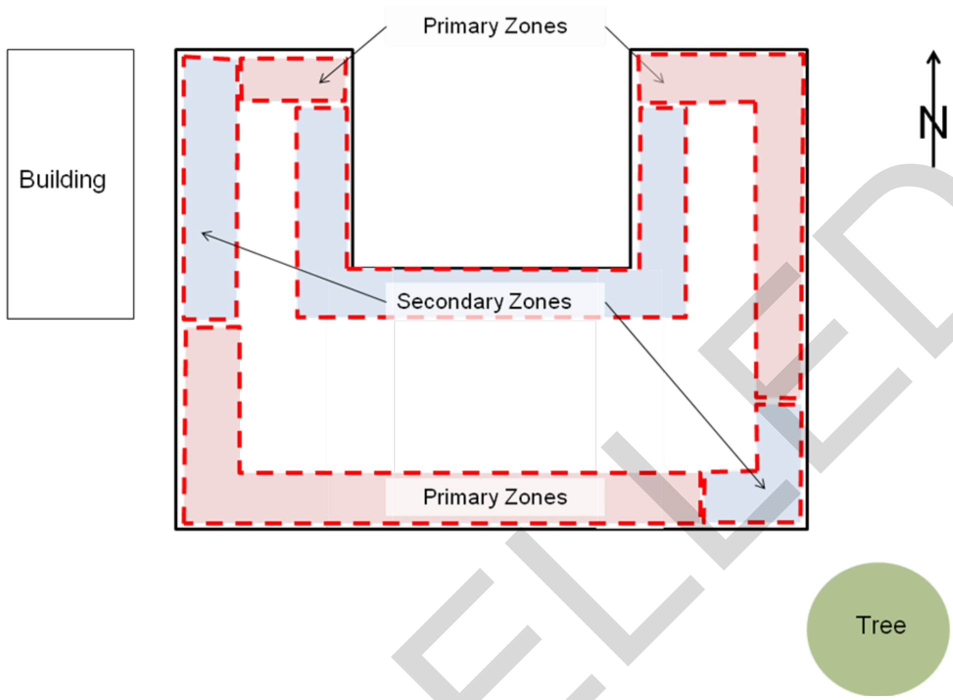


Figure 2-11. Daylight Control Zones with Obstructions (Lower Floors).



2-9.5.1 Task Dominant Areas.

Task dominant area examples include offices, conference rooms, classrooms, maintenance areas and other regularly occupied areas. Daylight dimming provides the highest level of satisfaction since the lighting smoothly responds to daylight availability versus an abrupt on/off. Ideally, manual dimming with an upper daylight limit provides the greatest flexibility and highest acceptance since people have control over their areas. In addition, occupancy and vacancy sensors turn off the lighting if no one is in the area.

2-9.5.2 Non-Task Dominant Areas.

Non-task dominant area examples include transition areas such as corridors, lobbies, atriums or support areas such as cafeterias, restrooms, and storage areas. Exterior lighting is typically a non-task dominated area. Automatic daylight on/off or bi-level switching is acceptable in these areas, yet dimming is still preferred. Occupancy sensors in these public areas will save the most energy, though lights can be turned off with an energy management system. If occupancy devices allow adequate time, especially in transition areas, then the lighting is not disrupted during normal hours of operation.

2-9.5.3 Automated Shading.

Automated shading should be considered in spaces utilizing daylight harvesting to preserve the functionality of the daylight harvesting system and maximize the energy savings of the system. The shades shall be controlled to reduce glare and unwanted heat gain while still allowing natural light to enter the space. When utilizing automated shading the following shall be considered:

- For ease of use the automated shades will be operated by common controls (i.e. same appearance and design) with the lighting control system.
- For maximum energy savings the automated shading system shall position the shades based on a combination of time of day, façade direction, and sky conditions.
- For maximum design flexibility and ease of installation, shade systems should have the capability to address each shade individually.
- The shading system shall have a manual override that allows the occupant to temporarily adjust the shades to any desired position. The system will revert back to automatic control after a specified period of time.
- Based on the application and size of the windows or skylights, the shading system may employ drive (motor) technology that is either line-voltage or low-voltage in nature; an overall installed cost assessment of the shading system and the necessary equipment to integrate to the lighting control and building management systems shall be done to determine the overall best value, installed cost solution for the project. /2/

2-9.6 Manual Switching.

\2\ There are several strategies to implement switching. Manual switching may be an ideal strategy where automatic control is not desired such as electrical rooms. The energy savings is diminished though, so a switch should be integrated with an occupancy based sensor. /2/

2-9.7 Time Switching.

Timed switching can be incorporated into wall switches for small spaces not conducive to occupancy based controls.

2-9.8 Time Clocks.

Time clocks control larger areas or groups of luminaires. \2\ They automatically adjust lighting levels based on the time of day or astronomical events such as sunrise and sunset. This type of control may be applicable in spaces where there is constant occupancy, limited daylight, and minimal activity in non-peak hours of the day./2/

2-9.9 Personal Control.

This provides an occupant with the ability to control and dim their own lighting even in an open office configuration. \2\ Personal controls may be accomplished with personal control over task lighting at a workstation. /2/

\2\

2-9.10 Network Control Systems.

If a networked control system is to be used for the lighting, then the system must be certified in accordance with the Department of Defense Assurance Certification and Accreditation Process (DIACAP) and the Service implimentaion policy. For additional information on the Certification and Accreditation process, see *DoDI 8510.01.*

A network control system will be required to integrate into a building automated, energy management system. Even in cases where integration with a building management system is not feasible, it may be appropriate to have a stand-alone lighting network control system. There are varying methods to create a network control system. A wireless based system may provide the greatest flexibility and configuration options because zones can be created through software for spaces that may be reconfigured over time.

2-9.11 Interior Controls Summary.

Refer to Table 2-2 for a summary of control strategies and their applications.

Table 2-2. Summary of Control Strategies and Their Application.

	Switching	Dimming	Network Controls	Building Automated System
Space Type	Enclosed	Open, shared	Enclosed Open, shared	Enclosed Open, shared
Occupant Type	Stationary Single user	Stationary Multiple users	Stationary Non-stationary Single or multiple users	Stationary Non-stationary Single or multiple users
Tasks Type	Simple	Precision	Simple Precision	Simple Precision
Cost	$	$$	$$$	$$$
Construction Type	Retrofit New Construction	Retrofit New Construction	Retrofit New Construction	Retrofit New Construction
Daylight Availability	Yes	Yes	Yes	Yes
Potential Energy Savings	Low-Medium	Medium	Medium-High	Medium-High
Integration with Other Systems (HVAC)	No	No	No	Yes

Table 2-3. Recommended Control Devices for Different Building Applications.[4]

Space Type	Wallbox Occ. Sensor	Ceiling/Wall Occ. Sensor	Personal Occ. Sensor	Vacancy Sensor	Time Switch	Time Clock	Multilevel Switching	Manual Wallbox Dimmer	Wireless Remote Dimmer	Photoswitch	Photosensor
Assembly & Light Manufacturering			○			●	○			○	●
Auditoriums		●					○	●	●		
Classrooms		●					●	●	●	○	●
Concourses, Lobbies, Malls						●	●			●	●
Conference Rooms	○	●		●			○	●	●		●
Exterior Lighting		○				●	○			●	
File/Storage Rooms		●		●	●						
Grocery/Supermarket		●			○	●	●			○	○
Gymnasiums		●					○			○	
Hallways		●				●				●	○
Laboratories		●	○				○	●			●
Library Reading Areas		●				○	○				●
Library Stacks		●			●	○	○				
Locker Rooms		●				○	○				
Lunch/Break Rooms	○	●		●			○			○	
Medical Suite/Exam Rooms	○	●		●			●	●			
Museums		○					●	●		○	●
Open Offices		○	●			●	●	●			●
Private Offices	○	●	●	●		●	●	●	●		●
Restaurants						○	●	●	○		○
Restrooms	○	●			○		○				
Retail Sales Area						○		○		○	○
Warehouse		●			○	●	●			○	○

● = good application ○ = limited application

[4] New Buildings Institute, Inc. "Lighting Controls", *Advanced Lighting Guidelines,* Chapter 8. 2001 Edition, 8-5, 8-12. Neither the sponsors, authors, editors, advisors, publisher, or the New Buildings Institute, Inc. nor any of its employees make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any data, information, method, product or process disclosed in this document, or represents that its use will not infringe any privately-owned rights, including but not limited to, patents, trademarks or copyrights. © 2001 by New Buildings Institute, Inc. All rights reserved.

Table 2-4. Lighting Control Energy Savings Examples by Application and Control Type[5]

Space Type	Controls Type	Lighting Energy Savings (Demonstrated in Research or Estimated as Potential)	Study Reference
Private Office	Occupancy sensor	38%	*An Analysis of the Energy and Cost Savings Potential of Occupancy Sensors for Commercial Lighting Systems*, Lighting Research Center/EPA, August 2000.
	Multilevel switching	22%	*Lighting Controls Effectiveness Assessment*, ADM Associates for Heschong Mahone Group, May 2002.
	Manual dimming	6-9%	*Occupant Use of Manual Lighting Controls in Private Offices*, IESNA Paper #34, Lighting Research Center.
	Daylight harvesting (sidelighting)	50% (manual blinds) to 70% (optimally used manual blinds or automatic shading system)	"Effect of interior design on the daylight availability in open plan offices", by Reinhart, CF, National Research Council of Canada, Internal Report NRCC-45374, 2002.
Open Office	Occupancy sensors	35%	National Research Council study on integrated lighting controls in open office, 2007.
	Multilevel switching	16%	*Lighting Controls Effectiveness Assessment*, ADM Associates for Heschong Mahone Group, May 2002.
	Daylight harvesting (sidelighting)	40%	"Effect of interior design on the daylight availability in open plan offices", by Reinhart, CF, National Research Council of Canada, Internal Report NRCC-45374, 2002.
	Personal dimming control	11%	National Research Council study on integrated lighting controls in open office, 2007.
Classroom	Occupancy sensor	55%	*An Analysis of the Energy and Cost Savings Potential of Occupancy Sensors for Commercial Lighting Systems*, Lighting Research Center/EPA, August 2000.
	Multilevel switching	8%	*Lighting Controls Effectiveness Assessment*, ADM Associates for Heschong Mahone Group, May 2002.
	Daylight harvesting (sidelighting)	50%	*Sidelighting Photocontrols Field Study*, Heschong Mahone Group, 2003.

[5]New Buildings Institute, Inc. "Lighting Controls", *Advanced Lighting Guidelines*, 2010. Neither the sponsors, authors, editors, advisors, publisher, or the New Buildings Institute, Inc. nor any of its employees make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any data, information, method, product or process disclosed in this document, or represents that its use will not infringe any privately-owned rights, including but not limited to, patents, trademarks or copyrights. © 2001 by New Buildings Institute, Inc. All rights reserved. /2/

\2\

2-10 EXTERIOR LIGHTING CONTROL STRATEGIES

2-10.1 Manual Switching.

Manual switching is not ideal for controlling exterior lighting, except in residential applications where a single switch would suffice.

2-10.2 Occupancy Based Controls.

The use of motion sensors in exterior applications is widely accepted in residential applications. In commercial or industrial applications, occupancy sensors can be implemented in some applications. It is important to ensure that the occupancy sensor being used does not leave any 'dead' zones where occupancy cannot be detected for safety concerns.

2-10.3 Adaptive Lighting.

Adaptive lighting is concept of adjusting the light levels to suit the activity level. This is accomplished with bi-level switching and motion sensors or preset continuous dimming. When no occupancy is detected in a zone, or late at night when traffic and pedestrian volumes are known to be minimal, lighting levels are reduced to a minimum of 50% full light output. Adaptive lighting is ideally suited for wall mounted, roadway, area, pathway, parking lot or pedestrian luminaires.

2-10.4 Photosensor.

Photosensors can be used as an exterior lighting control strategy. A single photosensor can be installed on each luminaire or on a lighting control center linking a group of luminaires together. The photosensor has a shorter rated life than the luminaire or light source and must be diligently maintained.

2-10.5 Time Clock.

Time clocks or time switches are utilized to automatically turn the lights on or off on a daily basis. Typically, time clocks are programmed to turn on and off based on astronomical events such as sunset and sunrise or when activity has ceased.

2-10.6 Network Control Systems.

****1\ Exterior control systems are beginning to follow the same path as interior addressable systems. By communicating with the ballast, \2\ driver, generator /2/ or power control unit of each roadway or area luminaire, a centralized control system can monitor a wide range of characteristics including energy consumption and outages. Additionally, this control strategy accommodates the concept of adaptive lighting standards. This concept recognizes that lighting criteria provides for the worst case scenario – conditions that may only exist for a fraction of the night or year. With more advanced control systems and dimmable sources, exterior lighting can provide the appropriate amount of light for the time of day, time of year, weather conditions, etc. while significantly reducing energy use. /1/ \2\See Chapter 5 Lighting Equipment for additional information on exterior lighting controls. /2/

/2/

2-11 SUSTAINABILITY ISSUES.

2-11.1 Sustainability refers to a broad range of design strategies aimed at reducing the resource use and environmental impact of the built environment. Areas of concern include energy efficiency, resource conservation, reuse, and recycling, indoor air quality. The concept of holistic design brings all of these issues into consideration. This design approach integrates various building disciplines and systems. Integrated design requires an understanding of how one building system affects other systems and how to optimize their interdependence. For example, utilizing energy efficient light sources and turning off \2\ luminaires /2/ that are not required, minimizes electricity requirements for the building lighting system. However, these same strategies also reduce the amount of heat produced by all light sources. With this reduction in heat, a smaller mechanical system may be required to cool the building. Less space required for mechanical equipment may mean more space for program requirements.

2-11.2 Requirements for sustainable design:
\1\

1. Provide sustainable design to achieve the required LEED or other agency certification level in accordance with UFC 4-030-01. /1/

2. Use the most energy efficient light source suitable for the application. Some inefficient light sources are prohibited. Refer to \2\ Light Sources /2/ in Chapter 5, "Lighting Equipment" for prohibited light sources.

3. Minimize light pollution and light trespass by not overlighting and using shielded exterior luminaires. Refer to Chapter 3, "Sustainability Issues – Light Pollution, Light Trespass".
4. Evaluate sustainable measures using life cycle cost analysis rather than initial cost comparisons. Refer to Chapter 3, "Sustainability Issues – Economic Issues".
5. Light sources containing mercury should be recycled. Refer to Chapter 3, "Sustainability Issues – Material Issues". This cost must be included in a life cycle cost analysis.

2-11.3 Considerations for sustainable design:
Consider daylighting techniques. Refer to Chapter 3, "Sustainability Issues" and Chapter 4, "Daylighting". If daylight strategies are used, additional coordination is required with the architect and mechanical engineer. Additionally, electric lighting controls must be incorporated to take advantage of the potential energy savings.

2-12 SECURITY.

2-12.1 In most exterior applications, security is best achieved by reducing glare. In some circumstances such as entries and checkpoints, glare can be used to increase vertical illuminance on approaching vehicles or individuals while increasing visibility for guards and patrols. \1\ Refer to Chapter 6 of this UFC as well as *MIL-HDBK-1013/1A, Design Guidelines for Physical Security of Facilities*. /1/

2-13 MAINTENANCE ISSUES.

2-13.1 Inventory Minimization.

Light source types should be consolidated across luminaire types to minimize the number of various light sources that need to be stocked by maintenance. When designing lighting systems for a facility, trade-offs should be carefully considered between specifying the most appropriate wattage light source and introducing too many light source types on a project. This may include maximizing the use of 4' linear fluorescent light sources.

2-13.2 Group re-lamping involves replacing all of the light sources in a particular area after a specified time of operation rather than spot re-lamping as individual light sources burn out. The benefits of this approach include a more consistent light level and reduced maintenance costs, especially in areas that require lifts or scaffolding for light source replacement.

2-13.3 Accessibility.

When designing lighting systems, especially in high ceiling areas such as atriums, provisions must be made for maintenance access and light source replacement. Wall mounted indirect luminaires are easier to access than downlights. Lowering devices may lower pendants to the floor for maintenance. Safety hooks may be provided for securing to while working on a high luminaire. If a lift will be used, a path of travel must be determined that accommodates the lift equipment.

2-13.4 Equipment Life.

Select light sources, ballasts, \2\ drivers, generators,/2/ and controls that are rated or guaranteed for long useful lives. An incandescent light source may have a very low initial cost but may have to be replaced several times a year, while an induction light source or SSL may not be replaced for decades.

2-13.5 Considerations for improved maintenance:

1. Minimize light source types on an individual project.
2. Group re-lamp luminaires within individual areas.
3. Provide all luminaires with means of re-lamping and maintenance.
4. Select equipment and sources with long operating lifetimes. Refer to Chapter 5, "Lighting Equipment – \2\ Light Sources",/2/ for average light source life of various sources.

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CHAPTER 3: SUSTAINABILITY ISSUES

3-1 INTRODUCTION.

\1\ Provide sustainable design to achieve the required LEED or other agency certification level in accordance with UFC 4-030-01. /1/ Incorporating \1\ sustainable goals /1/ into the design process requires a careful analysis of both the cost and the benefits of the strategies outlined in the rating system. Any design strategy has both synergies and tradeoffs with other building systems and the project budget. Lighting design addresses several sustainable issues and presents multiple strategies that can be considered in a particular project: daylight utilization, lighting controls, energy efficiency, materials, light pollution, and light trespass. All of these issues have significant impacts on the project budget that can best be evaluated with a life-cycle cost analysis. Additionally, the most sustainable solution to a new building project may be to renovate an existing building. In this situation, certain lighting issues must be addressed to improve the efficiency and visibility of an existing system.

3-2 BUILDING RATING SYSTEMS.

Because interpretations of sustainability vary dramatically, building rating systems serve as a defined baseline for and a means of comparison between building projects. Sustainable design inherently requires integrated design. Rating systems provide design and construction teams with a framework of sustainable and efficient strategies and the synergies and trade-offs that exist between them. Refer to the Whole Building Design Guide, Design Objectives at http://www.wbdg.org/design/designobjectives.php and Daylighting at http://www.wbdg.org/resources/daylighting.php for more information.

\1\/1/

3-2.1 The US Green Building Council, Leadership in Energy and Environmental Design (LEED™) Rating System. The LEED™ Version \2\ 2.2 /2/ rating system measures the "green" performance of new and existing commercial, institutional, and high-rise residential buildings. The system is divided into six categories: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, and Innovation and Design Process.[6] Within each category, multiple credits can be obtained in addition to certain prerequisites that must be met to qualify the project. All of the credits outline quantifiable and verifiable criteria. The lighting design for a project currently affects several credits and prerequisites: Sustainable Sites Credit 8, Light Pollution Reduction; Energy and Atmosphere Prerequisite 2, Minimum Energy Performance, Credit 1, Optimize Energy Performance; and Indoor Environmental Quality Credit 6, Controllability of Systems and Credit 8, Daylight and Views. Refer to the latest version of the LEED™ rating system for exact requirements.

3-2.1.1 Sustainable Sites Credit 8, Light Pollution Reduction. This credit addresses exterior site lighting and its contribution to light pollution and potential for light

[6] US Green Building Council. "Introduction". LEED™ Reference Guide. Copyright 2001. p 3.

trespass. These issues are addressed in Chapter 3 “Sustainability Issues” along with strategies to minimize both.

3-2.1.2 Energy and Atmosphere Prerequisite 2, Minimum Energy Performance. This prerequisite requires that the provisions of ASHRAE/IES 90.1 be met as a minimum baseline of building energy efficiency.

3-2.1.3 Energy and Atmosphere Credit 1, Optimize Energy Performance. This credit addresses the overall building energy consumption. Because lighting can be a significant electrical load and also a cooling load on the HVAC system, reducing the lighting energy use minimizes the total building energy requirements. Strategies outlined in this UFC such as daylight integration, surface brightness, controls, and light source selection all serve to reduce the energy used by the lighting system.

3-2.1.4 Indoor Environmental Quality Credit 6, Controllability of Systems. Building occupants prefer to have control over their interior environment including the lighting system. This credit requires a certain degree of control per unit area of the lighting.

3-2.1.5 Indoor Environmental Quality Credit 8, Daylight and Views. The controlled introduction of daylight into interior spaces reduces the lighting energy requirement and improves the comfort of the occupants. This credit outlines requirements for access to daylight and to view glazing within a space.

\1\/1/

3-2.1.6 Facility Delivery Process, Holistic Deliver of Facility. This credit requires that building systems (including lighting) be evaluated on a life cycle cost basis rather than first cost alone.

3-2.1.7 Current Mission, Operation and Maintenance. The lighting system must be included in the operation and maintenance program. Also, select lighting equipment that is appropriately durable and also makes sense with the life cycle cost analysis.

3-2.1.8 Current Mission, Soldier and Workforce Productivity and Retention. Many of the visibility issues outlined in Chapter 2 “Lighting Design Considerations”, including daylight, glare, and surface brightness all affect occupant comfort and productivity.

3-2.1.9 Future Missions, Functional Life of Facility and Supporting Systems. Evaluate the expected life of lighting equipment and the cost of replacement in the building life cycle costs analysis.

3-2.1.10 Future Missions, Adaptation, Renewal and Future Uses. Consider lighting system designs that are not dependent on current furniture layout and are flexible for changes in use. Task / ambient lighting systems, as described in Chapter 2, “Lighting Design Considerations”, achieve this goal.

3-3 COSTS / BENEFITS.

While the cost and benefit of any design strategy must be evaluated with respect to an individual project, some issues are common to the sustainable design of any facility.

3-3.1 Daylighting.
Utilizing daylight to provide the light in the building has the benefit of reducing lighting energy requirements while improving the quality of the indoor spaces. However, it also requires a significant increase in design time and coordination between structural, mechanical, and electrical systems. This strategy may require additional modeling to ensure that daylight is provided without glare or increased heat gain. This results in increased design requirements. Additionally, in DoD facilities, Antiterrorism (AT) criteria (see UFC 4-010-01) increase the required strength of glazing. Therefore, the addition of glazing may significantly increase the cost over a commercial building. However, worker productivity benefits may still outweigh these costs.

3-3.2 Controls.
Lighting controls have the benefit of reducing energy use when lighting is not required. However, the cost of the control device increases the initial system cost. For most applications, typical energy savings pay for control devices in approximately 3-7 years. The time period may be less when worker satisfaction is considered. This payback makes lighting control an attractive energy saving strategy. It is important to note that electric lighting controls must be incorporated with a daylight design to gain any energy savings from the daylight.

3-3.3 Energy Efficiency.
The careful selection of light sources to utilize the most efficient and lowest wattage light source for the application reduces energy use and cost. This results in a significant benefit with a low cost increase. The increase in light source cost between incandescent sources and more efficient, longer life, fluorescent sources is typically paid back in energy savings and replacement costs within a few years.

3-3.4 Materials.
The mercury content of fluorescent, \2\ induction /2/ and HID light sources poses an environmental threat when sent to a landfill or incinerator. By law, commercial and military facilities must recycle these light sources. This cost must be considered when developing a life-cycle cost analysis.

3-3.5 Light Pollution / Light Trespass.
Light pollution and trespass are reduced with the selection and location of lighting equipment. The benefit of addressing this issue is increased visibility and a minimal impact on the night sky. There is not necessarily an associated increase in cost. Shielded \1\/1/ luminaires are not necessarily more expensive than non-\1\ shielded /1/luminaires. When considering glare and veiling luminance criteria in addition to illuminance or \2\ luminance /2/ criteria, more luminaires may not be necessary. Designing to minimize light pollution and trespass encourages minimizing the amount of equipment and avoiding overlighting exterior areas. Both of these aspects may reduce initial cost.

3-4 UTILIZING DAYLIGHT.

The introduction and control of daylight into interior spaces has a twofold benefit. It can reduce the amount of energy that is necessary to light interior spaces and it also has a significant effect on the indoor environmental quality for the occupants.

3-4.1 Daylight is a reliable and efficient light source.

When properly controlled, it can provide quality and adequate light levels without becoming a source of glare or overheating a space. Architectural shading devices including overhangs and canopies can provide sufficient ambient light while eliminating direct glare. Chapter 4, "Daylighting", discusses strategies and technical details for successfully providing daylight to achieve these goals.

3-4.2 The introduction of daylight into interior spaces has a well-documented effect on the productivity of occupants and the education of students. In a study done by the Heschong Mahone Group[7], students who worked in daylighted classrooms progressed 26% faster on reading exams and 20% faster on math exams than students working in a classroom with less daylight. \2\ In another study completed by the Heschong Mahone Group[8], office workers were found to perform 10%-25% better on tests of mental function when the best daylight views were available to them./2/

3-4.3 Daylighting strategies can be divided into passive or active systems. Passive systems such as overhangs are the most common and refer to the location, profile, orientation, and shading of glazing on a building. Optimizing these components result in a building that admits daylight without excessive heat gain or glare. Because all of the devices and components are stationary, these techniques are categorized as passive. In comparison, active daylighting systems have moving parts, typically to track the sun throughout the day. An example of an active system includes a skylight with a moving mirror that captures direct sunlight and redirects it through the skylight, into the building.

For additional information on this topic, refer to the Sustainable MOU Technical Guidance on Daylighting: http://www.wbdg.org/references/mou_daylight.php

3-5 LOW ENERGY USE.

Energy efficiency in buildings necessitates a holistic approach to the design of the building systems and the integration between systems. The American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE) and the IES have produced ANSI/ASHRAE/IES 90.1. This document addresses efficiency standards that must be met for minimum energy performance. Per EPAct 2005, federal buildings must be designed to 30 percent below \1\ ANSI/ASHRAE/IES 90.1-2007 /1/ or the International Energy Code, if life cycle cost effective and sustainable design principles

[7] The Heschong Mahone Group, "Daylighting in Schools", http://www.h-m-g.com/projects/daylighting/summaries%20on%20daylighting.htm

[8] The Heschong Mahone Group, "Windows and Office: A Study of Office Worker Performance and the Indoor Environment". http://www.h-m-g.com/downloads/Daylighting/A-9_Windows_Offices_2.6.10.pdf

must be applied.

3-5.1 Efficacy refers to the amount of light (lumens) that is produced by a light source for every watt of energy. Different light sources produce light at different efficacies. Incandescent light sources have the lowest efficacy while fluorescent, \2\ SSL, /2/ induction, and metal halide sources have highest efficacies. Efficacy must be considered along with the application to select the most efficacious source that will light the surface or task appropriately.

3-5.2 Efficacy is often the focus of energy efficiency in lighting systems. While this is important, it is not the only strategy for reducing energy consumption. As described in the Surface Brightness, Task / Ambient, and Controls sections of Lighting Design Considerations, what the lighting design illuminates, how it is layered into separate systems, and how it is controlled (in response to daylight and occupancy) all affect the energy consumption. Increasing surface brightness can reduce the amount of energy necessary to light a space. Dividing the lighting system into task and ambient components allows the ambient system to use less lighting energy and an increase in light levels is provided only where it is required: at the task, not throughout the entire space. By controlling these lighting components separately, only the energy that is required at any given time is consumed.

3-6 MATERIAL ISSUES.

3-6.1 Mercury Content.

Fluorescent, metal halide, induction and high-pressure sodium light sources contain liquid mercury to produce the mercury vapor necessary for operation. When light sources are broken or incinerated the mercury may be released into the soil or the atmosphere. Mercury has been linked to potential health risks. Some light source manufacturers offer product series that feature reduced mercury content.

3-6.2 Recycling.

Traditional light source types except incandescent sources contain some level of mercury. These light sources should be recycled to avoid release of any mercury into landfills. The cost of recycling light sources should be included in any life-cycle cost analysis.

3-6.3 Light Source Life.

The life expectancy data given by light source manufacturers refers to the approximate time at which 50% of the light sources in a group are no longer operating, \2\ except for LED which is the operating time over which the LED light source will maintain 70% (L70) of its initial light output. /2/ The life of standard incandescent and tungsten halogen sources can be extended by dimming them 5% - 10%. Frequent switching of fluorescent sources can reduce the light source life. However, the use of rapid start or programmed ballasts reduces the impact of frequent starting on the light source life. Recent developments in light source technology have introduced long life light sources that have four to five times the life of standard incandescent light sources. Examples include SSL and induction light sources with useable lives of 50,000-70,000 hours.

3-7 LIGHT POLLUTION.

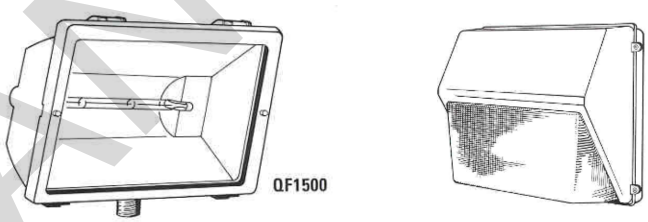
Light pollution or sky glow is caused by light aimed directly up into the sky and by light reflected off the ground or objects. Sky glow prevents the general public and astronomers from seeing the stars.

Floodlights, wall packs and other un-shielded luminaires are the major contributors to sky glow. Overlighting, even with shielded luminaires, reflects unnecessary light back into the atmosphere and adds to the sky glow. This often occurs at outdoor areas such as motor pools and sports fields.

Figure 3-1. Los Angeles, 1908 (left), Los Angeles, 2002 (right).

[9]

Figure 3-2. Unshielded and non-cutoff luminaires lead to light pollution

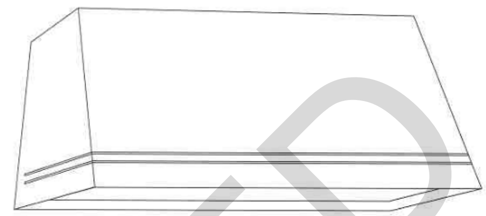


3-7.1 To minimize light pollution, use fully shielded luminaires for area and roadway lighting as illustrated in Figure 3-3. The use of full cutoff \1\ (fully shielded) /1/ luminaires may reduce uniformity and therefore require greater pole heights or spacing. \1\ Unshielded /1/ luminaires may also be used at low mounting heights if the lumen output of the light source is limited to 4200 lumens. These applications, such as pedestrian and entry lighting, typically require greater vertical illuminance for facial identity. For a more detailed description of \2\ fully shielded /2/ and shielded luminaires, see Table 5-3 in Chapter 5, “Lighting Equipment”. Provide uniform low glare lighting and do not overlight exterior areas. Also, control lighting with time clocks, photocells,

[9] © 2003 by Prof. Dr. Gerhard Eisenbeis University of Mainz/Germany

and motion sensors such that lighting is only energized when needed.

Figure 3-3. Examples of IES \2\ fully shielded /2/ luminaires.

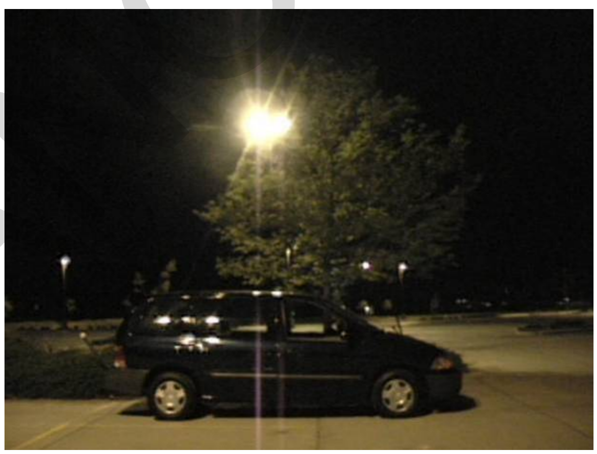


3-8 LIGHT TRESPASS.

Light trespass is referred to as nuisance glare or the “light shining in my window” effect. It is usually caused by a glare source that is bright compared to the darker night surround. Since glare inhibits our ability to “see” tasks and decreases contrast, all designs must minimize glare.

3-8.1 Uncontrolled light sources (floodlights) are usually the cause of light trespass. Not only does light trespass cause neighbor annoyance, but it also increases light pollution.

Figure 3-4. Glare results in loss of visibility.



3-8.1.1 To minimize light trespass, use only fully shielded luminaires for area lighting. When unshielded luminaires such as wall packs and decorative luminaires are used at low mounting heights, reduce the light source brightness to that of a 4200 lumen light source (similar to a 55 watt induction light source) or less. Do not overlight areas because reflected light can also result in complaints and poor visibility by increasing visual adaptation. Also, consider dimming or turning lighting off when not needed and activate with motion sensors or timers when activity occurs.

Figure 3-5. Fully shielded or IES \2\ fully shielded /2/ luminaires (left) are recommended. Do not use unshielded floodlights (right).

3-8.1.2 \2\ LEED Credit for Light Trespass. When pursuing the LEED credit for light pollution and light trespass, designers must consider the multiple-building environment of most military installations. The credit limits the amount of light trespass on adjacent properties. However, in many cases, spill light from one project may be desired to light another area. Adjacent projects all have the same owner. The credit calls for control of interior lighting during nighttime hours to prevent light from trespassing to exterior areas. Automatic lighting controls that turn lights OFF or to low dimmed levels during nighttime hours such as occupancy sensors or time clocks should be used to perform this function. Furthermore, automated window shades or dynamic glazing systems can be used on the windows to prevent light from escaping during nighttime hours. See the *LEED Application Guide for Multiple Buildings and On-Campus Building Projects* for guidance and more information./2/

3-9 ECONOMIC ISSUES.

The economic benefits of sustainable building strategies may not be immediately obvious until a life cycle cost estimate is evaluated. Various methods and programs can provide a life cycle cost for different building systems. The Federal Energy Management Program (FEMP) provides technical assistance for these methods.

3-9.1 Some strategies require no additional initial cost. Others may require a higher initial cost, but will often payback that cost increase within a few years. Some initial costs may provide for savings in other systems resulting in no net increase in the overall building cost. For example, skylights, shading devices, and lighting controls may increase the cost of the lighting and glazing systems, but it may result in a downsizing of the mechanical system and mechanical space required.

3-9.2 Not all economic issues are included in a life cycle cost. For example, the economic benefits of improved productivity in more comfortable daylighted buildings are not easily quantified. Additionally, energy efficiency reduces energy costs but also avoids the cost of externalities of energy production. Externalities are costs of energy production that are not included in the cost of the energy. Such externalities include costs of cleaning up pollution generated by a coal mine and a coal fired power plant. Other examples may include healthcare costs resulting from pollution-related illnesses.

3-10 RETROFITTING.

3-10.1 Many existing lighting systems can be replaced with new technology to provide appropriate lighting. Consider luminaires in good condition, whether relocated or salvaged, as an alternative to new lighting equipment when replaced with efficient technology. This may be a more cost effective solution to energy efficiency than new construction. \2\ In other situations however, a redesign may be more appropriate than a simple replacement of existing equipment. For example, closely spaced luminaires may be providing an unnecessary amount of uniformity or an excessive lighting level. A full redesign that provides an ambient light level as well as a higher task light level may prove to be the most cost effective solution over the life cycle of the building./2/

Replacement requires appropriate design analysis to ensure that acceptable results will be achieved. Redistribution of light should only be accomplished based upon sound design principles. Specular reflectors and parabolic retrofits should only be used after testing and system design is accomplished. The following paragraphs provide typical replacement possibilities; however, it is stressed that lighting design changes require proper evaluation on a case-by-case basis.

3-10.2 Existing Troffer Systems.

3-10.2.1 Typical Installations. Convert T-12 lighting systems to T-8 light sources and electronic high frequency ballasts. In most cases, de-lamp 4-lamp luminaires to either 2- or 3-lamp. White painted reflectors should be installed in older parabolic troffers. Install new lenses in lensed troffers if existing lenses are more than 7 years old.

3-10.2.2 T-12 fluorescent light sources come in a nominal 4 ft (1.2 m) length and are therefore suitable for retrofit with T-8 light sources. T5 and T5HO light sources are a metric length and slightly shorter than T-12 and T-8 light sources. These light sources cannot be supplied in place of the 4 ft (1.2 m) light sources and also may not be an appropriate brightness. Luminaires need to be specifically designed for use with T5 and T5HO light sources to control the brightness.

3-10.2.3 Specific light source and ballast combinations offer greater light output, extended life, or energy savings. They may be especially beneficial in retrofit applications to reduce the number of light sources or achieve energy savings. For more information, see Section 5-3.4.3.

3-10.2.4 Special Considerations for Computer Intensive Workspace. Most lensed troffers are not suited for computer workspaces. Consider relighting with a direct/indirect or semi-indirect pendant system.

3-10.3 Existing Downlights.

3-10.3.1 Typical Installations. Remove the incandescent light source and socket, and install a hardwired compact fluorescent adapter using a standard plug-based compact fluorescent light source. \2\ It is important to consider the base orientation for CFL sources as some may not be suitable for all orientations and source life may be compromised. /2/ In many cases, replacement of the reflector is also required to efficiently utilize the compact fluorescent light source. Compact fluorescent light source watts should be about 25 percent to 30 percent less than original incandescent light source watts to achieve similar light levels. \2\ Some of these sources can be dimmed when using a dimmable ballast in the luminaire. /2/

3-10.3.2 A typical installations. In some cases, hardwired conversions can be difficult or not cost effective. Use a medium based adapter with integral ballast and replaceable compact fluorescent light source. Compact fluorescent light source watts should be about 25 percent to 30 percent of less than original incandescent light source watts to achieve similar light levels. \2\ Some of these light sources can be dimmed. However, not all compact fluorescent or LED medium base light sources can be used with the base up or in a recessed housing. Check specifications for allowable applications. /2/

3-10.3.3 \2\ LED retrofits. LED components are now available for downlight replacements. As of this writing, very few acceptable A-lamp style LEDs are on the market. While this will certainly improve, be sure to consider equivalent lumen output, light source life, cost effectiveness, light source orientation (can it be installed with the base up) and light source enclosure (can it be installed in an enclosed housing). Other LED modules are available that replace the entire light source and reflector portion of the downlight. Additionally, few LED downlights come with an insulation contact (IC) rating. While these may provide some energy savings over incandescent, confirm the energy savings and cost effectiveness over fluorescent light sources. In some applications, LED may not be more efficient or cost effective than the established technologies. /2/ LED retrofits are only approved for replacement of CFL or incandescent sources (A lamp replacements) with Edison bases. At this time, LED retrofits are not approved for HID luminaires.

3-10.4 Existing Fluorescent Industrial Luminaires, Wraparounds, and Strip Lights.

3-10.4.1 Replace F40T12, and F48T12 light sources and magnetic ballasts with T-8 light sources and electronic high frequency \2\ program start /2/ ballasts.

3-10.4.2 For lighting systems employing F96T12 slimline and F96T12/HO light sources, consider all of the following:

- Retrofitting with electronic high frequency ballasts and continuing to use existing light sources.

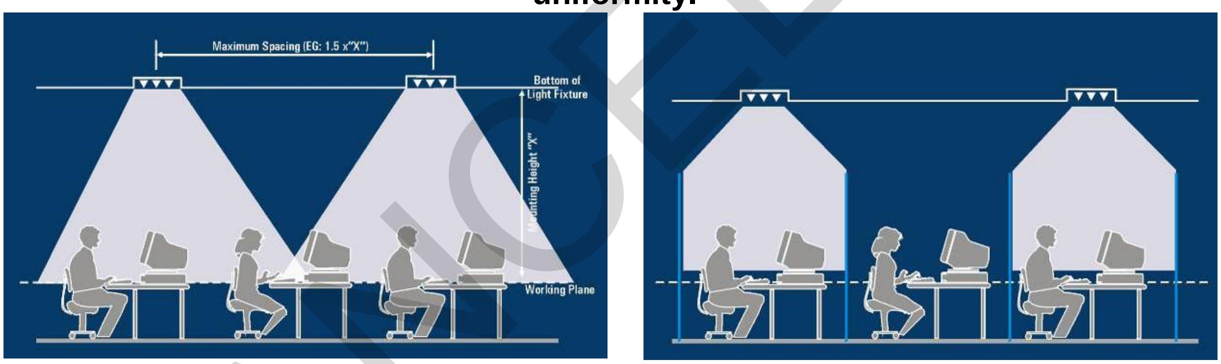
- Replacing 2.4 m (8 ft) light sources with 1.2 m (4 ft) T-8 light sources, possibly including high light output ballasts and high output T-8 light sources when replacing T12/HO light sources.
- Replacing 2.4 m (8 ft) light sources with T-8 2.4 m (8 ft) light sources and electronic high frequency ballasts.

3-10.5 Maintaining Uniformity.

Carefully consider changes in lighting systems and furniture systems so that lighting uniformity is not compromised. As shown in Figure 3-6, a lighting system that provides uniform illuminance on the work-plane in one furniture configuration may not provide the same uniformity in a different configuration.

3-10.5.1 In the case shown, an additional luminaire is required to adequately light the center workstation. This increases the amount of energy required to light the same area. In such a condition, the use of a semi-indirect, pendant system will provide better uniformity and at the same time allow for flexibility in the workstation layout.

Figure 3-6. A change in furniture configuration affects the task plane illuminance uniformity.[10]



3-10.6 Low Ceiling Applications.

3-10.6.1 In some applications, the ceiling height may be low and cannot be increased to accommodate pendant mounted lighting equipment. In these cases, the lighting design should still try to address the issue of surface brightness. One way to achieve surface brightness with low ceiling conditions is with recessed downlight / wallwash luminaires. The reflector on these luminaires looks similar to a standard downlight, but also uses a modification to light adjacent walls evenly. It is also designed to put light high on the wall next to the ceiling.

3-10.6.2 Indirect lighting provides better visibility for offices and computer tasks than parabolic luminaires. Additionally, the installation cost of pendants can be lower

[10] Used with permission. Hayden McKay Lighting Design.

than recessed troffer luminaires due to the reduced number of connection points. In low ceiling applications where a semi-indirect pendant system is not feasible, consider semi-specular parabolic troffers for lighting the interior of the space. Downlight / wallwashers around the perimeter of the space increase the surface brightness of the walls. This strategy is a better choice to eliminate glare than the use of lensed troffers. However, avoid shallow troffers designed to spread the light. These achieve wide distributions by lowering the light sources in the luminaire and thereby increasing the glare.

3-10.6.3 Semi-indirect pendant manufacturers offer short pendant luminaires for low ceiling applications. These luminaires use refined optics to spread light out and light the ceiling with a pendant length of under 0.3 m (12 in). These luminaires allow semi-indirect lighting systems in spaces with a ceiling height of 2.4 m (8 ft).

3-10.7 Existing HIDI, Floodlights, Downlights and Other Luminaires.

3-10.7.1 Replace mercury vapor lighting systems with one of the following approaches:

- Replace mercury vapor light sources with compatible metal halide or induction light sources, especially if increased light levels are required.
- For interior high bay applications, replace with a linear fluorescent or induction system. This replacement is especially appropriate for applications where switching or dimming could be encouraged to save energy in addition to improving visibility. Fluorescent retrofits are not a one-for-one replacement of HID luminaires but rather an alternate lighting system.

3-10.8 Existing Exit Signs.

3-10.8.1 Incandescent exit signs should be retrofitted with \2\ LED /2/ exit signs. Because of 1996 revised UL listing requirements for exit signs, consider replacing exit signs with all new \2\ LED /2/ signs.

\1\

3-10.9 Existing Exterior.

3-10.9.1 Evaluate each application to determine which broad spectrum technology (induction or SSL) suits the application and local environment conditions. SSL or induction should not be considered as a “one size fits all” solution.

3-10.9.2 Design replacement systems to minimize overall energy consumption, reduce maintenance costs, illuminate areas to the appropriate levels, improve uniformity, reduce light trespass/light pollution, and improve the night time visibility on DoD Installations. Simple retrofit projects will only yield minimum benefit.

3-10.9.3 Retrofit conversion LED light sources or LED lighting modules that have been designed and constructed to be installed in existing high-intensity discharge (HID), mercury vapor, or fluorescent luminaire enclosures are prohibited./1/

\2\

3-10.9.4 As of this writing, LED components and luminaires are being marketed for a wide range of retrofit applications. While the technology is improving rapidly and the cost is decreasing, it is imperative to evaluate the life cycle cost of any proposed retrofit. Most cost effective retrofit applications include areas where the long life of LED can reduce future maintenance costs. These include difficult to access cove lighting (such as high ceiling lobbies). Replacing compact fluorescent downlights with LED is not usually cost effective. It is also important to bear in mind heat management, photometric requirements, and ambient temperatures when considering LED retrofits.

3-10.10 Lighting Control System Replacement.

3-10.10.1 When developing a lighting replacement project consider lighting controls to improve the energy efficiency of the space. Use the installed cost of the system when analyzing the lifecycle cost for a lighting replacement with controls. When possible integrate the lighting control system directly into the HVAC system to provide reduced HVAC load requirements and improve the buildings energy efficiency.

3-10.10.2 Wireless lighting control options should be considered for lighting replacement projects (easy installation, lower installed cost, no power packs necessary). Wireless products include; but not are limited to, occupancy / vacancy sensors, daylight sensors, plug in switching modules, plug in dimming modules, and personal controls.

/2/

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CHAPTER 4: DAYLIGHTING

4-1 BENEFITS OF DAYLIGHT.

Daylight in interior spaces has multiple benefits. Daylighted environments provide a connection to the outdoors, are healthier for occupants and have the potential to save energy. Research has shown that children learn better[11], retail stores sell more product[12], and office workers are more productive[13] [14] in daylighted environments. Since daylight also helps to regulate our circadian cycle[15], introducing daylight into interior spaces is a top priority. Daylight is a natural resource that is more efficient than electric light and should be utilized to its fullest potential (Refer to Chapter 5, "Lighting Equipment" for efficacy of light sources). Per the requirements of the Sustainable MOU, achieve a minimum of daylight factor of 2 percent (excluding all direct sunlight penetration) in 75 percent of all space occupied for critical visual tasks. See http://www.wbdg.org/references/mou_daylight.php

4-2 PROJECT TYPES THAT BENEFIT FROM DAYLIGHT.

The introduction of daylight into any space has the potential to provide these benefits for the occupants as well as reduce building energy use. However, some project types are better suited than others to take advantage of daylight.

4-2.1 Open spaces with high ceilings such as hangars, warehouses, recreation centers, and maintenance areas offer good opportunities for toplighting with skylights and clerestories.

4-2.2 Perimeter spaces such as offices, lobbies, classrooms, cafeterias, and residential areas are all good sidelighting applications.

4-3 DAYLIGHTING ECONOMICS.

The use of daylight can produce more comfortable work environments. This benefit may be difficult to quantify, but the energy saved by dimming or switching electric light in response to daylight can be quantified. The implementation of skylights and clerestories as well as lighting control equipment such as dimming ballasts and photocells all increase initial cost. Additionally, for DoD facilities in areas of high threat, Antiterrorism (AT) criteria (see UFC 4-010-01) increase the required strength of all glazing. Therefore, the addition of glazing may \1\/1/ increase the cost over a

[11] The Heschong Mahone Group, "Daylighting in Schools", http://www.h-m-g.com/projects/daylighting/summaries%20on%20daylighting.htm

[12] The Heschong Mahone Group, "Skylighting and Retail Sales", http://www.h-m-g.com/projects/daylighting/summaries%20on%20daylighting.htm#Skylighting_and_Retail_Sales - PG&E 1999

[13] California Energy Commission. (2003). *Windows and Offices: A study of office worker performance and the indoor environment* (Catalogue No. P500-03-082-A-9).

[14] "Design Objectives, Productive", *Whole Building Design Guide*, 22 August 2002 http://www.wbdg.org/design/productive.php

[15] New Buildings Institute, Inc. "Lighting and Human Performance", *Advanced Lighting Guidelines,* Chapter 2. 2001 Edition, p.2-12-13

commercial building. Careful analysis must consider these costs to determine the payback of daylighting strategies. The following case studies describe projects where daylighting strategies and energy efficient lighting and controls have been added to an existing building.

4-3.1 Philip Burton Federal Building[16] [17].

This lighting control retrofit project incorporated advanced lighting controls and daylight sensors for 16,720 m^2 (180,000 square feet) of the 20-story Philip Burton Federal Building in San Francisco. When adequate daylight entered the space, unnecessary lighting was turned off. Energy savings ranged from 30% to 41% for zones of luminaires nearest the windows and 16% to 22% for interior zones of luminaires. Using this type of control equipment, the payback for equipment ranges from 4.7 to 6.4 years.

4-3.2 California State Automobile Association[18].

In this renovation, skylights with automatic louvers control the amount of light entering the building based on the amount of available daylight. Barometric exhaust vents in these skylights release heat gain from the skylight wells. Dimmable electronic ballasts raise and lower the electric lighting based on the amount of light in the space. High performance windows and manual shades were also utilized. Overall lighting energy use was reduced by 32% with these strategies.

4-4 SYSTEM INTEGRATION.

If the majority of areas are daylighted, then the electric lighting becomes supplemental during daytime periods. Since our appetite for light is less in the evening and nighttime hours, daylighting does not need to be duplicated with electric lighting. Design electric lighting to supplement the daylighting. For example, when daylight is plentiful, the electric lighting must be dimmed near the daylight source. In other areas where the daylight penetration is not as great, the electric lighting can be increased. Electric lighting controls (daylight, occupancy, and \2\ vacancy sensors /2/) can typically save up to 50% of the lighting energy in existing buildings and up to 35% in new buildings[19].

4-4.1 Requirements for system integration.

1. Control the electric lighting in response to the daylight by dimming it in task oriented areas such as offices, conference rooms, classrooms or

[16] "Philip Burton Federal Building", *Pacific Gas and Electric Company*, Daylighting Initiative, 1999, http://www.pge.com/includes/docs/pdfs/shared/edusafety/training/pec/daylight/1487Gate_repaginated.pdf
[17] Rubinstein, Francis; Jennings, Judith; Avery, Douglas; "Preliminary Results from an Advanced Lighting Controls Testbed", Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, CA, March 1998 http://eetd.lbl.gov/btp/papers/41633.pdf
[18] "California State Automobile Association Office", *Pacific Gas and Electric Company*, Daylighting Initiative, 1999, http://www.pge.com/includes/docs/pdfs/shared/edusafety/training/pec/daylight/1487CSAA_repaginated.pdf
[19] New Buildings Institute, Inc. "Lighting Controls", *Advanced Lighting Guidelines,* Chapter 8. 2001 Edition, p. 8-1

turning it off in non-task areas such as circulation and lounge areas.

2. Do not attempt to duplicate daylight with electric light – supplement it.

3. Commission controls to maximize and tune energy benefit.

4-5 MAXIMIZE DAYLIGHT POTENTIAL.

Building orientation, views, side and top lighting, shading devices, and selective glazing are all critical to maximizing daylight potential. All of the following recommendations are for the northern hemisphere. In the southern hemisphere, recommendations regarding north and south orientations are reversed. Also, interior spaces should have high ceilings and light reflective surfaces to allow deep daylight penetration. Provide architectural and shading devices for daylight and view windows. In areas of high threat, lightshelves tend to be discouraged because of blast mitigation. These objects can become additional projectiles during a blast. Refer to the Whole Building Design Guide, *Balancing Security/Safety with Sustainability Objectives*, http://www.wbdg.org/resources/balancing_objectives.php.

4-5.1 Over 60% of existing square footage of interior spaces (within the US) has access to roofs for top-lighting and 25% of existing national square footage has access to side-lighting.[20]

\2\

4-5.2 Building Shape.

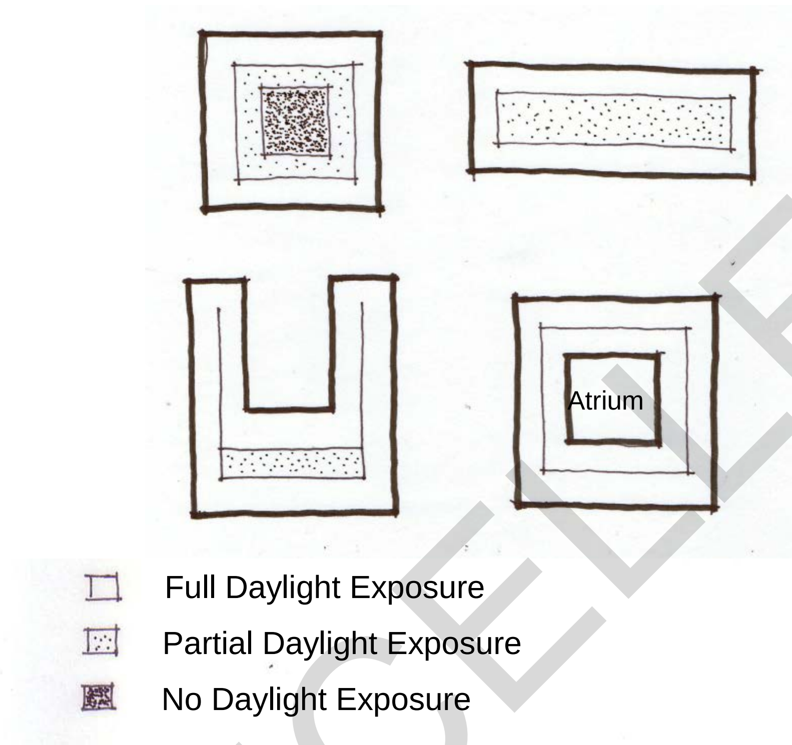
The building shape and massing has a significant impact on how much daylight can reach the occupied spaces and therefore, how well various daylighting strategies will work in the building. Deep floor plates create dark interior spaces that will necessitate electric lighting even during the day. Narrower plates allow daylight penetration throughout the entire building section. See Figure 4-1 for the effects of building shape and massing on daylight availability.

/2/ /1/

[20] Heschong, Lisa, "Daylighting Workshop", Pacific Energy Center, (March 2003).

Figure 4-1. Effects of building massing on daylight availability.

\2\ These four building footprints have equal floor area but provide very different levels of daylight availability.



/2/

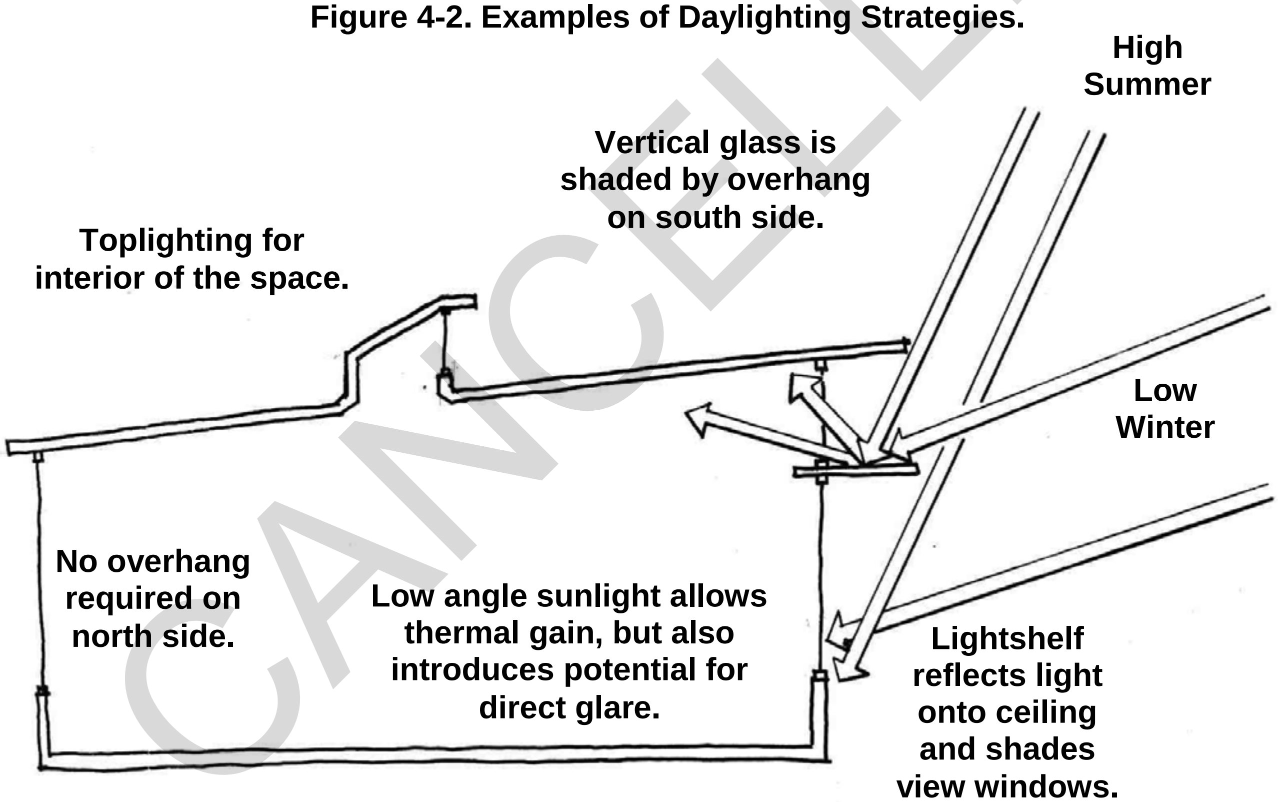
4-5.3 Considerations to maximize daylight potential:

- \2\ Use the building shape to access daylight. /2/
- Maximize view windows on the north and south facades.
- Provide high ceilings to allow deeper daylight penetration.
- Bring daylight high into the space to maximize penetration.
- Where possible, consider external light shelves to provide shading for view windows.
- Where possible, consider internal light shelves to provide shading for clerestories and also a surface for reflecting light onto the ceiling.
- Provide separate shading devices for daylight windows and view windows.
- Utilize selective glazing to maximize visible transmittance (high T_{vis}) and

minimize solar radiation (low shading coefficient).

- Use high reflectance values on ceiling and wall surfaces to balance out the daylight.
- Avoid daylight barriers such as solid walls near the building perimeter.
- Use clerestory and transom glazing to share daylight from perimeter windows to interior spaces.
- \2\ Consider using an automated shading system to control solar gain, daylight transmittance, and glare. System should be integrated with the electric lighting control system and building management system and allow occupants personal control of the shades during key events and times. /2/

Figure 4-2. Examples of Daylighting Strategies.



4-6 GLAZING ORIENTATION.

Building orientation is critical to maximizing daylight potential. \2\ Building orientations that maximize north and south exposures provide the most effective orientations while East and West exposures may allow excessive heat gain and are hard to control direct sun penetration. Southern exposures have the potential of providing over 50% of the daylight for the building space. The success to daylighting on southern exposures is controlling the direct sunlight penetration with shading devices. Northern exposures /2/

require minimal shading in the winter months. East and West orientations require manual shading devices. Vertical blinds control daylight well on this orientation.

Figure 4-3. Building orientation can maximize daylight exposure.

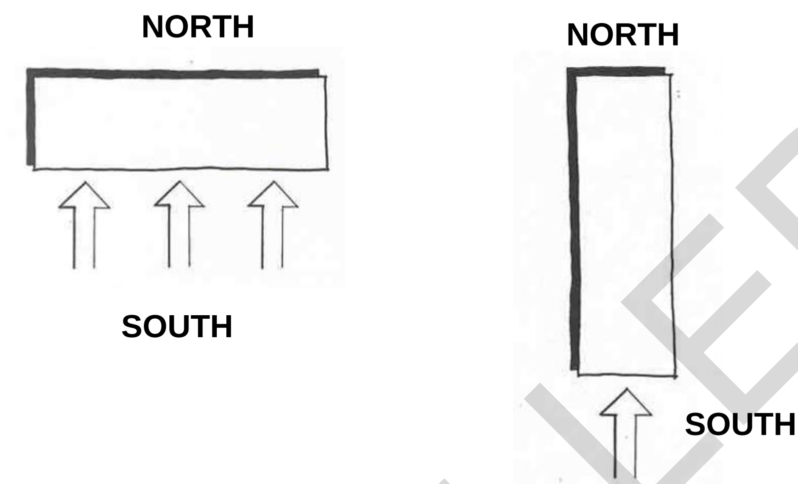


Figure 4-4. Example of architectural shading devices.

4-6.1 Considerations for orienting glazing:

- Orient building to maximize north and south exposures.
- North facing windows provide the most even illumination.
- If orientation is off-axis from north and south, provide shading devices for south-east and south-west exposures.
- Provide architectural shading devices for south orientations.

- Provide manual shading devices for south orientations. Horizontal blinds best control the high angle light on southern exposures.

- Provide manual shading devices for east and west orientations. Vertical blinds best control the low angle light on east and west exposures.

4-7 GLAZING CHARACTERISTICS.

Use selective glazing to optimize and tune glass based on its purpose and use (clerestory or vision). Clerestory glass may require high visibility transmittance without color distortion while minimizing infrared penetration.

4-7.1 Considerations for glazing characteristics:

- Maximize glazing transmittance (T_{vis}) for daylight glazing (.70 or greater) for clerestories and other daylight fenestrations.

- Although the visible transmittance selected depends on personal preference, typically, use Tvis values in the medium range for view windows (.40 or greater).

- Minimize infrared transmittance by specifying a moderate to low shading coefficient (SC) or low solar heat gain coefficient (SHGC) (50% or lower)[21].

- Use high transmittance glazing greater than 60% to maximize daylight. Glazing should also have a high thermal resistance ratio in order to minimize heat gain.

- Use clear glazing. Do not use tinted or mirrored coatings.

Table 4-1. Comparison of glass types (from AlpenGlass Heat Mirror).

Sample Glass Types	Total Daylight Transmittance %	Solar Heat Gain Coefficient
Clear Double Insulating Glass (1/8" thick)	81	0.75
Laminated Glass (1/2" clear)	85	0.72
HM 88/Clear	72	0.57
HM SC75/Clear	62	0.36
HM 55/Clear	47	0.30

[21] Ernest Orlando Lawrence Berkeley National Laboratory, "Glazing Selection", *Tips for Daylighting with Windows, The Integrated Approach*, Section 4, p. 4-1.

4-8 QUANTITY OF GLAZING.

Through simple tools and modeling, glazing quantities can be optimized in order to provide maximum daylight potential while minimizing economic costs. Bring daylight in high through clerestories and top-lighting, yet provide view windows for occupant benefits. Also, bring daylight in from two directions if possible for balanced, uniform lighting.

4-8.1 Toplighting optimization varies between 3% and 9% skylight to floor area ratio.[22] The optimal amount of toplighting area factors in daylight contribution, cooling loads, and potential energy savings. In order to calculate toplighting area optimization, use a calculation program similar to "SkyCalc"[23]. Sunny climates with a cooling load dominated environment will require less toplighting than cooler overcast climates[24].

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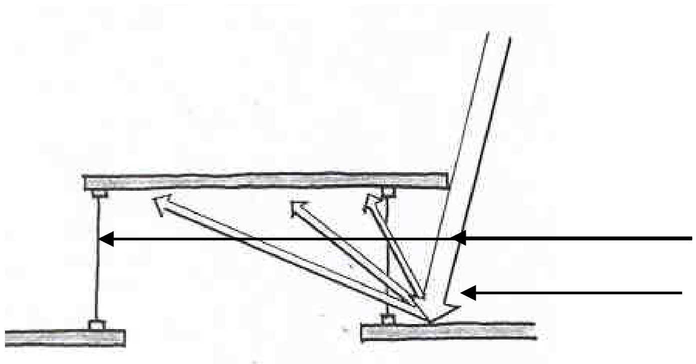
[22] New Buildings Institute, Inc. "Luminaires and Light Distribution, Daylight Systems", *Advanced Lighting Guidelines,* Chapter 7. 2001 Edition, p. 7-31

[23] The Heschong Mahone Group, "Optimizing Your Design", *Skylighting Guidelines,* Ch1, 1998, p.1-1-5-7.

[24] The Heschong Mahone Group, "Optimizing Your Design", *Skylighting Guidelines*, Ch5, 1998, p. 5-12-13.

Figure 4-5. Diagrams of Toplighting Strategies.

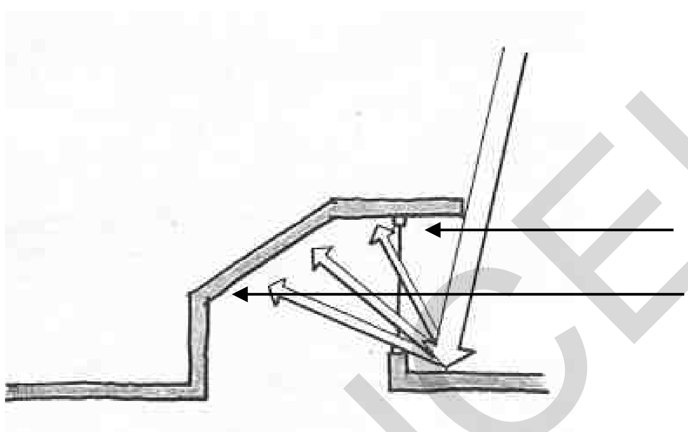


Vertical glass is shaded by overhang on south side.

No overhang required on north side.

Reflective roof directs light onto horizontal surface.

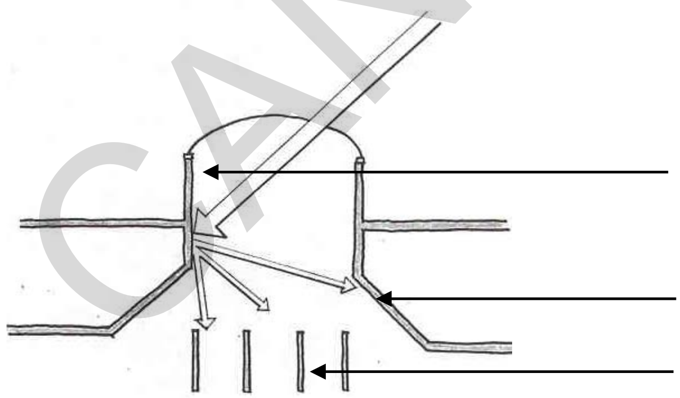
Roof Monitor



Vertical glass is shaded by overhang.

High reflectance surfaces redirect and diffuse sunlight.

Angled Clerestory



High reflectance surfaces redirect and diffuse sunlight.

Splay directs light and reduces contrast.

Vertical baffles block direct sunlight.

Horizontal Skylights with Splay

Figure 4-6 Examples of Toplighting Applications.

Figure 4-7. Example of Clerestory Application.

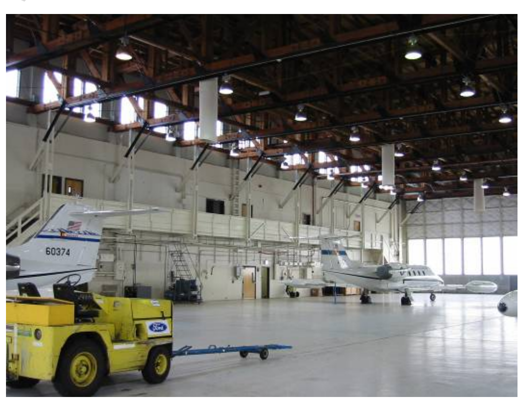
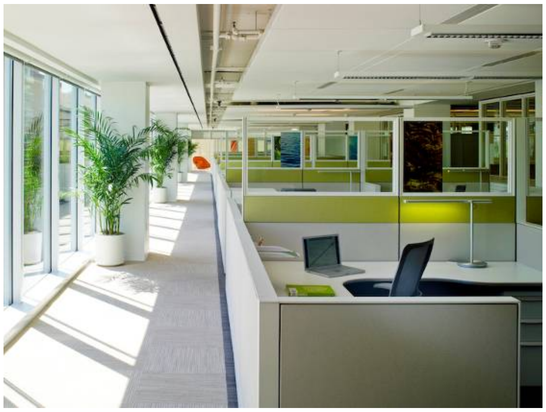


Figure 4-8. Examples of Sidelighting Applications.



Photograph: Eric Laignel

4-8-2 Considerations for quantity of glazing:

- Sidelighting windows should be located as high as possible since effective daylight penetration from windows is 1.5 times the height of the window[25].
- Use high continuous clerestories for the deepest daylight penetration and uniformity.
- In order to provide exterior views, provide glazing at eye level.
- Use view windows that have minimal wall area between windows. Avoid small windows located in large wall areas because of the uncomfortable contrast and glare that result[26].
- 0.09 m^2 (1 sq ft) of top lighting can provide illumination to about 10 times the area that Sidelighting provides yet does not provide the view[27].
- Space top lighting apertures approximately one and a half times the ceiling height for even illumination. Recess and splay (45º to 60º) skylights to minimize glare[28].

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[25] US Department of Energy, Energy Efficiency and Renewable Energy, “Sidelighting vs. Toplighting”, *National Best Practices Manual, Daylighting and Windows*, p. 73.
[26] New Buildings Institute, Inc. “Luminaires and Light Distribution, Daylight Systems”, *Advanced Lighting Guidelines,* Chapter 7. 2001 Edition, p. 7-35.
[27] US Department of Energy, Energy Efficiency and Renewable Energy, “Toplighting”, *National Best Practices Manual, Daylighting and Windows*, p. 75.
[28] US Department of Energy, Energy Efficiency and Renewable Energy, “Design Details”, *National Best Practices Manual, Daylighting and Windows*, p. 101.

- Toplighting systems located at least 1.5 times the mounting height on center can provide even daylight distribution.[29]

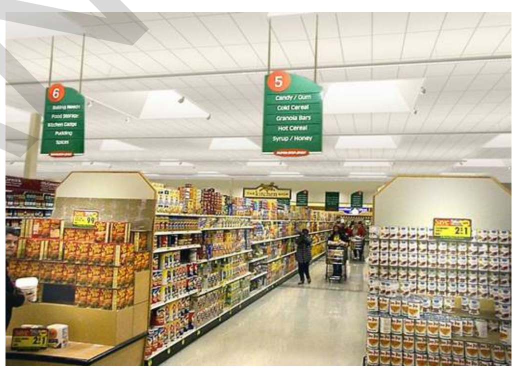
- Skylight area should be between 2% to 9% of the floor area depending on the climate optimization

4-9 GLARE AND CONTRAST CONTROL.

Glare and excessive contrast occur when side and top lighting devices allow direct sunlight penetration. Quality daylighting allows skylight and only reflected sunlight to reach the task. Punched openings also can cause uncomfortable contrast ratios.

Figure 4-9. Examples of Roof Shapes.

Figure 4-10 Example of Splayed Skylights.



4-9.1 Considerations for controlling glare and contrast:

- Provide external and internal shading as described in the paragraph

[29] The Heschong Mahone Group, “Designing with Skylights”, *Skylighting Guidelines*, Chapter 2, 1998, pp. 2-5.

entitled “BENEFITS OF DAYLIGHT “.

- Utilize top-lighting systems with vertical glazing to control direct radiation.
- If horizontal glazing is designed for top lighting systems, then provide splayed openings or translucent shielding below the skylight in order to minimize the contrast.
- Avoid punched windows; use continuous or mostly continuous side lighting.
- Use high reflectance surfaces for ceiling and walls \2\ (90% for ceilings and 60% for walls)[30]./2/
- \2\ Consider integrating use of automated window shading or dynamic glazing with the electric lighting control system to optimize the amount of daylight entering the space while minimizing the effects of solar heat gain and glare. /2/

4-10 ACTIVE DAYLIGHTING.

Active daylighting strategies and devices utilize a mechanical component to collect and distribute daylight. Such devices differ from the passive strategies that have previously been discussed which are stationary. The example shown in figure 4-10 turns a series of reflectors as the sun moves throughout the day. These reflectors catch the direct sunlight and redirect it through the skylight.

4-10.1 Such devices add extra initial cost and also pose additional maintenance issues. However, they also can make use of daylight for a longer period of time throughout the day. With tracking devices, effective daylighting can begin earlier in the morning and last later in the day than with stationary skylights. Careful evaluation of the lifecycle cost and the energy savings must be considered.

[30] “Lighting for Offices”, *Lighting Handbook Reference and Application*, Chapter 32, Tenth Edition (New York: The Illuminating Engineering Society of North America, 2011), p. 32.23.

Figure 4-11. Example of an Active Daylighting System that Tracks the Sun and Directs Daylight into the Building.

4-10.2 Solar-adaptive shading. Another actvie daylight control technology is solar-adaptive window shading whereby shades automatically adjust throughout the day based on sky conditions or the sun's location. This type of shading system blocks and reflects direct sunlight during the day to reduce solar heat gain and demand on the building's air conditioning system.

Figure 4-12 Example of Solar-Adaptive Shading

4-11 PHYSICAL MODELING.

Daylight levels depend on many factors such as window shapes, orientation, shading, and time of day. Therefore, physical models built to scale can provide information on light quality, shade, shadows, and actual light levels. By building the model with the actual proposed materials and orienting it with adjustments for latitude, season, and time of day, the light quality can be seen in the model. Such models inform the designer about quality issues including light patterns, shade, shadows, contrast, and penetration in the space. An illuminance meter inside the model will provide accurate predictions of expected light levels in the building.

4-12 COMPUTER SIMULATION.
A wide range of software programs model the sun's path and its impact on building geometry in addition to how it affects heat gain and energy use. In using any of the software, the designer must be aware of its limitations and assumptions, as well as the variables under the users' control. These tools provide a prediction of how building components will behave throughout changing conditions. They do not provide actual light levels or energy use. The following web sites detail the features of some of these programs and their applications.

- US Department of Energy – Energy Efficiency and Renewable Energy Building Energy Software Tools Directory: http://www.eere.energy.gov/buildings/tools_directory/
- Whole Building Design Guide Energy Analysis Tools: http://www.wbdg.org/resources/energyanalysis.php

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CHAPTER 5: LIGHTING EQUIPMENT

5-1 BUDGET CONSIDERATIONS.

5-1.1 Selecting Equipment.

5-1.1.1 Select luminaires based on application suitability, performance, aesthetics, local environmental conditions, and life cycle cost.

5-1.1.2 Select light sources, ballasts, power control \2\ units, drivers, generators /2/, and controls based on the application, performance, and life cycle cost.

5-1.2 Life cycle cost analysis.

There are many economic factors that need to be considered when designing a lighting system. Life cycle costs include initial costs (equipment procurement and installation), energy, and maintenance costs. Additional issues involve the impact of lighting on productivity. These costs are currently not represented in the life cycle cost analysis, but have been estimated for the total Federal sector at \$17.65/m^2 (\$1.64/SF per year)[31]. Since this is a significant factor, quality lighting decisions cannot be undervalued.

5-1.2.1 Initial costs.

5-1.2.2 Estimate equipment quantity and unit pricing for luminaires, light sources, ballasts, \2\ drivers, power supplies, generators /2/ and controls. Also estimate the labor cost. Do not use a percentage of initial costs because this can be misleading. For example, installing direct/indirect linear fluorescent pendants may be less labor since they require only one point of electrical connection, versus individual recessed lay-in luminaires.

5-1.2.2 Energy costs.

Energy costs should take into account not only the connected lighting loads, but also the actual loads due to daylight and manual dimming, occupancy \2\ and vacancy /2/ sensors, \2\ network controls /2/ and energy management systems. Peak power demand in most climates occurs during the sunniest days when daylight is the most available. If the peak demand can be lowered through controls, then the energy costs can be considerably lower.

5-1.2.3 Maintenance costs.

Life and reliability of the lighting equipment are inherent in maintenance costs. In addition, replacement procurement and installation costs are factored into the formula. When access to \2\ luminaires /2/ is difficult or requires special equipment, it is likely that group re-lamping is a more cost effective approach than replacing only failed lamps. LED light sources (which dim over time but rarely go out entirely) also lend themselves to

[31] "Economics of Energy Effective Lighting for Offices", *Federal Energy Management Program (FEMP) Lighting Resources,* http://www1.eere.energy.gov/femp/pdfs/economics_eel.pdf

group re-lamping to maintain consistent color and light output. Light sources that are reliable and need replacement every several years (versus months) need to be specified. In addition, specify compatible equipment. For example, when lighting is controlled with occupancy or vacancy sensors, the ballast \2\ or power control unit and light source need to respond to this type of frequent control. Light sources that work well with occupancy or vacancy sensors are rapid start and programmed start fluorescent, SSL /2/ and induction light sources. Instant start fluorescent and HID light sources are not compatible with occupancy \2\ or vacancy /2/ sensors.

5-1.3 Energy Models.

Even though energy efficient lighting reduces the building operating energy use, lower lighting energy also decreases HVAC loads. Decreased HVAC loads can represent initial cost savings. Energy models should be performed for each building to estimate the impact of daylighting, building envelope design, energy efficient electric lighting, lighting controls, HVAC loads and controls. These models will best inform the designers on system wide decisions and the life cycle cost impacts.

5-1.4 Federal economic analysis.

Refer to *FEMP Economics for Energy Effective Lighting for Offices* for life cycle cost analysis examples. Lighting system options have been calculated for open and small offices showing energy usage, illuminance levels, quality visual design factors, initial costs per square foot, annual operating costs per square foot, simple payback in years and Federal Savings to Investment Ratios.

5-1.5 IES economic analysis.

\2\ Chapter 18 "Economics" in the *Lighting Handbook* /2/ states multiple cost comparison methods. The Cost of Light calculates the unit cost of light per light source using light source efficacy, energy and replacement costs. Two other cost comparisons are explained including the Simple Rate of Return and more robust Life-Cycle Cost-Benefit Analysis.

5-2 LUMINAIRES.

Luminaires are comprised of a light source reflector, shade, lens, refractor, mounting hardware and an electrical connection. \2\ SSL /2/ luminaires include a power control unit to power the light source. Fluorescent and high intensity discharge luminaires include a ballast to operate the light source. Induction luminaires utilize a generator and low voltage luminaires require a transformer. Since electric lighting consumes \2\ approximately 32% of the electrical energy used in commercial buildings[32],/2/ it is important to use energy efficient equipment.

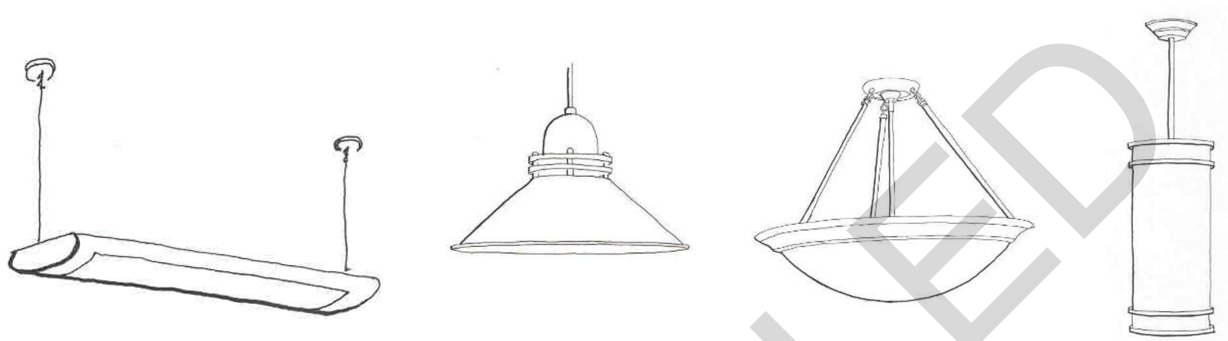
5-2.1 Pendant Mounted Luminaires.

Pendant mounted luminaires are suspended from the ceiling and may light down onto a table, uplight the ceiling, or provide a glow in all directions. Mount pendants at an

[32] "Energy Management", *Lighting Handbook Reference and Application*, Chapter 17, Tenth Edition (New York: The Illuminating Engineering Society of North America, 2011), p. 17.1.

appropriate height that will not result in a direct view of the source and provide adequate lighting levels. For example, in offices, linear fluorescent luminaires require sufficient ceiling height of 2.6 m (8 ft-6 in) or higher, although some newer T5 \2\ fluorescent /2/ pendants are designed for 2.4 m (8.0 ft) ceilings.

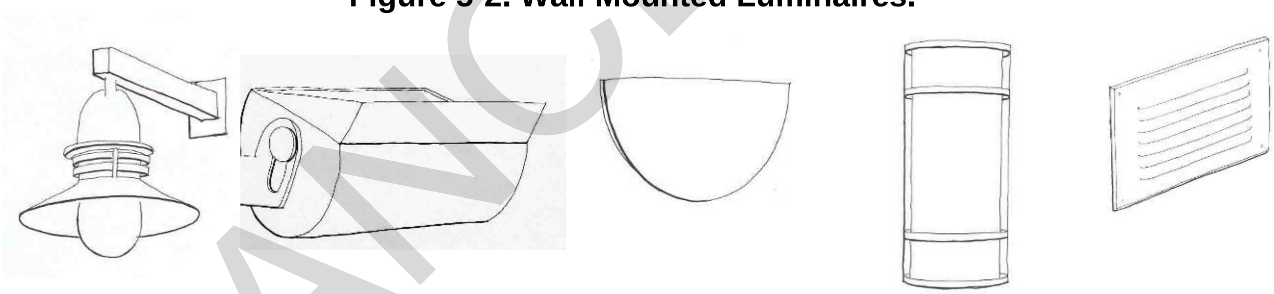
Figure 5-1. Pendant Mounted Luminaires.



5-2.2 Wall Mounted Luminaires.

Sconces or uplights may light the wall, ceiling, or provide a decorative glow. Steplights, often recessed into a wall, are located low on a wall can illuminate pathways and stairs.

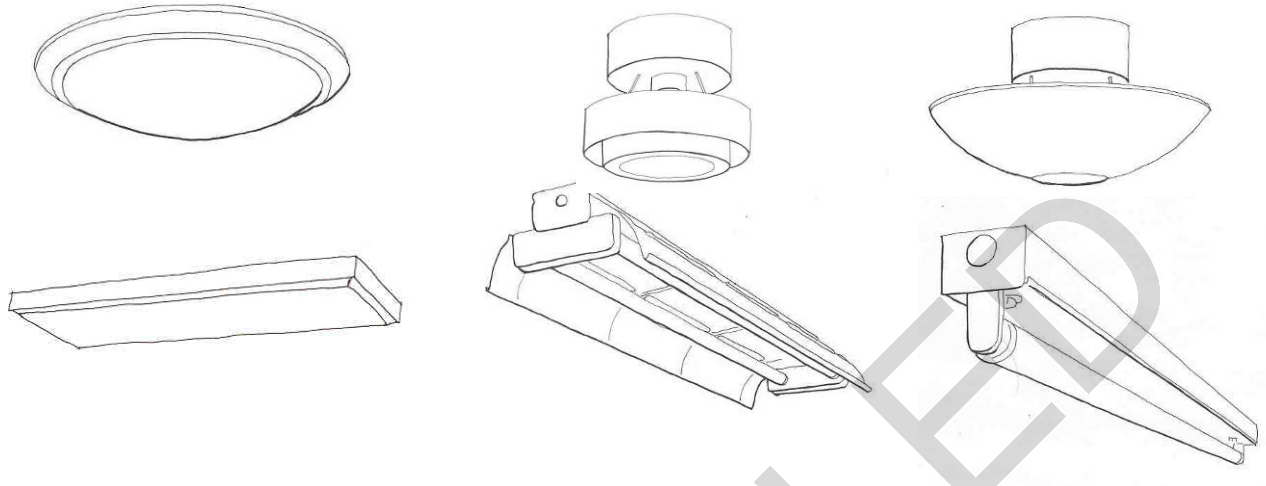
Figure 5-2. Wall Mounted Luminaires.



5-2.3 Ceiling or Surface Mounted Luminaires.

Ceiling or surface mounted luminaires provide a downlight and may also glow, depending on the type of housing and lens. Fluorescent \2\ and LED /2/ luminaires are available in linear or compact versions. This type of luminaire is mounted directly to the ceiling. Lenses should adequately diffuse the light so as not to become a glare source and to prevent an image of the light source from showing on the lens.

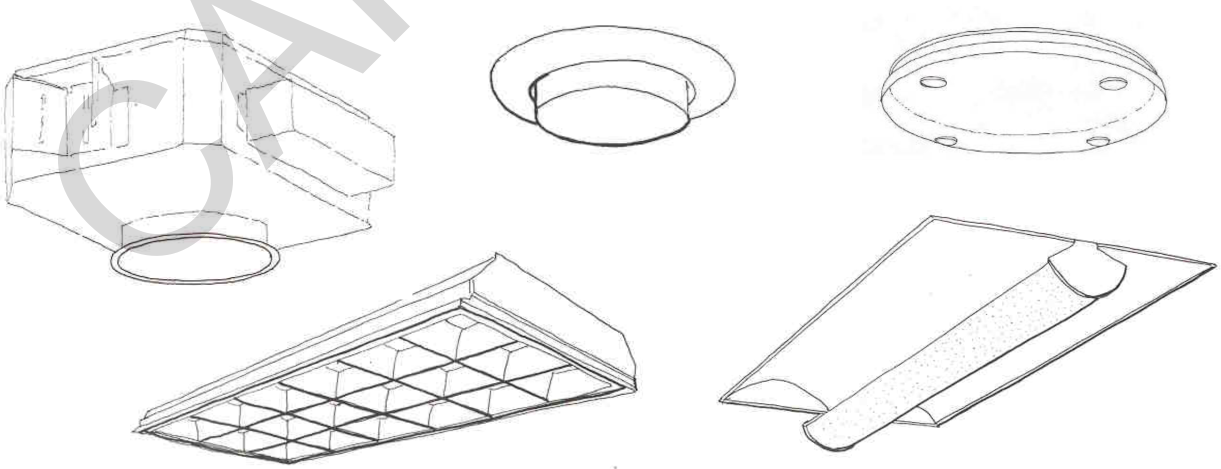
Figure 5-3. Ceiling / Surface Mounted Luminaires.



5-2.4 Recessed Luminaires.

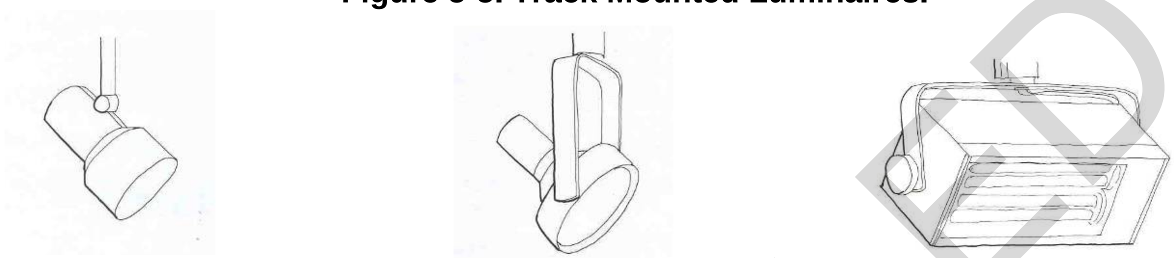
Luminaires that are recessed into the ceiling typically light the horizontal surface below, or possibly an adjacent wall. These types of luminaires are often used for general ambient lighting. However, they are most appropriately used as task lighting or accent lighting / wallwashing. Semi-recessed luminaires use a lens or shade, dropped below the ceiling plane, to provide a decorative element as well as put some brightness on the ceiling. All recessed luminaires have a housing above the ceiling that contains the light source and provides power. The housing must be suitable for the luminaire location. For example, in an insulated ceiling, the housing must be rated for contact with insulation or “IC” rated.

Figure 5-4. Recessed and Semi-Recessed Luminaires.



5-2.5 Track Lighting.
Track mounted luminaires are adjustable and can also be relocated along the length of track. These typically use tungsten halogen or low wattage metal halide directional sources especially appropriate for accent lighting, \2\ yet many LED sources are excellent. However, some track luminaires accommodate compact fluorescent light sources or linear LED /2/ and are therefore more suitable for wall washing.

Figure 5-5. Track Mounted Luminaires.



5-2.6 Exterior Luminaires.
Pole mounted luminaires for exterior lighting come in a wide range of heights, but can generally be grouped in one of three categories: high mast luminaires, area luminaires on 7.6 – 12.2 m (25 -40 ft) poles, and pedestrian scale luminaires on shorter poles.

\2\

5-2.6.1 Exterior Luminaire Classification.
The National Electrical Manufacturers Association (NEMA) classifies exterior luminaires by intensity distribution. Tables 5-1 and 5-2 describe the distribution and cutoff classifications. Table 5-1 refers to the illuminance patterns produced on the ground or horizontal; whereas Table 5-2 refers to the vertical candela distribution of light from an individual luminaire. Each successive classification provides more vertical illuminance, but also introduces more glare and stray uplight. Refer to Light Pollution in Chapter 3 for additional requirements. \1\ It is important to note that the classification of exterior luminaires has changed. The shielding classification such as Full Cutoff has been replaced by the BUG (Backlight-Uplight-Glare) rating system. Table 5-3 shows how the two classifications are correlated. A rating of 0-5 is applied to each of the three zones: Backlight Zone, Uplight Zone, and Glare Zone. For example, the term Full Cutoff corresponds to a “0” in the Uplight Zone (U0). For more information, see, IES TM-15. /1/

Table 5-1. Exterior Luminaire Distribution Classification.[33]

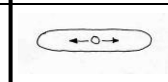
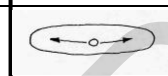
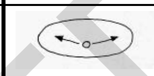
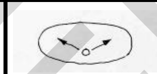
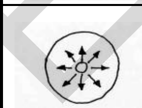
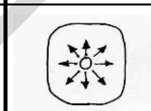
Type	Description	Plan View
Type I	Narrow, symmetric illuminance pattern.	
Type II	Slightly wider illuminance pattern than Type I.	
Type III	Wide illuminance pattern.	
Type IV	Widest illuminance pattern.	
Type V	Symmetrical circular illuminance pattern.	
Type VS	Symmetrical, nearly square illuminance pattern.	

Table 5-2. NEMA Field Angle Classifications.[34]

Beam Type	Beam Spread Degree Range	Projection Distance
1	10 to 18	240 ft and greater
2	18 to 29	200 to 240 ft
3	29 to 46	175 to 200 ft
4	46 to 70	145 to 175 ft
5	70 to 100	105 to 145 ft
6	100 to 130	80 to 105 ft
7	130 and up	under 80 ft

[33] "Luminaires: Forms and Optics", *Lighting Handbook Reference and Application*, Chapter 8, Tenth Edition (New York: The Illuminating Engineering Society of North America, 2011), p. 8.10.
[34] "Luminaires: Forms and Optics", *Lighting Handbook Reference and Application*, Chapter 8, Tenth Edition (New York: The Illuminating Engineering Society of North America, 2011), p. 8.9.

The backlight, uplight and glare (BUG) ratings for luminaires are useful in evaluating optical performance in exterior environments. The BUG ratings are based on zonal lumen calculations. More information can be found in IES TM-15-11 "*Luminaire Classification System for Outdoor Luminaires*". It is difficult to compare the BUG ratings to the previously used cutoff classifications as the cutoff classifications are determined from intensities (candela) of the light source above 80 degrees, rather than luminaire lumens. Table 5-3 below illustrates the lack of correlation between the previous classification system and the current BUG ratings.

Table 5-3: Correlation between BUG Ratings and Cutoff Classifications

BUG Rating	Full Cutoff	Cutoff	Semi-Cutoff	Non-Cutoff
B	B0-B5	B0-B5	B0-B5	B0-B5
U	U0	U1-U5	U1-U5	U1-U5
G	G0-G5	G0-G5	G0-G5	G0-G5

The three components of BUG ratings are illustrated in Figure 5-6 and described below:

Backlight: Backlight (B) Rating: Backlight creates light trespass on adjacent sites. The B rating takes into account the amount of backlight in the low (BL), medium (BM), high (BH) and very high (BVH) zones, which are in the direction of the luminaire opposite from the area intended to be lighted. The closer to a property line, the B rating is stricter or lower. If the luminaire is located more than two mounting heights from the property line, then the B rating is higher.

Uplight: Uplight (U) Rating: Uplight causes artificial sky glow. Lower uplight (UL) cause the most sky glow and negatively affects professional and academic astronomy. Upper uplight (UH) not reflected off a surface is mostly energy waste. The U rating defines the amount of light into the upper hemisphere with greater concern for the light at our near the horizontal angles (UL). Glare: Glare (G) Rating: Glare can be annoying or visually disabling. The G rating takes in to account the amount of frontlight in the high (FH) and very high (FVH) zones and amount of back light in the high (BH) and very high (BVH) zones.

In general, a higher BUG rating means that more light is emitted in the solid angles and the allowable rating increases with higher lighting zones. However, a higher B (backlight) rating simply indicates that the luminaire directs a significant portion of light behind the pole, so B ratings are designated based on the location of the luminaire with respect to the property boundary. A high B rating luminaire maximizes the spread of light, and is effective and efficient when used far from the property boundary. When luminaires are located near the property boundary, a lower B rating will prevent unwanted light from interfering with neighboring properties.

Figure 5-6. Exterior Luminaire BUG Classification.

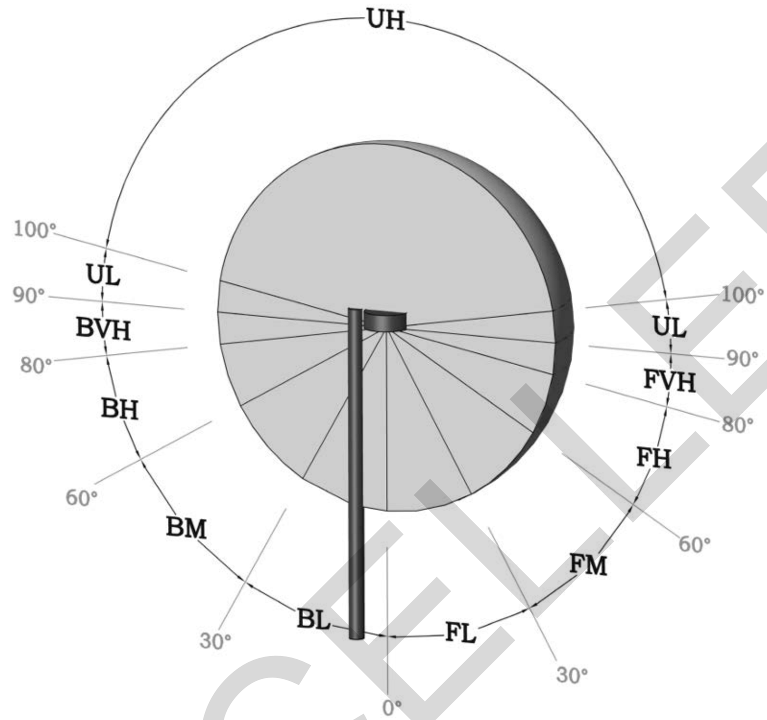


Table 5-4: Exterior Luminaire BUG Classification Key

UH	Uplight High
UL	Uplight Low
BVH	Backlight Very High
BH	Backlight High
BM	Backlight Medium
BL	Backlight Low
FVH	Forward Light Very High
FH	Forward Light High
FM	Forward Light Medium
FL	Forward Light Low

Exterior sports lighting luminaires are classified to the width of the beam spread and the projection distance to the field. Table 5-2 outlines these seven classifications.

/2/

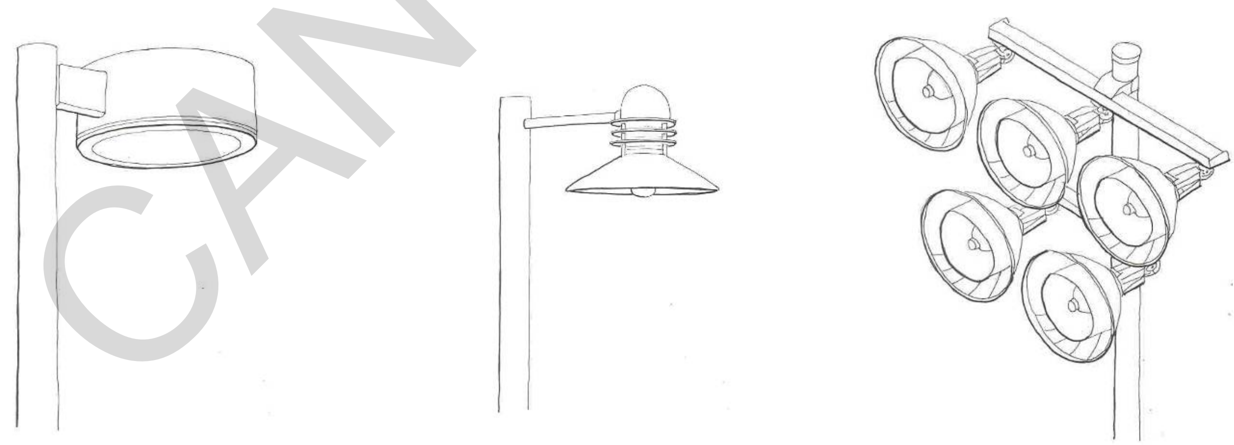
5-2.6.2 High mast luminaires light wide high traffic roadways such as interchanges. These luminaires should use \1\ fully shielded or /1/ IES \2\ Uplight (U0) rating and appropriate Glare (G) rating optics to minimize glare. Additional shielding may be required to avoid light trespass. Select appropriate Backlight (B) rating when light trespass is a critical design issue. /2/

5-2.6.3 Area luminaires light roads, parking lots, storage areas, and depots. Mount on 7.6 – 12.2 m (25 - 40 ft) poles. These luminaires should be fully shielded or use IES \2\ Uplight (U0) rating and appropriate Glare (G) rating optics to minimize glare. Additional shielding may be required to to avoid light trespass./2/ They should have a neutral aesthetic quality so that the luminaire "disappears" into its surroundings.

5-2.6.4 Sports Lighting Luminaires are shielded floodlights incorporating internal and external shields to control glare and light trespass.

5-2.6.5 Pedestrian poles light sidewalks, plazas, and other pedestrian areas. Mount on 3.7 m (12 ft) poles. These luminaires should have a low brightness but do not necessarily need to be \2\ U0 if the light source is under 4200 lumens, yet not rated over U3 /2/. Their aesthetic character should be appropriate for the surrounding buildings and landscape.

Figure 5-7. Pole Mounted Exterior Luminaires.



\2\

5-2.6.6 Lighting Zones

Lighting zones reflect the base (or ambient) light levels desired for an area. The use of lighting zones (LZ) was originally developed by the International Commission on Illumination (CIE) and appeared first in the US in IES Recommended Practice for

Exterior Environmental Lighting, RP-33-99. The Model Lighting Ordinance (June 14, 2011) includes the most recent definitions for lighting zones. It is recommended that the lowest possible lighting zone(s) be adopted.

Selection of lighting zone or zones should be based not on existing conditions but rather on the type of lighting environments the installation seeks to achieve. For instance, new development on previously rural or undeveloped land may be zoned as LZ-1.

Lighting zones are best implemented as an overlay to the established zoning especially on installations where a variety of zone districts exist within a defined area or along an arterial street. Where zone districts are cohesive, it may be possible to assign lighting zones to established land use zoning. It is recommended that the lighting zone includes churches, schools, parks, and other uses embedded within residential communities or to any land assigned to a lower zone.

For DoD installations, it is important to consider all activities of an area's land use. Lighting zones should consider the surrounding areas as well. For example, adjacent lighting zones should not hinder nighttime operations. Additionally, in OCONUS areas, it is important that the installation does not stand out as an exceptionally bright area compared to the adjacent development. Table 5-5 and Figure 5-8 show examples of how lighting zones may be applied to DoD installations.

5-2.6.6.1 LZ0 No Ambient Lighting

LZ0 are areas where the natural environment will be seriously and adversely affected by lighting. Impacts include disturbing the biological cycles of flora and fauna and/or detracting from human enjoyment and appreciation of the natural environment. Human activity is subordinate in importance to nature. The vision of human residents and users is adapted to the total darkness, and they expect to see little or no lighting. When not needed, lighting should be extinguished.

5-2.6.6.2 LZ1 Low Ambient Lighting

LZ1 are areas where lighting might adversely affect flora and fauna or disturb the character of the area. The vision of human residents and users is adapted to low light levels. Lighting may be used for safety and convenience but it is not necessarily uniform or continuous. After curfew, most lighting should be extinguished or reduced as activity levels decline.

5-2.6.6.3 LZ2 Moderate Ambient Lighting

LZ2 are areas of human activity where the vision of human residents and users is adapted to moderate light levels. Lighting may typically be used for safety and convenience but it is not necessarily uniform or continuous. After curfew, lighting may be extinguished or reduced as activity levels decline.

5-2.6.6.4 LZ3 Moderately High Ambient Lighting

LZ3 are areas of human activity where the vision of human residents and users is adapted to moderately high light levels. Lighting may typically be used for safety, security and/or convenience and is often uniform and/or continuous. After curfew, lighting may be extinguished or reduced as activity levels decline.

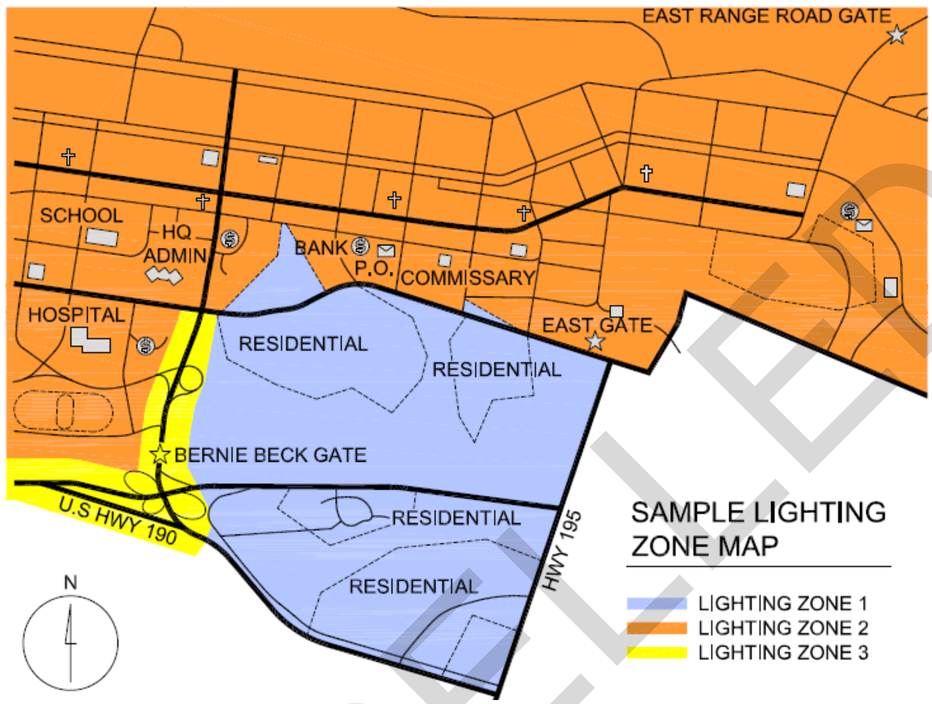
5-2.6.6.5 LZ4 High Ambient Lighting

LZ4 are areas of human activity where the vision of human residents and users is adapted to high light levels. Lighting is generally considered necessary for safety, security and/or convenience and it is mostly uniform and/or continuous. After curfew, lighting may be extinguished or reduced in some areas as activity levels decline.

Table 5-5. Lighting Zones and DoD Applications.

MLO Lighting Zones	*Title*	*DoD Installation/Application*	
LZ0	*No Ambient Lighting*	***Training areas*** *Night vision training areas, endangered waterfront areas other areas where there is expected no nighttime activity.*	
LZ1	*Low Ambient Lighting*	***Personnel Support Districts*** *Unaccompanied quarters, single and multi-family residential, campgrounds, administration, and other non-nighttime use areas, golf course, exercise fields and paths* ***Airfield*** *(Nearby facilities may be higher zone)*	
LZ2	*Moderate Ambient Lighting*	***Waterfront or Airfield Facilities*** *Administrative areas, common areas, service areas, parking* ***Training Facilities*** *Academic instruction, educational services, applied instruction, reserve training, operational simulators* ***Administrative Facilities*** *Offices, conference centers, command centers, parking* ***Personnel Support Districts*** *Officer clubs, lodge, food service, fire and security, ITT, medical and dental clinics, family services, schools, childcare facilities, youth programs, religious facilities, banks, exchange, commissary, libraries, morale, welfare and recreation, hobby shops, theaters, gyms indoor sport facilities, outdoor pools, sports (tennis, basketball) courts, baseball and football fields* ***Industrial Facilities*** *Shipyards, ordinance handling/storage, manufacturing facilities, maintenance shops, depots*	INCREASING NIGHT TIME ACTIVITY ↓
LZ3	*Moderately High Ambient Lighting*	***Waterfront Facilities*** *Wharf and pier areas* ***Airfield Facilities*** *Aircraft maintenance and hangars, air operations and headquarters, line shacks, terminal facilities, training areas, utility service areas*	
LZ4	*High Ambient Lighting*	*No areas qualify for this lighting zone.*	

Figure 5-8. Example Lighting Zones on a Sample Installation.



5-2.6.6.6 Considerations to Classify an Area at a Lower Lighting Zone

- Very low or no activity at night.
- Adjacent lighting zone, either DoD or Civilian, is lower and has a low level of activity.

5-2.6.6.7 Considerations to Classify an Area at a Higher Lighting Zone (Never higher than LZ3):

- Sensitive areas requiring a high level of security.
- High level of activity at night as well as high number of users.

/2/

5-2.7 Maintenance.

Consider luminaire maintenance in the design process. By selecting long-life sources, the frequency of re-lamping can be reduced. Evaluate the ability to perform future maintenance in the installed location. For example, lighting in atriums, high maintenance bays, and other difficult to access lighting can be very hard to maintain. Determine if the selected design will require a lift or scaffolding just to replace lights. Lowering devices can be incorporated to bring a pendant-mounted luminaire to an accessible level. In such cases as atrium applications, consider wall-mounted luminaires that indirectly light an area. In cases of poor or limited access, evaluate lighting quality and luminaire life as part of the design.

\1\/1/Group re-lamping should be the principal method of periodically replacing lights in a given area. Base the group re-lamping frequency on ensuring intended lighting levels are maintained above minimum levels. Spot re-lamping is not recommended in this regard because lighting levels will tend to eventually fall below intended levels. The group re-lamping interval should consider the light source mortality \2\ or lumen depreciation curves (provided by the manufacturer for each type of light source) so that spot re-lamping does not become an excessive maintenance burden. When light sources decrease light output by more than 30%, a re-lamping is recommended. This time period should be provided by the manufacturer for a 70% lumen depreciation of L70, for LED sources. /2/

Spot re-lamping should be performed as necessary for appearance and safety.

5-2.7.1 Accessibility.

Facility users are usually responsible for light source replacements at and below 3 m (10 ft). Evaluate the lighting system design to confirm that users will be able to periodically replace the installed light sources.

5-3 LIGHT SOURCES.

5-3.1 Light Source Comparisons.

\2\ Traditional light sources are typically called light sources, such as fluorescent, metal halide and high pressure sodium. /2/ Table 5-6 compares light sources types based on the following characteristics: efficacy (lumens of light per watt of energy), light source life (the expected time of operation until 50% of the light sources are out \2\ or L70 for LED light sources /2/), color temperature (the \2\ perceived /2/ color of light emitted from the light source), color rendering (how the light from the light source shows other colors), start (time until the light source is at full brightness), lumen maintenance (how the light output decreases over the light source life), effects of ambient temperature on the light source, and cost. This comparison illustrates that there is no “best” light source. Choose light sources based on the criteria that are most appropriate to the project. Efficacy may be the guiding criteria to save the most energy; color rendering may be the most important issue in an area where colors will be viewed; or light source life will be critical in hard to maintain areas.

Table 5-6. \2\ Comparison of Light Sources[35]/2/.

	Efficacy (lumens / watt)	Lamp Life (hours)	Color Temp. (Kelvin)	Color Rendering Index	Start Time	Re-strike Time	Lumen Maintenance (%)	Dimming Capabilities	Effects of Temperature	Initial Cost
Compact Fluorescent	60 - 75	10,000	2700 - 4100	82	0	0	83 - 87	with dimming ballast	longer start and warm-up time in low temperatures	Med
Linear Fluorescent T8	80 - 95	20,000	2700 - 4100	75 - 85	0	0	83 - 87	with dimming ballast	longer start and warm-up time in low temperatures	Low
Linear Fluorescent T5HO	80 - 95	20,000	2700 - 4100	75 - 85	0	0	90 - 95	with dimming ballast	full output only at 35 degrees C (95 degrees F). Lower temperatures increase start time and light output	Med
Induction	60 - 75	100,000	3000 - 4000	80+	0	0	80	will soon be developed	low temperatures decrease light output	Very High
Metal Halide	80 - 90	10,000 - 20,000	3000 - 4200	65 - 90	5-10 min	up to 15 min	80 - 85	yes, but expensive	none	High
High Pressure Sodium	90 - 105	24,000+	1900 - 2100	21 - 85	<5 min	1 min	88 - 92	none	none	High
Low Pressure Sodium	100 - 160	16,000	1800	poor	7-15 min	7 - 15 min	100	none	none	Med
Mercury Vapor	35 - 55	24,000	4000 - 5900	20 - 45	<10 min	<10 min	60 - 65	none	none	Med
LED	30 - 60*	50,000 (L70)	2700 - 6500	70 - 90	0	0	70% (at 50,000 hours)	dimmable	high ambient temperatures may adversely affect lumen depreciation and life	High
Tungsten Halogen	18 - 22	2000 - 4000	2800 - 3100	100	0	0	93 - 97	dimmable	none	Low
Incandescent	15 - 18	1000 - 3000	2700 - 3000	100	0	0	83 - 87	dimmable	none	Low

* This value reflects the efficacy of the entire luminaire and electronic system. While the LED efficacy is lower than other sources, it represents lumens leaving the luminaire per watt of power.

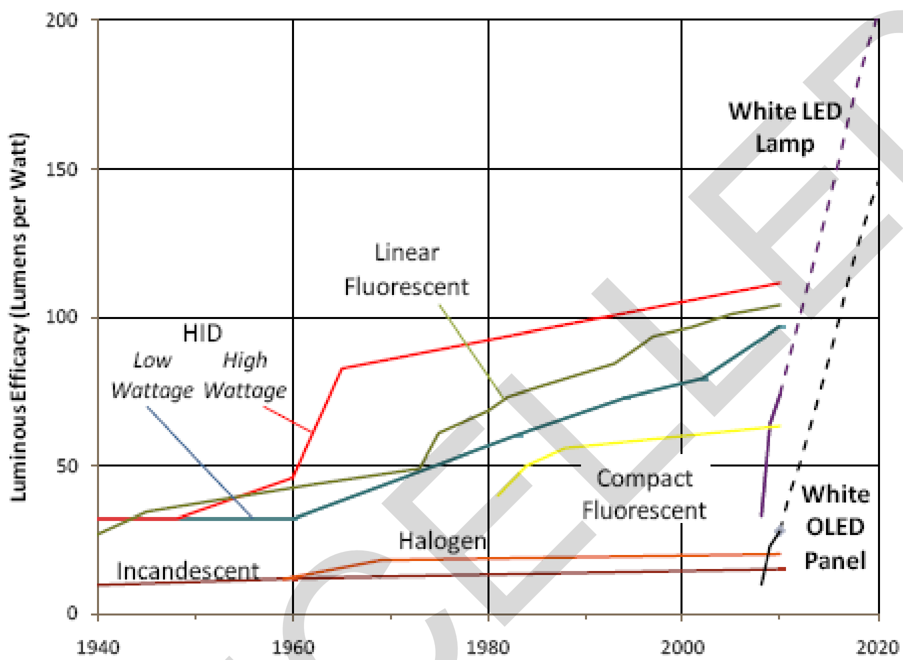
5-3.2 \2\ Light Source and SSL Luminaire efficacy./2/

Light Source Efficacy is the number of lumens produced by a light source per watt of electrical input. This quantity allows for a comparison between light source output and light source wattages. Linear and compact fluorescent light sources have a high efficacy, which is several times higher than incandescent light sources (general service light bulbs). Choose the highest efficacy light source that still meets the visual requirements for the application \2\ while considering the color temperature of the light source and the adverse effects shorter wavelengths may have on the environment Also, consider "effective lumens" (Chapter 2 Lighting Design Considerations) for exterior lighting applications. SSL luminaires contain the light source as an integral part of the entire luminaire. Therefore, they are rated with a *luminaire* efficacy rather than a *light source* efficacy. This represents the number of lumens exiting the luminaire per watt of system power. In order to compare an SSL system to a non-SSL system, multiply the

[35] Clanton & Associates, Inc. *In-House Research*. 2010.

non-SSL efficiency by the light source lumens. Dividing this value by the system wattage gives a luminaire efficacy that can be evaluated against the SSL system. Requesting the IES LM-79 (Electrical and Photometric Measurements of Solid-State Lighting Products) test data will list the luminaire efficacy. /2/

Figure 5-9. Efficacy Comparison of Light Sources for General Lighting[36.]



Ballast watts included for discharge light source systems. Sunlight and daylight ranges calculated inside of single pane clear glass and high performance glass.[37]

5-3.3 Compact Fluorescent Light Sources.

Compact fluorescent light sources (CFL) replace the standard incandescent light source. Because the CFL comes in a variety of wattages and sizes, and gives off a “glow” of light, it is ideal for wall sconces, decorative pendants, recessed wall washers, table lamps, torchieres, step lights, and exterior pedestrian lighting.

5-3.3.1 Select luminaires that are designed for the CFL complete with ballast, as

[36] US Department of Energy. “SSL Technology Status”. *Solid-State Lighting Research and Development: Multi Year Program Plan,* Chapter 3. 2011, p26.
[37] New Buildings Institute, Inc. “Light Sources and Ballast Systems”, *Advanced Lighting Guidelines,* Chapter 6. 2001 Edition, 6-3. Neither the sponsors, authors, editors, advisors, publisher, or the New Buildings Institute, Inc. nor any of its employees make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any data, information, method, product or process disclosed in this document, or represents that its use will not infringe any privately-owned rights, including but not limited to, patents, trademarks or copyrights. © 2001 by New Buildings Institute, Inc. All rights reserved.

opposed to luminaires that are designed for the standard incandescent but will accept a "screw in" type CFL replacement. \2\ Verify base orientation of CFL source prior to installation. Some base orientations may compromise rated life. /2/ Only use "screw in" replacements for a lighting retrofit when the cost of replacing the equipment is prohibitive. \2\ These can be dimmed. /2/

5-3.3.2 Low wattage CFL light sources (less than 13 watts) generally have a lower efficiency and shorter light source life than the CFL light sources of greater wattage. Also, use high wattage CFLs (42 watt and above) in luminaires where the light source brightness is hidden or shielded.

5-3.3.3 In decorative wall sconces, pendants, table lamps, and torchiers, use 3000K CFL. Use either 3000K or 3500K CFL for wall washers, exterior pedestrian and landscape lighting. In other cases, match the color temperature of all different kinds of light sources in an area.

5-3.3.4 Requirements for compact fluorescent light sources:

- Do not use compact fluorescent light sources less than 13 watts.
- Use electronic or electronic dimming ballasts for all CFL.
- Do not mix compact fluorescent light source color temperatures within a single building to minimize maintenance and the chance of visual confusion.
- U-Bent fluorescent light sources are not economically feasible and should not be used. (An economic analysis must be completed if there is another compelling design reason for using them.)

5-3.3.5 Considerations for compact fluorescent light sources:

- Use 3000K and 80 CRI as the default color temperature and color rendering index for residential, hospitality, food service, childcare, and healthcare projects.
- Use 3500K and 80 CRI as the default color temperature and color rendering index for commercial, office, and educational projects.

\2\

5-3.3.6 Dimming of compact fluorescent light sources.
To properly dim compact fluorescent light sources, a dimming ballast must be used. The majority of self-ballasted compact fluorescent light sources are not dimmable. Those that are, can be dimmed down to approximately 5% of the light output. If a CFL not suitable for dimming and is used with a dimmer, the light source life can be significantly reduced. /2/

5-3.4 Linear Fluorescent Light Sources.
Linear fluorescent light sources are recommended for the majority of ambient area lighting, including high spaces. Linear fluorescents come in a variety of wattages and sizes, yet the most common and energy efficient light sources are the T8, and T5HO. These light sources are ideal for linear pendants, linear recess wall washers, recess wall slots, cove lights, stack or aisle lights, industrial and recreational lighting.

5-3.4.1 The advantages of linear fluorescents include energy efficiency, high color rendering, instant on/off switching, dimming capability, long life, and cost effectiveness.

5-3.4.2 Depending on the application, the T5HO (high output) can provide a more efficient alternative to the T8. Because this light source produces a high level of light from a small light source envelope, care must be given to shield the light source from direct view unless used in a high ceiling application. In those cases, the luminaire reflector should be white and have an indirect component to balance out the light source brightness.

5-3.4.3 High performance T8 light sources sometimes referred to as “Super T8s,” have the advantages of better color rendition and additional light output. By using optimized ballasts with these high performance light sources, the light sources gain a significant life advantage as well. A particular system for (1) 1.2 m (4 ft) T8 light source produces 3100 initial lumens, uses 25 watts, provides 85 CRI, and has an average life of 30,000 hours. It is important to keep in mind that all of these additional advantages are only achieved when the optimized ballast is paired with the high performance light source. \2\ Reduced wattage light sources provide a slightly lower light output than a standard T8. Sometimes /2/ an improvement in one light source characteristic may be achieved at the expense of another. For example, the ballasts may or may not be available as dimming or rapid start. Such a premium light source can be used on a dimming ballast.The light source will have an average of 20,000 to 24,000 hours. See the section on ballasts for additional information. Refer to the controls section for compatible devices with various ballast types.

5-3.4.4 \2\ High color temperature fluorescent light sources are sometimes marketed as having improved performance characteristics. Often called Full Spectrum, Daylight, or Scotopic light sources, these light sources are usually nothing more than regular fluorescent light sources with a color temperature of 5000K and above. An array of health benefits are often attributed to full spectrum and daylight light sources with little independently verified research to support the claims. Scotopic light sources claim better visibility with these higher color temperatures. While it is true that visibility can improve with higher color temperatures, research only shows this to be true at scotopic and mesopic levels of brightness – incredibly low levels of light such as that created by a full moon. Photopic conditions occur in all interior spaces and receive no proven benefit from higher color temperature electric lighting. /2/

5-3.4.5 Requirements for linear fluorescent light sources:

- Use electronic or electronic dimming ballasts for all linear fluorescents.
- Do not mix linear fluorescent light source color temperatures within a single building to minimize maintenance and the chance of visual confusion.
- T12 light sources are prohibited. (The Energy Policy Act of 1992 ended production of many of these light sources.)

5-3.4.6 Considerations for linear fluorescent light sources:

- Use 3500K and 75+ CRI as the default color temperature and color rendering index.
- Use 3000K in housing and hospitality applications. Use 3500K in all other applications except for maintenance facilities where 4100K may be used.
- Consider T8, T5HO, and High Performance T8 light source/ballast combinations based on the application, initial cost, and potential energy savings.

\2\

5-3.4.7 Dimming of linear fluorescent light sources.
Linear fluorescent light source s can be economically dimmed down to approximately 5%.

/2/

5-3.5 Induction Light Sources.
Induction light sources are essentially fluorescent light sources without electrodes. Therefore, they have very high efficiencies and extremely long lives (70,000-100,000 hours). Induction light sources have many of the fluorescent light source advantages such as superior color rendering, instant on/off switching, \2\ dimming /2/ and long life.

5-3.5.1 Despite the high initial cost, these light sources offer significant cost benefits regarding low energy and maintenance costs. Because a typical re-lamping schedule may call for changing metal halide light sources after only 15,000 hours, while induction light sources can be changed after \2\ an L70 time (time when light source has depreciated to 70% of its initial output) of /2/ 60,000 hours, the savings in light source replacements and labor costs quickly pays for the higher installation cost. In some cases, the payback period may be as short as 5-7 years. Most importantly, the induction light source is extremely reliable. When compared against higher wattage HPS light sources, the energy savings of the induction light source reduces the payback period even more.

5-3.5.2 The ideal application for induction light sources are in areas where metal halide or high-pressure sodium light sources may be used, even though the induction light source is larger. Long life and instant on/off induction light source characteristics make it very reliable and easy to control with motion sensors. \2\ Dimming is also available for some induction light sources with a dimming generator. /2/

5-3.5.3 Considerations for induction light sources:

- Consider induction light sources for exterior area lighting, especially in "instant-on" applications. \2\ May be used for parking lots and garages, street lighting, and pedestrian lighting. /2/
- Consider induction light sources in low bay luminaires.
- Specify 4000 K light sources for exterior applications.

\2\

5-3.5.4 Dimming of induction light sources.
Dimming is possible for induction light sources and manufacturers are currently marketing systems for both continuous dimming and step dimming. As induction light sources are dimmed, the internal temperature is decreased and may increase the overall life of the light source.

/2/

5-3.6 Metal Halide and Mercury Vapor Light Sources.
Metal Halide light sources provide a small point source of white light. Metal halide light source efficacies and light source life are increasing with pulse start technology. The disadvantages of the metal halide light source are lumen depreciation and a long start up time. Additionally, these light sources also have a re-strike time. When a light source is warm and then turned off, it must cool sufficiently before it can be re-ignited. This time delay is the re-strike time of the light source. Even with these disadvantages, metal halide is a great source of white light, especially for exterior nighttime lighting, where it enhances peripheral vision.

5-3.6.1 Do not use mercury vapor light sources because of their poor color rendering properties and poor energy efficacy.

5-3.6.2 The ideal applications for metal halide light sources include exterior parking lots, roadway lighting, area lighting, indirect atrium lighting, and accent lighting.

5-3.6.3 Requirements for metal halide and mercury vapor light sources:

- Do not use mercury vapor light sources.
- Use electronic ballasts for metal halide light sources 150 watts and below. These ballasts are more reliable and use less energy than magnetic ballasts. Currently they are only available for 150 watt light sources and

lower. (If higher wattages become available from (3) manufacturers, they should be considered.)

5-3.6.4 Considerations for metal halide light sources:

- Consider metal halide light sources for exterior lighting in areas of pedestrian traffic and where light color and color rendering are important.
- Consider pulse start metal halides if possible. These light sources have improved lumen maintenance and longer light source life. (Available for vertical light sources only.)
- Consider metal halide PAR light sources (50 watts or lower) for accent lighting, including flags.
- Use metal halide light sources (100 watts and higher) in fully shielded or IES \2\ appropriate BUG rated /2/ luminaires.
- Specify 3000K coated metal halide light sources for exterior applications.

/2/

5-3.6.5 Dimming of metal halide and mercury vapor light sources.
Because metal halide light sources have a long start up time, they are not conducive to dimming. Continuous and step-dimming is currently available from 100-50%. Dimming of metal halide light sources is not recommended below 50% due to possible color shift and degradation of rated life. It is also important to allow ample warm up time of the light source (at least 15 minutes) prior to dimming. /2/

5-3.7 \1\ Light Emitting Diode (LED).
LED is a solid state light source which produces a directional narrow beam of light. LEDs are a broad spectrum light source that is instant on, dimmable, and advertise light source life \2\ (L70) /2/ of between 50,000 and 100,000 hours. LED luminaires incorporate multiple SSL sources with directional characteristics that allow for better control of the light distribution for applications such as area and roadway lighting. This reduces “hot spots” and results in a visible improvement in uniformity. \2\ LED luminaires may also produce more glare. Select luminaires that do not increase glare compared to other light sources. /2/ Although they have many advantages, LED sources generate significant heat requiring the luminaires to provide appropriate heat sinking \2\ and thermal feedback loops that reduce driver current as ambient temperatures rise./2/ Current LED product quality can vary significantly among manufacturers so diligence is required in the selection and application of this technology. Actual light source life \2\ of L70 /2/ of LED luminaires varies with luminaire design (heat dissipation) and ambient temperature. Improper application or poor luminaire design can lead to rapid lumen depreciation and premature failure. Due to incredibly long life span, a poorly chosen or designed SSL-LED system may plague an end user for years.\2\ While LEDs are

increasingly available for more and more applications, it is important to recognize the difference between these and other light sources. LEDs are very directional which makes them good at getting light out of the luminaire (luminaire efficacy) but this same attribute can also increase glare. /2/

5-3.7.1 Considerations for LED:

- Exit signs, other lighted information signs and traffic signals.

  \2\

- Step lighting, nightlights, task lighting, cove lighting, wall washing, downlighting, canopies, high bays, parking garages, and red lighting systems for guard stations.

- Street, parking, roadway, area and façade lighting.

- As of this writing, LEDs are NOT cost effective in linear fluorescent luminaires such as linear direct / indirect pendants and 2x4 or 2x2 troffers. Linear fluorescent light sources are quite energy efficient and very low cost. The glare from LEDs in this application is also typically greater than linear fluorescent light sources.

- Monochromatic LEDs may be used in place of LPS for sensitive environments such as wildlife habitat, observatories, wildlife nesting, or to meet dark sky requirements. LED light fixtures used in special environmental applications shall be products approved by the appropriate state and local governing authority. For marine applications, incorporate Fish and Wildlife, state, and local governing authority recommendations for lighting systems design and installation. The lighting manufacturer is responsible for obtaining any applicable certifications for their products..

- Monochromatic red LEDs may also be used to provide better dark adaptation in guard station task lights.

- For exterior lighting, high CCT has been shown to contribute to skyglow.[38 & 39] Therefore, designers should target a CCT of no greater than 4300K as stated on the manufacturer's cutsheet. Note, er ANSI C78.377R standard, nominal CCT of 4000K is 3985K +/-275K and nominal CCT of 4500K is 4503K +/-243K. Since one manufacturer might have a 4300K source another has a 4000K source it would be appropriate to indicate a range of CCT such as 4000K to 4500K nominal CCT in accordance with ANSI

[38] IES TM-12-12. Lamp Spectral Effects at Mesopic Lighting Levels. The Illuminating Engineering Society of North America. New York, NY.

[39] IES TM-18-08. Light and Human Health. The Illuminating Engineering Society of North America, New York, NY.

C78.277.

- All LED luminaires shall be dimmable.
- LED efficacy is given as the lumens leaving the entire luminaire assembly per watt of input power. This differs from the efficacy of other light sources which are rated as the number of lumens from the *light source* per watt of power. Consider this when comparing LED with other potential light sources. To accurately evaluate two systems, multiply the light source efficacy by the luminaire efficiency. This value can then be compared to the LED system.
- IES LM-79, LM-80 testing reports include all relevant information.

  /2/

- For Service specific applications and specifications:
  - Navy and Army comply with NAVFAC ITG 2010-03 - Application of Solid State Lighting (SSL)/Light Emitting Diode (LED) for Exterior Lighting, available at: http://www.wbdg.org/ccb/browse_cat.php?o=30&c=212
  - \2\ Air Force comply with ETL 12-15 Light-Emitting Diode (LED) Fixture Design and Installation Criteria for Interior and Exterior Lighting Applications /2/ available at: http://www.wbdg.org/ccb/browse_cat.php?o=33&c=125 /1/

\2\

5-3.7.2 Dimming of light emitting diodes.
LEDs can be dimmed with the proper compatible dimming equipment (driver and power supply). Because manufacturers may have proprietary dimming systems that are not compatible with all LEDs, it is crucial for the designer to coordinate that all components are compatible with one another. The efficacy of LED luminaires increases as they are dimmed because the internal temperature is decreased and the system operates more efficiently. The highest quality LED systems have the ability to dim from 100-1%. The next tier of performance can dim down to 20%. In applications where dimming is required, designers should be sure to check for flicker of the light at the lowest dimmed state and total harmonic distortion.

/2/

5-3.8 High-Pressure Sodium / Low-Pressure Sodium Light Sources.
High-Pressure Sodium light sources are typically used for exterior applications. Although high-pressure sodium light sources have long lives (20,000 hours) and appear to be efficacious, there are several problems with them. The most important is the lack of short wavelength light such as blue and green light. As a result, one's peripheral vision under nighttime exterior lighting conditions, does not respond well to the color of light of

the high-pressure sodium light sources. White light can be two to twenty times more effective for peripheral vision detection than high-pressure sodium. High-pressure sodium light sources are not advised for interior applications. Because short wavelength light controls the pupil, high-pressure sodium light sources cause objects to be “out of focus”. In addition, HPS light sources render color poorly. Refer to Chapter 2, “Lighting Design Considerations” for \2\ mesopic multipliersor /2/ Effective Luminance Factors. High-pressure sodium light sources \2\ are not recommended for exterior applications, but /2/ can be used where existing conditions and continuity of source types make it necessary.

5-3.8.1 Low-pressure sodium light sources provide poor nighttime visual acuity and poor color rendering.

5-3.8.2 Requirements for high and low pressure sodium light sources:

- Do not use low-pressure sodium light sources except for unique applications such as in sea turtle nesting areas.

5-3.8.3 Considerations for high-pressure sodium light sources:

- Consider white light sources such as induction, metal halide, LED, and fluorescent light sources rather than high-pressure sodium light sources where peripheral detection is important such as pedestrian walkways, parking areas, and other outdoor areas where pedestrians are present. Refer to \2\ Chapter 2, “Illuminance” /2/ for additional information on the effectiveness of white light.

- Consider high-pressure sodium to maintain continuity with existing conditions and adjacent projects.

\2\

5-3.8.4 Dimming of high pressure sodium light sources.
Because high pressure sodium light sources have a long start up time, they are not conducive to dimming. Continuous and step-dimming is currently available from 100-50%. Dimming of high pressure sodium light sources is not recommended below 50% due to possible color shift and degradation of rated life. It is also important to allow ample warm up time of the light source (at least 15 minutes) prior to dimming.

/2/

5-3.9 Incandescent and Tungsten Halogen Light Sources.
\1\ The use of standard incandescent is not allowed for new installations. /1/ Incandescent and tungsten halogen light sources use the most energy for the amount of light output, and also require high maintenance. \1\ /1/Avoid tungsten halogen light sources unless deemed necessary for the specialized application, such as accent

lighting a key feature or artwork. In these applications, consider using \2\ an LED or /2/ low wattage PAR metal halide as an alternative.

5-3.9.1 Requirements for incandescent and tungsten halogen light sources:

- Do not use standard incandescent light sources. Except for specialty applications such as photograph development areas.

5-3.9.2 Considerations for incandescent and tungsten halogen light sources:

- Limit the use of tungsten halogen light sources. When low-level accent lighting is necessary for a special application, use tungsten halogen light sources with a minimum efficacy of 20 lumens per watt.
- \2\ LED light sources /2/ can be used as an alternative to standard incandescent light sources especially in landscape lighting applications. These light sources have a significantly longer life.
- When tungsten halogen is absolutely necessary, the lighting must be on an easily accessible dimmer to extend light source life.
- Use alternative sources such as \2\ LED or /2/ compact fluorescent in place of standard incandescent lighting.

\2\

5-3.9.3 Dimming of incandescent and tungsten halogen light sources.
Incandescent and tungsten halogen light sources are dimmable. The life of these sources can be increased by dimming.

/2/

5-4 BALLASTS, \2\ DRIVERS, GENERATORS /2/ AND POWER SUPPLIES.

5-4.1 Electronic Ballasts.

The use of electronic ballasts as opposed to older technology core and coil ballasts reduces the energy requirements of fluorescent and HID sources. The nominal wattage of a fluorescent or HID light source is typically lower than the wattage that the light source/ballast system actually draws, or the “input watts”. For example, a thirty-two watt compact fluorescent light source draws thirty-five watts through the ballast when in operation. This input wattage is minimized with electronic ballasts. They also have the benefits of less noise, reduced flicker, smaller size, less weight, and lower starting temperature.

5-4.2 Linear Fluorescent.

Select ballasts for linear fluorescent light sources that operate at a high frequency (greater than 30 KHz) and low total harmonic distortion. Provide ballasts with a high \2\

ballast factor (greater than 0.95). Ballast factor describes the amount of energy consumed by the ballast as compared to a reference ballast. /2/ Provide programmed start ballasts for T5 and T5HO light sources that include end of life protection. \2\ Specify NEMA Premium ballasts whenever possible for all linear fluorescent light sources. These ballasts meet the highest current standards of efficiency. /2/

5-4.2.1 Instant Start fluorescent ballasts have the advantage of lower input wattages. However, if the light sources are switched frequently, the instant start will decrease the life of the light source. Therefore, the energy savings is only a benefit in applications where the light sources will be turned on and left on for a long period of time. These must not be used in applications where individual occupants have control over the lighting or with automatic controls such as daylight and occupancy or vacancy sensors.

5-4.2.2 Rapid Start fluorescent ballasts start the light source in a softer manner that takes a few seconds to turn on, but does not decrease the life of the light source with frequent switching. They do not have the same energy benefit as instant start ballasts.

5-4.2.3 Programmed Start fluorescent ballasts delay the heating of the light source when it is started. This ballast increases the light source life and also operates the light source at a slightly lower input wattage than rapid start ballasts. However, the input wattage is slightly higher than instant start ballasts. Some manufacturers are discontinuing the rapid start ballast and replacing them with programmed start. Use Programmed Start fluorescent ballasts in areas controlled with occupancy \2\ or vacancy sensors. /2/

5-4.3 Compact Fluorescent.

Select ballasts for compact fluorescent light sources that operate with a high power factor (greater than 90%). Provide programmed start ballasts for compact fluorescent light sources that include end of life protection. In exterior applications that experience cold temperatures, provide low temperature ballasts to improve start-up time.

5-4.4 High Intensity Discharge.

Provide HID ballasts with a high power factor (minimum of 90%). Provide electronic metal halide ballasts for \2\ all available wattages. Some manufacturers make electronic ballasts for up to 1000 watt light sources while other only go up to 400 watts. /2/ These ballasts are more reliable and use less energy than magnetic ballasts. Currently electronic ballasts are only available for 150 watt light sources and lower. If higher wattages become available from (3) manufacturers, they should be considered.

5-4.5 Induction.

Induction light sources require the support of both a high frequency generator and a power coupler. The overall operating system should include a five-year minimum warranty.

5-4.6 Solid State Lighting (SSL).

SSL requires a driver and low voltage power supply referred to as a power control unit. In some cases these may be combined into one unit while in others, they are purchased separately. It requires extra coordination with the luminaire manufacturer to make sure that all of these components work as a system. One power supply module may operate multiple SSL luminaires. Dimmable power and bi-level switching supplies are available \2\ and must be compatible with dimming controls. Dimming with other than compatible and tested dimming drivers can result in an increase in total harmonic distortion, light source flicker, and lower power factor. Total harmonic distortion must be less than or equal to 20%. Power factor must be greater than or equal to 0.9 /2/

5-4.7 Noise.

Electromagnetic (core and coil) ballasts operate with a "hum" while electronic ballasts produce little or no noise. Provide ballasts with a Class A noise rating.

5-4.8 Flicker.

HID light source sources will flicker due to the changes in line voltage. This flicker effect may be noticeable in certain applications and can be effectively eliminated with the use of high frequency electronic ballasts[40]. If electronic ballasts are not used, the phases can be rotated to minimize flicker.

\2\ SSL luminaires can flicker when dimmed, especially with incompatible dimming controls and inadequate electrical infrastructure. Provide dimmer compatible with SSL luminaires and ensure that electrical infrastructure is adequate to operate SSL luminaires. /2/

5-4.9 Interference.

Electronic ballasts \2\ and SSL /2/ drivers have the potential to cause Electromagnetic Interference (EMI) and Radio Frequency Interference (RFI) when operated near other high frequency electronic equipment. This can be a significant issue when installed near electronic medical equipment. To prevent such interference, specify magnetic ballasts in those areas. Another more energy efficient option that will also avoid such interference is low frequency electronic ballasts. Available from some manufacturers, these ballasts operate at low frequencies and will not interfere with sensitive equipment. These ballasts should be specified with <20% Total Harmonic Distortion (THD). \2\ SSL drivers must also be selected and rated for use near sensitive equipment, complying with FCC Title 47 Part 15. /2/

5-4.10 Effects of Temperature.

Ambient air temperature affects the performance and output of fluorescent, \2\ SSL, and induction /2/ light sources. In exterior, low temperature applications (less than ten degrees C) provide ballasts capable of low temperature light source starts. Light output will be reduced until the light source warms up to operating temperature. Mercury amalgams added to fluorescent light sources improve the light source performance and

[40] "Light Sources: Technical Considerations", *Lighting Handbook Reference and Application*, Chapter 7, Tenth Edition (New York: The Illuminating Engineering Society of North America, 2011), p. 7.45.

provide for operation over a wide temperature range. These light sources typically take slightly longer to reach normal operating temperature and full light output. Alternatively, some lamp manufacturers provide standard lamps with an additional low temperature jacket or sleeve. This type of casing can increase the air temperature immediately around the lamp and improve performance. \2\ Low temperature has a positive effect on SSL sources, improving their life. High temperatures improve the starting time of fluorescent light sources but also can degrade all electronic ballasts, drivers, and SSL. For SSL luminaires, LM79 and LM80 testing reports show the lumen depreciation over time and temperature. /2/

5-4.11 Life.

The operating temperature of ballasts, drivers, generators and power control units directly affects the life. The luminaire housing or enclosure should provide for adequate dissipation of heat. When ballasts, drivers, generators or power control units operate at excessive temperatures, the insulation degrades, resulting in a shortened ballast \2\ generator or power control unit life. High operating current in SSL luminaires can also shorten life. Review LM-80 and LM-79 data to determine actual life with designated operating current. /2/

5-5 LIGHTING CONTROLS.

\2\

5-5.1 Interior Lighting Control Equipment.

The light source and ballast or power unit need to be considered in designing a control system. Some light sources are more suitable for dimming or switching than others. Frequent switching may adversely affect the life of the light source. In other cases, undesirable color shift may occur when a source is dimmed. Especially with SSL lighting systems, power supplies and control systems must be compatible to avoid flicker and allow for smooth operation. Table 5-7 outlines some of the issues that need to be considered in matching control strategies with light sources. In all cases, lighting controls must be commissioned to optimal operation and user satisfaction.

Table 5-7. Lighting Control Considerations.

Light Source	Switching Considerations	Dimming Considerations
Compact Fluorescent	With frequent switching (including occupancy controls) use programmed or rapid start ballasts rather than instant start. Provide ballasts with end-of-life protection.	Requires electronic dimming ballasts and compatible controls. Some color shift occurs when dimmed. Systems can dim lights smoothly and effectively to 1% of initial light source output.
Linear Fluorescent	With frequent switching (including occupancy controls) use programmed or rapid start ballasts. Do not use instant start ballasts.	Requires electronic dimming ballasts and compatible controls. Some color shift occurs when dimmed. Systems can dim lights smoothly and effectively to 1% of initial light source output.
Induction	No operating issues.	Dimming is not \2\ readily /2/ available.
HID Sources	Inexpensive. Due to warm up and restart times, access to switches should be limited. Not suitable for occupancy or vacancy sensors or frequent switching.	Requires special ballasts and control systems. Dimming cannot decrease light below a minimum point. Light source efficacy of source diminishes with dimming. Significant color shift and light source life problems.
SSL	No operating issues \2\ except for flickering with incompatible power supply and controls. /2/	Requires a \2\ compatible dimming driver power supply with control system. Dimming should reduce lighting to at least 10% light output. /2/
Tungsten Halogen and Incandescent	No operating issues.	Will significantly extend light source life. Dimming is full range and appealing. Some energy savings.

5-5.1.1 Sensors.

5-5.1.1.1 Occupancy and Vacancy.

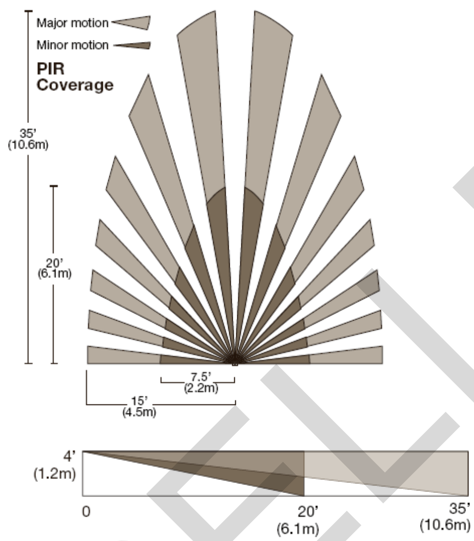
An occupancy sensor is used for interior applications to automatically turn the lights on when an occupant enters the space and automatically turn the lights off after a period of undetected occupancy.

A vacancy sensor requires the occupant to manually turn the lights on when they enter the space and the sensor automatically turns the lights off after a period of undetected occupancy. More energy is saved when using vacancy sensors as occupants may not always require electric lighting when entering a space.

5-5.1.1.1.1 Technologies

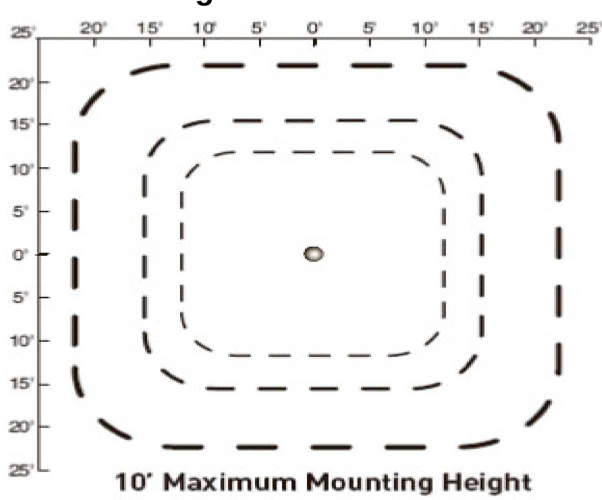
Passive infrared sensors detect the difference in heat between a human and the surroundings. Because of this, the sensor must be able to “see” the entire space and any obstruction such as partitions, shelves, or cabinets will block detection. Changes in ambient temperature will also reduce the effectiveness of the infrared sensors. The pattern of occupancy is dispersed in a fan shape where the distance between fan blades is small near the sensor, but increases as the fan blades are directed away from the sensor.

Figure 5-10. Coverage Pattern of PIR Sensor.



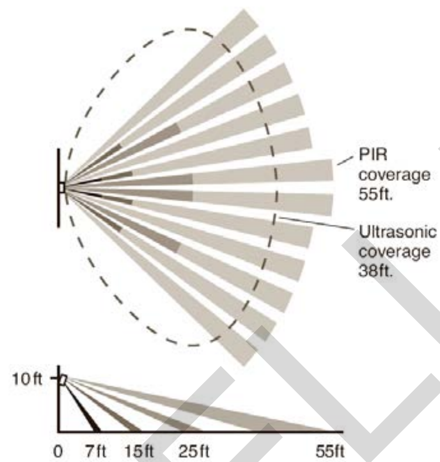
Ultrasonic technology relies on high frequency sound waves to detect movement in the space. This movement could be a person moving, or air movement created by a person's activity. This type of sensor is therefore appropriate for spaces that have partitions such as restrooms or open office areas. Such sensors need to be located so that they do not sense the "false-occupancy" of an air vent or a passer-by in an adjacent space. Room finishes such as carpeting may absorb the ultrasonic waves and reduce effectiveness.

Figure 5-11. Coverage Pattern of Ultrasonic Sensor.



These sensors combine both the capabilities of PIR and ultrasonic to detect occupancy. Both an ultrasonic and PIR detection of occupancy is required for the lights to turn on but only one sensor technology is required for the lights to remain on. This type of sensor is best used in large spaces with low occupant activity levels.

Figure 5-12. Coverage Pattern of Dual Technology Sensor. (Courtesy of Wattstopper/Legrand)



5-5.1.1.1.2 Considerations.

Each type of occupancy or vacancy sensor should be equipped with a time delay. This time delay leaves the lights on for a predetermined amount of time after the last occupant has been detected. The purpose of the time delay is to ensure that occupants are not left without lighting and to reduce the number of on/off cycles. Since occupancy patterns vary with time of day, day of the week and are not easily scheduled, it is best to select a time delay that works for both periods of increased and decreased occupant activity. Manufacturers typically have preset time delays at 5, 10, 15, 20, or 30 minutes. It is recommended that a time delay setting of 10 minutes be used for most spaces. Should another time delay setting be selected, consideration should be given to the increased energy consumption, ballast type, and increased life of the light source due to the reduced number of on/off cycles.

In addition to the time delay, there should also be a setting for the sensitivity. The sensitivity will need to be calibrated appropriately according to the activity in the space. For example, if there is limited movement in the space, the sensitivity should be calibrated to detect very slight movement.

Table 5-8. Guide for Using Sensors.

DO	DON'T
Use ultrasonic sensors in large open areas with partitions or furniture	Use ultrasonic sensors where there is high air flow.
Place sensors in proximity to where the main activity in the space will occur.	Install an in-wall sensor where it is blocked by furniture or behind the door.
Use PIR in enclosed spaces.	Use ultrasonic sensors in small, enclosed spaces where they may react to activity outside the space.
For large areas, create zones of light to manage light.	Install untrasonic or dual tech sensors higher than 12 feet.
Over lap sensor coverage patterns by at least 20% to ensure adequate coverage.	Install sensors within 6 feet of an HVAC vent.
Ensure PIR line of sight does not extend out doorways. This can be achieved by either sensor placement or lens masking.	Use PIR sensors when there are multiple obstructions (furniture, partitions) which prevent line of sight of the sensor.

5-5.1.2 Daylight Sensor Technlogies

Open loop photosensors determine the light level by measuring the outside light availability. Based upon the light level measured, a signal is sent to the electric lighting to either increase or decrease the light level depending on the exterior daylight availability.

Closed loop photosensors determine the light level in a space by measuring the inside light availability. Based upon the light level measured, a signal is sent to the electric lighting to either increase or decrease the light level depending on the interior daylight availability.

Table 5-9. Summary of Daylight Sensors.

Use This Equipment	In This Type of Space	And Be Aware for These Issues
Open loop	Spaces where the outside daylight availability gives an accurate representation of the daylight entering into the space.	-Sensor should be placed outside or inside pointed towards the daylight opening -Use multiple sensors for spaces with more than one daylight opening -Outside conditions are accounted for, but not space conditions (geometry and reflectance)
Closed loop	Spaces where a constant level of illumination is desired.	-Room surfaces (reflectances) may affect the light level readings -More reliable and effective at measuring light levels than open loop photosensors

5-5.1.3 Self-Adapting

Self-adapting technologies “learn” how the space is used by occupants and adjusts the lights as necessary. The technology responds in real-time and automatically adjusts both the sensitivity of the sensor and the delay time. Self-adapting sensors are best used in spaces where neither the occupants nor the activities vary from day to day. Self-adapting technology is not recommended for classrooms and conference rooms, but may be ideal for private offices.

5-5.1.4 Manual Lighting Controls

Considerable energy savings can be achieved by allowing occupants to control (on/off) or vary the light levels.

Dimming lights savings energy. The savings is nearly linear (i.e. Dimming fluorescent lights by 30% saves 25% in electricity, dimming them by 50% saves 40% in electricity and so on). Furthermore, users seldom require maximum light levels and studies show that allowing users to adjust illuminance for different tasks saves 35-42% lighting energy.

5-5.1.4.1 Switches

Manual controls for occupants can be a good way to increase worker autonomy and give occupants greater control ability, although the energy savings is not as great as automatic controls. Manual switches work best in spaces where there is only one occupant in control of the space, such as private offices. Bi-level and multi-level switches equipment is possible to increase energy savings and control flexibility.

5-5.1.4.2 Dimmers.

Manual dimming occurs with a control action initiated by the occupant. This type of dimming may be useful in spaces where several different activities can take place. A conference room is an example where the lights may need to be dimmed for an A/V presentation, but also may need to be full output for meetings. Manual dimming also results in high satisfaction rating for occupants and should be encouraged for regularly occupied areas.[41]

5-5.1.5 Automatic Lighting Controls

Automatic dimming is a more sophisticated form of dimming that allows the lights to dim automatically given the conditions of the space. Automatic dimming is used in conjunction with daylight sensors.

Continuous dimming provides a seamless transition of light level to occupants. The light level is adjusted over a period of typically several seconds does not distract occupants which is ideal for daylight availability dimming. Step dimming creates more abrupt changes in light level. The range of dimming is limited to a few preset light levels and does not allow for transitions and may be noticeable, even distracting, to occupants.

5-5.1.6 Time Controls

5-5.1.6.1 Time Switch

Automatic switching takes place in conjunction with occupancy controls when the space becomes unoccupied. The lights turn off after a designated period of inactivity.

5-5.1.6.2 Time Clock

A time clock is a device that automatically adjusts the lights at a specific time or based on astronomical events such as sunrise or sunset. Manufacturers typically allow the preset time to vary between 5 minutes and 12 hours. This type of control may be applicable in spaces where there is constant occupancy, limited daylight, and minimal activity in non-peak hours of the day.

5-5.1.6.3 Schedule

A preset schedule can be programmed to automatically turn the lights on or off based upon trends in occupancy. Different schedules are created for weekdays, weekends, evenings, and holidays.

5-5.1.7 Network Control System

A network control system can be connected in a number of different ways. Implementing addressable ballasts or drivers provides digital addresses for all ballasts \2\ or drivers /2/ and connects them as a system through network cabling. The digital addresses allow control over each ballast or driver individually and allow for flexibility of the system as the needs of the space evolve over time. A wireless system communicates with all devices (sensors, dimming ballasts, dimming drivers and area controllers) over radio frequency.

[41] "Research Study Dimming Control Condition". *Light Right Consortium.* 2001-2003. http://www.lightright.org

The zoning of such a system is configured through software and provides flexibility as the needs of the space evolve over time.

The IES Technical Memorandum (IES TM-23-2011) *"Lighting Control Protocols"* provides technical information regarding the varying architectures, topologies and protocols that are currently available for lighting controls. The document may be useful especially when integrating one protocol with another or integrating a lighting control system with a building automation system. Typical uses are outlined along with limits/extents, interoperation with other protocols, and designer responsibilities / specification recommendations.

5-5.2 Exterior Lighting Control Equipment

5-5.2.1 Sensors

A photocell is a device that measures the illuminance level and is set to turn on or off the luminaire at a preset illuminance level. The light levels are set to ideally have the luminaires turn on before sunset and extinguish after sunrise.

Motion sensors used for exterior luminaires are the same as for interior luminaires. As such, the coverage patterns can be too small and result in coverage gaps when used to control exterior luminaires.

5-5.2.2 Time Clocks

Astronomic time clocks are intelligent control devices that automatically turn the lights on or off based upon a preset time, such as sunset or sunrise. The astronomic time clock keeps track of what day it is and geographic location of the luminaires. As the exact time of sunset and sunrise fluctuates throughout the year, the time clock adjusts accordingly.

5-5.2.3 Network Control Systems

5-5.2.3.1 Power Line Carrier

A power line carrier network system uses the physical electrical wiring to communicate between devices. Each luminaire has its own device and therefore its own unique address. The devices can then all be linked together to form a network that is adjustable through a software program. From the software, zoning can be established as well as scheduling. Additionally, maintenance issues can be identified. In order to dim, a separate dimming ballast or dimming driver may be required.

5-5.2.3.2 Radio Frequency

A radio frequency (RF) lighting control system uses embedded RF transmitters/receivers to connect devices (sensors, user controls, power equipment) to one another. These systems can be stand alone or part of a networked lighting control solution, to include automated shading systems. An installed-cost assessment should be done to determine where RF based lighting controls and shading systems can or should be utilized on any project, regardless of whether the project involves new construction or retrofit/renovation. Care should be taken to evaluate the RF lighting control solution on the frequency range it operates in (is it densely or sparsely populated?), how the system propagates and ensures proper RF communication between devices, RF device installation and cost, and whether the type of space being controlled supports the use of RF devices. A mock up of the RF lighting control system is a recommended best practice to ensure that the system will perform as expected in the application/operating environment.

5-5.3 Lighting Control Signals

Line-voltage lighting control signals operate at voltages of 120-277VAC, and use standard line voltage wiring pathways between devices. Because line-voltage control wires can be run in the same conduit with other line-voltage wires, this type of control wiring is conducive for both new construction and some retrofit applications where existing wiring can be used for lighting control signals.

Low-voltage lighting control signals operate at voltages of 0-24 VDC/VAC. This type of control wiring is often used to connect control devices or sensors together in a lighting control system. Depending on the space and the application, low-voltage control wiring may require separation from line-voltage control wiring or must use special cabling (plenum versus non-plenum rated).

Regardless of the type of signals required by the lighting control system, an installed cost assessment of the wiring required to implement a lighting control solution should be done to determine the best technology for the application.

5-5.4 Commissioning

Particular care should be placed on commissioning and tuning/optimizing the performance and integration of the lighting control system, to include integration to other building systems. Adequate time and guidance for pre-wire walk through, mock ups, system start up and function testing, system integration and end-user training should be a part of every lighting control specification. A detailed sequence of operations should be developed early in the design process and updated as required so that system commissioning and integration to other building systems is optimized. Lighting control system manufacturers and system integrators should be evaluated on their ability to provide timely and proper field engineering, material and technical support to the system and project. Consider specifying additional post-occupancy visits for system optimization, staff training and technology updates.

5-5.5 Network Certification

If a lighting control system is a stand alone network or to be connected to a base network, it must be certified in accordance with the Department of Defense Assurance Certification and Accreditation Process (DIACAP) and the Service implimentaion policy.

For additional information on the Certification and Accreditation process, see DoDI 8510.01. /2/

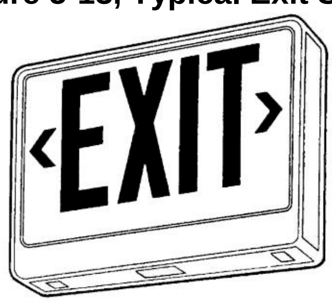
5-6 EMERGENCY AND EXIT LIGHTING.

5-6.1 Introduction.

\2\ Mark and illuminate means of egress in accordance with NFPA 101. /2/ The purpose of emergency lighting is to ensure the continuation of illuminance along the \2\ means /2/ of egress from a building and provide adequate light for the orderly cessation of activities in the building. The purpose of exit lights is to identify the \2\ means /2/ of egress. Both types of lighting must be powered from both a normal power source and an emergency source, with automatic switching from one to the other.

5-6.2 In some specific situations, emergency lighting might be required for specific spaces or work areas that are not on the \2\ means \2\ of egress. There are often areas where work of a critical nature must continue regardless of loss of normal power, such as a computer \2\server /2/ room. In health care facilities, including hospitals, skilled nursing homes, and residential custodial care facilities, lighting for the \2\ means /2/ of egress (including exit signs) and elevator cabs is considered “life safety” lighting and must be connected to the life safety branch of the facility’s emergency power system. Task illumination at anesthetizing locations, patient care areas, laboratories, intensive care units, recovery rooms, and other locations as required by NFPA 70, Article 517 are considered “critical” lighting and must be powered from the critical power branch of the facility’s emergency power system. In applications where the loss of light, even momentary, would endanger personnel or risk other loss or damage, provide lighting systems to maintain constant illumination through the use of an uninterruptible power supply of sufficient capacity to permit an orderly cessation of activity. This lighting is in addition to \2\ means of egress /2/ lighting.

Figure 5-13, Typical Exit Sign



5-6.3 Requirements for emergency lighting:

- Although an elevator is not considered a component in the required means of egress, all elevators must provide lighting in accordance with ANSI A17.1 or ANSI A17.3 as applicable.

- Where emergency lighting is required, arrange the system so that the failure of any individual lighting element, such as the burning out of a light bulb, cannot leave any space in total darkness.

5-6.4 Requirements for exit marking:

- Lettering on all exit signs for an installation must be one uniform color. Each base must establish either red or green as the standard lettering color. Installations in or near jurisdictions with established exit sign lettering colors should adopt similar red or green standards. Do not replace existing exit signs meeting NFPA 101 requirements simply to standardize sign colors. When signs must be replaced for other reasons, use the installation color.

- Installations overseas can use different colors, pictorials, or bilingual lettering as necessary to comply with local national standards. All exit signs must be immediately obvious as an exit marking to a recently transferred or visiting U. S. citizen. Additional markings are permitted to comply with host nation standards.

5-6.4.1 Acceptable Exit Signs:

- Use LED exit signs with illuminated letters displayed on an opaque background unless directed otherwise for particular applications.

5-6.4.2 Prohibited Exit Signs:

- Radioluminous. All existing signs were required to be replaced by 1 June 1996.

- Incandescent. Do not use signs \2\ lighted /2/ by incandescent light sources. When replacement is dictated by energy conservation, maintenance, or construction requirements, replace the signs with LED exit signs, or \2\ retrofit them with LED /2/ conversion units.

- \2\ Photo luminescent. Refer to UFC 3-600-01 Fire Protection for the use of this type of exit sign. /2/

5-6.5 Testing of Emergency Lighting Equipment.
Because of the periodic testing requirements, accessibility of equipment is an important design consideration. Ensure that emergency lighting equipment is installed in conspicuous and accessible locations to facilitate the periodic testing requirements.

5-7 INSTALLATION REQUIREMENTS.
The National Electrical Contractors Association (NECA) and the IES have produced extensive documentation on recommended practices for lighting installation. These documents include: NECA/IES 500 and NECA/IES 502. Installation, operation, and

maintenance issues are also detailed in ANSI C2-2002.

5-7.1 Wetness.
Determine whether “dry”, “damp”, or “wet” conditions apply.

5-7.2 Environmental Conditions.
Determine whether any special environmental conditions apply, such as a corrosive or explosive atmosphere, extremely cold or hot locations, marine/salt water atmosphere, clean room, food preparation area, or other unusual requirements

5-7.3 Structural Support.
Determine the supporting means for the lighting systems, including specific considerations for seismic reinforcement and other conditions.

5-7.4 Ceiling System.
When lighting systems are intended to be recessed into or mounted onto ceilings, determine the ceiling system type and capacity for lighting, including plenum height and other factors. Determine whether the ceiling is fire rated. Consider insulation locations and IC ratings of luminaires for residential projects.

5-7.5 Power System.
Determine the available voltages, frequency, and capacity of power sources for lighting.

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CHAPTER 6: SECURITY LIGHTING

6-1 PHYSICAL SECURITY DEFINITIONS.

6-1.1 Physical Security.

That part of security concerned with physical measures designed to safeguard personnel; to prevent or delay unauthorized access to equipment, installations, material, and documents; and to safeguard them against espionage, sabotage, damage, and theft.

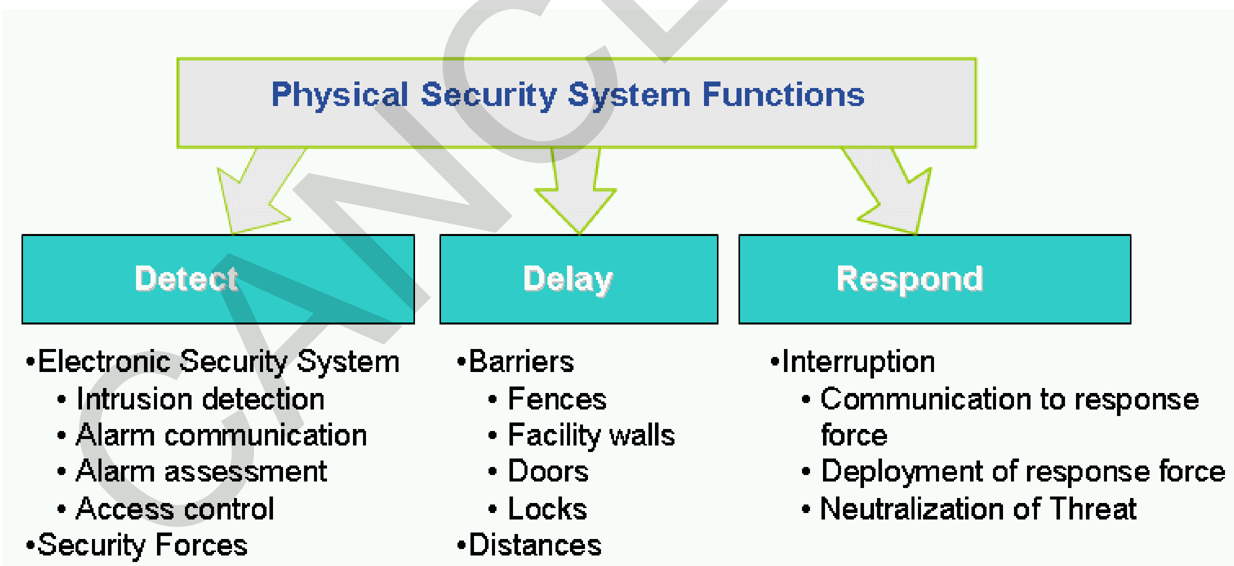
6-1.2 Physical Security System.

A system comprised of people, equipment, and operational procedures that control access to critical facilities or assets. Security lighting is one of the elements that comprise the equipment component of a physical security system. Figure 6-1 diagrams some of the components of a physical security system.

6-1.3 Security Lighting.

Security lighting provides illumination during periods of darkness or in areas of low visibility to aid in the detection, assessment, and interdiction of aggressors by security forces. Security Lighting is sometimes referred to as protective lighting.

Figure 6-1. Diagram of security lighting with other physical security measures.



6-2 SECURITY LIGHTING OVERVIEW.

6-2.1 Security Lighting Objectives.

Security lighting is one component of a larger physical security system. While the level of protection may vary, the lighting must supplement and facilitate all other measures taken to ensure the security of an asset. These other measures may take the form of security forces at an entry control point, sensitive inner areas, boundaries, or the use of closed circuit television (CCTV) cameras. In all cases, the lighting enhances visibility for either an individual or device and facilitates their performance.

6-2.1.1 In the simplest form, security lighting provides a clear view of an area for security personnel while reducing concealment opportunities for aggressors. A physical security system must be able to detect a threat, assess the threat, and then neutralize the threat.

6-2.1.2 Deterrent value.
Security lighting at a site may deter lesser threats and aggressors. While a security lighting system will not deter sophisticated criminals or terrorists, it may influence unsophisticated criminals or vandals. The mere presence of light will increase the probability of detection or capture and may induce these types of aggressors to look for an easier target.

6-2.1.3 Similarly, the effective use of lighting can enhance the perception of security, which is important to the personnel who work within a secure area. This can be accomplished with glare reduction, lighted surfaces, proper uniformity, and adequate illuminance.

6-2.2 Defining Requirements.
Defining the requirements of a physical security system and its components involves an interdisciplinary planning team. The team considers all interests relating to a project to determine how security fits into the total project design. The specific membership of the planning team will be based on local considerations, but in general, the following functions should be represented; facility user, antiterrorism officer, operations, security, logistics, engineering, life safety, and others as required. That team will use the process in UFC 4-020-01 to identify the design criteria, which includes the assets to be protected, the threats to those assets (the Design Basis Threat), and the levels of protection to be provided for the assets against the identified threats. In addition to those criteria elements, the team must also identify user constraints such as appearance, operational considerations, manpower requirements or limitations, energy conservation and sustainment costs. Some areas such as water boundaries that cannot be patrolled should not be illuminated.

6-3 SECURITY LIGHTING DESIGN.
The security lighting system must aid in the detection of aggressors and assist personnel in the assessment and response to potential threats. \2\ All security lighting designs must be coordinated with Security Forces. /2/ The type of site lighting system provided depends on the installation environment and intended use.

6-3.1 Lighting Systems.
There are three types of lighting systems used for security lighting:

6-3.1.1 Continuous Lighting.
The most common security lighting system is a series of fixed lights arranged to illuminate a given area continuously.

6-3.1.2 Standby.

With this system, the luminaires are either automatically or manually turned on at times when suspicious activity is detected by security personnel or an intrusion detection system. A standby system creates the impression of activity and may offer a deterrent value while also achieving energy conservation. Consider \2\ SSL /2/ and electrodeless fluorescent (induction) light source systems in lieu of light sources that require re-strike.

6-3.1.3 Moveable.

Movable lighting (stationary or portable) consists of manually operated searchlights that may be lighted during hours of darkness or as needed. This system is normally used to supplement continuous or standby lighting. This system will not be discussed in these criteria.

6-3.2 Controlled Lighting.

Controlled lighting is best used when it is necessary to limit the width of the lighted strip along the perimeter due to adjoining property. Care should be taken to minimize or eliminate silhouetting or illuminating security personnel on patrol. Use fully shielded luminaires mounted in the horizontal plane to reduce glare. Figures 6-2 and 6-3 show different configurations of controlled lighting.

6-3.2.1 Glare Projection.

One technique for Glare projection lighting is to place lights slightly inside a security perimeter and directed outward. Glare projection should only be utilized in remote locations when the glare of lights directed across surrounding territory will neither annoy nor interfere with adjacent operations and only when the threat environment dictates. It is a deterrent to potential intruders because it makes it difficult to see inside the area being protected. It also protects security personnel by keeping them in comparative darkness and enabling them to observe intruders at a considerable distance beyond the perimeter. Figure 6-4 and 6-5 show examples of glare projection.

Figure 6-2. Example of controlled lighting: single fence line.

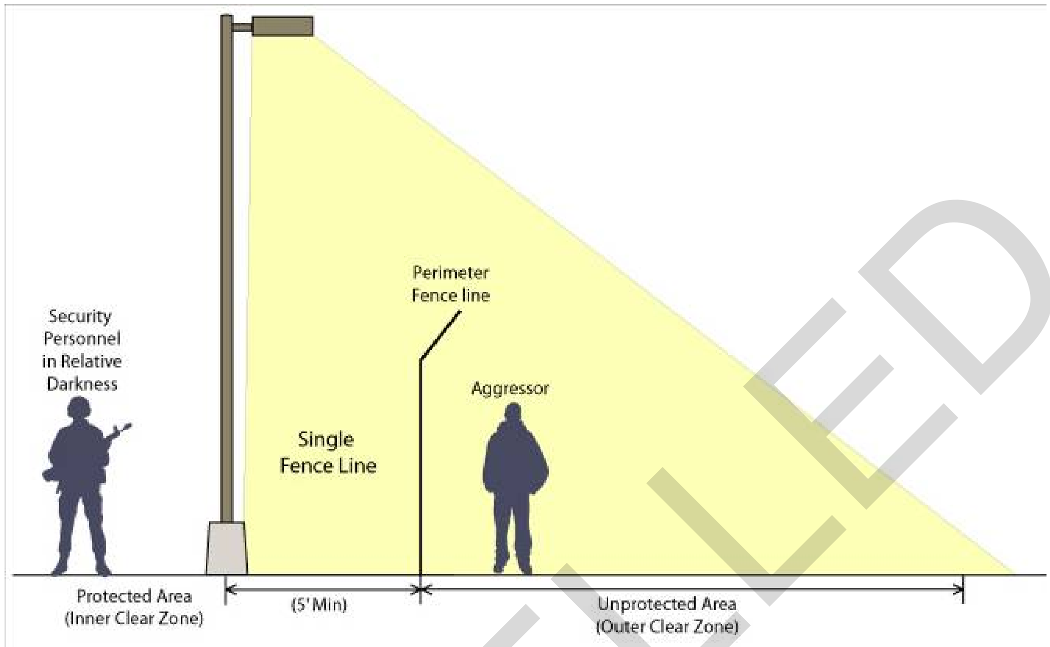


Figure 6-3. Example of controlled lighting: double fence line.

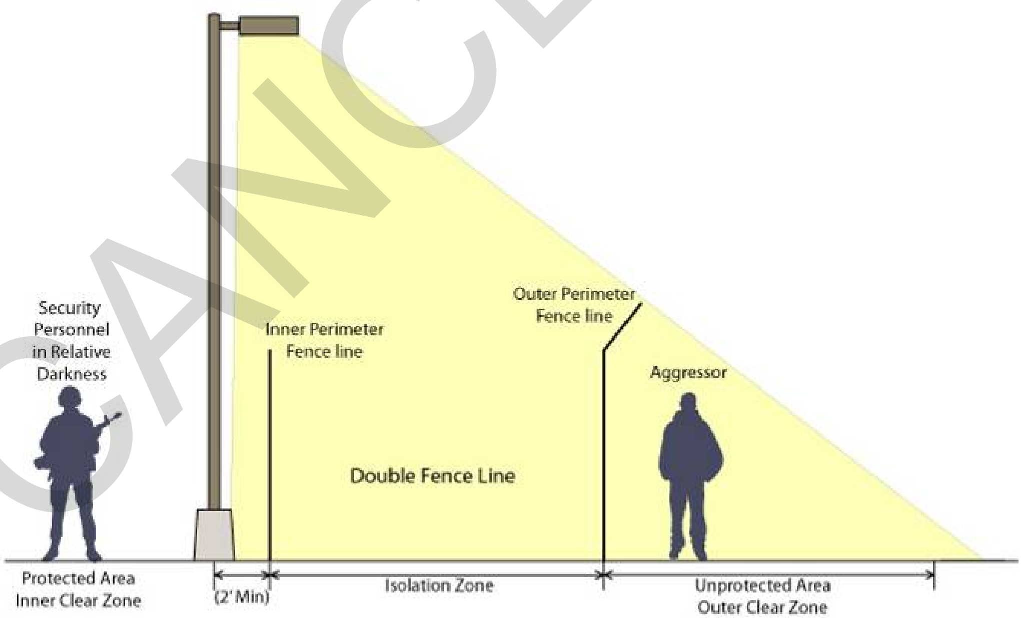


Figure 6-4. Example of glare projection: single fence line..

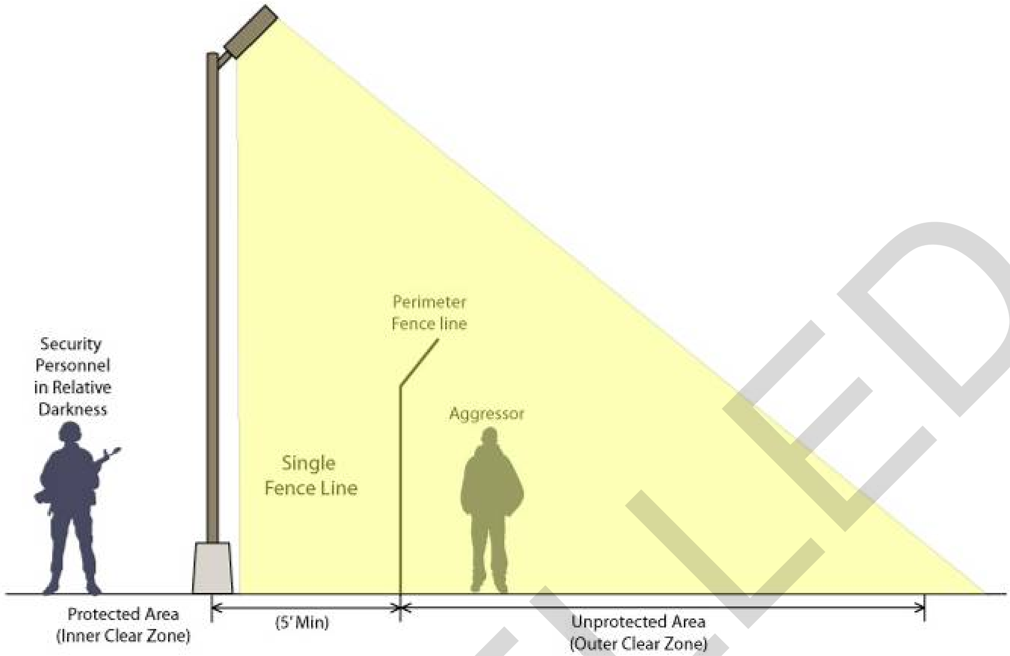
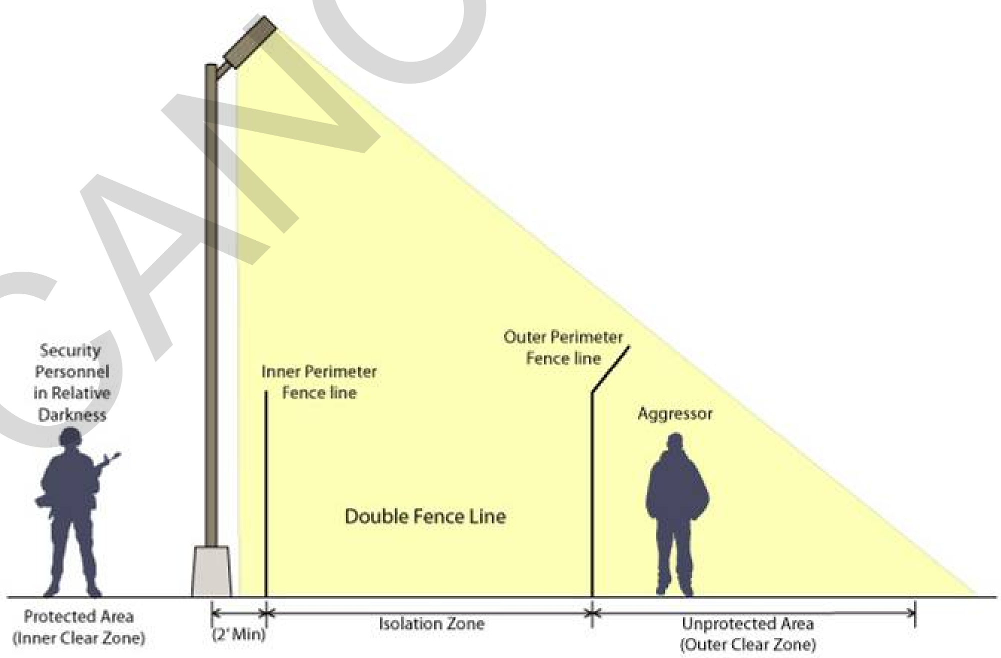


Figure 6-5. Example of glare projection: double fence line.



6-3.3 When designing a security lighting system, consider the viewer of the scene. Conditions for adequate visibility may differ widely depending on how a particular scene will be surveyed. The human eye sees quite differently from the lens of a security camera. Additionally, a camera may not require visible light at all or be hampered by the addition of visible light. In many applications, the lighting will be for guards, patrols, or other security personnel. The human eye responds to light to provide two types of vision: off-axis and on-axis.

6-3.3.1 Off-axis detection refers to peripheral vision. This type of vision is very sensitive to movement as well as glare. Its poor visual acuity does not allow off-axis vision to distinguish details or recognize objects or people. Under low light levels, off-axis vision is enhanced by white light. White light sources include metal halide, \2\ LED, /2/ fluorescent, and induction.

6-3.3.2 On-axis focus refers to viewing objects immediately within our field of view (or straight ahead). The visual acuity is much higher for on-axis vision and it is not as sensitive to glare. This type of vision allows for the identification of objects and people.

6-3.4 Integration with other security measures. When possible, consider integrating the lighting equipment with other architectural or landscape features. For example, some manufacturers offer hardened light poles which offer the strength of a bollard at the base while providing a mounting location for the luminaire.

6-4 SECURITY LIGHTING CRITERIA.

6-4.1 Acceptable ranges of illuminance, luminance, and uniformity should be provided for security tasks. In all cases, mission safety or operational requirements govern over security lighting requirements. For example, if security lighting requires 0.2 fc, and a lighting level of 5 fc is required to perform a task or operation, then 5 fc will be the requirement. Illuminance values appropriate for security personnel may range from a minimum of 1 lux (0.1 fc) for large open areas to a minimum of 100 lux (10 fc) in area of ID checks for entry control points. If guards must perform any written task (such as inside a guardhouse), the illuminance on the task plane may reach an average 300 lux (30fc). However, this value should not be exceeded and should also be limited to the task plane only. Illuminance values in excess of this may inhibit the individual's ability to adapt to lower lighted areas outside. See Table 6-1 for more detail.

6-4.2 Color rendering index is a measure of the ability of a light source to reproduce the colors of various objects being lit by the source. For individuals, the color rendering index is vital to the threat identification objective of security lighting and should be a minimum of 80. Guards must be able to accurately describe and report the threat. White light sources such as metal halide, \2\ LED, /2/ induction, and fluorescent all render color much better than the yellow light of sources such as high pressure sodium. \2\ Refer to Chapter 2, "Illuminance" for properties and benefits of white light. /2/

6-4.3 Color temperature is the color appearance of the light source. A lower color temperature refers to a warmer colored light source while a higher temperature designates a cooler color. While individuals typically prefer warmer colors, cooler colors may be considered in security applications to improve visual acuity and help to maintain alertness. A minimum color temperature of 3500 K should be specified.

6-4.4 Level of Protection (LOP) defines the degree to which the asset is protected from the threat. Various facilities may require various levels of protection. The levels of protection are established using UFC 4-020-01, and should be provided as part of the design criteria. The LOP of any area determines the amount and type of security lighting necessary.

6-4.4.1 Low Level of Protection (LLOP).
Illumination is only required at building entries and exits. The luminaires should be low brightness and well shielded so that it does not become a glare source in the much darker surroundings.

6-4.4.2 Medium Level of Protection (MLOP).
Requires LLOP criteria and illumination of the building exterior. Fully shielded luminaires mounted on the building wall can illuminate the exterior of the building without adding light to the surrounding area or cause light trespass to neighboring properties.

6-4.4.3 High Level of Protection (HLOP).
Requires MLOP criteria and illumination of the area around the facility. This lighting may still be accomplished with wall mounted lighting on the building. By using a different luminaire distribution, light can be directed to the surrounding area rather than just at the building. For larger areas, poles may be necessary to light further from the building. With fully shielded luminaires, a perimeter width of 2-3 times the mounting height can be illuminated. When a perimeter fence is required for security, HLOP would dictate illumination of the perimeter fence including any required clear or isolation zones to aid in the detection, assessment, and interdiction of aggressors by security forces. In general, controlled lighting should be utilized except when dictated by local threat environment.

6-4.5 Design Coordination.

6-4.5.1 Architectural.
Coordinate luminaire locations with building entries, building surfaces, and mounting locations. Building mounted luminaires can provide surface brightness and eliminate the cost of a pole.

6-4.5.2 Site.
Coordinate locations of luminaires with gates, fences, standoff requirements, trees and shrubs. Avoid locations which will result in shadows that could be used by aggressors for hiding.

6-4.5.3 Electronic Security Systems.

Investigate ways that the lighting system may be integrated with the alarm system. Are some lights automatically turned on when a zone goes into alarm? How might the lighting change once an alarm has been initiated? Design the lighting system so that luminaires are not in the field of view of the camera. Verify the camera illumination requirements and limitations for proper function and display.

6-4.5.4 Operational.
Determine how a facility will be secured. Coordinate security lighting strategies, lighting controls, and timers with planned patrol routes, schedules and operational procedures.

6-5 SECURITY LIGHTING APPLICATIONS.
Chapter 2, Lighting Design Considerations, describes general strategies for providing good visibility in an energy efficient manner. These strategies include controlling glare, providing good lighting uniformity, and addressing other issues such as surface brightness and controls. The following specific strategies pertain to security lighting. Refer to Chapter 2 and Chapter 8 for additional information.

6-5.1 General Area Security Lighting.
Luminaires located along the fence perimeter provide uniform horizontal and vertical illuminance. Use adjacent building facades or other structures to mount area lighting. This can add brightness to the surrounding environment and reduce the amount of equipment needed.

6-5.2 Building Security Lighting.

6-5.2.1 Entrances and Exits.
Increasing the light level at the building entrance guides visitors and other personnel to the appropriate building entry. It also serves as exit lighting to guide individuals out of a building for life safety in case of an emergency. The security lighting at these locations should protect against forced-entry and provide enough light for threat assessment. Building entrances and exits must be lighted for all levels of protection. Use concealed, fully shielded or low brightness sources to limit glare while still increasing brightness.

6-5.2.2 Building Exterior.
Lighting of the building frequently includes some area lighting as well. By using fully shielded, wall mounted luminaires; both the building and the adjacent area can be illuminated. Mounting luminaires at the top of the facade and aiming the light down will increase the facade brightness and also reduce light trespass and light pollution.

6-5.3 Perimeter Lighting.

6-5.3.1 Illumination of a restricted area perimeter when required includes the exterior and interior clear zones adjacent to the fence or, in some applications, the area between a dual fence line (isolation zone). Provide poles, power circuits, and transformers within the protected area. Coordinate pole locations with the user to ensure that the applicable egress requirements and patrol routes of the clear zone are not violated. The distance of poles from a single fence line will not be less than 5 feet and 2 feet for a dual fence line. Perimeter lighting can be either continuous or standby, controlled or glare projection depending on the application and local threat environment.

6-5.3.2 Controlled lighting.

Illumination levels for controlled lighting shall be adequate to detect a moving aggressor, either visually or by use of CCTV. Provide fully shielded luminaires mounted in the horizontal plane to minimize glare. Glare may hinder security personnel visibility and interfere with authorized activities or activities outside the installation.

6-5.3.3 Glare Projection.

Provide glare projection only to illuminate flat areas which are free of obstructions for a minimum of 100 feet outside the fence. Glare projection should only be utilized in isolated or expeditionary locations in high threat environments. When designing for glare lighting, the designer must check for light pollution ordinances of the local jurisdiction.

6-5.4 Entry Control Facilities.

Refer to UFC 4-022-01 for Entry Control Facility Criteria. Entry Control Facilities are separated into several zones. The lighting design for each zone is described in the following paragraphs.

6-5.4.1 Approach Zone.

While the approach zone can vary significantly between locations, it should be illuminated to lead motorists safely to the access zone. \2\ Fully shielded or U0 /2/ luminaires mounted in the horizontal plane should be used to minimize glare. To reduce adaptation issues for the motorist, gradually increase (transitional lighting) lighting levels as the motorist approaches the access zone. Motorist's eyes take time to adjust to sudden changes in light level, low to high and especially high to low. Increased light levels over the length of this zone will give the driver a few seconds to adapt to the brightness. It is important in both the Approach zone and the Response Zone. Extensive discussion of transitional lighting can be found in IES RP-22-05, Tunnel Lighting. To reduce glare for security personnel, provide signage to instruct motorists to turn off headlights as they approach the access zone.

6-5.4.2 Access Zone.

Lighting in the access zone provides the highest light levels in the entry control facility. The lighting system must provide for identification and inspection. For most of the access zone, \2\ fully shielded or U0 /2/ luminaires will provide adequate lighting for most of these visual tasks. However, vertical illuminance on motorists' faces can be improved with the use of low brightness light sources (less than 3500 lumen light source output). Luminaires mounted to the side and behind security personnel will improve identification tasks.

6-5.4.3 Response Zone.

From the access point, roadway lighting should gradually return to lower light levels (transitional lighting) while still providing adequate uniformity. Provide \2\ fully shielded or

U0 /2/ luminaires mounted in the horizontal plane to minimize glare for motorists and security personnel in the response zone. In addition, provide signage to instruct motorists to turn headlights back on after leaving the access zone.

6-5.4.4 Pedestrian ACP.

Pedestrian zones must provide light for both pedestrians and security personnel. Pedestrians must have a clear view of gates and card access readers and security personnel must be able to see pedestrians approaching the ACP. Provide \2\ fully shielded or U0 /2/ luminaires mounted in the horizontal plane to minimize glare.

6-5.4.5 Vehicle Inspection.

In areas where security personnel must identify visitors, check credentials, and read shipping manifests, lighting must not interfere with the operations while vehicles approach, stop for inspection, and proceeds. Having to continually adapt to different illuminance and brightness levels could lead to eyestrain and reduced performance by security personnel. Additional task lighting should come from behind the guard and light the person to identify or the vehicle to inspect.

6-5.4.6 Guard Shack.

Inside the guard shack, task lighting must be provided for reviewing identifications, paper work, and possibly computer tasks. However, the interior light levels must be kept at a lower ambient light level than the exterior. Otherwise, the security personnel will have reduced visibility and those approaching the shack will have a clear view of the interior. While the ambient light level may be very low, task lighting at a desk or workstation can still be increased to a higher level. The location and shielding of interior lighting must minimize the chance of veiling reflections on the glass that may limit visibility to the outside. All luminaires must be dimmable to adjust inside lighting levels. Colored light should not be used for task lighting when color is to be distinguished.

6-5.4.7 Over Watch Position.

These locations must maintain an unobstructed view through the access and response zones. Additionally, inside the over watch itself, lighting must be kept to extremely low levels or eliminated entirely to prevent the lighting of the security personnel. All luminaires must be dimmable to adjust lighting levels. While red colored light has been used in such applications to maintain the eye's dark adaptation, colored light should not be used for task lighting when color is to be distinguished in the task.

6-5.5 Waterfront Security Lighting.

Waterfront areas consist of a defined perimeter (landside and waterside), restricted area, entry control facilities at the entrance into the waterfront area, access control points located at each pier, and pedestrian access control points along the perimeter. In waterfront areas, utilize high mast lighting to reduce the number of poles minimizing obstructions to waterfront operations and maintaining clear paths for equipment and vehicles. Provide \2\ fully shielded or U0 /2/ luminaires mounted in the horizontal plane to limit direct and reflected glare. Light sources should be metal halide (MH), \2\ induction or SSL /2/ to improve color rendering and nighttime visibility. In some regions, white light sources may interfere with the marine environment. Coordinate marine issues with the local environmental authority.

6-5.5.1 Piers and Wharves.
Provide \2\ fully shielded or U0 /2/ luminaires to limit glare. In general, high mast lighting provided for waterfront operations supply adequate illuminance for security requirements. Coordinate number, height, and location of poles and the associated concrete pedestals to minimize obstructions to pier and wharf operations. Refer to UFC 4-152-01 for Pier and Wharf operational lighting requirements.

6-5.5.2 Pierhead and Wharf Guard Towers.
Lighting inside the guard towers must not degrade security personnel's nighttime visibility. All luminaires must be dimmable and should be mounted at or near desk level. Switch task and general lighting separately. When colors are not used to distinguished tasks (colored lights or controls for alarm annunciations), consider red light sources for task lighting to reduce adaptation problems. Manually operated searchlights may be required to assist security personnel to locate and assess waterside threats within the restricted zone. Lighting controls must be under the direct control of security personnel. Coordinate lighting requirements with security personnel.

6-5.5.3 Water surface.
High mast lighting on pier and wharfs provide adequate illuminance for security requirements. Glare, poor distribution, and excessive light levels reduce security personnel's ability to assess surface and subsurface threats.

6-5.5.4 Underwater Lighting.
Underwater lighting is not normally required for detection of subsurface threats and is discouraged due to limited benefit, high installation cost, and maintenance issues. For high value assets, Electronic Harbor Security Systems (EHSS) may be provided for the detection and assessment of surface and subsurface threats.

6-5.5.5 Underdeck Lighting.
Dedicated luminaires located beneath the pier are not normally required and are discouraged due to limited benefit, high installation cost, and maintenance issues.

6-5.5.6 Lower Deck Lighting.
On the lower deck of a double deck pier, provide utility and work areas with illuminance levels based on the tasks performed. Lower deck lighting in roadway and open areas must be multilevel and divided into sections to localize lighting control. Alternate control of luminaires between photocell and manual light switch. Provide an average of 0.5 fc (5.4 lx) with luminaires under photocell control. To reduce energy consumption, consider occupancy \2\ or vacancy /2/ sensors for control of lighting in enclosed spaces.

6-5.5.7 Lighting Interference.
Security lighting can visually interfere with lighting used as aids to navigation (ATON) by ships. Lighting ashore can camouflage, outshine, or otherwise conceal ATON. Ensure that lighting ashore and in the waterfront compound does not conflict with or otherwise

conceal the ATON lights. Coordinate security lighting requirements with Port Operations.

6-5.6 Airfields.

UFC 3-260-01, Airfield and Heliport Planning and Design, specifically prohibit light emissions – either directly or indirectly (reflected) – that may interfere with pilot vision in runway clear zones. Exterior lighting must meet all FAA and airfield operational regulations. These regulations restrict the height and location of poles located near airfields. Coordinate security lighting with installation's airfield safety officer and FAA regulations. Use \2\ fully shielded or U0 /2/ luminaires to reduce glare which may affect airfield operations.

6-5.7 CCTV camera.

6-5.7.1 Cameras respond to a luminous environment differently than the human eye. The field of view of a camera refers to the extent of the scene that can be viewed at one time. Some devices may use motorized swivels to pan across a scene and increase the viewing area. Cameras adjust the view based on the brightest point in this field. If it must adjust for a hot spot, areas under low illuminance levels may not be visible at all. Uniform illuminance and \2\ fully shielded or U0 /2/ luminaires are vital to limit hot spots and improve CCTV system performance. Figure 6-6 illustrates how a large portion of the camera's view may be washed out if it must adjust to an excessively bright light source. Any luminaire that falls within the camera's field of view at any time must be shielded. If a light source can be seen directly by the camera, the glare and high contrast will limit the visibility of the entire scene. Therefore, the source of illumination is best located above the level of the camera.

Figure 6-6. CCTV camera's view of scene with excessive glare.

6-5.7.2 Color rendering index.
For color cameras, the color rendering index of the sources lighting the area should be above 80. While color rendering is less important for monochrome systems, high pressure sodium light sources should still be avoided as their limited spectral distribution may render a fuzzy image.

6-5.7.3 Uniform vertical illuminance.
CCTV cameras typically record objects and people in elevation. Therefore, the security lighting system must provide adequate and uniform vertical illuminance. As in many security lighting applications, the amount of vertical illuminance is far more important than horizontal. Vertical illuminance should average 0.2 to 0.5 footcandles at 5 feet above the ground. Furthermore, it should have a very uniform coverage of 4:1 average to minimum. These criteria refer to vertical illuminance values measured in the same direction of the camera line of sight. Vertical illuminance does not need to be this high in all directions. Color cameras may require higher light levels than monochrome cameras. Review camera manufacturer recommendations and coordinate with the security system designer when designing the lighting system.

6-5.8 Infrared (IR) cameras.
IR cameras utilize IR sources to illuminate the field of view. Light in the IR spectrum is not visible to the human eye. IR cameras then pick up the reflections of these wavelengths from objects in the area.

6-5.9 Thermal imaging.
Devices using thermal technology do not require any light source to operate. They create images based on the heat differences between humans, vehicles, the ground, and foliage. Unlike other camera technologies, thermal imagery is not affected by glare from headlights or light sources. While this technology can indicate the presence of people and objects in complete darkness, they do not provide the detailed images obtainable from visible light or IR cameras.

6-5.10 Specific Lighting Criteria.
The specific lighting criteria and design issues may vary with application. For this reason, see the appropriate security lighting application in Chapter 8. Table 6-1 summarizes the minimum horizontal and vertical illuminance levels for typical facility applications. The inner clear zone noted in the table refers to the area along a perimeter fence line within the facility or installation. The isolation zone refers to the area between a double fence line. The outer clear zone describes the area along the perimeter fence on the outside of the protected area. Isolation and clear zones are typically 30 feet (9.1 meters) in width. It is important to note however that overlighting can cause just as many visibility problems as underlighting. In typical applications, the maximum light levels should not be more than double the recommended average value.

6-6 ELECTRICAL REQUIREMENTS.

6-6.1 Backup power is not required for all security lighting systems. The assessment of risk and asset value will determine this need. For critical security lighting systems, several different types of systems are available for providing backup power in the event of a power outage. All offer various advantages and disadvantages. They vary in amount of time that they can provide power, amount of downtime between a power outage and backup power, and cost. The back-up power system must also consider the re-strike time of some light sources. Metal halide and high pressure sodium light sources both require a certain amount of time to cool-down before they can be re-ignited. This time may reach up to fifteen minutes. While these sources can still be used, an intermittent light source may be required. Consider \2\ SSL /2/ and Electrodeless fluorescent (induction) light source systems in lieu of light sources that require re-strike. Refer to the Light Sources section in Chapter 5, Lighting Equipment. Refer to service specific guidance regarding facilities and equipment authorized backup power. \2\ See service specific certification requirements in Chapter 1, Lighting Design Criteria./2/

6-6.1.1 Generators are commonly used to provide backup power but have some downtime between the outage and when the generator restores power. Minimum downtime can be as low as ten seconds. While this is one of the least expensive solutions, operations must be able to sustain the short period of darkness.

6-6.1.2 An Uninterrupted Power Supply (UPS) is a battery source that provides instantaneous power in case of a power loss. UPS systems have a high initial cost and are expensive to maintain. Therefore, only provide a UPS for security lighting systems associated with the protection of critical assets or security operations when continuous, full brightness lighting is required.

6-6.1.3 Flywheels provide instantaneous power in the case of power loss in the form of the kinetic energy in a constantly rotating wheel. This energy can be harnessed immediately in the event of a power outage and used to power critical lighting. These devices vary widely in price and capacity.

6-6.1.4
Individual battery packs are available for some luminaires. In the event of a power outage, these packs can power the lighting for times ranging from five minutes to two hours, depending on the battery capacity. For fluorescent or induction sources, the battery will power the ballast directly although the light source may not provide full light output.

6-6.2 Partial Back-up Systems.
Light sources requiring a re-strike can be specified with a partial back-up system such as quartz-restrike. In this case, the luminaire contains a primary light source, such as metal halide, and then a smaller quartz light source. In the event of a power outage, the metal halide source will require a cool down time before it can be re-ignited. During this period the quartz light source uses generator-supplied power to light the area. The lighting level will not be as high, but interim lighting will be provided. When the primary source returns to full brightness, the quartz light source is extinguished. A separate, complete back-up lighting system does not provide an economical or effective design solution. Consider

Electrodeless fluorescent (induction) light source or \2\ SSL /2/ systems in lieu of light sources that require re-strike.

6-6.2.1 Circuiting Techniques.
Circuiting luminaires onto separate circuits in the same space will not provide backup power but will limit vulnerabilities during a fault or circuit failure. If the lighting system is divided onto two or more circuits, the loss of one will not affect the entire lighting system. Multiple circuits should be installed, except where their use is clearly impractical. The overcurrent devices, transformer, and wiring should be located within the protected area. Locate circuits underground to minimize the possibility of sabotage or vandalism. Equipment and design should provide for simplicity and economy in system maintenance. To minimize security degradation during faults, feeders may be 3-phase, 4-wire with single pole overcurrent devices at the service equipment. Consecutive luminaires will be connected to alternate phases of 3-phase feeders.

6-6.3 Controls.
On-off control will be automatic or manual as appropriate.

6-6.3.1 Automatic.
Perimeter and area lighting on-off control will be automatic and will be activated during periods of darkness, at other times when visibility is reduced, or by electronic security systems. In expeditionary environments, automatic on-off control must be capable of being deactivated which may require either automatic or manual on-off control depending upon the site. In some applications, motion sensors can be used to turn on lights when someone approaches. This indicates to patrols or other personnel that activity is taking place in a particular area and should be assessed. Such control strategies will reduce energy consumption and may also startle and deter unsophisticated criminals.

6-6.3.2 Manual.
Wherever manual on-off control is appropriate, on-off controls will be accessible to and operable only by authorized personnel. Systems that are designed to remain off until needed, will have on-off control at the surveillance location and will meet instant-on requirements. Electrodeless fluorescent (induction) fluorescent or SSL would be the appropriate luminaire choice for this type of application.

Table 6-1. Minimum Lighting Criteria for Unaided Guard Visual Assessment.

Application				Minimum Illuminance (All Lighted Areas)		Uniformity (Maximum Allowed)
Type	Lighting	Area	Width Feet (m)	Locations to Light	Footcandles (lux)[a]	(Max : Min)
Perimeter	Controlled	Inner Clear Zone	30 (9.1)	Inner lighted edge	0 (0)[e]	--
	Controlled	Isolation Zone[f]	30 (9.1)	Between fence lines	1.0 (10)[b]	6:1
	Controlled[c]	Outer Clear Zone	30 (9.1)	Outer clear zone edge	0.2 (2) OR 0.4 (4)[g]	10:1
Building Lighting	Controlled	LLOP	--	Building Entry and Exits	0.1-0.3 (1-3)	20:1
	Controlled	MLOP	--	Same as LLOP and exterior walls.	0.2-0.5 (2-5)	15:1
	Controlled	HLOP	30' (9.1)	Same as MLOP and area around facility.	0.5-1.0 (5-10)	10:1
Entry Control Facility / Access Control Point	Controlled	Pedestrian	--	Entry	5 (50)	3:1
		Vehicular (Approach and Response Zones)	--	Pavement and sidewalk	3 (30)	4:1
		ID Verification		Guard station	10 (100)	3:1
		Search Areas	--	Pavement	10 (100)	3:1

[a] Horizontal plane at 3' above finished grade unless otherwise noted.
[b] Vertical illuminance, 6" above finished grade.
[c] Glare lighting may be required in expeditionary or high threat environments to extend clear zone.
[d] Width is application dependant. Typical clear zone 30'.
[e] Minimize illuminance in Inner Clear Zone. Some applications may require illumination of inner clear zone (backlighting).
[f] Only applies to dual fence line applications.
[g] Vertical illuminance, 3' above finished grade, at outer edge.

/1/

CHAPTER 7: INTERIOR APPLICATIONS

7-1 INTRODUCTION.

This chapter identifies typical interior facility applications and explains the critical design issues for each. Each application details a conceptual lighting design for a sample space with a sketch and equipment recommendation. This sample represents one solution that addresses the design issues and meets the appropriate criteria. It is not the only solution and alternate schemes will result in acceptable designs.

Air Force restricts use of LEDs for many of the application templates provided in this Chapter, consult service specific guidance.

7-2 LIGHTING CALCULATIONS FOR INTERIOR SPACES.

7-2.1 Criteria.

Lighting for interior areas is measured with a variety of parameters. Maximum, minimum, and average illuminance values are often listed as target criteria. Uniformity criteria may be described with multiple terms including maximum to minimum and maximum to average. The most appropriate criteria vary with the type of application. The following lists this UFC's interpretation of the IES criteria and how it is used in the applications shown in this chapter:

- Minimum illuminance: This provides the low end of the range of acceptable light levels. This is typically used to define the light level required to perform a specific task.
- Maximum illuminance: This provides the high end of the range of acceptable light levels. This is typically used to prevent overlighting of an area.
- Average illuminance: This criterion is typically used to give an approximate light level. Unless noted otherwise, the values given in this chapter designate an average illuminance value.
- Maximum to minimum uniformity: This is typically used to prevent excessive contrast. This is most important in work areas where individuals will spend large amounts of time such as office spaces.

7-2.2 Lumen Method.

The lumen method is a calculation procedure that can be performed by hand or by simple, spreadsheet formulas. It determines the average illuminance in a space, and is reliable only for spaces with a regular and uniform "grid" of luminaires in which general lighting, providing task light levels everywhere, is appropriate. The lumen method also can be used for determination of "ambient" illumination in rooms in which localized "task lights" are used strictly for task light. Refer to IES RP-23 or the *Lighting Handbook* for additional information.

7-2.3 Point Calculations Using Flux Transfer Calculations.

Commercially available computer programs that assume Lambertian (matte or flat) room surfaces can perform point calculations. These calculations indicate illuminance at specific points and are capable of exitance and luminance calculations as well. Some programs can incorporate objects in space to assess the lighting in a non-empty room. Many programs generate perspective views of illuminated rooms, although due to the lack of specular reflectivity these rooms do not have a photo-realistic appearance.

7-2.4 Point Calculations Using Radiosity Calculations.

Commercially available computer programs that allow for diffuse and specular room surfaces can perform point calculations. These calculations indicate illuminance at specific points and are capable of exitance and luminance calculations as well. Some programs can incorporate objects in space to assess the lighting in a non-empty room. Many programs generate perspective views of illuminated rooms, which in some cases can be quite realistic.

7-2.5 Daylighting Calculations.

Refer to IES RP-21 or the *Lighting Handbook*. Daylight availability can be estimated using these methods. Many point calculation programs can also model daylight contributions. In addition, some commercially available computer programs such as AGI32 and *SkyCalc*[36] will determine the contribution of daylight at a specific time and date and under specific weather conditions.

7-2.6 Task Lighting Calculations.

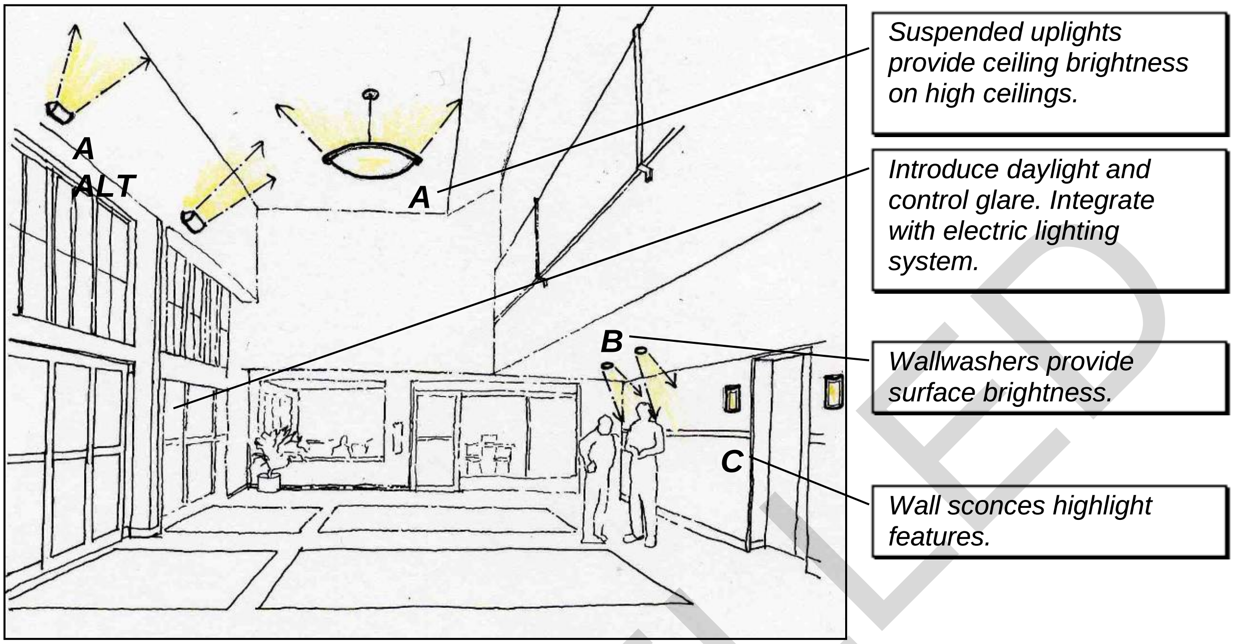
Due to near-field photometric effects, the illuminance patterns created by task lights are presently not accurately calculable. Evaluate task lights on the basis of measured results or manufacturers' information.

7-2.7 Energy Calculations.

Perform energy calculations in the manner and using the forms described in the ANSI/ASHRAE/IES 90.1 User's Manual. Use Tables 15-11 and 15-12 for the Federal values to be used in ANSI/ASHRAE/IES 90.1 calculations. These tables provide the federally required maximum allowable unit power density in terms of watts per square foot, which varies with the type of area and function \1\ Refer to section 1-4 for the EPACT 2005 requirements for energy reduction. /1/ Commercially available software programs, such as DOE II, Energy 10, and BLAST, simulate multiple building systems to provide a better understanding of energy benefits and trade-offs of various design strategies. For a complete list and description of these programs refer to the Whole Building Design Guide *Energy Analysis Tools,* (http://www.wbdg.org/resources/energyanalysis.php).

[36] The Heschong Mahone Group, *Skylighting Guidelines*, 1998.

OFFICES — Large Lobbies



\1\

EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended decorative luminaire.*	*Compact fluorescent, \2\ LED /2/or metal halide light sources\2\/2/*	*Daylight dimming.*
A ALT	*Wall mounted uplight.*	*Compact fluorescent , \2\ LED, /2/ or metal halide light sources\2\/2/*	*Daylight dimming.*
B	*Recessed wallwasher.*	*Compact fluorescent light source, or \2\LED./2/*	*Daylight dimming.*
C	*Wall mounted sconce.*	*Compact fluorescent \2\ or LED /2/ light sources.*	*Timeclock On / Off, coordinated with building schedule.*

/1/

CRITICAL DESIGN ISSUES:

- Daylighting Integration and Control: Many lobbies are designed with daylight as a primary feature of the space. By integrating lighting controls with the daylight design, electric lighting equipment can be dimmed or turned off when not required.
- Appearance of Space and Luminaires: Because lobbies are often the first space visitors to the building see, the aesthetic appearance of the space and the luminaires is an important criterion. Luminaire layout should avoid "visual clutter" of the space.

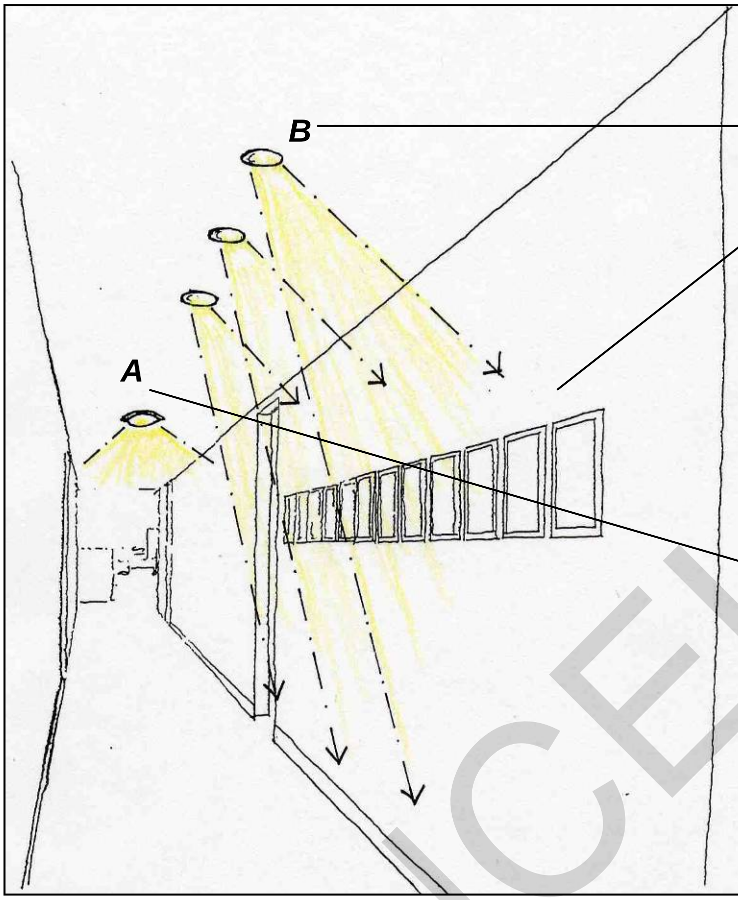
- Luminance of Room Surfaces: Downlighting the volume of a space from a high ceiling consumes a lot of energy. Lighting the wall and ceiling surfaces can achieve increased brightness with less energy. Typically people spend a limited amount of time in such spaces and are not occupied with difficult visual tasks. Therefore, the luminances of the surfaces are far more important than the horizontal illuminance.
- Color Appearance (and Color Contrast): The color of accent walls, architectural features, and artwork needs to be rendered accurately. For this reason, tungsten halogen, fluorescent, \2\ LED /2/ or ceramic metal halide light sources with a high color-rendering index (CRI) should be used to accent such features.
- Modeling of Faces or Objects: Ambient lighting for lobby spaces should include indirect lighting and come from multiple directions and angles. For example, if multiple systems such as sconces, pendants, and wallwashers all provide light from multiple directions, three-dimensional objects will appear three dimensional in form. However, if all of the lighting is aimed straight down at the floor, objects in the space will have harsh shadows and appear “flat”.
- Target Horizontal Illuminance (± 10%): 100 lux (10 fc) average, \2\ egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

As in most interior spaces, lobbies require the lighting of surfaces as opposed to volumes. In such high spaces, high wattage downlights are often recessed into the ceiling and aimed at the floor. After traveling through the entire volume of the space, very little light reaches the floor only to illuminate a low reflectance surface. Downlights can also create harsh shadows on people and objects.

A more effective and energy efficient lighting scheme illuminates high reflective surfaces as well as specific features in an ambient / accent approach. In the figure above, decorative pendants light the ceiling. This ambient system also can be easily integrated with the available daylight in the space. Wall washers illuminate walls and artwork and sconces identify the elevator doors, assisting in wayfinding for building visitors.

OFFICES — Corridors



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Surface mounted luminaires.*	*Compact fluorescent \2\ or LED /2/ light sources. \2\/2/*	*\2\Required occupancy sensors and bi-level switching or dimming for low use corridors or after hours./2/ Daylight dimming if available. \2\/2/*
B	*Recessed downlight / wallwashers.*	*Compact fluorescent light source \2\ or LED. /2/*	*Daylight dimming if available. \2\Required /2/ ooccupancy sensors \2\ and bi-level switching or dimming /2/ for low use corridors or after hours.*
B ALT	*Recessed linear downlight / wallwashers.*	*Linear fluorescent \2\ T8 or T5 light source./2/*	*Daylight dimming if available. \2\ Required /2/ occupancy sensors \2\ and bi-level switching or dimming/2/ for low use*

			corridors or after hours.

/1/

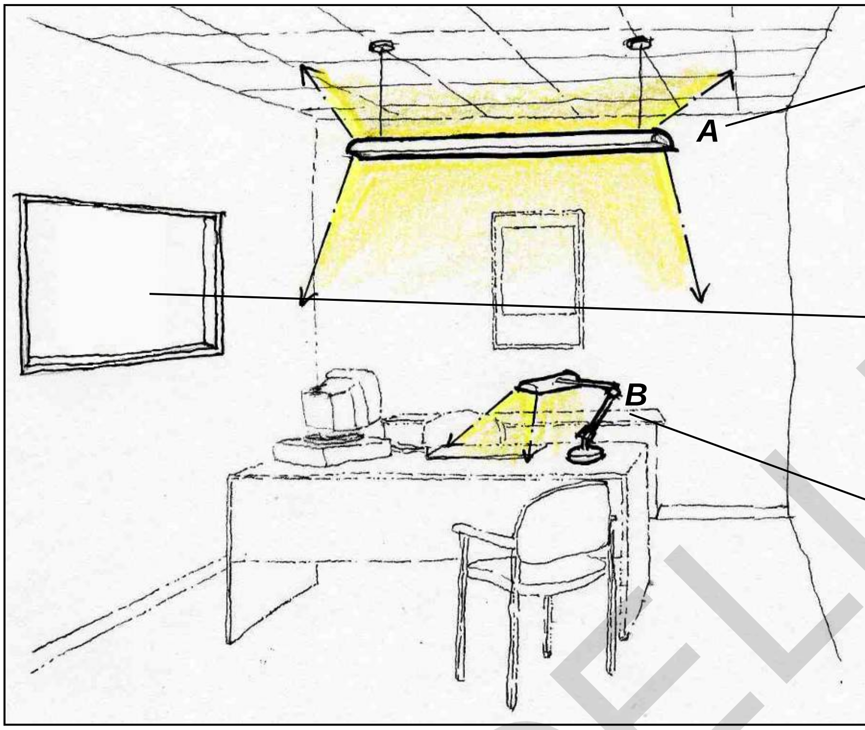
CRITICAL DESIGN ISSUES:

- Daylight Integration and Control: If daylight can be introduced into corridors, the corridor's electric lighting can be dimmed or turned off when there is adequate light. In infrequently used corridors, occupancy sensors can also be used to provide light only when needed.
- Direct Glare: Avoid direct glare even in transitional spaces such as corridors.
- Light Distribution on Surfaces: Lighting surfaces increases the perceived brightness of the space, makes the space feel larger, and can reduce the amount of energy required.
- Modeling of Faces or Objects: Light should come from multiple directions to adequately light individuals in the corridor. A system of downlights will cast harsh shadows on an occupant's face.
- Point(s) of Interest: Lighting photos, art, or other displayed features in a corridor can break the repetition of the lighting and add interest to the corridor. It also illuminates a surface that is prominent in the occupant's field of view.
- Target Horizontal Illuminance (± 10%): 50 lux (5 fc) average, \2\ egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

Although people spend little time in such transitional spaces, corridors can feel small and cramped with poor lighting and can represent a significant energy use. Lighting ceiling and wall surfaces increases the surface brightness and the overall perceived brightness of the space. This also makes the space feel larger and wider and can do so with the same or less energy than a downlighting only scheme. Surface mounted luminaires add vertical brightness on faces and also can help in indicating corridor intersections.

OFFICES — Individual Offices



Direct / indirect luminaires selected and located to prevent direct and reflected glare.

Introduce and control daylight. Integrate with electric lighting control.

Task lighting increases illuminance on task, allowing ambient light levels to be lower.

\1\

EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended linear, indirect / direct luminaire, mounted 0.5 – 0.9m (18" – 36") below ceiling. (There are some luminaires available for ceiling heights of 8'.)*	*\2\Linear fluorescent T8 or T5HO light sources./2/*	*\2\ Required /2/ occupancy \2\ or vacancy /2/ sensor. Consider daylight dimming when applicable. Control ambient and accent lighting separately.*
B	*Task light.*	*LED, compact, or linear \2\ T8 fluorescent light source./2/*	*\2\ Required occupancy or vacancy sensor./2/*

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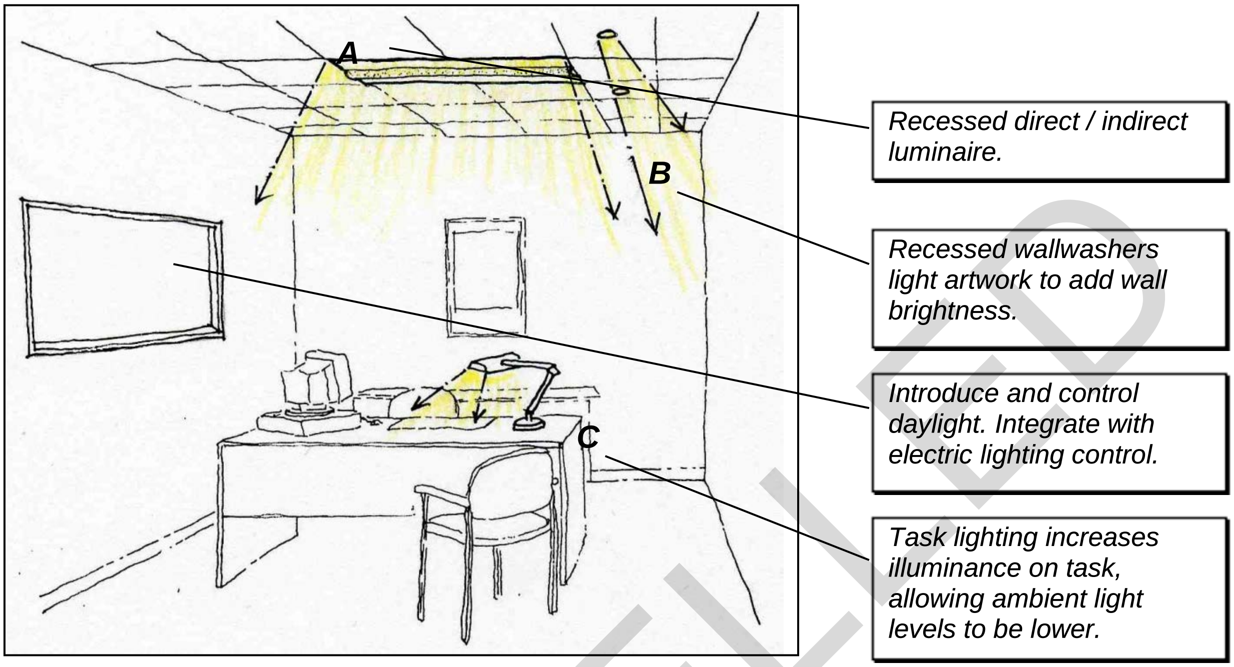
OFFICES — Individual Offices (Alternate Scheme)



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Recessed linear direct/indirect luminaire.*	*\2\Linear fluorescent T8 or T5HO light sources/2/*	*\2\Required /2/ occupancy \2\ or vacancy /2/ sensor. Consider daylight dimming when applicable. Control ambient and accent lighting separately.*
B	*Recessed downlight / wallwasher.*	*Compact fluorescent light source \2\ or LED, /2/*	*\2\ Required /2/ occupancy\2\ or vacancy /2/ sensor. Consider daylight dimming when applicable. Control ambient and accent lighting separately.*
C	*Task light.*	*LED, compact, or linear fluorescent \2\ T8 light sources./2/*	*\2\ Required occupancy or vacancy sensor./2/*

/1/

CRITICAL DESIGN ISSUES:

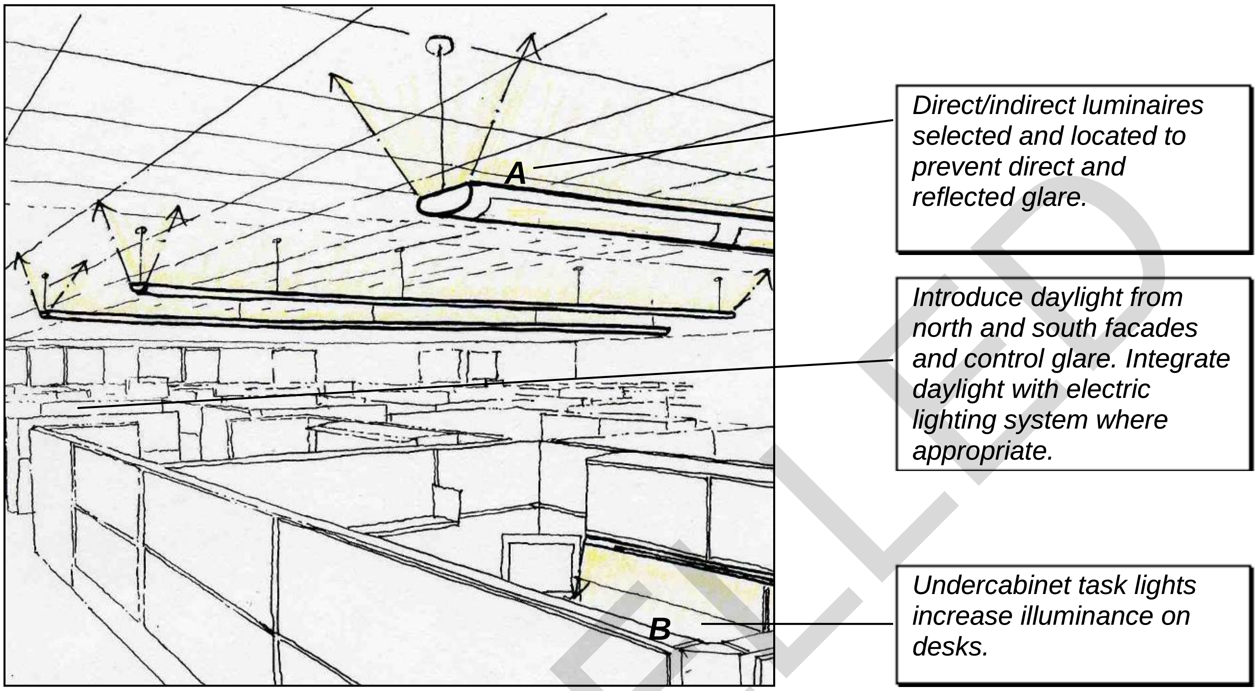
- Direct Glare: Light sources in the luminaire are shielded with louvers, perforations, or lenses to avoid a view of the light sources and the resultant direct glare.
- Luminances of Room Surfaces: Room surfaces need to be illuminated to control the contrast between the occupant's task and the surrounding surfaces in that person's field of view. This is especially important with computer use when a person views a bright screen in the foreground. If the background is too dark, the contrast will lead to eyestrain and fatigue.
- Uniformity: Luminance uniformity should not exceed 5:1 in immediate work surrounds, not including accent lighting.
- Reflected Glare: When viewing tasks with a glossy finish, bright luminaire components such as visible light sources or bright lenses reflect in the surface of the task. This situation can make reading tasks annoying and at times impossible.
- Source / Task eye geometry: Task areas and luminaire locations need to be identified to avoid shadows and direct and reflected glare.
- \2\ Controls: Use vacancy sensors in these areas or occupancy sensors with a manual on / auto off feature. This requires the occupant to turn the lights on manually but turns them off automatically if unoccupied. /2/
- Target Horizontal Illuminance (± 10%): 300 lux (30 fc) average ambient, 500 lux (50 fc) average on the task

DISCUSSION:

A task/ambient approach to the lighting in an individual office results in separate control over an ambient system (typically a suspended direct/indirect luminaire) and task lighting (a desk or undercabinet light). In larger offices or interior offices, additional wallwashing may be necessary to add wall surface brightness. By providing a high illuminance level on the task only and not the entire room, energy is saved in the ambient system, which does not have to produce as much light. This approach also provides a comfortable and flexible lighting environment.

ASHRAE requires individually occupied spaces with full height partitions to have a separate control device. Control devices \2\ must be either occupancy or vacancy /2/ sensors (individual or incorporated into wall switches).

OFFICES — Open Offices



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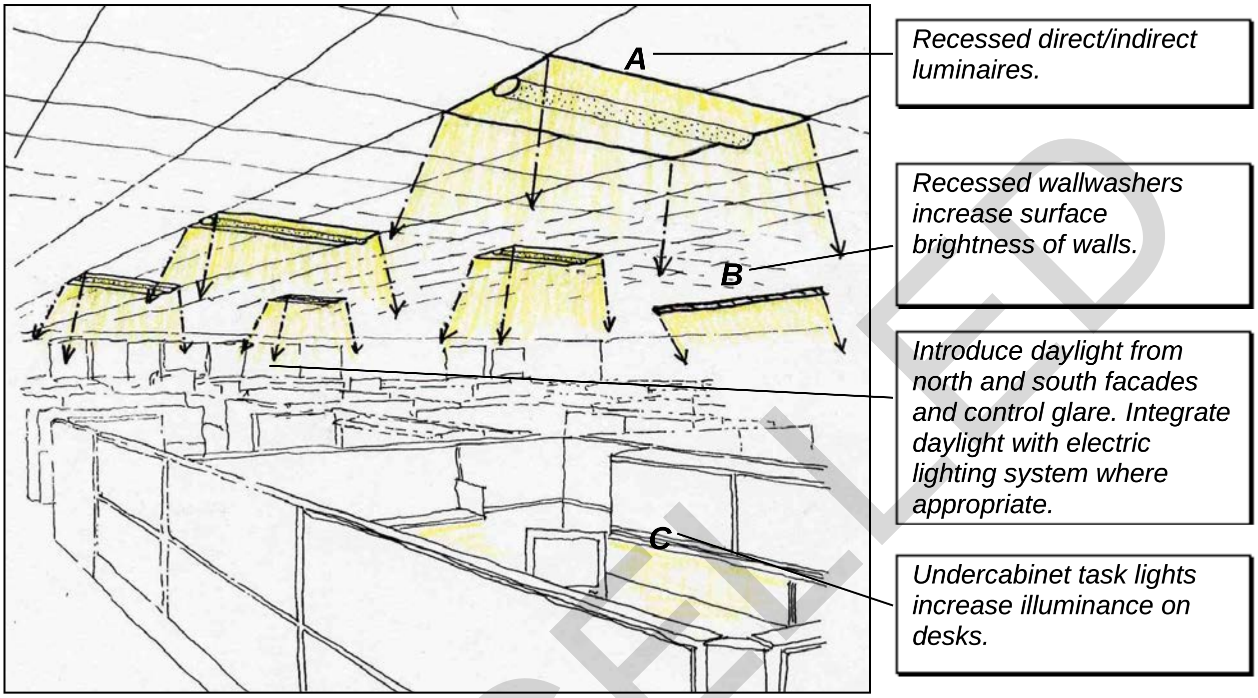
EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended linear, indirect / direct luminaire, mounted 0.5 – 0.9m (18” – 36”) below ceiling. (There are some luminaires available for ceiling heights of 8’.)*	*\2 Linear fluorescent T8 or T5HO light sources./2/*	*Daylight dimming. Manual dimming over workstations is also available. Consider the use of occupancy sensors for cubicle groups.*
B	*Under cabinet task lighting designed for minimal veiling reflections.*	*\2\LED /2/ or linear fluorescent T8 light sources\2\./2/*	*Manual on/off or on local occupancy \2\ or vacancy /2/ sensor.*

/1/

OFFICES Open Offices (Alternate Scheme)



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Recessed linear, direct/indirect luminaire.*	*\2\Linear fluorescent T8 or T5HO light sources./2/*	*Daylight dimming. Manual dimming over work stations is also available. Consider the use of occupancy sensors for cubicle groups.*
B	*Recessed wallwashers.*	*\2\Linear fluorescent T8, T5HO, \2\ LED /2/ or compact fluorescent light sources./2/*	*Daylight dimming. Consider the use of occupancy sensors for cubicle groups.*
C	*Under cabinet task lighting.*	*\2\LED /2/ or linear fluorescent T8 light sources./2/*	*Manual on/off or on local occupancy \2\ or vacancy /2/ sensor.*

/1/

CRITICAL DESIGN ISSUES:

- Direct Glare: Light sources in the luminaires are shielded with louvers, perforations, or lenses to avoid a view of the light sources and direct glare.
- Luminances of Room Surfaces: Room surfaces need to be illuminated to control the contrast between the occupant's task and the surrounding surfaces in that person's field of view. This is especially important with

computer use when a person views a bright screen in the foreground. If the background is too dark the contrast will lead to eyestrain and fatigue. In a large open office, the ceiling may be more prominent in someone's field of view than the walls.

- Uniformity: Luminance uniformity should not exceed 5:1 in immediate work surrounds, not including accent lighting.
- Reflected Glare: With high computer use, the ceiling brightness must be uniform to prevent reflected glare in computer screens. When viewing tasks with a glossy finish on a desktop, bright luminaire components such as visible light sources or lenses reflect in the surface of the task. This situation can make reading tasks annoying and at times impossible.
- Source / Task eye geometry: Task areas and luminaire locations need to be identified to avoid shadows and direct and reflected glare.
- Target Horizontal Illuminance (± 10%): 30 lux (30 fc) average ambient, 500 lux (50 fc) average on the task, \2\ egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

A task/ambient approach to the lighting in open offices results in separate control over an ambient system (typically a suspended direct/indirect luminaire) and task lighting (a desk light or undercabinet luminaire). Design the under cabinet task light to minimize veiling reflections by directing light away from or to either side of the task. By providing a high illuminance level on the task only, and not the entire room, energy is saved in the ambient system, which does not have to produce as much light. This approach also provides a comfortable and flexible lighting environment. Manual dimming can also be incorporated with the use of remote controls at individual workstations that control only the nearby luminaires.

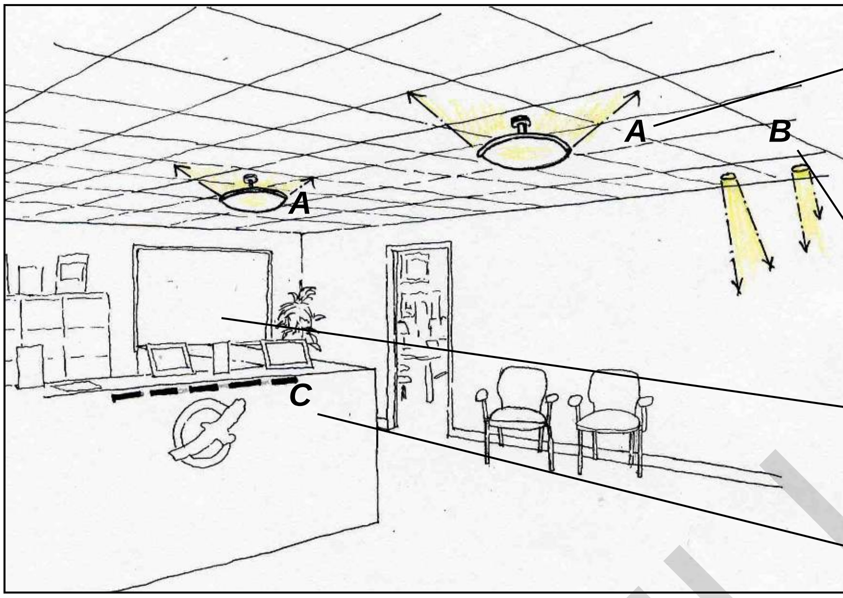
Integrating daylight with the electric lighting system greatly enhances the visual comfort of the space and can save significant amounts of energy. Depending on the configuration of workspaces and windows, lighting near the perimeter of the space may be controlled as a separate lighting zone from the lighting towards the interior of the space. In such a case, perimeter luminaires may be turned off entirely during the day while only using some portion of the lighting in the interior of the office.

RULES OF THUMB:

- Luminaire spacing: When beginning a design, start with 3.0 – 3.7m (10 – 12 ft) spacing for T8 luminaires (5.5 – 6.0 m or 18 – 20 ft for T5HO systems) and modify accordingly to meet critical design issues.
- Pendant length: Pendant lengths range from 0.5 – 0.9 m (18 in – 3 ft). High performance luminaires may achieve a minimum of 0.3 m (12 in) pendant lengths. Specialty luminaires for low ceiling applications may be mounted even closer to the ceiling.

- Lighting Power Density: Per \1\ ANSI/ASHRAE/IES 90.1-2007 /1/, the lighting power density for open office areas shall not exceed 1.0 watts/sq ft using the Building Area Method and 1.1 watts/sq ft using the Space-by-Space Method.

OFFICES — Waiting Areas



Suspended or surface mounted luminaires provide surface brightness and vertical illuminance.

Recessed wallwashers or accent lights increase wall brightness and highlight features.

Introduce and control daylight. Integrate with electric lighting system to reduce energy use.

Task lighting increases the illuminance on a task, allowing the ambient light levels to be lower.

\1\

EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended or surface mounted decorative luminaire.*	*Compact fluorescent light sources.\2\/2/*	*Consider daylight dimming.*
A ALT	*Recessed direct / indirect linear luminaire.*	*Linear fluorescent \2\T8 or T5HO /2/ light sources.\2\/2/*	*Consider daylight dimming.*
B	*Recessed downlight/wallwasher.*	*Compact fluorescent \2\ or LED /2/ light sources.\2\/2/*	*Consider daylight dimming.*
B ALT	*Recessed linear downlight / wallwashers.*	*Linear fluorescent \2\ T8 or T5HO /2/ light sources. \2\/2/*	*Daylight dimming if available.*
C	*Task lighting.*	*\2\ /2/ LED or linear fluorescent T8 \2\ /2/ light sources\2\./2/*	*Manual on / off or local occupancy \2\ or vacancy /2/ sensor.*

/1/

CRITICAL DESIGN ISSUES:

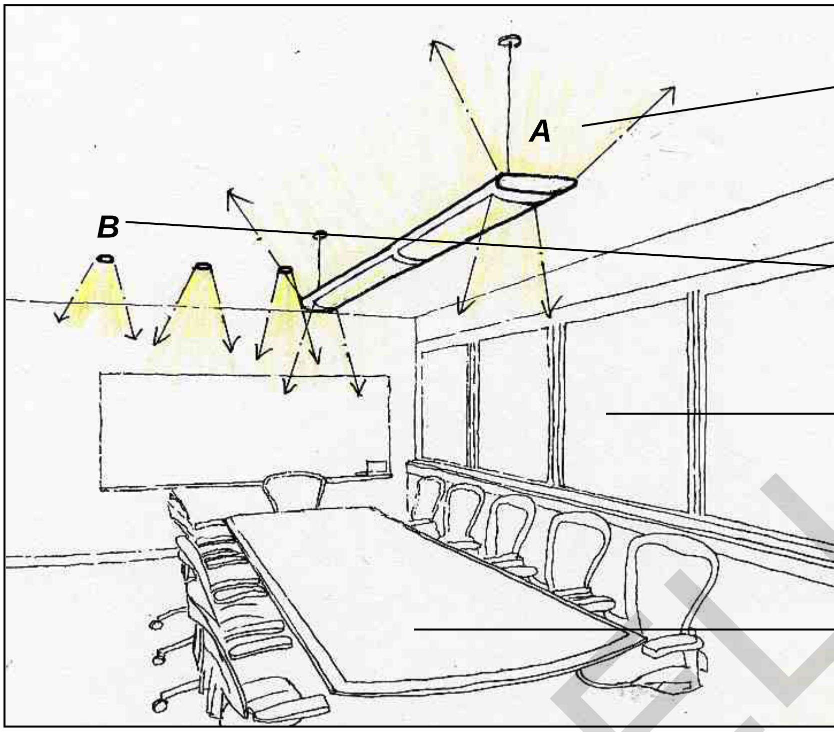
- Daylighting Integration and Control: If daylight can be introduced into waiting areas, the electric lighting can be \1\ dimmed or /1/ turned off when there is adequate light.
- Appearance of Space and Luminaires: Because facility visitors often occupy waiting areas, the aesthetic appearance of the space and the luminaires is an important criterion.

- Target Horizontal Illuminance (± 10%): 100 lux (10 fc) average ambient, 500 lux (50 fc) average on the task, \2\ egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

An effective and energy efficient lighting scheme illuminates high reflective surfaces as well as specific features in an ambient / accent approach. In the figure above, decorative pendants or surface mounted luminaires light the ceiling. This ambient system also can be easily integrated with the available daylight in the space. Wall washers illuminate walls and artwork. Because the walls make up a significant portion of our field of view, brightness on these surfaces increases the overall perceived brightness of the space.

OFFICES — Conference Rooms



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended linear, indirect / direct luminaire, mounted 0.5 – 0.9m (18" – 36") below ceiling. (There are some luminaires available for ceiling heights of 8'.)*	*\2\/2/ Linear fluorescent T8 or T5HO light sources. \2\/2/*	*\2\Required manual on/ occupancy or vacancy sensor off./2/ Daylight dimming if available. Manual dimming. \2\/2/*
B	*Recessed downlight / wallwashers.*	*Compact fluorescent light source \2\ or LED./2/*	*\2\Required manual on/ occupancy or vacancy sensor off./2/ Daylight dimming if available. Manual dimming. \2\/2/*
B ALT	*Recessed linear downlight / wallwashers.*	*Linear fluorescent \2\ T8 or T5HO /2/ light source. \2\/2/*	*\2\Required manual on/ occupancyor vacancy sensor off./2/ Daylight dimming if available. Manual dimming. \2\/2/*

/1/

CRITICAL DESIGN ISSUES:

- Appearance of Space and Luminaires: Because building visitors often meet in conference rooms, the aesthetic character of the luminaires is an important consideration.

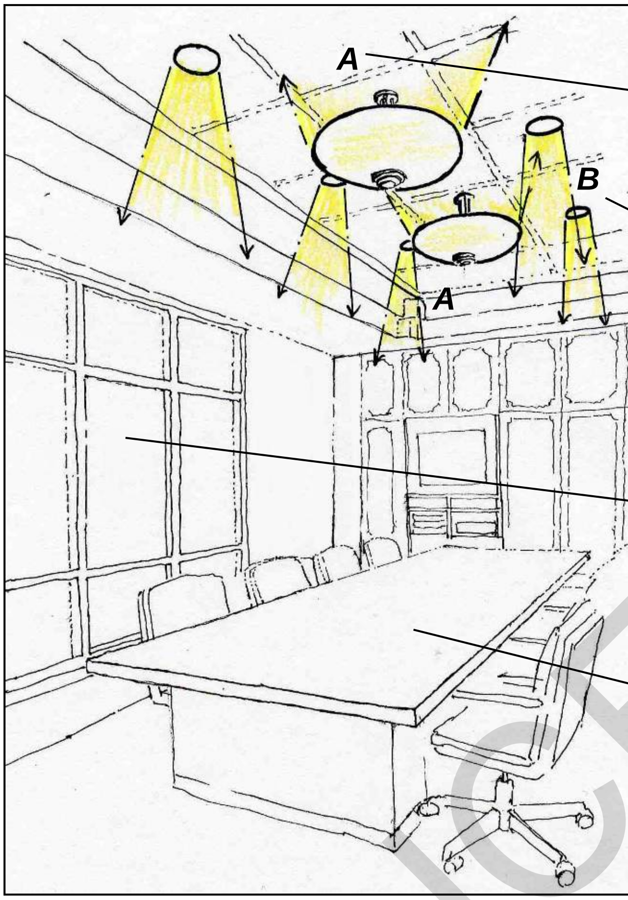
- Direct Glare: Light sources in the luminaires are shielded with louvers, perforations, or lenses to avoid a direct view of the light sources and the resultant glare.
- Light Distribution on Surfaces: Illuminate the room surfaces uniformly, especially the ceiling and walls. Patterns of light or shadows on surfaces can be distracting and confusing.
- Light Distribution on Task Plane: The lighting system should provide a uniform distribution of light on the conference table with minimal shadowing. This will provide a comfortable environment for writing tasks without causing fatigue or eyestrain.
- Luminance of Room Surfaces: Luminance, or brightness, of the room surfaces determines the perception of the conference room. With a bright, uniform ceiling and evenly washed walls, the space will feel bright and visually comfortable.
- Modeling of Faces or Objects: Because presentations and meetings are typical tasks in conference rooms, the lighting system should model people comfortably and accurately. Lighting that softly illuminates individual's faces without harsh shadows or excessive contrast reveals facial expressions and enhances such non-verbal communication.
- System Control and Flexibility: Control of luminaires should allow for multiple scenes or uses of the space. For example, a slide presentation may require lower ambient light levels, but adequate light on the table for occupants to take notes or read a handout. Window shades can darken the room for presentations. Other uses such as meetings may require more light. ASHRAE lists mandatory provisions for lighting control in this type of space if multi-scene control is not used. These provisions include occupancy based control to turn off lights within 30 minutes of all occupants leaving the space.
- Target Horizontal Illuminance (± 10%): 300-500 lux (30-50 fc) average, \2\ egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

The general ambient lighting must include an indirect component. A system comprised of downlighting only poorly illuminates room surfaces and puts harsh shadows on occupant's faces. Using an indirect component as part of the overall system will create a brighter space with better room surface luminances and render people more comfortably.

The lighting in a conference room should adapt to multiple uses of the space. At times, a presentation may require light on a white board or presentation wall. Other presentations may require a darker space for slide shows but still provide some light on the table so occupants can still take notes. For meetings, general lighting from a pendant over the table may be all that is required. Zone the luminaires separately to allow for the creation of multiple scenes depending on the space's use.

OFFICES — Boardrooms / Large Conference Rooms



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended decorative, indirect / direct luminaire.*	*Compact fluorescent light source\2\./2/*	*Daylight dimming if available. Manual dimming. Manual on/ occupancy \2\ or vacancy /2/ sensor off.*
B	*Recessed downlight / wallwashers.*	*Compact fluorescent light source /2/ or LED. /2/*	*Daylight dimming if available. Manual dimming. Manual on/ occupancy sensor off.*
B ALT	*Recessed linear downlight / wallwashers.*	*Linear fluorescent \2\ T8 or T5HO/2/ light source.*	*Daylight dimming if available. Manual dimming. Manual on/ occupancy sensor off.*

/1/

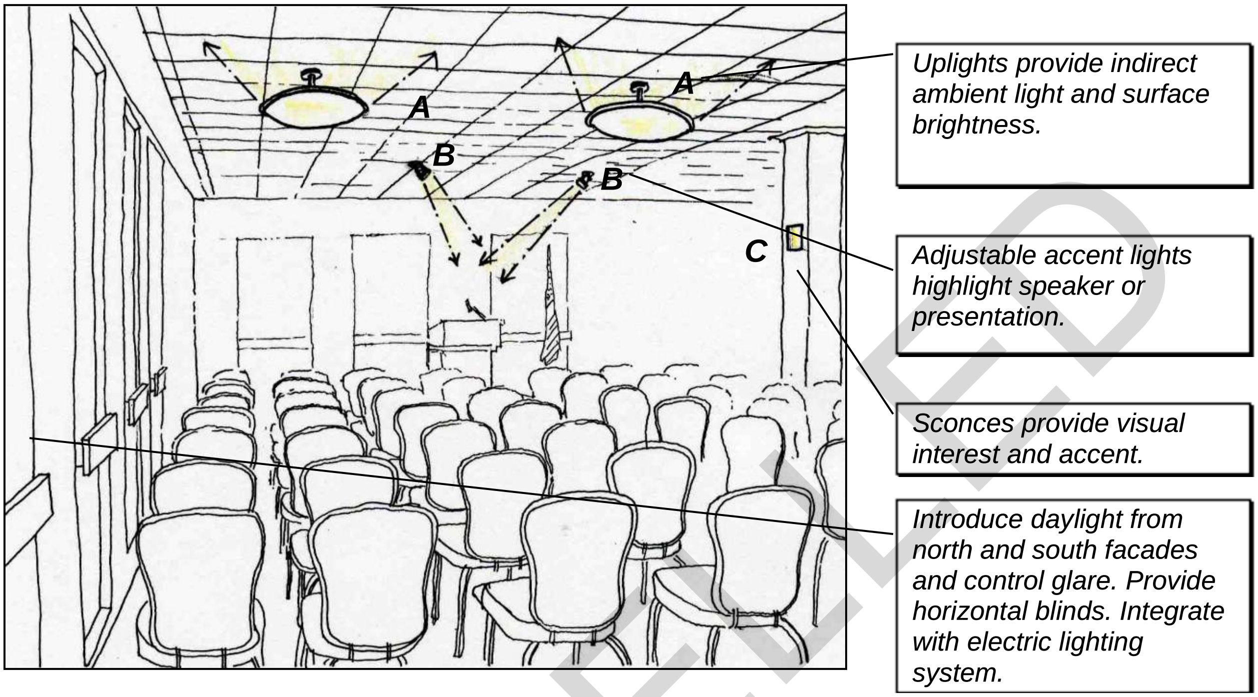
CRITICAL DESIGN ISSUES:

- Appearance of Space and Luminaires: Because building visitors often meet in boardrooms and large conference rooms, the aesthetic character of the luminaires is an important consideration.
- Direct Glare: Light sources in the luminaires are shielded with louvers, perforations, or lenses to avoid a direct view of the light sources and the resultant glare.
- Luminance of Room Surfaces: Luminance, or brightness, of the room surfaces determines the perception of the room. With a bright, uniformly lighted ceiling and evenly washed walls, the space will feel bright and visually comfortable. Increase brightness on architectural features or artwork to highlight certain areas.
- Modeling of Faces or Objects: Like conference rooms, presentations and meetings are typical tasks in boardrooms and the lighting system should model speakers as well as meeting participants. Lighting that softly illuminates individual's faces without harsh shadows or excessive contrast reveals facial expressions and enhances such non-verbal communication.
- Reflected Glare: When viewing tasks with a glossy finish on a tabletop, bright luminaire components, such as visible light sources or bright lenses reflect in the surface of the task. This situation can make reading tasks annoying and at times impossible.
- Target Horizontal Illuminance (± 10%): 300-500 lux (30-50 fc) average, \2\ egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

Similar to conference rooms, the lighting of boardrooms and large conference rooms should adapt to multiple uses of the space. At times, a presentation may require light on a white board or presentation wall. Other presentations may require a darker space for slide shows but still provide some light on the table so occupants can still take notes. For meetings, general lighting from a pendant over the table may be all that is required. Zone the luminaires separately to allow for the creation of multiple scenes depending on the space's use. Manual dimming allows a wide range of light levels for these varied requirements. Manual blinds for windows provide additional control over the daylight and ambient light levels. ASHRAE lists mandatory provisions for lighting control in this type of space if multi-scene control is not used. These provisions include occupancy based control to turn off lights within 30 minutes of all occupants leaving the space.

OFFICES — Ceremonial Areas



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended uplight.*	*Compact fluorescent light source.\2\/2/*	*Control as a separate, dimmable zone or as part of a scene controller.*
B	*Surface or recessed adjustable accent light.*	*\2\ LED ,/2/ Tungsten halogen PAR spot or narrow floodlight.*	*Control as a separate, dimmable zone or as part of a scene controller.*
C	*Wall mounted sconce.*	*Compact fluorescent \2\ or LED 2 light sources./2/*	*Control as a separate, dimmable zone or as part of a scene controller.*

/1/

CRITICAL DESIGN ISSUES:

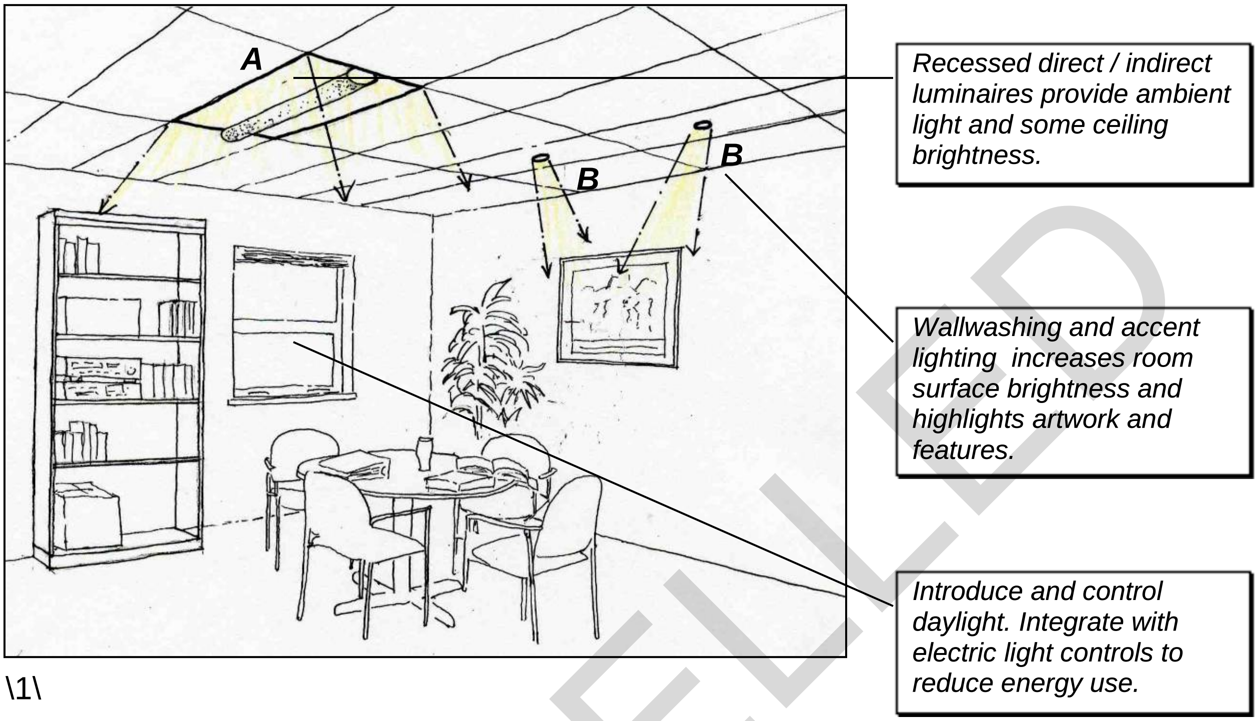
- Luminance of Room Surfaces: By lighting room surfaces, the ceremonial area will feel bright and comfortable. Balance contrast between surfaces with no brighter, accented surfaces. By keeping ambient lighting low, accent lighting on a speaker or presentation will be more effective.
- Modeling of Faces or Objects: Accent lighting on a speaker should come from multiple directions to eliminate harsh shadows and render faces or objects accurately.

- Target Horizontal Illuminance (± 10%): 100 lux (10 fc) average for ambient lighting, \2\ egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

Similar to conference rooms or auditoriums, the lighting of ceremonial areas should adapt to multiple uses of the space. At times, a presentation may require accent light on a speaker. Other presentations may require dimmer lighting for slide shows. Manual or automated blinds for windows provide additional control over the daylight and ambient light levels. If the space is used for receptions or gatherings, a higher light level might be appropriate. Zone the luminaires separately to allow for the creation of multiple “scenes” depending on the space’s use.

OFFICES — Lounge Areas



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Recessed direct / indirect linear luminaire.*	*Linear fluorescent T8 \2\ or T5HO /2/ \2\ /2/ light source., \2\/2/*	*\2\Required occupancy or vacancy sensor. Consider daylight/2/ dimming \2\ if available. ./2/*
B	*Recessed downlight / wallwasher.*	*Compact fluorescent light source \2\ or LED./2/*	*\2\Required occupancy or vacancy sensor. Consider daylight dimming if available. /2/*

/1/

CRITICAL DESIGN ISSUES:

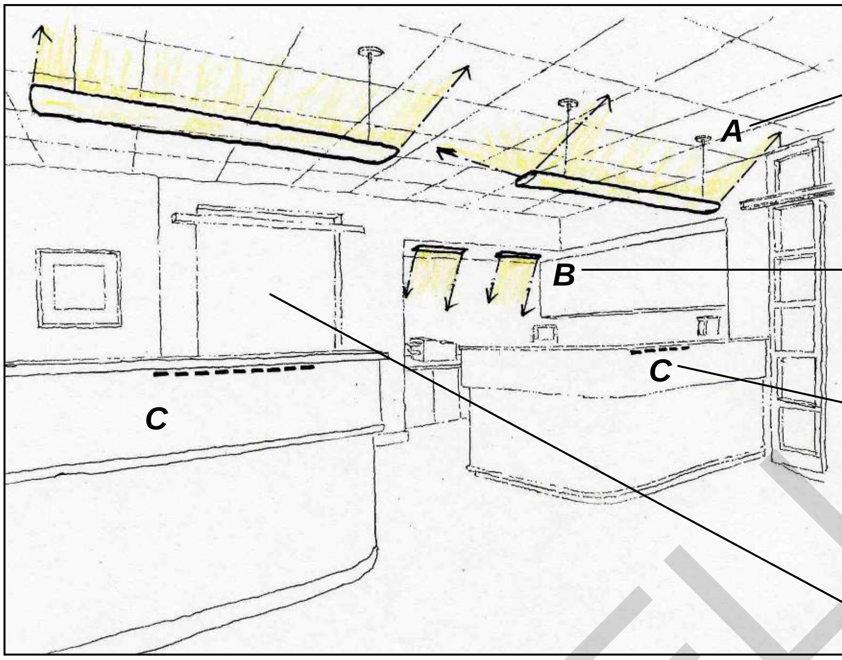
- Daylighting Integration and Control: The introduction of daylight into lounge areas can help to make it a more relaxing and inviting space. Use daylight controls to \1\ dim or /1/ turn off unnecessary electric lighting. ASHRAE lists mandatory provisions for lighting control in this type of space if multi-scene control is not used. These provisions include occupancy based control to turn off lights within 30 minutes of all occupants leaving the space.
- Appearance of Space and Luminaires: Select luminaires to enhance the appearance of the room and accent features of the space. Luminaire layout should avoid visual clutter of the space.

- Luminance of Room Surfaces: The room will feel bright if surfaces are illuminated. A recessed direct / indirect luminaire puts some light on the ceiling if the shielded "basket" drops below the ceiling plane. The use of downlight wallwashers highlights artwork or just adds to the overall brightness of the space.
- Color Appearance (and Color Contrast): The color of accent walls, architectural features, and artwork needs to be rendered accurately.
- Modeling of Faces or Objects: With casual conversation taking place in lounges, individual's faces should be illuminated well without harsh shadows.
- Target Horizontal Illuminance (± 10%): 100 lux (10 fc) average, \2\ egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

The introduction of daylight is a priority in lounge areas. Additionally, an ambient / accent approach to the lighting system will provide visual interest in the space and also some variety and flexibility in the control. While breaking the system into ambient and accent components, take care to avoid visual clutter with too many types of luminaires or poor layout. The luminaire selection should reinforce a casual and comfortable atmosphere.

OFFICES — Office Support Areas



Direct/indirect luminaires selected and located to prevent direct and reflected glare.

Recessed wallwashers increase wall brightness.

Task lighting increases the illuminance on a task, allowing the ambient light levels to be lower.

Introduce and control daylight on north and south facades. Integrate with electric light controls to reduce energy use.

\1\

EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended linear, indirect / direct luminaire, mounted 0.5 – 0.9m (18" – 36") below ceiling. (There are some luminaires available for ceiling heights of 8'.)*	*\2\/2/Linear fluorescent T8 or T5HO light sources. \2\/2/*	*Daylight or manual dimming. Consider the use of occupancy sensors for cubicle groups.*
B	*Recessed linear wall washer.*	*\2\ /2/ Linear fluorescent T8 \2\ /2/ light sources \2\/2/*	*Manual on / off or local occupancy sensor.*
C	*Task lightings.*	*\2\ /2/ LED or linear fluorescent T8 \2\ /2/ light source. \2\/2/*	*Manual on / off or local occupancy \2\ or vacancy /2/ sensor.*

/1/

CRITICAL DESIGN ISSUES:

- Direct Glare: Visible light sources and bright lenses can cause glare, leading to eyestrain and eye fatigue.
- Luminances of Room Surfaces: Lighting the walls and the ceiling improves the perception of brightness in the space. It also reduces excessive contrast between surfaces that are in an occupant's field of view.
- Reflected Glare: Bright light sources and lenses can be reflected in polished room surfaces, computer screens, and glossy printed tasks. These reflections reduce the contrast of tasks making reading extremely

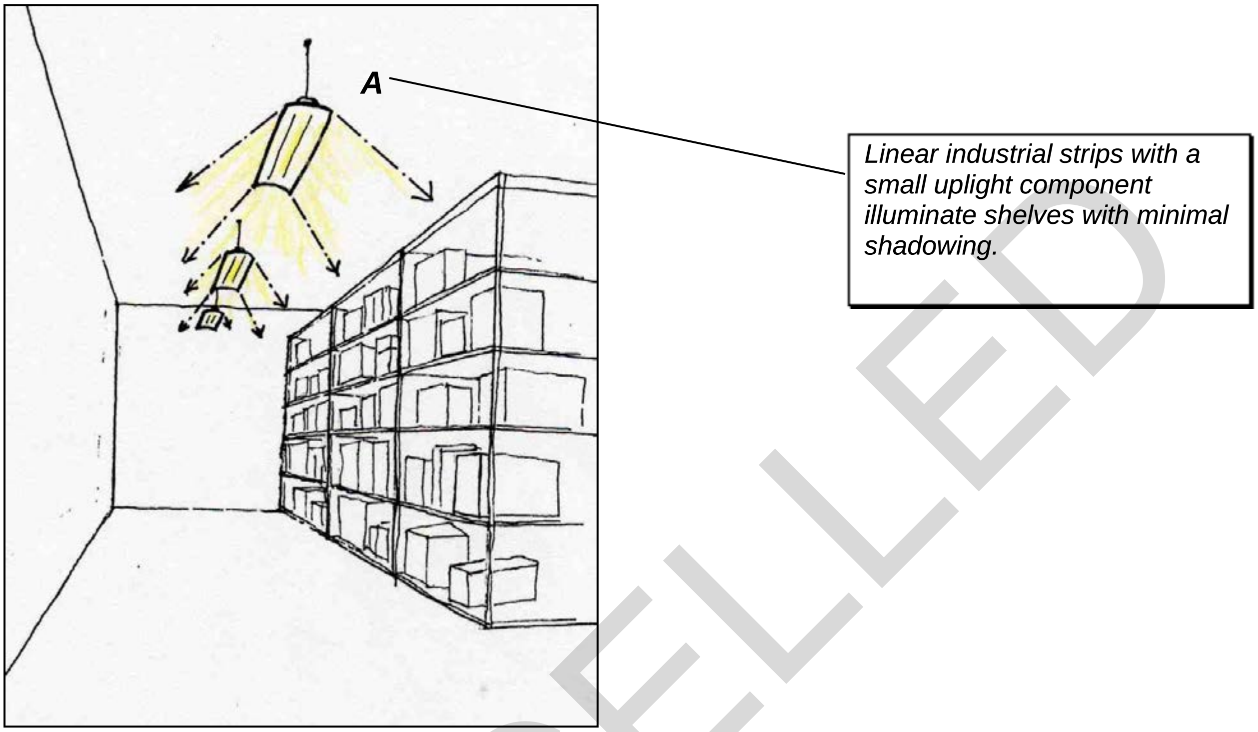
difficult. Shielding or diffusing light sources and specifying matte finishes where appropriate can improve the visual quality of the space and avoid reflected glare. Locate under-cabinet task lights to direct light away from or to either side of the task.

- Source / Task eye geometry: Identify task areas and design lighting to minimize shadows and glare (both direct and reflected).
- Target Horizontal Illuminance (± 10%): 300 lux (30 fc) average ambient, 500 lux (50 fc) average on task, \2\ egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

Office support areas require the same range of lighting levels as other office task spaces. By breaking the lighting system into ambient and task components, the ambient levels can be low while increasing the illuminance on the task only. This approach reduces energy consumption while giving occupants some flexibility and control over their workspace.

OFFICES Storage Rooms



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EQUIPMENT REQUIREMENTS: /1/

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended or surface mounted linear luminaire.*	*\2\ /2/Linear fluorescent T8 light sources (or T5HO light sources for ceilings over 15') \2\ or induction light /2/ source.\2\/2/*	*\2\Required occupancy sensor with bi-level switching or dimming. Step dimming for storage rooms with daylight /2/.*

/1/

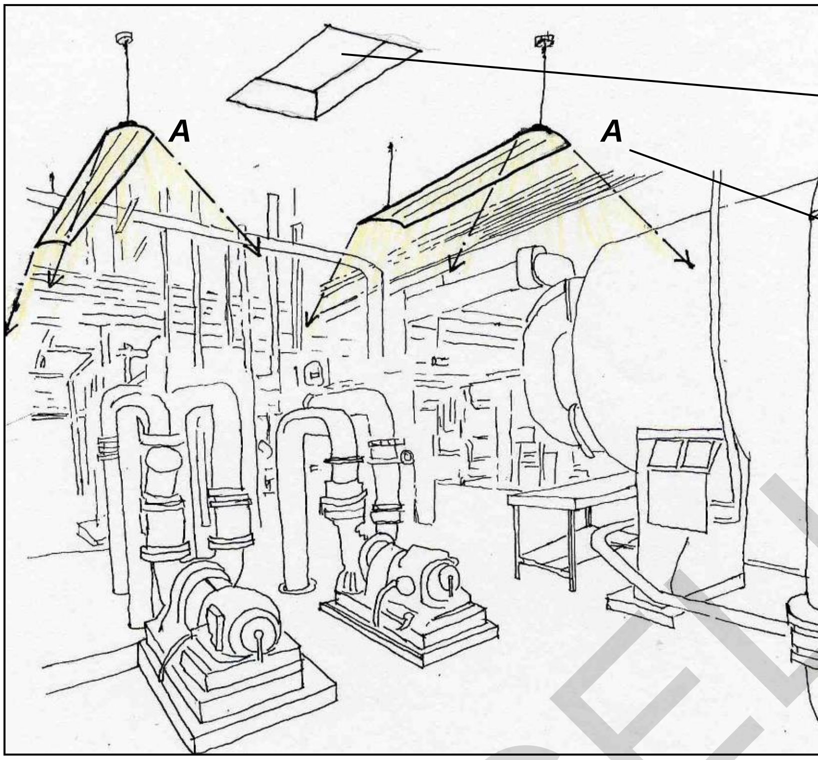
CRITICAL DESIGN ISSUES:

- Color Appearance (and Color Contrast): In storage rooms, individuals may need to locate and sort items. Light source sources should have a high color-rendering index to accurately portray colors and labels.
- Source / Task eye Geometry: Locate luminaires to minimize direct glare and light shelves uniformly with minimal shadowing.
- Target Vertical Illuminance (± 10%): 100 lux (10 fc) average

DISCUSSION:

In storage rooms, uniform vertical illuminance on shelves helps with the identification of items. In small storage closets, a linear fluorescent strip mounted horizontally above the door provides indirect light and minimizes shadows on the shelves. Add wire guards to luminaires where they may be struck and damaged.

OFFICES — Mechanical Rooms



Consider daylight with toplighting strategies or clerestories.

Located to avoid mechanical equipment and minimize shadowing.

\1\

EQUIPMENT REQUIREMENTS: /1/

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended linear industrial luminaire with 5%-10% uplight component.*	*Linear fluorescent T8 light sources (or T5HO light sources for ceilings over 15'). \2\/2/*	*On / off switch.*

/1/

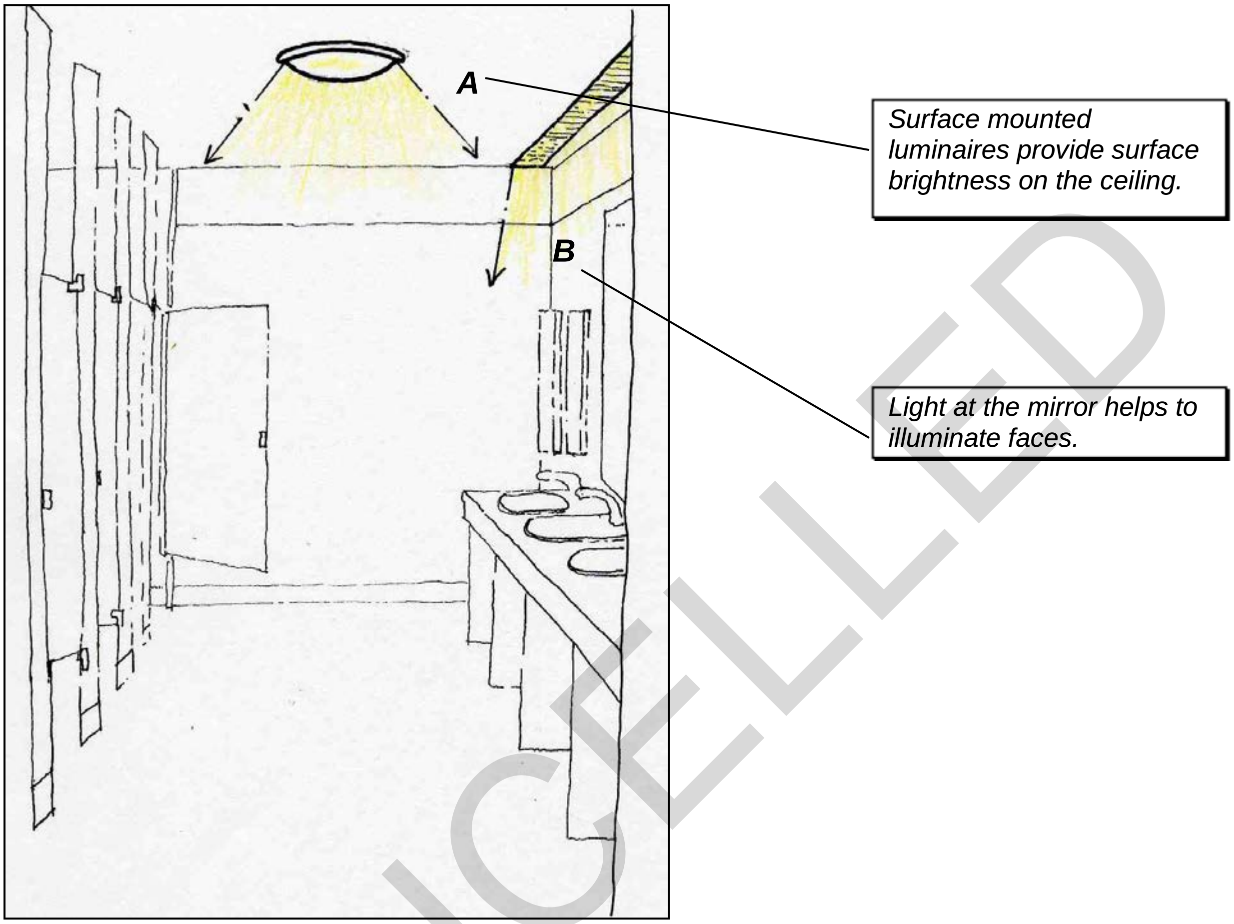
CRITICAL DESIGN ISSUES:

- Shadows: Locate and orient luminaires to avoid shadowing of mechanical equipment. Typically, equipment repair requires portable task lighting. Therefore, lighting should provide clear access to systems but not necessarily enough light to make repairs.
- Target Horizontal Illuminance (± 10%): 300 lux (30 fc) average

DISCUSSION:

Adequate light needs to be provided for ease of navigation through mechanical rooms \2\ and maintenance of equipment./2/ Although mechanical rooms may not be used frequently or for long periods of time, if the lights are left on, a significant amount of energy can be wasted before the next use of the space. \2\ Do not use vacancy/occupancy sensors or timers to turn off lights./2/ Add wire guards to luminaires where they may be struck and damaged.

OFFICES Restrooms



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EQUIPMENT REQUIREMENTS: /1/

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Surface or wall mounted luminaire.*	*Compact fluorescent light sources.\2\/2/*	*\2\Required occupancy or vacany/2/ sensor.*
B	*Recessed linear wall slot.*	*\2\ /2/ Linear fluorescent T8 light sources.\2\ /2/*	*\2\Required occupancy or vacancy/2/ sensor.*

/1/

CRITICAL DESIGN ISSUES:

- Color Appearance (and Color Contrast): The color-rendering index of fluorescent light sources should be high to render colors well and avoid a pale or blue look to individual's faces.
- Modeling of Faces or Objects: With light coming from multiple directions and angles, faces and objects can be modeled well without harsh shadows.

- Target Horizontal Illuminance (± 10%): 50 lux (5 fc) average, higher light level at mirrors, \2\ egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

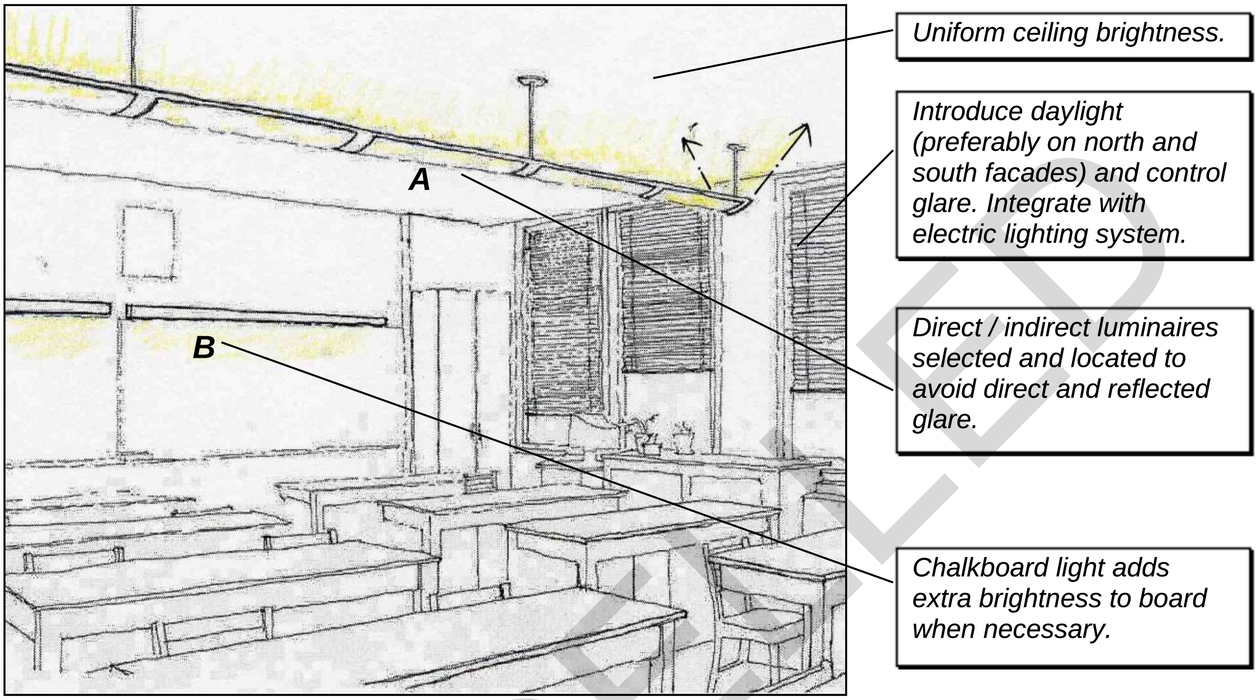
DISCUSSION:

While the recommended ambient light level for restrooms is low, lighting the walls and putting some brightness on the ceiling will increase the perceived brightness of the space. Increased light levels are appropriate at the sink or counter near the mirrors.

Occupancy sensors should control the lighting in restrooms where luminaires are frequently left on for an extended period of time. Ceiling mounted, ultrasonic sensors recognize occupants even in a space with high partitions. Locate and aim the sensor to switch on when the door opens and then turn off after a pre-determined amount of time.

\1\ Refer to "Residential Housing – Bathrooms" for the lighting of private restrooms. /1/

EDUCATIONAL FACILITIES Classrooms



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended linear, indirect / direct luminaire, mounted 0.5 -0.9m (18" – 36") below ceiling. (There are some luminaires available for ceiling heights of 8'.)*	*\2\ /2/ Linear fluorescent T8 or T5HO light sources. \2\/2/*	*Daylight dimming if available. Manual dimming. \2\Required /2/ manual on/ occupancy \2\ or vacancy /2/ sensor off.*
B	*Linear chalkboard light.*	*\2\ /2/Linear fluorescent T8 or T5HO light sources. \2\/2/*	*Manual dimming and ON / OFF.*

/1/

CRITICAL DESIGN ISSUES:

- Daylight Integration: Studies have shown a correlation between classrooms with daylight and improved test scores. Good quality daylight that comes from south and north facing view windows and clerestories is preferred. Glare needs to be controlled, and lighting controls should \1\ dim /1/ electric lighting when not required.
- Direct Glare: Since students are viewing the teacher and observing either whiteboard or overhead projector information, minimize glare from overhead electric lighting. Indirectly lighting the classroom with minimal direct light is the most effective glare free environment.

- Reflected Glare: Reflected glare occurs with overhead lighting reflecting on the student's desk and reading material. Indirectly lighting the classroom with minimal direct light reduces reflected glare.
- Light Distribution on Task Plane (Uniformity): Avoid uneven lighting such that some desks are significantly brighter than other desks. This occurs with either direct sunlight falling onto desks, or with recessed direct parabolics. Indirectly lighting the classroom with no more than 50% direct light provides the most uniform lighting.
- Horizontal and vertical illuminance: Horizontal illuminance is important for the student's desks. Vertical illuminance is important to view instructors, students, and the white boards.
- Target Horizontal Illuminance (± 10%): 500 lux (50 fc) average, \2\ egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

Multiple studies done show improved test scores (over 20%) with students who are in classrooms with daylight. Orient classrooms so that daylight can enter the classroom, preferably from two directions, without direct glare.

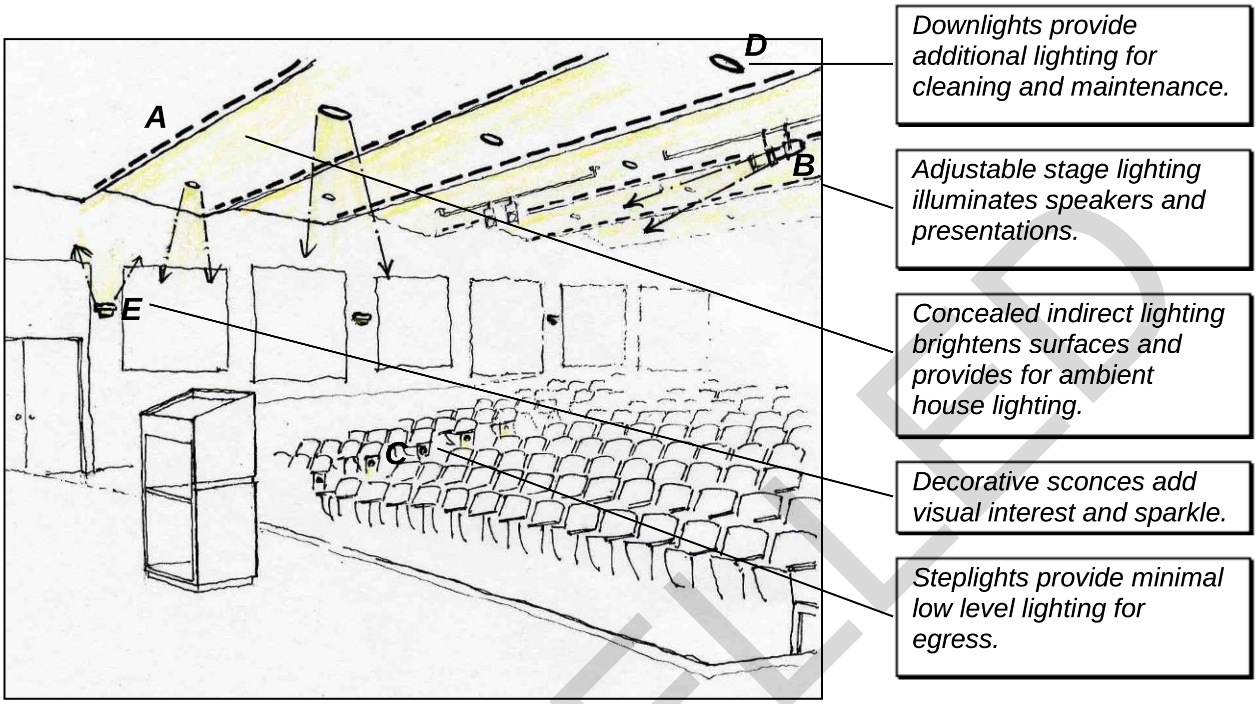
The electric lighting should light the ceiling in order to reduce direct and reflected glare potential. Yet, some direct light component is important to balance out the luminances within the classroom. The use of a white board light has been shown to improve student retention by highlighting written information.

Controls in the classroom are also important, especially with the increase in computer projection. Giving the teacher the ability to dim the lighting provides enough light for note taking, yet minimizes the direct glare on the screen. ASHRAE lists mandatory provisions for lighting control in this type of space if multi-scene control is not used. These provisions include occupancy based control to turn off lights within 30 minutes of all occupants leaving the space.

RULES OF THUMB:

- Luminaire spacing: When beginning a design, start with 3.0 – 3.7 m (10 – 12 ft) spacing for T8 luminaires and modify accordingly to meet critical design issues.
- Pendant length: Pendant lengths range from 0.5 – 0.9 m (18 in – 3 ft). High performance luminaires may achieve a minimum of 0.3 m (12 in) pendant lengths. Specialty luminaires for low ceiling applications may be mounted even closer to the ceiling.
- Lighting Power Density: Per \1\ ANSI/ASHRAE/IES 90.1-2007 /1/, the lighting power density for classrooms shall not exceed 1.2 watts/sq ft using the Building Area Method and 1.4 watts/sq ft using the Space-by-Space Method.

EDUCATIONAL FACILITIES — Auditoriums



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Concealed linear uplight.*	*\2\ /2/ Linear fluorescent T8 or T5HO light sources \2\ or LED strip./2/*	*Control as a separate zone or as part of an auditorium wide dimming control system.*
B	*Adjustable spotlight.*	*Tungsten halogen PAR38 spot or narrow floodlight.*	*Control as a separate zone or as part of an auditorium wide dimming control system.*
C	*Surface mounted steplight on edge of stair or in seats.*	*LED or compact fluorescent. \2V2/*	*Control as a separate zone or as part of an auditorium wide dimming control system.*
D	*Surface, recessed, or suspended downlight.*	*Compact fluorescent \2\ or LED /2/ light sources.\2V2/*	*Control as a separate zone or as part of an auditorium wide dimming control system.*
E	*Wall mounted sconce.*	*Compact fluorescent \2\ or LED /2/ light sources.\2V2/*	*Control as a separate zone or as part of an auditorium wide dimming control system.*

/1/

CRITICAL DESIGN ISSUES:

- System Control and Flexibility: Auditorium controls should allow for a variety of scenes or lighting configurations. The system must provide for simple operation and require little or no training or special knowledge.
- Color Appearance and Color Contrast: Because speakers and presentations change, light sources should render color well. Additionally, the room surface finishes need to be carefully considered and illuminated with the appropriate light source.
- Direct Glare: Since occupants are viewing the lecturer and observing presentation information, minimize glare from overhead electric lighting.
- Modeling of Faces and Objects: The speaker should be lighted with spotlights from both sides rather than straight on. This will prevent harsh shadows while still modeling the speaker's face. Such lighting increases the recognition of facial expressions and the effectiveness of non-verbal communication.
- Horizontal and Vertical Illuminance: Horizontal illuminance is important for the occupants taking notes. Vertical illuminance is important to view instructors, students, and presentations.
- Target Horizontal Illuminance (± 10%): 100 lux (10 fc) average for house ambient lighting; 500 lux (50 fc) average for speaker lighting, \2\ egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

The lighting for an auditorium should be made up of multiple components. This design approach allows users flexibility in controlling the lighting. It also saves energy by using only the lighting power that is required for a particular event or program. Additionally, this "system" approach (as well as the goal of lighting surfaces) encourages integration of light and architectural elements.

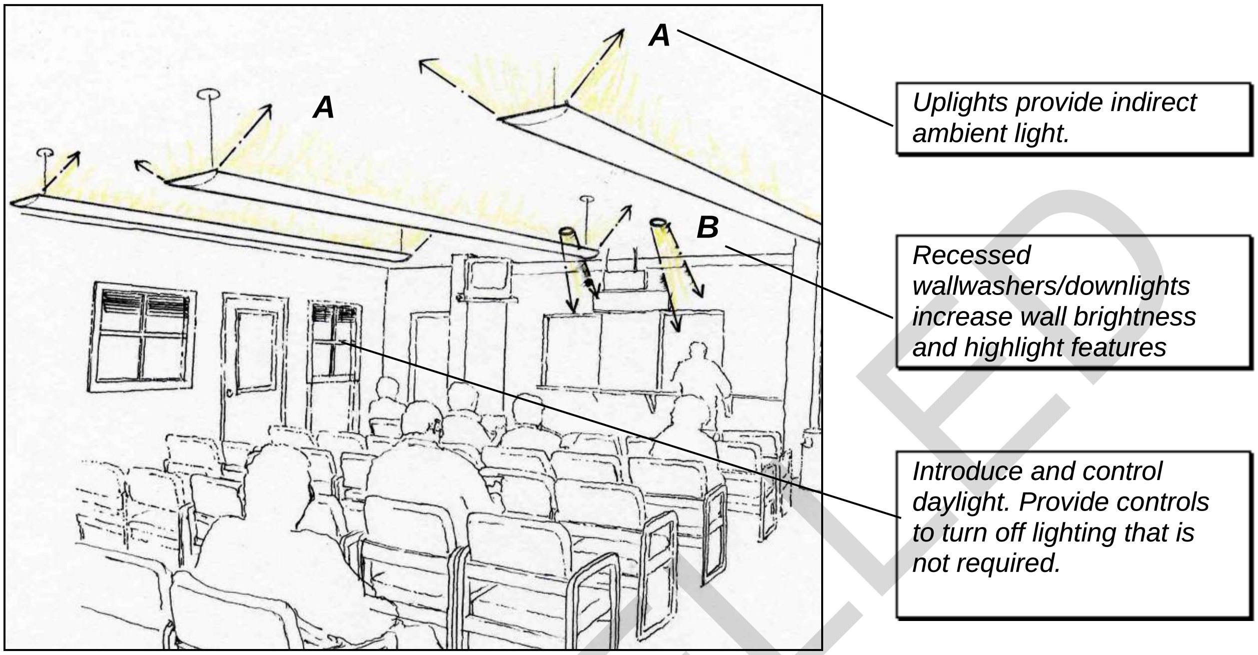
- Ambient Lighting: The ambient lighting may include multiple components to light the walls, ceiling, and other elements in the space. Recessed coves or suspended pendant uplights might light the ceiling surface. Acoustic panels may form coves for indirect lighting. Additional ambient lighting may occur at the perimeter of the auditorium in the form of wall washing.
- House Lighting: Downlights can provide additional house lighting for maintenance and cleaning or at a time when higher light levels are required. In combination with the ambient lighting, an illuminance range of up to 300 lux (30 fc) could be achieved.
- Stage Lighting: Stage lighting will highlight a lecturer and presentation.

Egress Lighting: Lighting along the edge of the aisles or possibly in the chairs can illuminate the aisles to some minimum level during a presentation to allow for safe egress.

With the lighting for the space divided into multiple components (or zones), these zones can then be configured with a control system to make up preset "scenes". Each scene is a combination of different zones set to "on" (or "off") and dimmed to a selected level of light. This selected combination corresponds to a particular event or program. Once the scenes are programmed, the push of one button raises and lowers all of the lights to their predetermined levels. The following outlines some typical events that could be assigned a preset scene:

- Pre / Post Lecture: Ambient lighting may be on full; stage lighting could be off or dimmed to a low level; egress lighting would be off.
- Lecture: Ambient and house lighting may be dimmed to a low level or on enough for note taking; stage lighting would light the speaker; egress lighting would be on.
- AV / ITV Presentation: Ambient and house lighting would be very low or off and still adequate for note taking; stage lighting would be off to accommodate the AV presentation; egress lighting would be on.
- Cleaning / Maintenance: Ambient and house lighting would be on full; stage lighting would be on; egress lighting would be off.

HEALTHCARE FACILITIES — Waiting Rooms



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended linear indirect / direct luminaire.*	*\2\ /2/Linear fluorescent T8 \2\ /2/ light source.\2\/2/*	*Daylight dimming.*
A ALT	*Suspended decorative uplight.*	*Compact fluorescent light sources.\2\/2/*	*Daylight dimming.*
B	*Recessed downlight / wallwashers.*	*Compact fluorescent light sources \2\ or LED. /2/*	*Control accent lighting separately from ambient light.*
B ALT	*Recessed linear downlight / wallwashers.*	*Linear fluorescent T8 light source. \2\/2/*	*Control accent lighting separately from ambient light.*

/1/

CRITICAL DESIGN ISSUES:

- Daylighting Integration and Control: The introduction of daylight into waiting rooms provides a connection to the outdoors as well as a potential lighting energy savings. By integrating controls with the daylight design, electric lighting equipment can be \1\ dimmed or /1/ turned off when not required.
- Appearance of Space and Luminaires: Because waiting rooms are often the first space visitors to the facility see, the aesthetic appearance of the space and the luminaires is an important criterion.

- Luminance of Room Surfaces: Lighting the wall and ceiling surfaces can achieve increased brightness with less energy. Typically people may be reading or watching TV in such spaces and are not occupied with difficult visual tasks. Therefore, the luminances of the surfaces are far more important than the horizontal illuminance.
- Target Horizontal Illuminance (± 10%): 100 lux (10 fc) average, \2\ egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

As in most interior spaces, waiting areas require the lighting of surfaces to increase the perceived brightness. By utilizing an indirect pendant, the lighting system illuminates the ceiling surface and provides indirect ambient light. This comfortable light minimizes shadows and also avoids glare from the light source. The indirect lighting of surfaces also integrates well with daylight. In some designs, luminaires close to windows may be controlled separately and switched off during times of the day when daylight provides adequate brightness in the space.

HEALTHCARE FACILITIES — Pharmacy

\1\

EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Recessed indirect / direct linear luminaire.*	*\2\ /2/Linear fluorescent T8 light sources.\2\/2/*	*Control ambient and task lighting separately.*
A ALT	*Recessed parabolic linear luminaire.*	*\2\ /2/ Linear fluorescent T8 \2\ or T5HO /2/ light sources.\2\/2/*	*Control ambient and task lighting separately.*
B	*Under shelf task light.*	*\2\ /2/LED or linear fluorescent T8, \2\ /2/ light sources.\2\/2/*	*Control ambient and task lighting separately.*

/1/

CRITICAL DESIGN ISSUES:

- Color Appearance (and Color Contrast): Task and ambient lighting should accurately render colors of medication.
- Direct Glare: Shield light sources with diffusers, lenses, or louvers to eliminate direct glare.
- Flicker (and Strobe): Flicker of fluorescent light sources can become an annoyance to anyone under them for an extended period of time. While sensitivity to flicker varies dramatically between individuals, electronic ballasts typically avoid this problem.

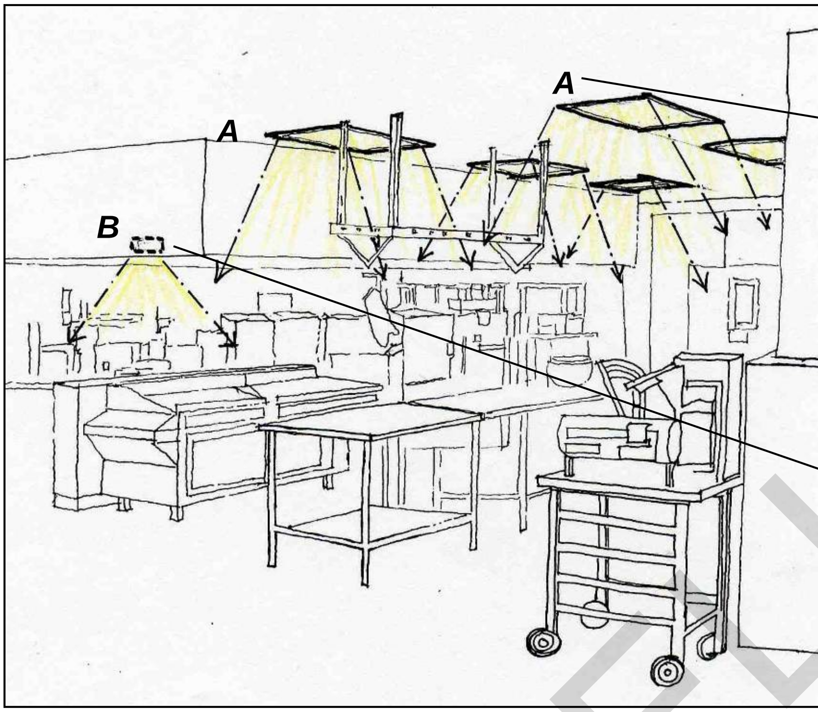
- Light Distribution on Task Plane (Uniformity): Uniformly illuminate the task plane as well as room surfaces, without shadows or confusing patterns of light.
- Modeling of Faces and Objects: The use of direct/indirect light or light from multiple directions fills in shadows and renders texture and three-dimensional objects.
- Reflected Glare: Select and locate luminaires to avoid veiling reflections on the countertop. Such reflected glare will impair viewing of tasks on the counter. Locate under-shelf task lights to direct light away from or to either side of the task.
- Horizontal and Vertical Illuminance: Adequate illuminance levels need to be provided for both horizontal tasks on the counter as well as vertical tasks on shelves or equipment.
- Target Horizontal Illuminance (± 10%): 500 lux (50 fc) average, \2\ egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

While pharmaceutical tasks require a high light level, a task-ambient system reduces the amount of light that needs to be provided by the ambient system. Task lighting then increases the light level where and when it is required.

Recessed ambient lighting equipment often fails to provide the surface brightness necessary for a comfortable visual environment. Spending all day in such an environment can lead to eyestrain and fatigue. Surface brightness can be improved by utilizing the benefits of an indirect / direct luminaire or lens to put more light on the ceiling or walls. Additionally, wallwashers, where appropriate, illuminate fixed shelves, or improve the room surface brightness.

FOOD SERVICE Kitchens



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EQUIPMENT REQUIREMENTS: /1/

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Recessed linear downlight with gasketed lens.*	*\2\ /2/ Linear fluorescent T8 \2\ /2/ light source\2\./2/*	*Control ambient and task lighting separately.*
B	*Surface mounted task light under counter or under hood. (Often procured as part of the hood.)*	*Linear T8 or compact fluorescent light sources \2\ or LED. /2/*	*Control ambient and task lighting separately.*

CRITICAL DESIGN ISSUES:

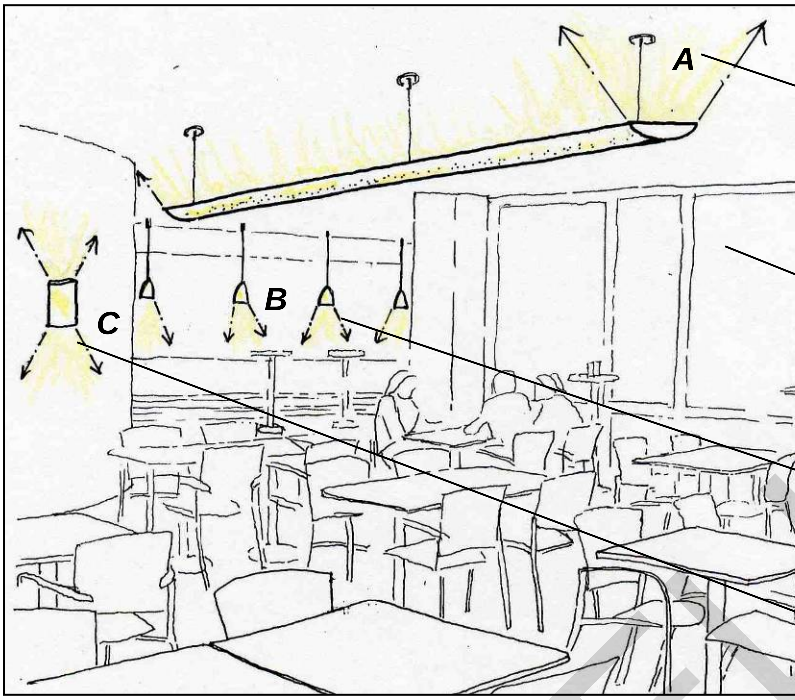
- Color Appearance: The color of food should be accurately rendered with high color-rendering index fluorescent light sources.
- Reflected Glare: If lighting is improperly placed directly in front of the cook, reading recipes and preparing food can be a challenge. Minimize reflected glare with proper lighting equipment locations.
- Shadowing: Minimize contrast with ambient and task lighting to fill in shadows. This is especially important on work surfaces where people will be using knives and other kitchen tools.

- Source / Task Eye Geometry: Overhead ambient lighting and under-counter task lighting will minimize confusing shadows. Locate luminaires so that shadows are minimized and the light is where it is needed.
- Target Horizontal Illuminance (± 10%): 500 lux (50 fc) average on cooking and food preparation surfaces. A task light is often provided with grill hoods. Verify that it will provide adequate illuminance on the cooking surface. \2\ Egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

Because kitchens require high light levels with minimal shadowing, a diffuse direct system is a good choice. Recessed lensed and gasketed luminaires typically provide a high light level and allow for easy maintenance. Additional task lighting under cabinets and under exhaust hoods increases the task illuminance and fills in shadows on the task plane. Refer to UFC 4-722-01 for additional requirements.

FOOD SERVICE — Cafeterias



Indirect / direct luminaires light the ceiling while still providing a small direct component.

Daylight should be introduced into the space, controlled, and integrated with the electric lighting.

Low wattage accent lighting helps to highlight points of interest.

Wall sconces provide surface brightness and visual interest.

\1\

EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended linear indirect / direct luminaire.*	*\2\ /2/ Linear fluorescent T8 or T5HO light sources\2\./2/*	*Control with daylight sensors. \2\ Daylight dimming./2/*
B	*Suspended low voltage decorative accent light.*	*\2\ LED or low voltage halogen light source. /2/*	*Control ambient and accent lighting separately. Consider the use of occupancy sensors.*
C	*Wall mounted sconce.*	*Compact fluorescent \2\ or LED /2/ light source\2\./2/*	*Control ambient and accent lighting separately. \2\ Daylight dimming./2/ Consider the use of occupancy sensors.*

/1/

CRITICAL DESIGN ISSUES:

- Color Appearance: The appearance of food served in a cafeteria should be vivid and aesthetically pleasing. Often halogen light sources illuminate food at the point of display. Where fluorescent light sources are used, they should be specified with a high color-rendering index (CRI).
- Modeling of Faces or Objects: The modeling of food texture and appearance is especially important where it is displayed and served.

Directional accent light, in addition to the ambient light, highlights the food and provides adequate modeling.

- Point(s) of Interest: Accent lighting should focus attention and provide some level of way finding and direction for occupants. Accenting signs and special sections creates visual interest in the space as well as guidance through a serving line.
- Direct Glare: When minimizing glare, consider direct views from the cafeteria or serving area (a relatively low light level) into a kitchen with a relatively high light level. Additionally, accent lighting should attract attention without becoming a glare source.
- Target Horizontal Illuminance (± 10%): 100 lux (10 fc) average; 500 lux (50 fc) average on food display, \2\ egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

The lighting system in a cafeteria should create a visually comfortable environment with occasional accent lighting to add interest to the space and assist in way finding. It is important to note that accent lighting can only be effective when the ambient light level is lower. People see and respond to *changes* in brightness. A highlighted area must be between three and five times brighter than the surroundings to be perceived as a brighter area. A high ambient light level makes accent lighting nearly impossible without using an enormous amount of energy.

If daylight can be introduced into the space, it should be controlled to reduce glare and heat gain. Additionally, integrate control of the electric lighting system with the available daylight with sensors and dimmers or switches to reduce the amount of lighting energy consumed when it is not required. Refer to UFC 4-722-01 for additional requirements.

FOOD SERVICE — Enlisted Dining Rooms

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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Wall mounted indirect luminaire.*	*Linear T8 or T5HO or compact fluorescent light sources\2\./2/*	*Integrate control of luminaires with available daylight. \2\ Daylight dimming./2/*
B	*Suspended luminaire.*	*Compact fluorescent light sources /2/ or LED. /2/ \2\/2/*	*Integrate control of luminaires with available daylight. \2\ Daylight dimming./2/*

/1/

CRITICAL DESIGN ISSUES:

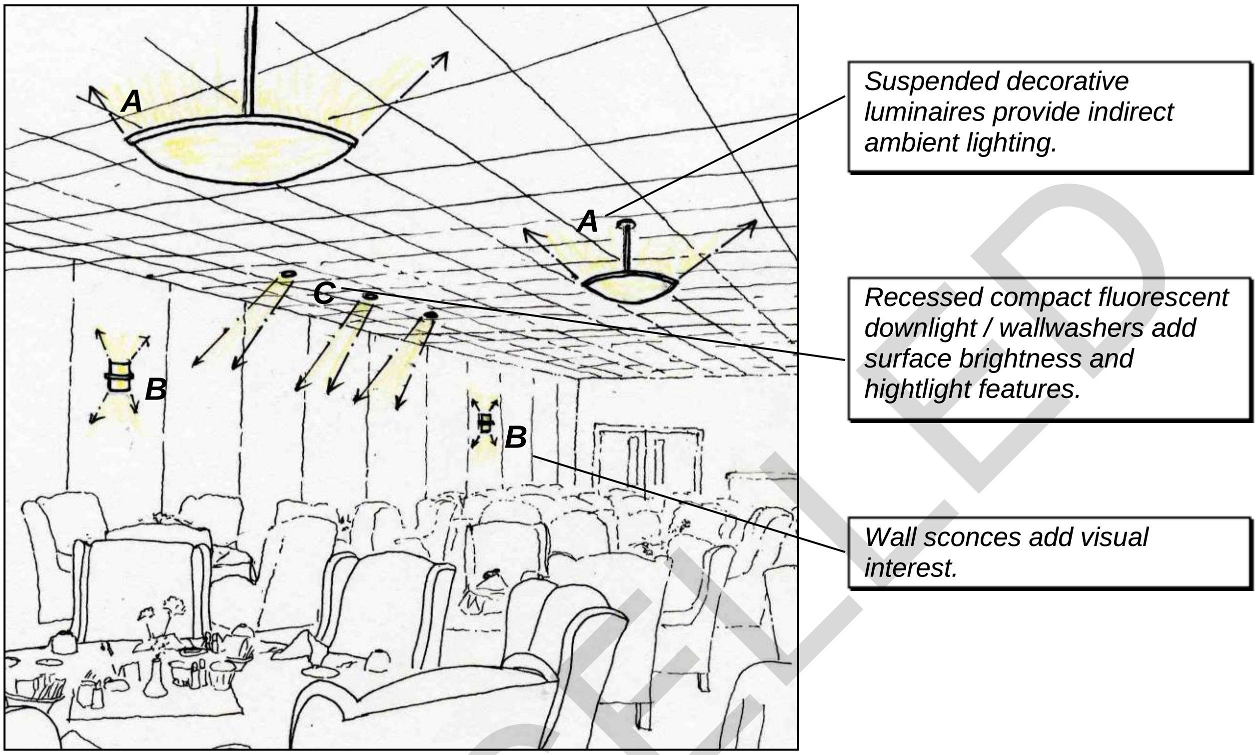
- Color Appearance: The appearance of food served in the dining areas should be vivid and aesthetically pleasing. Often halogen light sources illuminate food at a point of display. Where fluorescent light sources are used, they should be specified with a high color-rendering index (CRI).
- Modeling of Faces or Objects: The modeling of food texture and appearance is especially important where it is displayed and served. Directional accent light, in addition to the ambient light, highlights the food and provides adequate modeling.

- Direct Glare: Avoid excessive luminaire brightness in dining rooms where people will be sitting for long periods of time. Accent lighting should use low wattage light sources and be aimed to minimize direct glare.
- Target Horizontal Illuminance (± 10%): 100 lux (10 fc) average; 500 lux (50 fc) average on food display, \2\egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

The lighting system in a dining area should provide a soft ambient light and a visually comfortable environment with occasional accent lighting to add interest to the space. It is important to note that accent lighting can only be effective when the ambient light level is low enough for a contrast to be noticeable. People see and respond to *changes* in brightness. A highlighted area must be between three and five times brighter than the surroundings to be perceived as a brighter area. A high ambient light level makes accent lighting nearly impossible without using an enormous amount of energy.

Suspended luminaires over serving tables add a decorative accent, but should not consume a lot of energy. This decorative effect can be achieved with a very low wattage light source. Additionally, because the luminaire may be in someone's field of view, a low wattage light source will prevent direct glare. Refer to UFC 4-722-01 for additional requirements.



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended decorative uplight.*	*Compact fluorescent light source., \2\./2/*	*Control ambient and accent lighting separately. Provide dimming.*
B	*Wall mounted sconce.*	*Compact fluorescent \2\ or LED /2/ light sources. \2\./2/*	*Control ambient and accent lighting separately.*
C	*Recessed downlight wallwasher.*	*Compact fluorescent light sources \2\ or LED. /2/*	*Control ambient and accent lighting separately. Provide dimming.*
C ALT	*Recessed linear downlight / wallwashers.*	*Linear fluorescent T8 or T5HO light source. \2\/2/*	*Control ambient and accent lighting separately. Provide dimming.*

/1/

CRITICAL DESIGN ISSUES:

- Color Appearance (and Color Contrast): The appearance of food served in the dining areas should be vivid and aesthetically pleasing. Often halogen light sources illuminate food at a point of display. Where fluorescent light sources are used, they should be specified with a high color-rendering index (CRI).

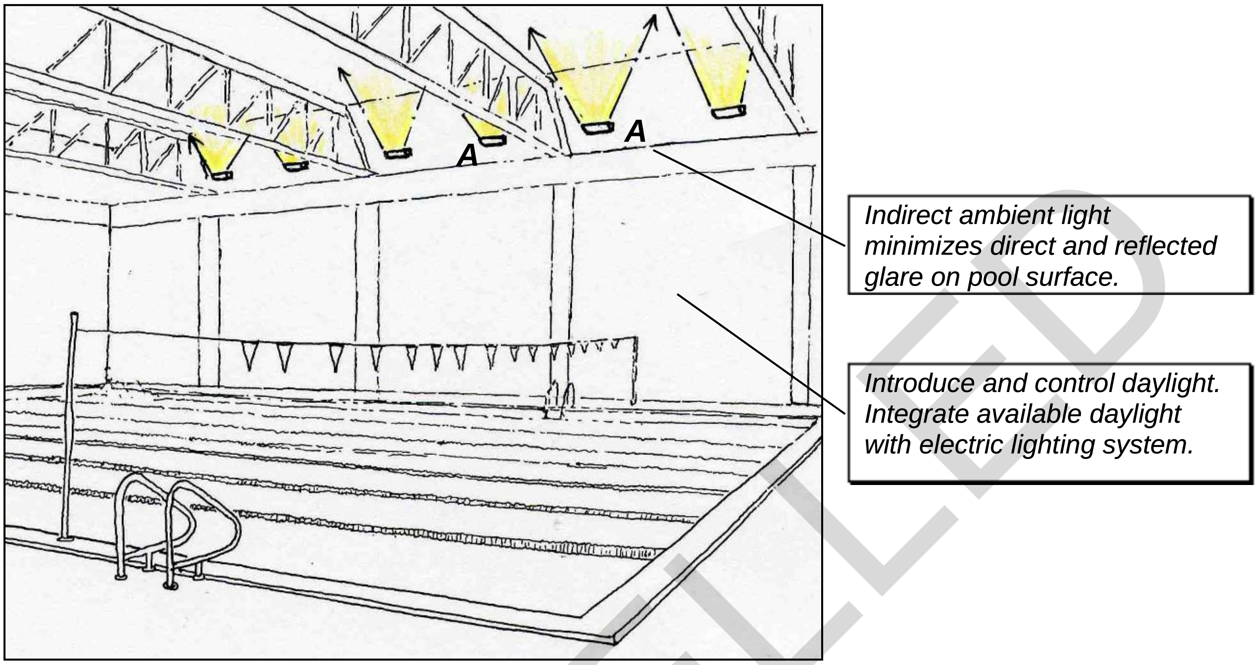
- Appearance of Space and Luminaires: Because officer dining rooms may also host guests from time to time, carefully consider the aesthetic character and appearance of the lighting equipment. Additionally, consider the surfaces and features of the space that should be accented and illuminated.
- Modeling of Faces or Objects: The modeling of food texture and appearance is especially important where it is displayed and served. Additionally, lighting should illuminate the diners softly and provide adequate modeling of their faces.
- Direct Glare: Avoid excessive luminaire brightness in dining rooms where people will be sitting for long periods of time.
- Target Horizontal Illuminance (± 10%): 100 lux (10 fc) average; 500 lux (50 fc) average on food display. \2\ Egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

The lighting system in officers' dining areas should provide a soft ambient light and a visually comfortable environment with occasional accent lighting to add visual interest to the space. It is important to note that accent lighting can only be effective when the ambient light level is low enough for a contrast to be noticeable. The human eye sees and responds to *changes* in brightness. A highlighted area must be between three and five times brighter than the surroundings to be perceived as a brighter area. A high ambient level makes accent lighting nearly impossible without using an enormous amount of energy. Carefully choose the surfaces and architectural features that are accented for the desired effect.

Suspended luminaires over tables add a decorative accent, but should not consume a lot of energy. This decorative effect can be achieved with a very low wattage. Additionally, because the luminaire may be in someone's field of view, a low wattage light source will avoid direct glare. Dimming control provides a range of light levels and allows for multiple lighting "scenes". Refer to UFC 4-722-01 for additional requirements.

RECREATIONAL FACILITIES — Indoor Swimming Pools



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Wall mounted uplight.*	*Linear T5HO fluorescent \2\ induction, or metal halide. /2/*	*Manual on/off or dimming control with daylight.*

/1/

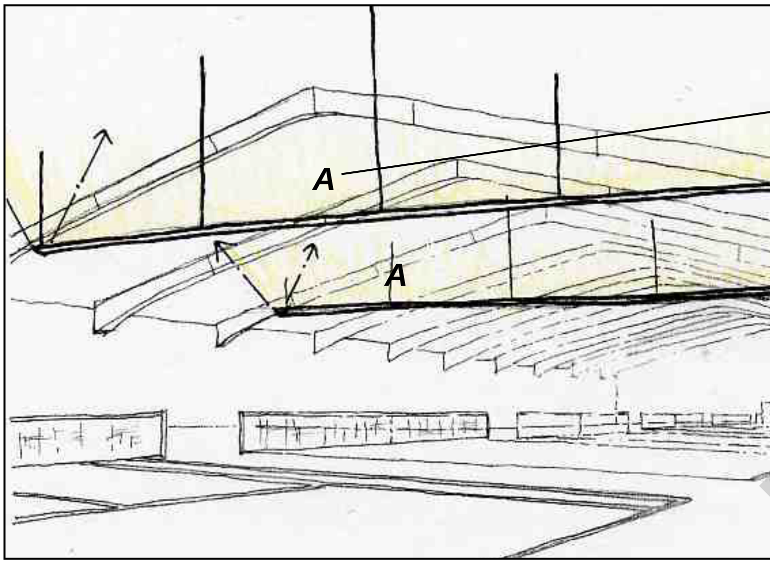
CRITICAL DESIGN ISSUES:

- Direct Glare: Select, locate and shield luminaires to avoid direct glare.
- Reflected Glare: Select luminaires to avoid a direct component that would result in direct glare. This is especially important considering that the water and a wet deck provide specular surfaces.
- Target Horizontal Illuminance (± 10%): For recreational class of play: 300 lux (30 fc) average. For other classes of play, see IES RP-6. Refer to UFC 4-740-02 for additional requirements. \2\ Egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

The lighting design should avoid direct and reflected glare on the water surface. Also consider maintenance and accessibility. Locate luminaires above the deck and at the edge of the pool to allow for access and re-lamping.

RECREATIONAL FACILITIES — Indoor Tennis Courts



Suspended indirect ambient light minimizes shadowing and prevents direct glare.

Introduce and control daylight. Integrate available daylight with electric lighting system.

\1\

EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended linear indirect/direct luminaire.*	*\2\ /2/ Linear fluorescent T8 or T5HO light sources.\2\/2/*	*Manual on/off or dimming control with daylight.*

/1/

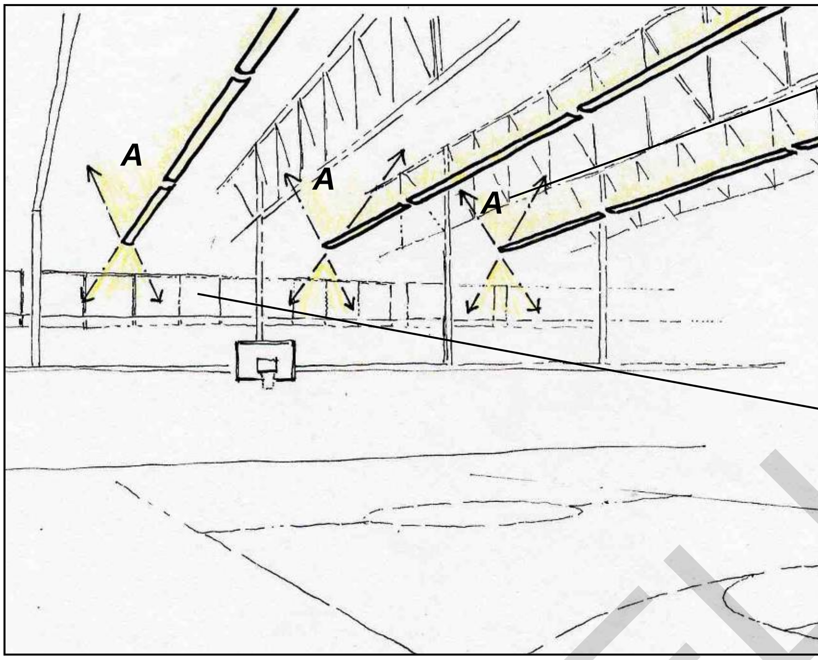
CRITICAL DESIGN ISSUES:

- Direct Glare: Locate and shield or lens luminaires to avoid direct glare. With indirect fluorescent luminaires this is not an issue.
- Flicker (and Strobe): Flicker and strobe of fluorescent luminaires is generally not an issue when using electronic ballasts. If it does occur, it can impair the viewing of high-speed objects such as a tennis ball.
- Light Distribution on Task Plane (Uniformity): The lighting system needs to uniformly illuminate the court. Any dark spots or patterns of light will create confusing and distracting areas.
- Target Horizontal Illuminance (± 10%): For recreational class of play: 500 lux (50 fc) average. For other classes of play, see IES RP-6. Refer to UFC 4-740-02 for additional requirements. \2\ Egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

Traditionally tennis courts are illuminated with metal halide light sources. While this is a common solution, indirect T5HO fluorescent uplights can provide a much better visual environment. Additionally, the initial cost of the system is the same or less expensive than a metal halide system and the fluorescent maintenance and energy costs are lower. When daylight is plentiful, the fluorescent lighting can be dimmed or turned off.

RECREATIONAL FACILITIES — Indoor Basketball Courts



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended linear luminaire (50% direct / 50% indirect).*	*\2\ /2/ Linear fluorescent T8 or T5HO light sources.\2\/2/*	*Manual on/off or dimming control with daylight.*

/1/

CRITICAL DESIGN ISSUES:

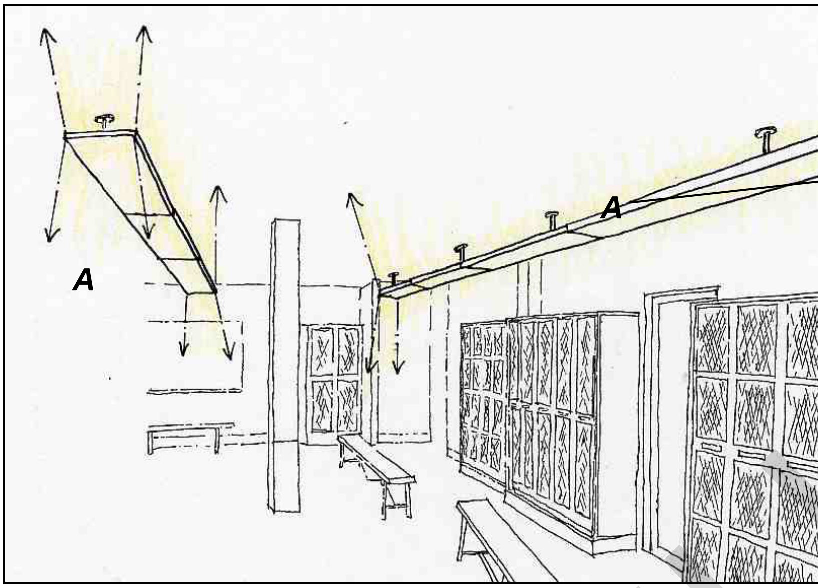
- Direct Glare: Locate and shield or lens equipment to avoid direct glare.
- Light Distribution on Task Plane (Uniformity): The lighting system needs to uniformly illuminate the court. Any dark spots or patterns of light will create a confusing and distracting area.
- Reflected Glare: Polished wood floors can reflect the image of the light source above causing an annoying distraction.
- Shadows: Minimize shadows to enhance the view of the ball and other players.
- Target Horizontal Illuminance (± 10%): For recreational class of play: 300 lux (30 fc) average. For other classes of play, see IES RP-6. Refer to UFC 4-740-02 for additional requirements. \2\ Egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

Traditionally basketball courts and gymnasiums are illuminated with metal halide light sources. While this is a common solution, indirect T5HO fluorescent uplights can provide a much better visual environment. Such a system reduces direct and reflected glare. Additionally, the initial cost of the system is the same or less expensive than a metal halide system and the fluorescent maintenance and energy costs are lower.

Consider multiple uses of such spaces. Often basketball courts may be used for other sports such as volleyball and even social functions. Provide a lighting system that can provide the highest light level that may be required and then utilize controls to address various uses of the space. In the case of a fluorescent system, light sources within luminaires can be switched separately. For metal halide designs, consider circuiting luminaires alternately so that a partial quantity can be switched off. Refer to UFC 4-740-02 for additional requirements.

RECREATIONAL FACILITIES — Locker Rooms



\1\

EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended linear indirect / direct luminaire.*	*\2\ /2/ Linear fluorescent T8 or T5HO light sources.\2\/2/*	*Control with occupancy or vacancy sensors.*
A ALT	*Surface mounted linear strip on top of lockers.*	*\2\ /2/ Linear fluorescent T8 or T5HO light sources.\2\/2/*	*Control with occupancy or vacancy sensors.*

/1/

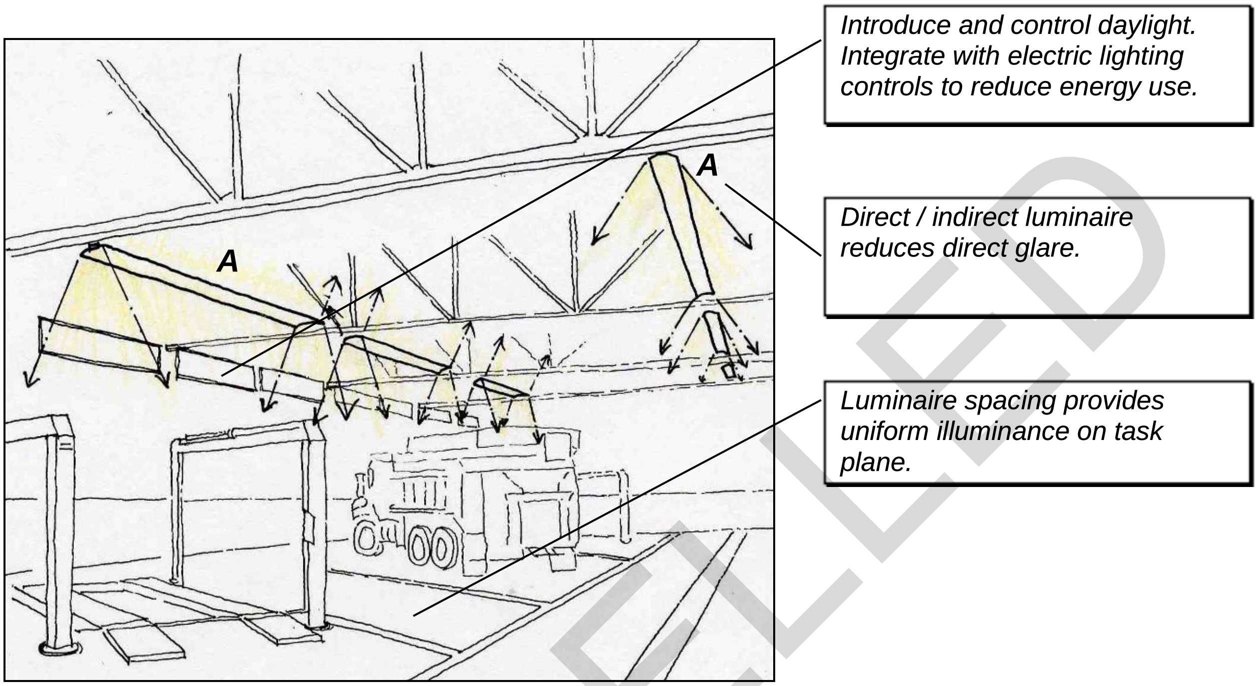
CRITICAL DESIGN ISSUES:

- Color Appearance (and Color Contrast): In order to identify colors of clothes it is very important to provide fluorescent lighting with good color-rendering properties.
- Shadows: By providing an indirect component of the lighting system, it will put some light into the lockers even when someone is standing in front of it. If a downlight only system is used light may be blocked by the user and the locker interior will be dark.
- Target Horizontal Illuminance (± 10%): IES recommends 100 lux (10 fc) average. Refer to UFC 4-740-02 for additional requirements. \2\ Egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

The ambient lighting for a locker room is low with little task lighting required, with the exception of a higher light level at sinks. In addition to the scheme presented here, linear fluorescent strips can also be mounted on top of the banks of lockers, uplighting the ceiling in a completely indirect lighting system.

MAINTENANCE FACILITIES Vehicle Storage / Repair Areas



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended linear direct / indirect luminaire.*	*\2\ Linear fluorescent T8 or T5HO light sources.\2\/2/*	*Dimming control with available daylight.*
A ALT	*Surface mounted low bay luminaire.*	*Induction light source*	*Control with occupancy and daylight sensors.*
B	*Portable task lighting.*	*\2\ LED /2/ or compact fluorescent light source.*	*Manual on/off.*

/1/

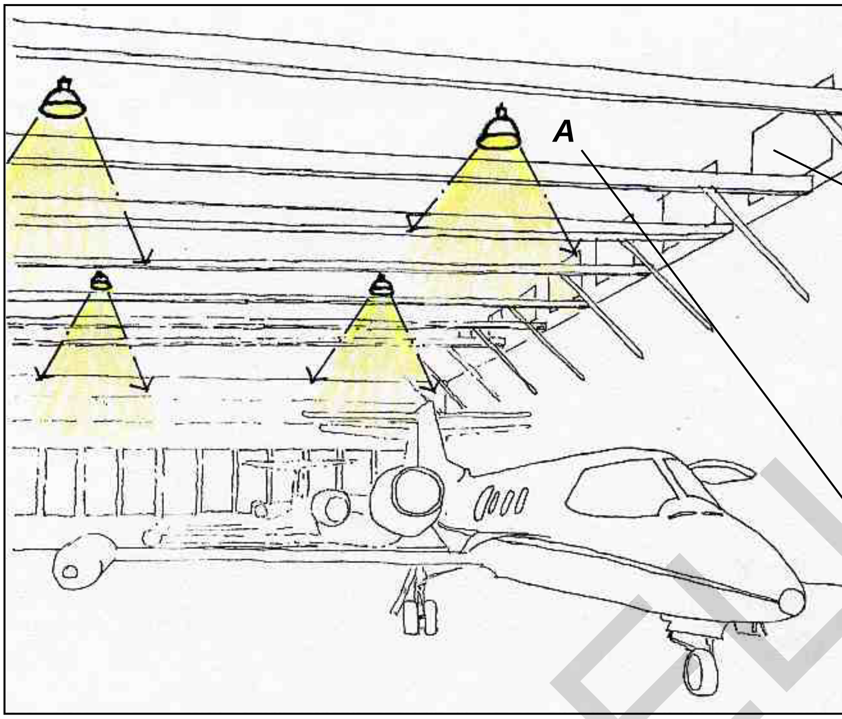
CRITICAL DESIGN ISSUES:

- Direct Glare: Direct glare is not only an annoyance when experienced for a short period of time, but can also cause fatigue when working for an extended period. Because the luminaires are located relatively high above the task plane, direct glare will most likely be avoided. Fluorescent light sources also distribute brightness over a large area, also reducing glare from the luminaire.
- Flicker (and Strobe): This strobe effect is critical when working with high-speed machinery. If the garage will be used as a shop with any kind of rotating tool, high quality electronic ballasts need to be specified to avoid a flicker effect.

- Light Distribution on Surfaces: With a small indirect component from the luminaires, the ceiling will have some surface brightness that reduces contrast and improves visual comfort in the space.
- Light Distribution on Task Plane (Uniformity): Design luminaire layout to uniformly distribute light over the work-plane to avoid dark areas in the space.
- Shadows: Select and locate luminaires to avoid shadows on the work-plane. Task lighting can also increase the illuminance on the task as well as eliminate shadows.
- Source / Task Eye Geometry: Locate luminaires relative to tasks to avoid direct glare and prevent shadowing.
- Illuminance on Task Plane: Maintenance on vehicles often requires high lighting levels. This may be accomplished with high vertical south and north oriented clerestories. Electric lighting, such as linear high output fluorescents can provide direct and indirect lighting for the most uniform application when daylight levels are insufficient. Portable task lighting can increase illuminance to the required level at the particular task.
- Target Horizontal Illuminance (± 10%): 500 lux (50 fc) average, \2\ egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

Although light level is important to achieve in a vehicle repair area, uniformity and the prevention of glare and shadowing also must be achieved to provide a comfortable and functional workspace. Portable task lighting allows for higher light levels at the task location without increasing the overall ambient level throughout the space.



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended luminaire.*	*Induction light source or metal halide.*	*Integrate controls with available daylight. \2\Dimming for induction, switching for metal halide./2/*
A ALT	*Suspended linear luminaire with small uplight component.*	*\2\ /2/Linear fluorescent T8 or T5HO light sources\2./2/*	*Control with occupancy and daylight sensors.*
B	*Portable task lighting.*	*\2\ LED /2/ or compact fluorescent light source.*	*Manual on/off.*

/1/

CRITICAL DESIGN ISSUES:

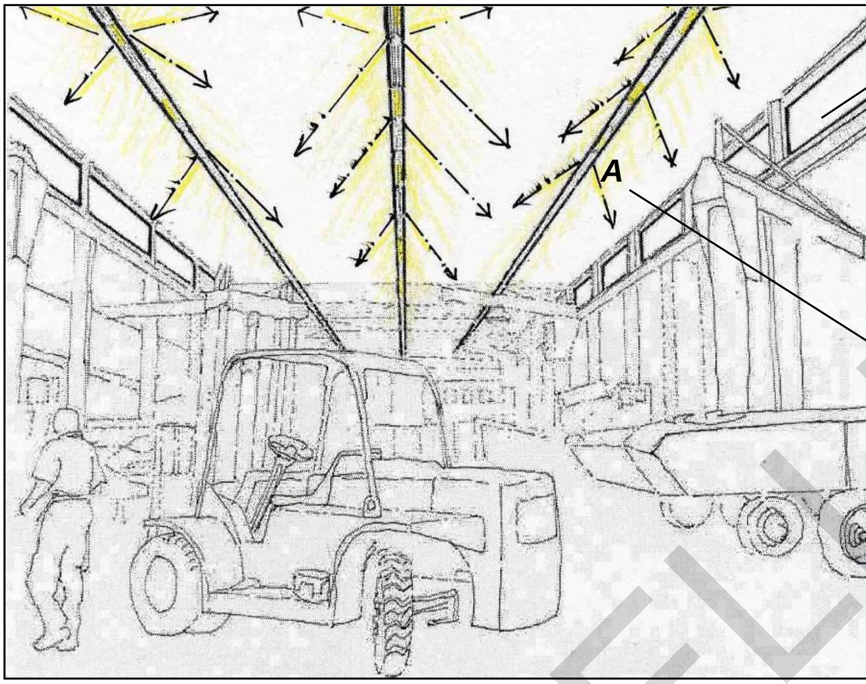
- Direct Glare: Because the luminaires are located relatively high above the task plane, direct glare will most likely be avoided. Fluorescent light sources distribute brightness over a large area (larger than metal halide light sources), further reducing glare from the luminaire.
- Flicker (and Strobe): This strobe effect is critical when working with high-speed machinery. If the hangar will be used as a shop with any kind of rotating tool, high quality electronic ballasts need to be specified to avoid a stroboscopic effect.

- Light Distribution on Surfaces: With a small indirect component from the luminaires, the ceiling above will have some surface brightness, reducing contrast between ceiling and luminaire, improving visual comfort in the space.
- Light Distribution on Task Plane (Uniformity): Design luminaire layout to uniformly distribute light over the work-plane to avoid dark areas in the space.
- Shadows: Select and locate luminaires to avoid shadows on the repair areas of the hangar. Portable task lighting can also increase the illuminance on the task as well eliminate shadows.
- Target Horizontal Illuminance (± 10%): 500 lux (50 fc) average, \2\ egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

By introducing daylight high in the space, much of electric lighting can be turned off during the day. Although light level is important to achieve in a hangar, uniformity and the prevention of glare and shadowing also must be achieved to provide a comfortable and functional workspace. Portable task lighting allows for higher light levels at the task location without increasing the overall ambient level.

MAINTENANCE FACILITIES Motorpools



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Surface mounted or suspended industrial luminaire.*	*\2\ /2/ Linear fluorescent T5HO light sources\2\./2/*	*Dim lights with occupancy and daylight sensors.*
A ALT	*Surface mounted low bay luminaire.*	*Induction light source.*	*Dim lights with occupancy and daylight sensors.*
B	*Portable task lighting.*	*\2\ LED /2/ or compact fluorescent light source.*	*Manual on/off.*

/1/

CRITICAL DESIGN ISSUES:

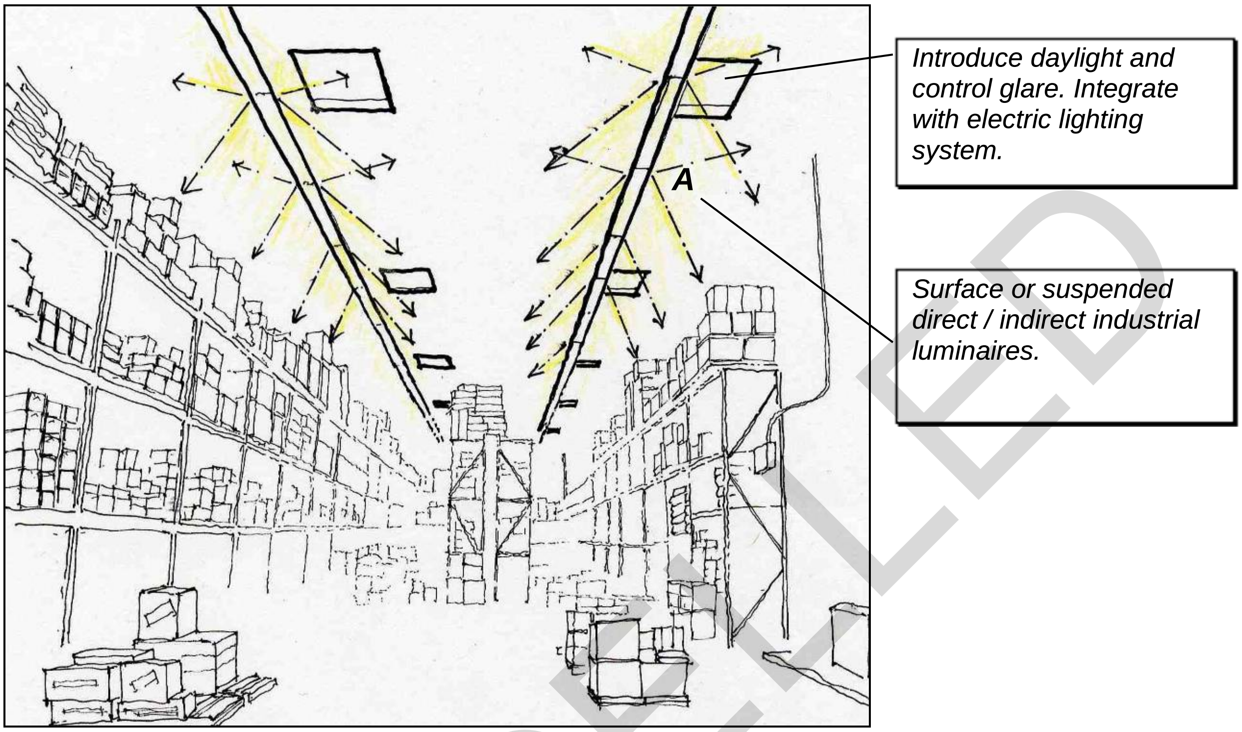
- Horizontal and vertical illuminance: Maintenance on vehicles may require high lighting levels. This may be accomplished with high vertical south and north facing clerestories. Electric lighting, such as linear fluorescent light sources can provide direct and indirect lighting for the most uniform application when daylight levels are insufficient.
- Source/Task Eye Geometry: When maintaining vehicles, it is very important to have the light coming from an angle that will not cause extraneous shadows. Linear sources such as clerestories and linear fluorescent light sources will minimize confusing shadows. Portable task lighting is encouraged to increase light levels at the location of a particular task.

- Color Appearance and Contrast: Maintaining vehicles demands excellent color-rendering and contrast recognition such as for metal-to-metal parts and components. The lighting system must provide good color rendering and enhance contrast.
- Target Horizontal Illuminance (± 10%): 500 lux (50 fc) average, \2\ egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

Just as important as the light level, the light distribution in motor pools should minimize shadows and illuminate uniformly over the task plane. Portable task lighting allows for higher light levels at the task location without increasing the overall ambient level. A combination of daylight and diffuse fluorescent lighting provides a high level of visibility. If daylight is plentiful, the electric lighting can be turned off or dimmed.

MAINTENANCE FACILITIES Warehouses



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended industrial luminaire with 5% - 10% uplight.*	*\2\ Linear fluorescent T8 or T5HO light sources/2/*	*\2\ Step dim /2/ lights with occupancy and daylight sensors.*
A ALT	*Surface mounted low bay luminaire.*	*Induction light source.*	*\2\ Step dim /2/ lights with occupancy and daylight sensors.*

/1/

CRITICAL DESIGN ISSUES:

- Horizontal and Vertical Illuminance: Toplighting is one strategy to introduce daylight and provide uniform light levels. Electric lighting, such as linear fluorescent light sources can provide direct and indirect lighting when daylight levels are insufficient.
- Source/Task Eye Geometry: Locate luminaires to minimize direct glare and to light shelves uniformly with minimal shadowing.
- Color Appearance and Contrast: In warehouses, individuals may need to locate and sort items. Provide light source sources with a high color-rendering index to accurately portray colors and labels.

- Target Vertical Illuminance (± 10%): Varies with use of space: 50 lux (5 fc) average for inactive storage - 300 lux (30 fc) average for active warehousing. Egress lighting as required (see Section 5-6 Emergency and Exit Lighting).

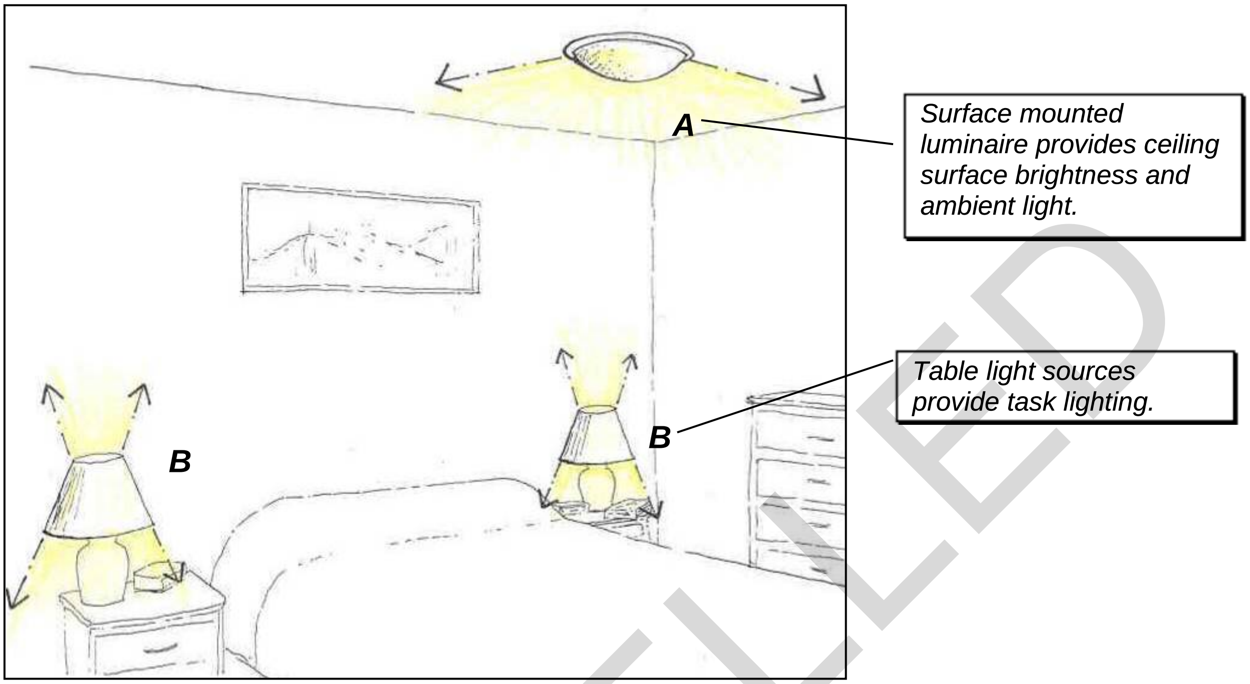
DISCUSSION:

The lighting for warehouses depends on the use of the facility. For infrequent use where the warehouse is used mostly for storage, the light level can be very low and preferably activated by a motion sensor. If sorting or inspection will be taking place or if people will be spending an extended period of time in the space, the light level should be higher.

It is also important to select a luminaire and develop a layout that provides vertical illuminance on the shelves. This facilitates identification of stored items.

If daylight can be introduced into the space, lighting control \1\ need to dim /1/ the electric lighting system with the available daylight, turning off unnecessary luminaires. Additionally, occupancy sensors not only save energy by turning on the luminaires only when needed, but also provide a convenience for anyone entering and leaving the space with hands full.

RESIDENTIAL HOUSING — Bedrooms



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Surface mounted luminaire.*	*Compact fluorescent \2\ or LED /2/ light sources\2\./2/*	*Manual on/off.*
A ALT	*Wall mounted sconce.*	*Compact fluorescent \2\ or LED/2/ light sources. \2\/2/*	*Manual on/off.*
B	*Table lamp.*	*Compact fluorescent \2\ or LED /2/ light sources\2\./2/*	*Manual on/off.*

/1/

CRITICAL DESIGN ISSUES:

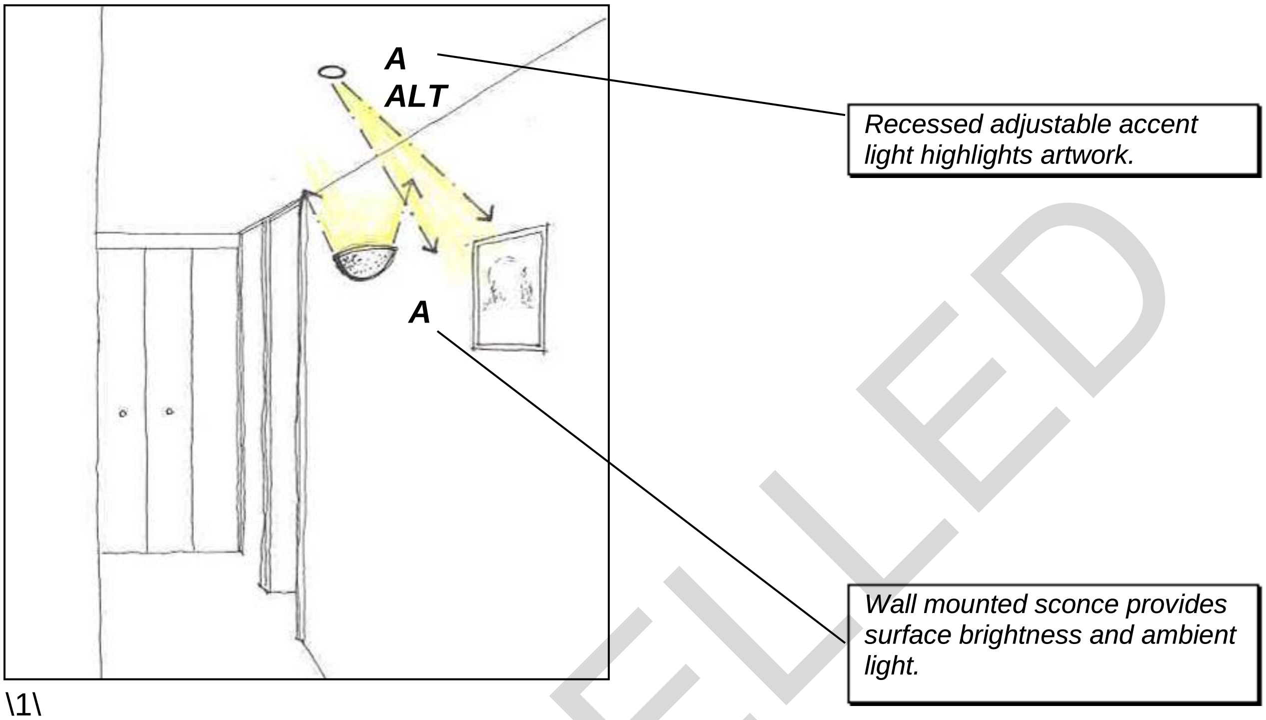
- Direct Glare: Locate and aim sources to avoid direct glare. This is especially important regarding lighting located above the bed to light artwork. Luminaires in this position may cause direct glare for a person reading bed.
- Reflected Glare: For a person reading in bed, locate task lighting to avoid reflected glare and veiling reflections on reading material.
- Horizontal and Vertical Illuminance (for reading): Task lighting needs to provide adequate illuminance on reading material. The light level required for reading should not be achieved with the ambient lighting alone. Task lighting (in the form of bedside lamps) allows flexibility and greater control over the lighting energy use.

- Target Horizontal Illuminance (± 10%): 50 lux (5 fc) average with higher light levels provided by table lamps for reading tasks.

DISCUSSION:

Compact fluorescent \2\ and LED /2/ lighting is now available in residential luminaires such as table lamps, wall sconces, and overhead lighting. Dimming is available with dimmable ballasts \2\ or drivers /2/. Also, the 3000K-light source color closely resembles that of an incandescent light source.

RESIDENTIAL HOUSING — Hallways



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Wall mounted sconce.*	*Compact fluorescent \2\ or LED /2/ light sources\2\./2/*	*Manual on/off with multi-location control. Consider the use of occupancy \2\ or vacancy /2/ sensors and dimming.*
A ALT	*Recessed or surface mounted accent light.*	*Controlled beam, tungsten halogen \2\ or LED /2/ light source \2\./2/*	*Manual on/off with multi-location control. Consider the use of occupancy \2\ or vacancy /2/ sensors and dimming.*
A ALT	*Surface mounted luminaire.*	*Compact fluorescent \2\ or LED /2/ light sources\2\./2/*	*Manual on/off with multi-location control. Consider the use of occupancy \2\ or vacancy /2/ sensors and dimming.*

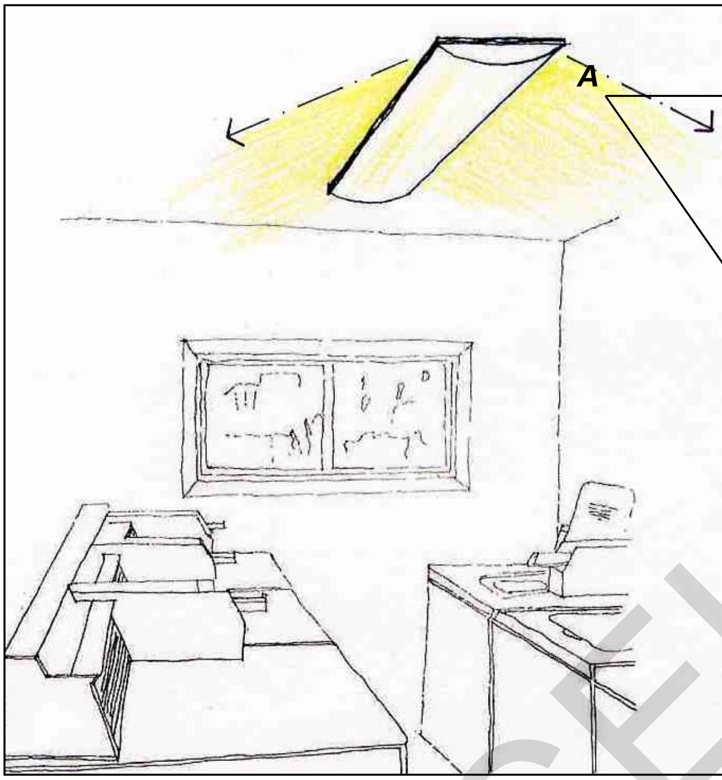
/1/

CRITICAL DESIGN ISSUES:

- Direct Glare: Always avoid direct glare, even in areas that are occupied briefly. In the case of hallways, low brightness luminaires create a soft ambient lighting environment for wayfinding without the annoyance of direct glare.

- Horizontal and Vertical Illuminance: Adequate light levels need to be provided for safety in hallways. With low brightness luminaires and uniform surface brightness in the space, these light levels can be low relative to adjacent spaces.
- Target Horizontal Illuminance (± 10%): 30 lux (3 fc) average.

RESIDENTIAL HOUSING — Laundry Rooms



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EQUIPMENT REQUIREMENTS: /1/

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Surface mounted linear luminaire.*	*\2\ /2/Linear fluorescent T8 light sources\2\./2/*	*Control with occupancy sensors.*

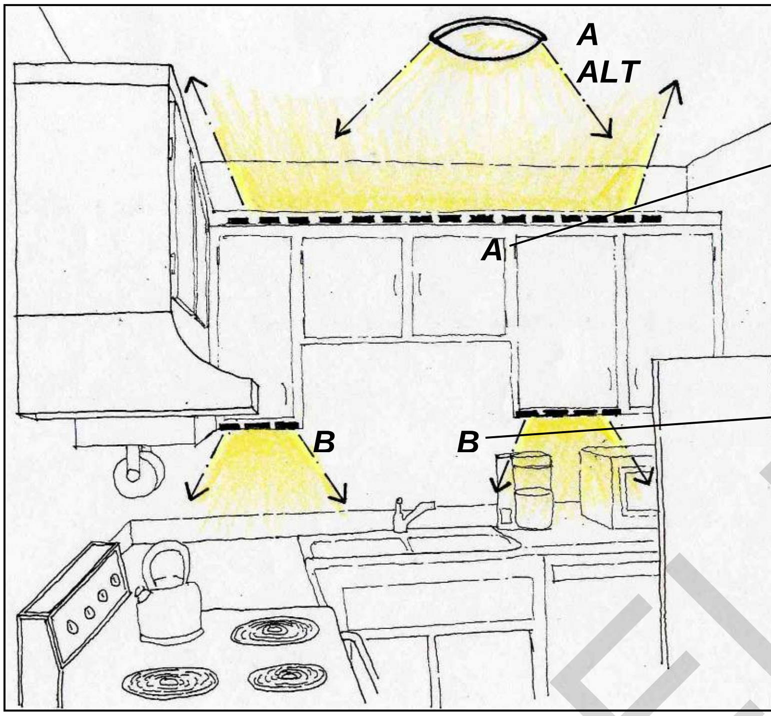
CRITICAL DESIGN ISSUES:

- Color Appearance and Contrast: In order to identify clothes colors (such as matching blue or brown socks), it is very important to provide fluorescent lighting with good color-rendering properties. In addition, the contrast on the task should be minimal. Locate the lighting so that body shadows do not interfere with seeing the task.
- Target Horizontal Illuminance (± 10%): 300 lux (30 fc) average.

DISCUSSION:

Laundry rooms provide a good opportunity for the use of occupancy sensors. In this type of space, people usually leave with their hands full so automatic control of the lights is a convenience as well as an energy savings. Because the room is used infrequently, lights left on will be on for a long time.

RESIDENTIAL HOUSING Kitchens



Concealed strips uplight the ceiling. (Ceiling brightness could also be achieved with a surface mounted luminaire.)

Undercabinet tasklights illuminate countertop.

Introduce daylight with the use of windows, skylights, or light tubes. Provide controls to turn off lighting that is not required.

\1\

EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Surface mounted linear strip.*	*\2\ /2/Linear fluorescent T8 light sources\2\./2/*	*Control ambient and task lighting separately.*
A ALT	*Ceiling mounted luminaire.*	*Compact or linear fluorescent \2\ or LED/2/ light sources\2\./2/*	*Control ambient and task lighting separately.*
B	*Surface mounted undercabinet tasklight.*	*\2\ /2/ Linear fluorescent T8 \2\ or LED /2/ light sources\2\./2/*	*Control ambient and task lighting separately. Consider dimming control.*
B ALT	*Surface mounted linear or surface/recessed puck.*	*\2\LED./2/*	*Control ambient and task lighting separately. Consider dimming control.*

/1/

CRITICAL DESIGN ISSUES:

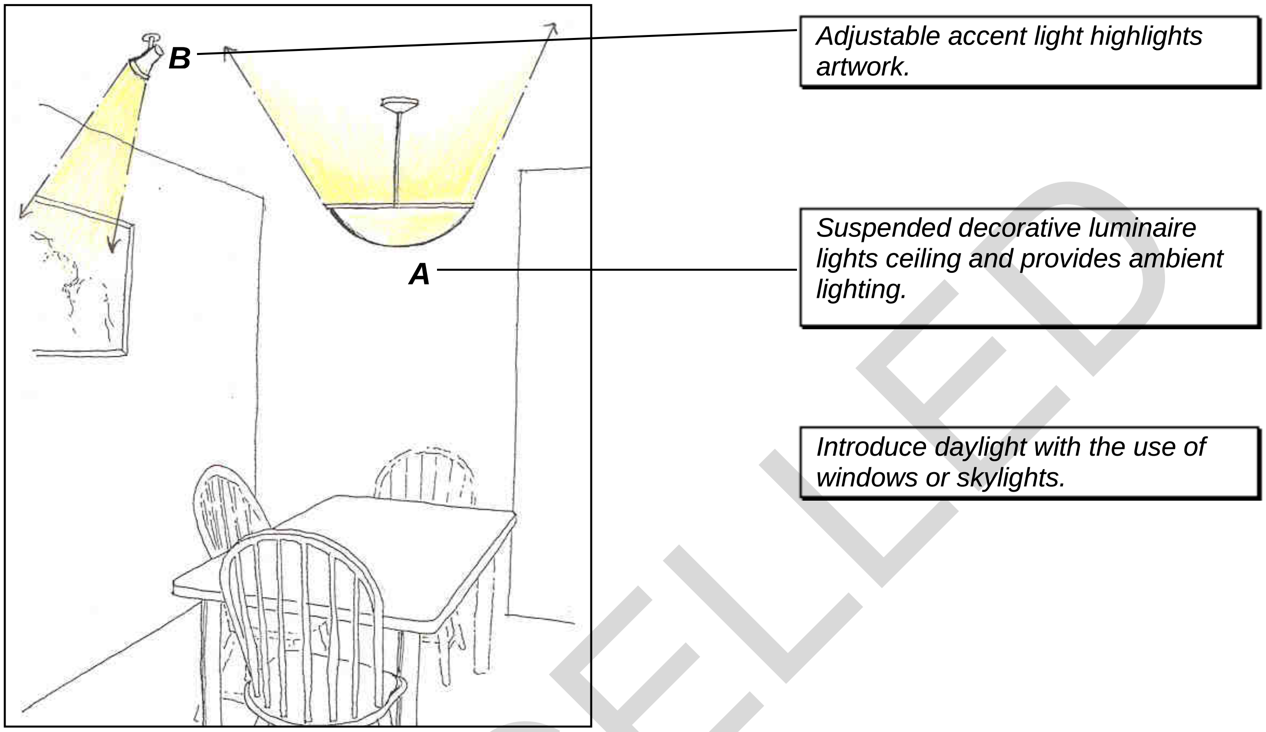
- Color Appearance and Contrast: In kitchens, the color appearance of food is very important. Kitchens are also the gathering places for friends and family, so good color appearance and realistic contrast should be achieved.
- Direct Glare: During food preparation or conversation, direct glare can become an irritant. Using indirect ambient lighting and under-counter task lighting can greatly reduce the direct glare.

- Reflected Glare: If lighting is improperly placed directly in front of the cook, reading recipes and preparing food can be a challenge. Minimize reflected glare with proper lighting equipment locations.
- Source/Task Geometry: Overhead ambient lighting and under-counter task lighting will minimize confusing shadows. Locate luminaires so that shadows are minimized and the light is where it is needed.
- Horizontal and Vertical Illuminance: In order to prepare food, read recipes and communicate with friends and family, adequate lighting levels need to be provided. Dimming the lighting can not only save energy, but give flexibility to the occupant.
- Target Horizontal Illuminance (± 10%): 300 lux (30 fc) average.

DISCUSSION:

Traditionally, kitchen lighting has been accomplished with a single overhead luminaire located in the center of the kitchen. With this arrangement, preparing food at the counter is a challenge, since the body shadows the work area. Ideally, locate luminaires above the cabinets so that the kitchen is filled with indirect ambient light. Then, locate under-cabinet luminaires for localized task lighting. Direct, recessed lighting is appropriate over the sink area or other areas without overhead cabinets.

RESIDENTIAL HOUSING — Dining Room



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended luminaire.*	*Compact fluorescent \2\ or LED /2/ light sources\2\./2/*	*Control ambient and accent lighting separately. Provide dimming.*
A ALT	*Ceiling mounted luminaire.*	*Compact fluorescent \2\ or LED /2/ light sources\2\./2/*	*Control ambient and accent lighting separately. Provide dimming.*
B	*Recessed or monopoint mounted adjustable accent light.*	*Tungsten halogen \2\ or LED /2/ directional light source. \2\ /2/*	*Control ambient and accent lighting separately. Consider dimming to extend light source life.*

/1/

CRITICAL DESIGN ISSUES:

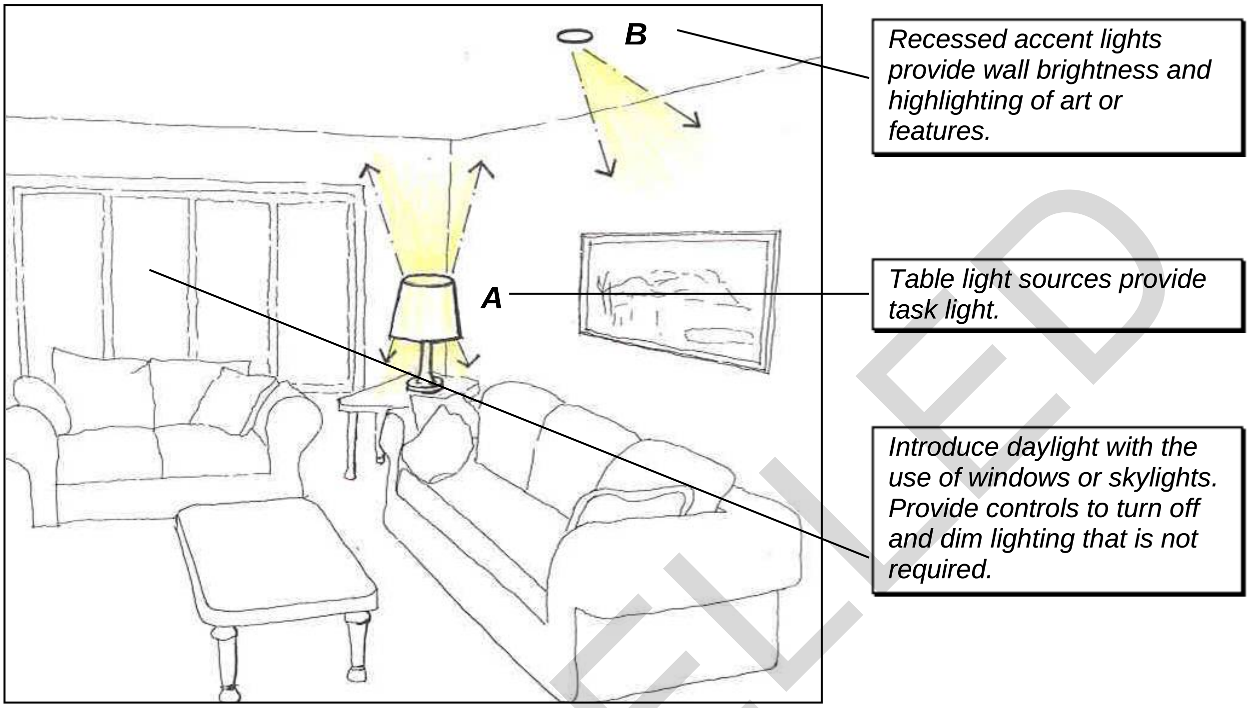
- Color Appearance and Contrast: In dining rooms, the color appearance of food is very important. Dining rooms are also the gathering places for friends and family, so good color appearance and realistic contrast should be achieved.
- Direct Glare: Direct glare can become a distraction during dinner and should be avoided by providing appropriate low glare sources for ambient lighting and by aiming accent lighting away from those seated at the table.

- Modeling of Faces and Objects: Low glare light from multiple sources provides adequate shadowing, depth perception, and modeling of any object in the room, including people.
- Horizontal Illuminance: Because dining tables may also be used as a desktop, adequate light levels must be maintained on the work plane. This amount of light should not be the default ambient light level, but should be controlled lighting that is only provided when necessary.
- Target Horizontal Illuminance (± 10%): 50 lux (5 fc) average.

DISCUSSION:

Like living rooms, dining rooms are often used for variety of tasks. A dining room table may serve as a game table or desk as well as a dinner table. The lighting needs to provide a range of light levels to accommodate this range of use. Compact fluorescent \2\ and LED /2/ dimming is available with dimming ballasts \2\ or drivers /2/ for many decorative luminaires.

RESIDENTIAL HOUSING Living Rooms



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EQUIPMENT REQUIREMENTS: /1/

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Table lamp.*	*Compact fluorescent \2\ or LED /2/ light sources\2\./2/*	*Manual on/off.*
A ALT	*Floor light source or torchiere.*	*Compact fluorescent \2\ or LED /2/ light sources\2\./2/*	*Manual on/off.*
A ALT	*Wall mounted uplight.*	*Compact fluorescent \2\ or LED /2/ light sources\2\./2/*	*Include the use of dimmers.*
B	*Recessed wall washer or adjustable accent light.*	*Compact fluorescent \2\ or LED light sources/2/ \2\/2/or tungsten halogen directional light source.*	*Include the use of dimmers. Control ambient and accent lighting separately.*

CRITICAL DESIGN ISSUES:

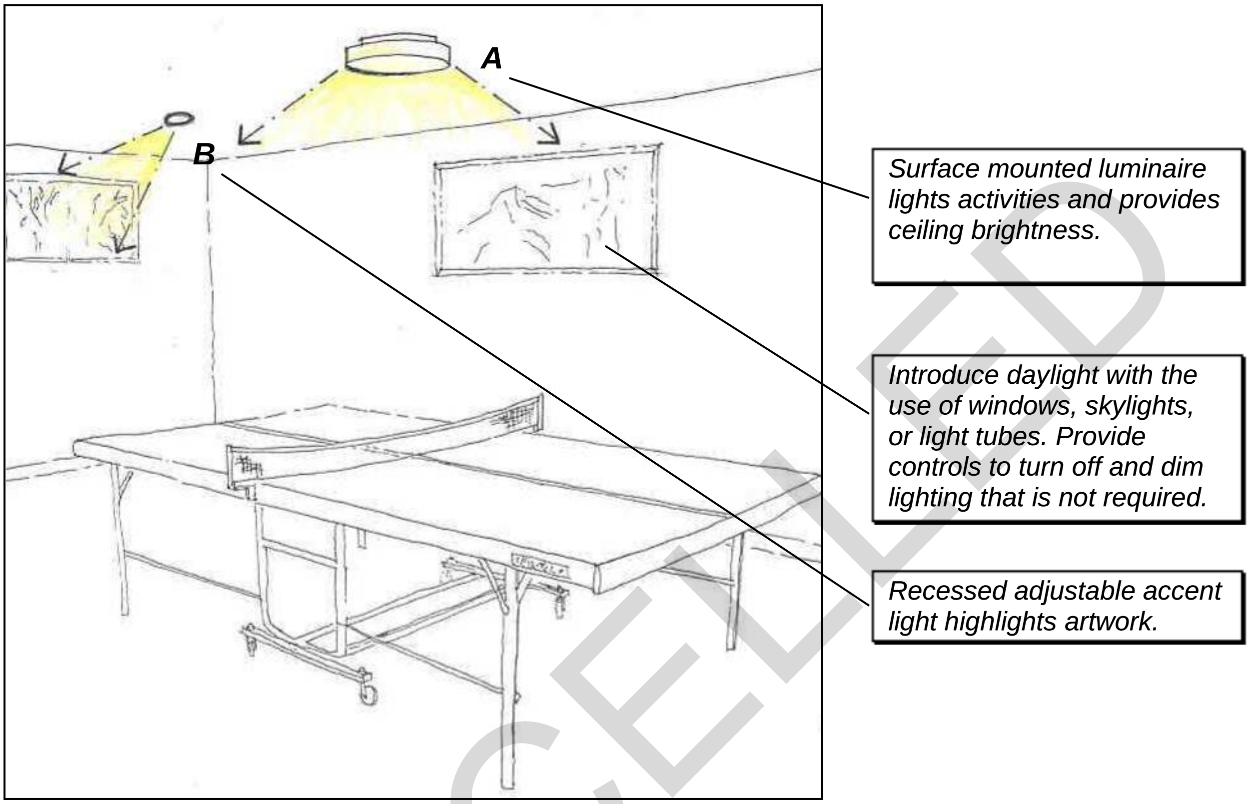
- Direct Glare: Light sources should not cause direct glare for a group of people visiting in a living room, or for a single person reading. Indirect, concealed sources provide for comfortable ambient light while eliminating direct glare.
- Reflected Glare: For a person reading, locate task lighting to avoid reflected glare on reading material.

- Target Horizontal Illuminance (± 10%): 30 lux (3 fc) average.

DISCUSSION:

Living rooms often host a variety of activities. For this reason, controlling the lighting separately and with dimmers, not only saves energy but also allows occupants to adapt the lighting for the current use of the space. This may include casual or formal gatherings, or use by one person. Compact fluorescent \2\ or LED /2/ luminaires are available with dimmable ballasts \2\ or drivers /2/. Tungsten halogen floor torchieres, while popular in such spaces, represent an enormous waste of energy and a significant fire danger. Far more efficient compact fluorescent torchieres are becoming increasingly available.

RESIDENTIAL HOUSING — Rec Rooms



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EQUIPMENT REQUIREMENTS: /1/

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Ceiling mounted luminaire.*	*Compact fluorescent \2\ or LED /2/ light sources\2\./2/*	*Control ambient and task lighting separately. Consider the use of \2\ vacancy/2/ sensors.*
B	*Recessed wall washer or adjustable accent light.*	*Compact fluorescent \2\ or LED light sources /2/ or tungsten halogen directional light source.*	*Include the use of dimmers and \2\ vacancy sensors/2/. Control ambient and accent lighting separately.*

CRITICAL DESIGN ISSUES:

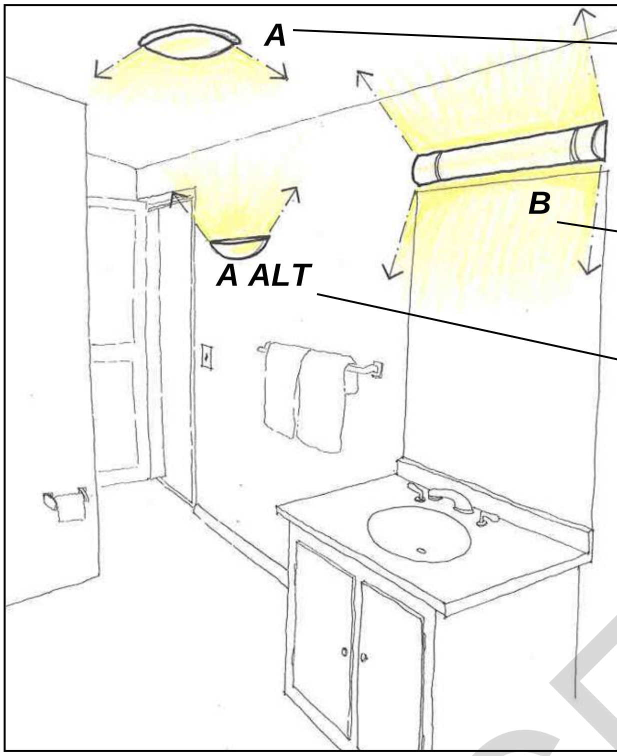
- Direct Glare: Locate and aim sources to avoid direct glare. This is especially important where luminaires are lighting a game table.
- Reflected Glare: position luminaires to avoid reflected glare in any specular surface, especially a TV screen. This type of glare can also occur with glossy ready materials such as magazines.

- Horizontal Illuminance (for reading): Task lighting needs to provide adequate illuminance on reading material. The light level required for reading should not be achieved with the ambient lighting alone. Task lighting (such as table lamps or drafting lamps) allows flexibility and greater control over the lighting and energy use.
- Target Horizontal Illuminance (± 10%): 300 lux (30 fc) average, egress lighting as required (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

Recreation rooms may host a variety of activities. Because of this, some flexibility and control will allow the lighting to adapt to the specific use. Provide adequate light levels for reading and games. However, glare must be avoided, especially for such games as ping-pong or pool. Consider the use of \2\ vacancy /2/ sensors for rec rooms to turn lights off when unoccupied.

RESIDENTIAL HOUSING — Bathrooms



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Surface mounted luminaire.*	*Compact fluorescent \2\ or LED /2/ light sources\2\./2/*	*Control ambient lighting separately from task (vanity) lighting.*
A ALT	*Wall mounted sconce.*	*Compact fluorescent \2\ or LED /2/ light sources\2\./2/*	*Control ambient lighting separately from task (vanity) lighting.*
B	*Wall mounted linear vanity light.*	*\2\ /2/ Linear fluorescent T8 light sources\2\./2/*	*Control ambient lighting separately from task (vanity) lighting.*
C	*Surface mounted or recessed shower light.*	*Compact fluorescent \2\ or LED /2/ light sources\2\./2/*	*Control shower luminaire separately.*

/1/

CRITICAL DESIGN ISSUES:

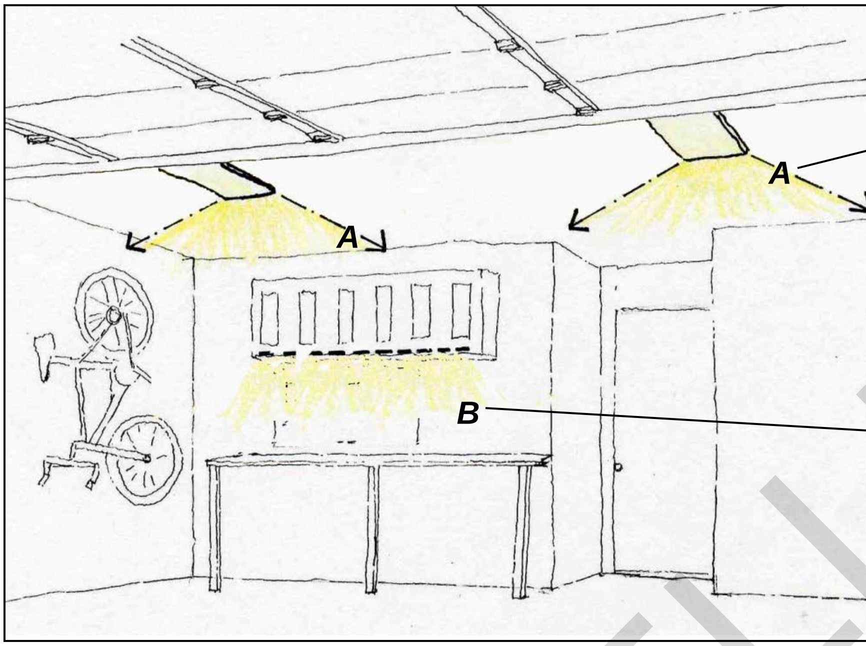
- Color Appearance and Contrast: For make-up application and grooming, the color temperature and rendering characteristics of the light sources should be as high as possible. These will render color accurately and as well as provide adequate color contrast.

- Luminances of Room Surfaces: Illuminate room surfaces to light people softly and eliminate sharp contrasts.
- Modeling of Faces or Objects: Light sources placed strategically eliminate harsh shadows on an occupant's face. For example, downlights in a bathroom will cause these shadows and should be avoided while a ceiling mounted luminaire or wall sconce with low brightness will illuminate faces softly.
- Direct Glare: Direct glare in a bathroom will become an irritant while trying to shave or apply make-up. Avoid this by keeping the room surfaces bright and using low glare luminaires.
- Reflected Glare: With the use of adjustable mirrors, bathroom spaces should be designed with reflected glare in mind. Low glare luminaires will eliminate this as well as direct glare.
- Source / Task Eye Geometry: Locate light sources appropriately to avoid shadows on someone's face. This location should also minimize shadows throughout the space.
- Horizontal and Vertical Illuminance: Appropriately located task lighting provides higher illuminance levels at the point of the task. For example, at the mirror, a vanity light provides the necessary light levels for make-up application.
- Target Horizontal Illuminance (± 10%): 300 lux (30 fc) average.

DISCUSSION:

Bathroom lighting is often achieved with incandescent "globe" vanity lights. While inefficient, these point sources do provide light from multiple directions on peoples' faces. A more efficient solution uses linear fluorescent \2\ or LED /2/ vanity luminaires or a built-in valence, providing up/down light with a fluorescent light source. In combination with other luminaires that light the room surfaces, the same soft lighting can be provided.

RESIDENTIAL HOUSING Garages



Lensed luminaires provide high ambient light levels while minimizing direct glare. Luminaires are located so that garage door does not block light.

Additional task lighting under cabinets lights workbench.

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EQUIPMENT REQUIREMENTS: /1/

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Surface mounted linear luminaire.*	*\2\ /2/ Linear fluorescent T8 light sources\2\./2/*	*Control with occupancy sensors.*
B	*Surface mounted linear tasklight.*	*\2\ /2/Linear fluorescent T8 light sources or \2\LED strips./2/*	*Manual on/off. \2\ Consider vacancy sensors./2/*

CRITICAL DESIGN ISSUES:

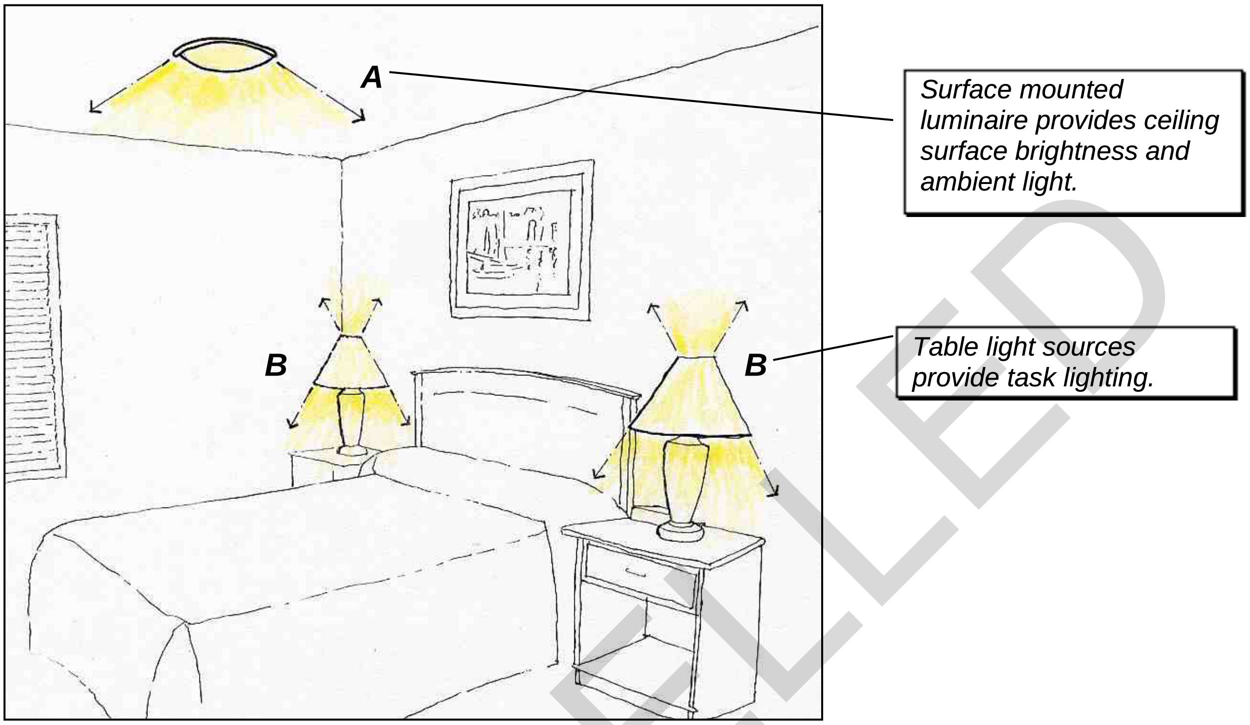
- Direct Glare: Direct glare is not only an annoyance, but can cause fatigue when working for an extended period. In a garage, minimize luminaire brightness with a lens.
- Flicker (and Strobe): This strobe effect is critical when working with high-speed machinery. If the garage will be used as a shop with any kind of rotating tool, specify quality high frequency electronic ballasts to avoid a flicker effect.
- Source / Task Eye Geometry: Locate ambient light sources and task lighting to avoid the shadowing of a workbench or tool area.
- Horizontal and Vertical Illuminance: Task lighting needs to adequately light small tasks that might take place at a workbench. Additionally, provide outlets for portable task lighting that might be used while working on a vehicle.

- Target Horizontal Illuminance (± 10%): 200 lux (20 fc) average.

DISCUSSION:

Garages used only for car storage require very little ambient light. However, if the garage will be used as a shop, ambient levels can be increased slightly and task lighting should definitely be added to increase illuminance at the task.

HOUSING — Bachelors Quarters (Barracks)



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Surface mounted luminaire.*	*Compact fluorescent \2\ or LED /2/ light sources\2\/2/.*	*Manual on/off.*
A ALT	*Wall mounted sconce.*	*Compact fluorescent \2\ or LED /2/ light sources\2\./2/*	*Manual on/off.*
B	*Table lamp.*	*Compact fluorescent \2\ or LED /2/ light sources\2\./2/*	*Manual on/off.*

/1/

CRITICAL DESIGN ISSUES:

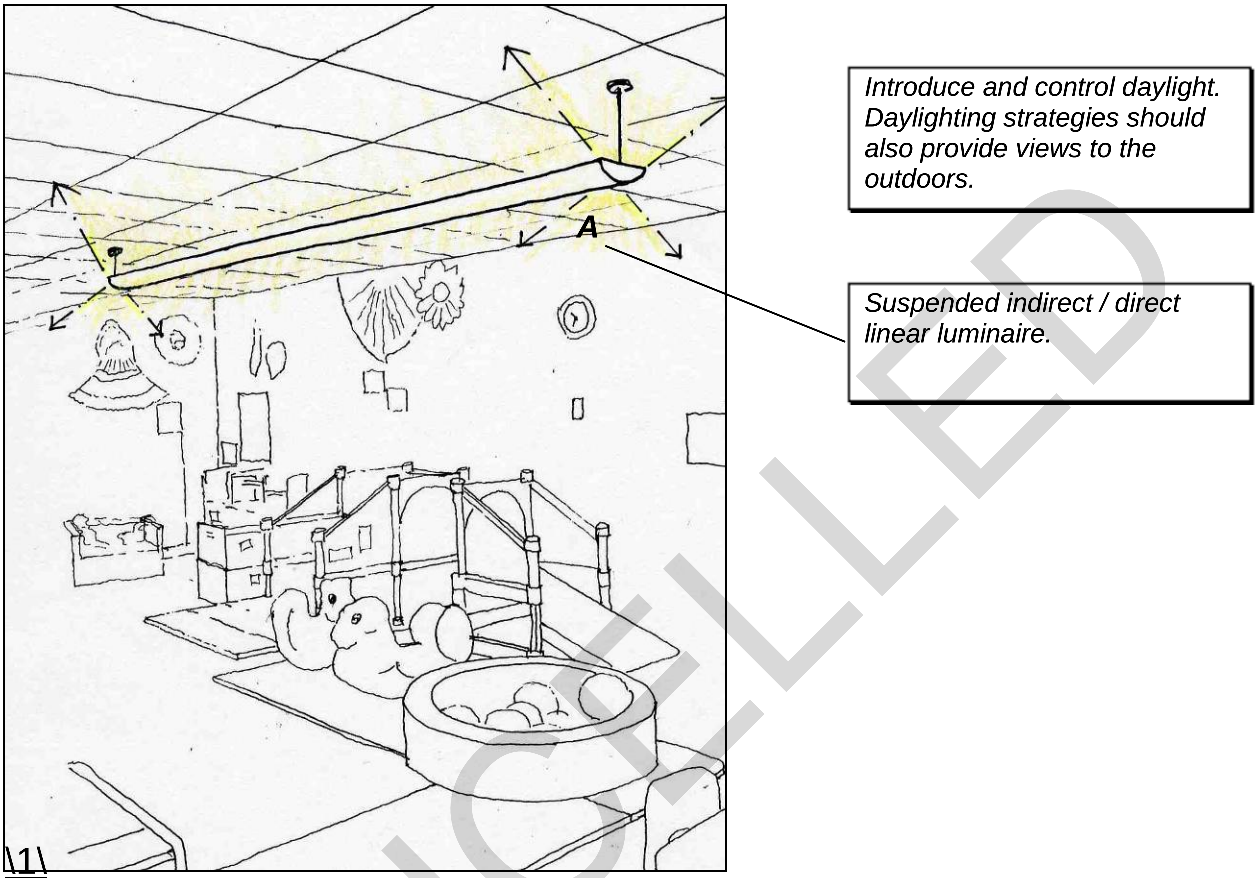
- Direct Glare: Locate and aim sources to avoid direct glare. This is especially important regarding lighting located above the bed to light artwork. Luminaires in this position may cause direct glare for a person reading bed.
- Reflected Glare: For a person reading in bed, locate task lighting to avoid reflected glare and veiling reflections on reading material.
- Horizontal and Vertical Illuminance (for reading): Task lighting needs to provide adequate illuminance on reading material. The light level required for reading should not be achieved with the ambient lighting alone. Task lighting (in the form of bedside table lamps) allows flexibility and greater control over the lighting energy use. Use task lighting for desks.

- Target Horizontal Illuminance (± 10%): 50 lux (5 fc) average with higher light levels provided by table lamps for reading tasks.

DISCUSSION:

Compact fluorescent lighting is now available in residential luminaires such as table lamps, wall sconces, and overhead lighting. Dimming is available with dimmable ballasts \2\ or drivers /2/. Also, the 3000K-light source color closely resembles that of an incandescent light source. Provide task lighting at tables or desks in the room. (See UFC 4-721-10 or UFC 4-721-01.)

CHILDCARE FACILITIES — Daycare Indoor Play Areas



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended indirect / direct linear luminaire.*	*Linear fluorescent T8 or T5HO light sources\2\./2/*	*Manual on/off and dimming control with daylight. Also consider additional control with occupancy \2\ or vacancy /2/ sensors.*
A ALT	*Surface mounted luminaire.*	*Compact fluorescent \2\ or LED /2/ light sources\2\./2/*	*Manual on/off and dimming control with daylight. Also consider additional control with occupancy \2\ or vacancy /2/ sensors.*

/1/

CRITICAL DESIGN ISSUES:

- Direct Glare: Children and supervisors spend a significant amount of time in these play areas, so avoid direct glare.
- Reflected Glare: Select and locate luminaires to avoid veiling reflections on books or reading tasks on horizontal surfaces. The reflection of an unshielded light source on reading material will obscure the task.

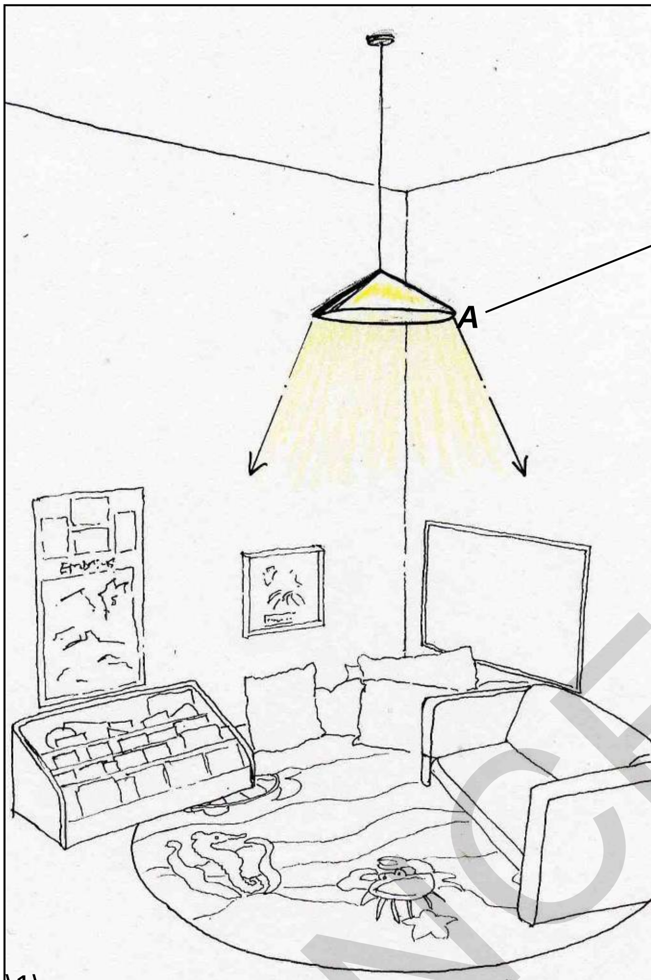
- Horizontal and Vertical Illuminance (for reading): The lighting system must provide adequate light levels for reading and writing. While this light level may be achieved with the ambient lighting, table lamps or task lighting may also increase local reading lighting levels.
- Target Horizontal Illuminance (± 10%): 300 lux (30 fc) average, egress lighting as required (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

Indoor play areas that rely heavily on daylight and provide a connection to the outdoors will create a much more pleasant environment. By providing the electric lighting controls, energy consumption can be reduced when it is not required. Dimming controls are also important to lower light levels during rest time.

Suspended uplights provide indirect ambient light and a softly lit environment without shadows or direct glare. It is important to utilize luminaires that also have a small direct component to add some sparkle and visual interest. This type of light also integrates well with daylight, allowing for continuous surface brightness on the ceiling. As an alternate to suspended luminaires, non-linear surface mounted luminaires also provide some surface brightness.

CHILDCARE FACILITIES — Daycare Indoor Rest Areas



Suspended luminaire lowers the "perceived ceiling" and helps to create a space within a larger space.

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EQUIPMENT REQUIREMENTS: /1/

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Suspended luminaire.*	*Compact fluorescent \2\ or LED /2/ light source\2\./2/*	*Control separately from other area lighting. Provide with dimming controls.*
A ALT	*Surface mounted luminaire.*	*Compact fluorescent\2\ or LED /2/ light source\2\./2/*	*Control separately from other area lighting. Provide with dimming controls.*

CRITICAL DESIGN ISSUES:

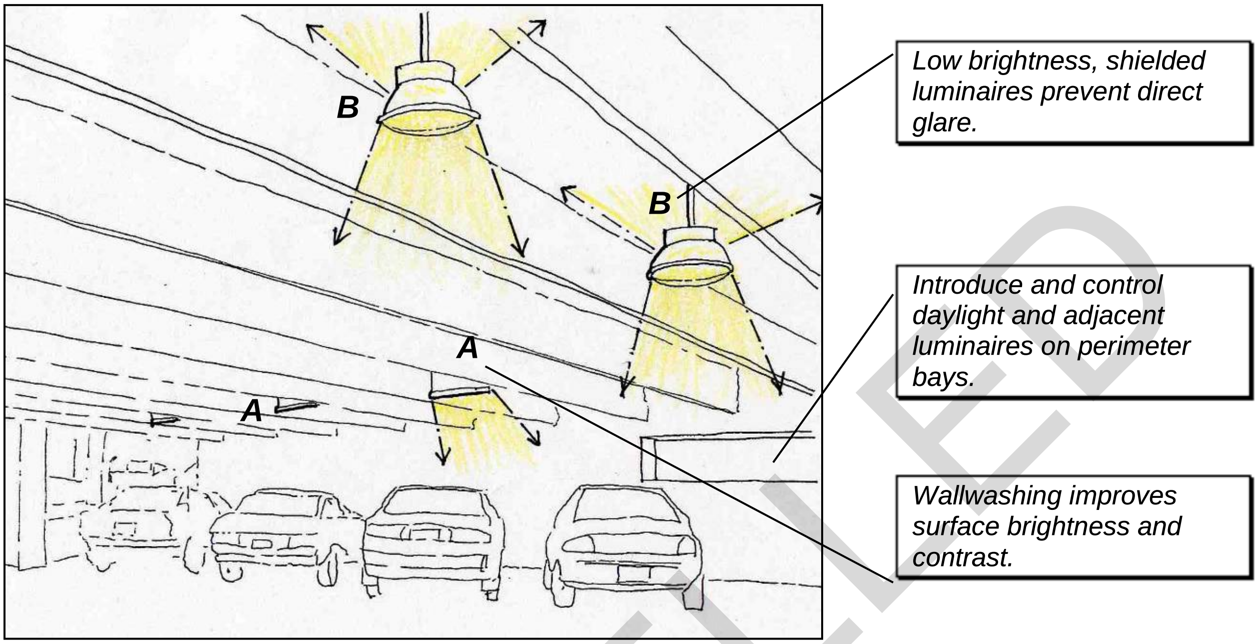
- Direct Glare: Select luminaires to prevent direct glare. Luminaires may use lenses or louvers to shield any view of the light source. Decorative, glowing luminaires should use low wattage light sources.
- Reflected Glare: Select and locate luminaires to prevent veiling reflections on reading material.

- Horizontal and Vertical Illuminance (for reading): While enough light must be provided for reading, the ambient light level can be very low. A softly lit area with a low light level will result in a more restful space.
- Target Horizontal Illuminance (± 10%): 100-200 lux (10-20 fc) average, \2\ egress lighting as required /2/ (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

Indoor rest areas require a soft ambient light that prevents direct or reflected glare. A decorative, suspended luminaire visually separates this area from a larger space. Dimmable lighting will provide a wide range of lighting levels for various activities.

PARKING FACILITIES — Parking Structures



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Surface mounted linear wall washers.*	*\2\ /2/Linear fluorescent T8 or T5HO light sources\2\./2/*	*\2\ Step dim /2/ lights with occupancy and daylight sensors.*
B	*Suspended/Surface mounted parking garage luminaire.*	*\2\ LED /2/ or induction light source\2\/2/.*	*\2\ Step dim /2/ lights with occupancy and daylight sensors.*
B ALT	*Suspended/Surface mounted parking garage luminaire.*	*Metal halide.*	*Manual on/off.*

/1/

CRITICAL DESIGN ISSUES:

- Direct Glare: While driving a vehicle in a parking structure, the glare from the luminaires cannot interfere with the motorist's visibility. All lighting must limit the direct glare into the driver's eyes.
- Modeling of Faces and Objects: Lighting needs to highlight pedestrians. This can be accomplished with low glare luminaires that are located in front of common pedestrian conflict zones such as crosswalks and circulation corridors.
- Peripheral Detection: Use white light sources to enhance peripheral detection.

- Reflected Glare: Locate luminaires over the vehicle parking areas to minimize the potential of reflected glare in the driveways.
- Shadows: Shadows need to be helpful, not confusing. This is especially important on stairs, where the shadows clearly indicate where the stair treads are located.
- Source / Task Eye Geometry: Motorists must be able to clearly see pedestrians and to navigate through the parking structure. The lighting should not present glare to inhibit these important tasks.
- Vertical Illuminance: Lighting the interior vertical walls of the parking structure gives guidance to circulation areas and the surrounds of the structure. Also, pedestrians and other vehicles have vertical surfaces that must be detected.
- Target Horizontal Illuminance (± 10%): Varies depending on use and security requirements; 50 lux (5 fc) average, \2\ /2/ egress lighting as required (see Section 5-6 Emergency and Exit Lighting).

DISCUSSION:

The most important areas to light in a parking structure are the interior walls, providing indirect light for guidance and for lighting the fronts of parked vehicles. Secondly, overhead lighting should be located over the parked vehicles. If the lighting is over the drive lanes, the luminaire brightness could inhibit the driver's ability to navigate and detect pedestrians. Parking garages need to be painted a high reflectance value in order to make the lighting most effective. Treat the top, open-air deck of the parking structure the same as parking lots.

Use daylight whenever possible, and turn off or dim lighting when daylight is adequate near the perimeter. In addition, provide more lighting at entrances during the day to help in the visual transition from daylight to a darker garage. At night, these daylight luminaires must be turned off.

CHAPTER 8: EXTERIOR APPLICATIONS

8-1 INTRODUCTION.

This chapter identifies typical exterior facility applications and explains the critical design issues for each as outlined in the Quality of the Visual Environment section of the IES Handbook, 10th Edition. Each application details a conceptual lighting design for a sample space with a sketch and equipment recommendation. This sample represents one solution that addresses the design issues and meets the appropriate criteria. It is not the only solution and alternate schemes will result in acceptable designs.

Air Force restricts use of LEDs for many of the application templates provided in this Chapter, consult service specific guidance.

8-1.1 Exterior lighting sources.

Broad spectrum (white light) sources such as metal halide, induction, SSL, and fluorescent provide better visibility at low light levels than high pressure sodium light sources. \2\ The IES 10th Edition Handbook has developed a methodology to apply white light multipliers to illuminance values. Refer to Illuminance section in Chapter 2 for more details./2/ Additionally, induction light sources have the added benefits of instant-on switching and long lifetimes. However, high pressure sodium can be used to match existing equipment for both ease of maintenance and visual continuity.

8-1.2 Exterior security lighting is an important issue for many facilities and not all of the specific criteria are addressed in this section. For additional information, refer to *MIL-HDBK-1013/1A, Design Guidelines for Physical Security of Facilities*

8-1.3 The lighting designer should coordinate the design and luminaire selection with the landscape designer. Such coordination should include the location of poles which may conflict with tree locations.

8-1.4 Per \1\ ANSI/ASHRAE/IES 90.1-2007 /1/, lighting for all exterior applications not exempted in 9.1 shall have automatic controls capable of turning off exterior lighting when sufficient daylight is available or when the lighting is not required during nighttime hours.

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8-1.5 Per EPACT 2005, the exterior lighting power density must exceed the ASHRAE allowable by 30% if considered a building load and 20% if considered a non-building load. Typically, any building mounted or façade lighting is considered a building load while free-standing site lighting is considered a non-building load.

8-1,6 Provide TVSS at panelboards for all circuits feeding exterior lighting systems.

/1/

8-2 CALCULATIONS OF LIGHTING FOR EXTERIOR AREAS.

8-2.1 Criteria.

Lighting for exterior areas is measured with a variety of parameters. Maximum, minimum, and average illuminance values are often listed as target criteria. Uniformity criteria may be described with multiple terms including maximum to minimum and maximum to average. Additionally, \2\ luminance, /2/ veiling luminance and small target visibility criteria can also be used to measure roadway lighting. The most appropriate criteria vary with the type of application. The following lists this UFC's interpretation of the IES criteria and how it is used in the applications shown in this chapter:

- Minimum illuminance: This provides the low end of the range of acceptable light levels. This is typically used in applications where lighting will be continuous or cover a large area such as roadways and parking lots.
- Maximum illuminance: This provides the high end of the range of acceptable light levels. This is typically used in applications where lighting will be continuous or cover large areas such as roadways and parking lots. It is also used to prevent overlighting of an area.
- Average illuminance: This criterion is typically used to give an approximate light level. Typically this is used for areas where the lighting may not be continuous and therefore give a better value than maximum and minimum.
- Maximum to minimum uniformity: This is often used in applications where lighting will be continuous or cover large areas such as roadways and parking lots. It is less useful to define lighting in areas such as entries where lighting may be designed to highlight a particular point. Table 8-1 lists recommended ratios for various applications.
- Average to minimum uniformity: This is another criteria used to ensure adequate uniformity. This is an easy value to calculate with typical lighting software, but more difficult to measure and verify in final installations. Table 8-1 lists recommended ratios for various applications.

Table 8-1. Recommended Illuminance Uniformity Ratios for Exterior Applications.

Application	Average / Minimum Ratio	Maximum / Minimum Ratio
Expressways and Major Roadways	3 : 1	
Collector Roadways	4 : 1	
Local Roadways	6 : 1	
Parking Facilities (primarily day-use)		20 : 1
Parking Facilities (night-use)		15 : 1
Pedestrian Walkways and Bikeways	4 : 1	

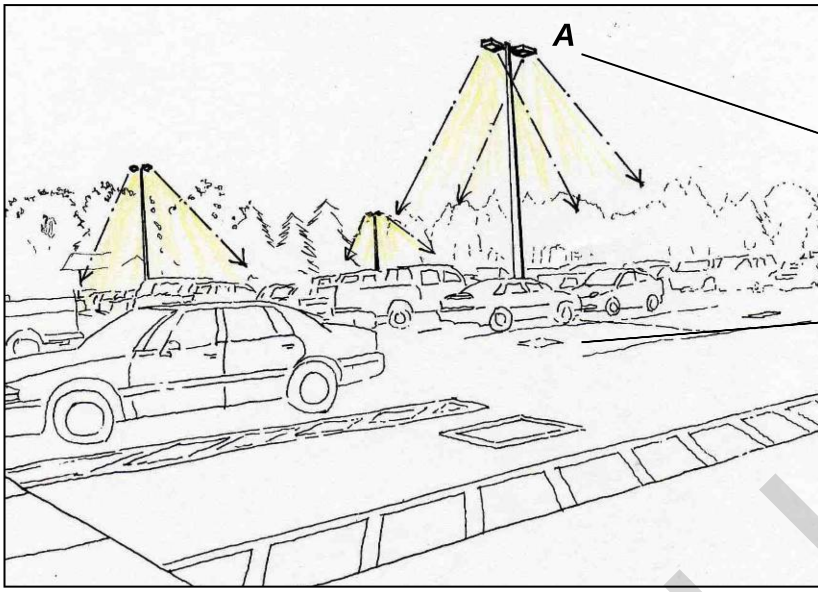
8-2.2 Point Calculations for Flood and Spot Lighting.

Point calculations are a calculation procedure that can be performed by hand or in simple, spreadsheet formulas. They determine the illumination at a point in either the horizontal or the vertical plane, and are reliable only for single luminaires. Manufacturers often provide photometric data in "iso-footcandle" form, which permits rapid assessment of the performance of a single luminaire.

8-2.3 Automated Calculations for Exteriors.

Commercially available computer programs perform point-by-point calculations. These programs permit multiple luminaires and can take buildings and other obstacles into account. Most programs generate CAD-compatible site isolux plots and analytical statistics related to illuminance and uniformity. Luminance, veiling luminance, and small target visibility should also be calculated for roadway applications.

PARKING FACILITIES — Parking Lots



Fully shielded or full cut-off luminaires control glare and reduce light pollution and trespass.

Spacing of luminaires provides uniform horizontal illuminance in parking areas.

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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Pole mounted luminaire.*	*LED, induction, or metal halide.*	*Control with photocell \2\ or timeclock, Bi-level switch or step dim with /2/ motion sensor (only with \2\ LED and /2/ induction light source).*

/1/

CRITICAL DESIGN ISSUES:

- **Direct Glare:** Because the surroundings may be very dark at night, direct glare from luminaires and excessive contrast of surfaces must be considered. Luminaires should use shielded light sources and as low a wattage as possible.
- **Light Pollution / Trespass:** The use of fully shielded or IES full-cutoff luminaires eliminates direct light above the horizontal plane. Using cut-off optics and low wattage light sources can minimize light pollution. Shielded luminaires minimize the chance of light trespass on a neighboring property or building.
- **Modeling of Faces or Objects:** By providing light from multiple directions, objects and people are accurately rendered and modeled.
- **Peripheral Detection:** Our sense of security relies heavily on peripheral vision. Research shows that peripheral vision and detection are enhanced

under white light. White light (as opposed to more orange light produced by high pressure sodium) allows faster peripheral detection than the "fuzzy" high pressure sodium light sources. Also, colors are rendered more accurately under white light.

- **Reflected Glare:** Wet surfaces also often provide a surface that has the potential for reflected glare. Luminaires need to be selected and located to minimize this as much as possible.
- **Shadows:** Poles should be located and spaced such that the light from the luminaires minimizes shadows that could conceal potential hazards.
- **Vertical Illuminance:** Vertical illuminance lights individuals' faces as well as potential hazards.
- **Target Horizontal Illuminance:** Follow the Recommended Maintained Illuminance Values for Parking Lots outlined in *IES RP-20-98, Lighting for Parking Facilities*. Nighttime use areas such as retail and libraries should use the higher "Enhanced Security" values. Facilities that are primarily daytime use only such as offices should use the "Basic" values. Average illuminance levels are typically 10 -20 lux (1-2 footcandles) although maintaining the min, max, and uniformity criteria is more important than meeting an average level.

DISCUSSION:

Parking lot lighting should provide uniform illuminance and/or luminance while avoiding direct glare. By utilizing fully shielded \2\ or U0 /2/ luminaires, the direct beam light that contributes to light pollution will be eliminated. Because poles are often located at the perimeter of lots and next to adjacent properties, light trespass must be carefully considered and prevented. \2\ Fully shielded or U0 /2/ luminaires, house-side shields, and low wattage light sources all help to reduce the chance of light trespass.

RULES OF THUMB:

- Spacing to mounting height: When beginning a design, start with a 4:1 spacing to mounting height ratio and modify accordingly to meet critical design issues.
- Distribution: Use Type V distributions for luminaires within the parking areas. Use Type III and IV distributions for luminaires along the perimeters.

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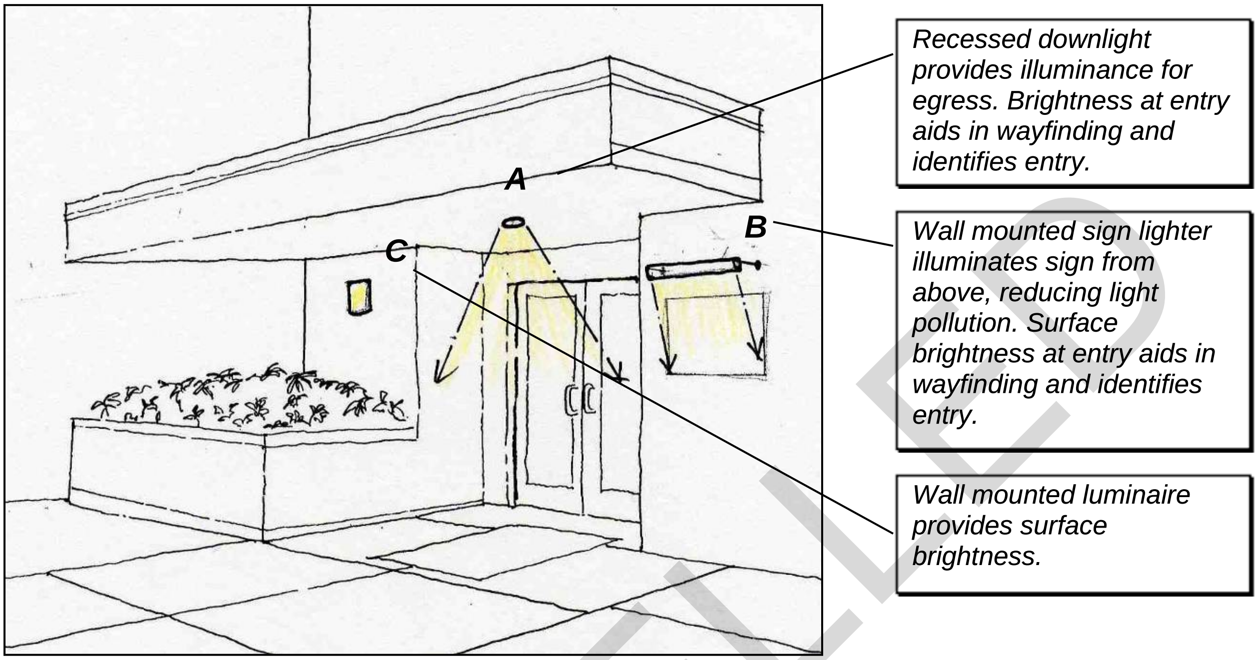
Summary of Total Cost for Analysis Period.

Light Type	Luminair Quantity	Equipmen	Energy	Replacement	**Total Cost for Analysis Period**	Difference 20 Year Analysis Perio	Averag Annua Difference
High Pressure Sodium	16	$25,12	$24,80	$5,600	**$55,528**		
Metal	16	$25,28	$24,22	$15,36	**$64,860**	-	-

BUILDING LIGHTING — Entrances



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Recessed downlight.*	*Compact fluorescent light source \2\ or LED. /2/*	*Control with photocell or timeclock.*
B	*Wall mounted linear wall washer.*	*\2\ LED or /2/ linear fluorescent light sources\2\./2/*	*Control with photocell, timeclock, or occupancy sensor.*
C	*Wall mounted Luminaire.*	*Compact fluorescent \2\ or LED /2/ light sources\2\./2/*	*Control with photocell or timeclock.*

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CRITICAL DESIGN ISSUES:

- **Appearance of Space and Luminaires:** Luminaires should be carefully selected to match the aesthetic character of the building and contribute to a welcome designation to the building entry.
- **Direct Glare:** Because the surroundings may be very dark at night, direct glare from luminaires and excessive contrast of surfaces must be considered. Luminaires should use shielded, low wattage light sources.
- **Light Distribution on Surfaces:** The lighting system should illuminate the walkway uniformly to avoid dark patches. This uniformity is just as important as the light level provided on the walking surface.
- **Light Pollution / Trespass:** The use of fully shielded \2\ or U0 /2/ luminaires eliminates direct light above the horizontal plane. While all

lighting contributes to light pollution, direct light has the largest contribution. Using cut-off optics and low wattage light sources can minimize light pollution. Shielded luminaires minimize the chance of light trespass on a neighboring property or building.

- **Modeling of Faces or Objects:** By providing vertical illuminance from multiple directions, pedestrians' faces will be visible and accurately rendered.
- **Peripheral Detection:** Detecting hazards near buildings relies heavily on peripheral vision. Research shows that peripheral vision and detection are enhanced under white light. White light (as opposed to more orange light produced by high pressure sodium) renders objects sharper and provides excellent peripheral detection compared to high pressure sodium.
- **Point(s) of Interest:** Lighting should provide for wayfinding and indicate points of interests, such as the building entry.
- **Reflected Glare:** Polished surfaces can reflect a light source image if luminaires are not carefully located. Wet surfaces also often provide a surface that has the potential for reflected glare. Luminaires need to be selected and located to minimize this as much as possible.
- **Shadows:** Lighting should be selected and located to eliminate shadows near entries. This increases an individual's sense of security.
- **Surface Characteristics:** As noted under the reflected glare item, surface characteristics and finishes affect the lighting design. Dark surfaces will reflect little light and may appear dark even when illuminated. Polished (rather than matte) surfaces may reflect a light source image.
- **Vertical Illuminance:** Vertical illuminance serves to light objects that may be hazards as well as other pedestrians.
- **Target Horizontal Illuminance (± 10%):** 50 lux (5 footcandles) average.

DISCUSSION:

Building entrances may use one or all of the luminaire types and strategies outlined. Lighting designs use these concepts to consistently designate a hierarchy of buildings and entries to a single building in addition to providing egress lighting and wayfinding. For example, the main entry to a building should be the brightest and may be the only one with sign lighting. Secondary entrances may be designated with a wall \1\ mounted /1/ or downlight only. White light, as produced by metal halide, \2\ LED, /2/ fluorescent, and induction light sources is two to thirty times more effective for nighttime visibility than high pressure sodium.

BUILDING LIGHTING — Housing Areas

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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Wall mounted, \2\ U0 or U1/2/.*	*Compact fluorescent \2\ or LED /2/ light source\2\./2/*	*Manual on/off or motion sensor.*
B	*Wall mounted, fully shielded, \2\ U0 or U1./2/*	*\2\ LED or /2/ compact fluorescent light source\2\./2/*	*Control with timeclock or photocell. \2\ Bi-level switch or step dim with motion sensor./2/*
C	*Pole mounted, \2\ U0 or U1 /2/ pedestrian luminaire.*	*LED, induction, high output compact fluorescent, or metal halide light source\2\./2/*	*Control with timeclock or photocell. \2\ Bi-level switch or step dim with motion sensor. /2/*
C ALT	*Bollard, (Typically, these luminaires provide poor facial lighting. Best used as indicators rather than for area or pedestrian lighting.)*	*\2\ LED or /2/ compact fluorescent light source\2\./2/*	*Control with timeclock or photocell. \2\ Bi-level switch or step dim with motion sensor./2/*

/1/

CRITICAL DESIGN ISSUES:

- **Direct Glare:** Because the surroundings may be very dark at night, direct glare from luminaires and excessive contrast of surfaces must be considered. Luminaires should use shielded, low \2\ lumen light sources./2/
- **Light Distribution on Surfaces:** Wall mounted luminaires should light the wall or nearby walkways rather than trying to flood light an area. Lighting the wall surface shows people and objects in silhouette, prevents direct glare, and minimizes light pollution.

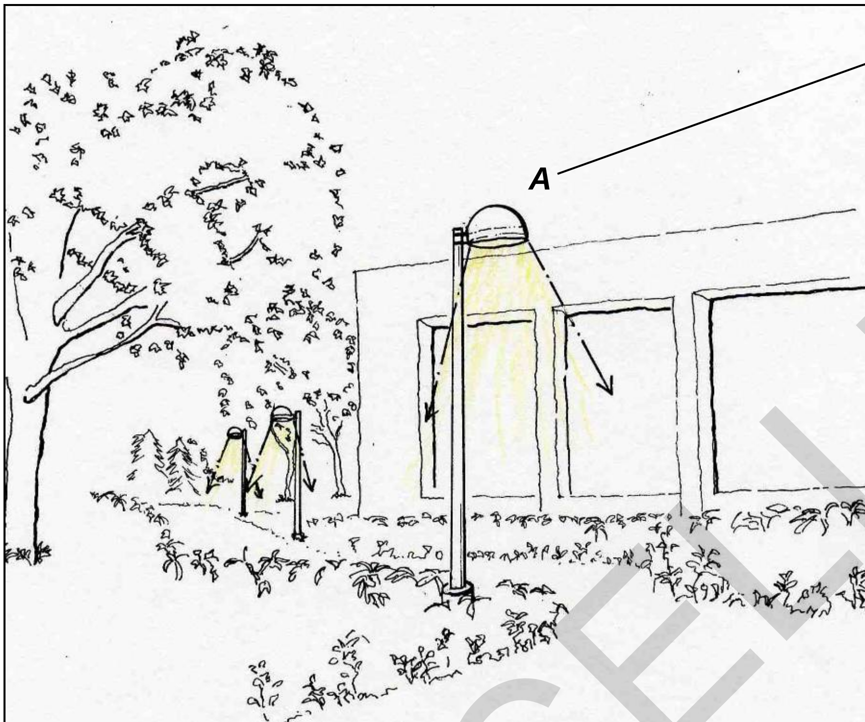
- **Light Pollution / Trespass:** Fully shielded \2\ or U0 /2/ luminaires prevent light from leaving the luminaire above the horizontal plane. This light contributes to light pollution and should be eliminated wherever possible. Shielded luminaires and \2\ low lumen light sources /2/ minimize the chance of light trespass. Houseside shields also limit spill light onto an adjacent building or property.
- **Modeling of Faces or Objects:** By providing vertical illuminance from multiple directions, pedestrians' faces will be visible and accurately rendered.
- **Peripheral Detection:** The detection of hazards near buildings relies heavily on peripheral vision. Research shows that peripheral vision and detection are enhanced under white light. White light (as opposed to more orange light produced by high pressure sodium) renders objects sharper and provides excellent peripheral detection compared to high pressure sodium.
- **Reflected Glare:** Polished surfaces can reflect a light source image if luminaires are not carefully located. Wet surfaces also often provide a surface that has the potential for reflected glare. Luminaires need to be selected and located to minimize this as much as possible.
- **Shadows:** Lighting should be selected and located to eliminate shadows near entries. This increases an individual's sense of security.
- **Vertical Illuminance:** Vertical illuminance serves to light objects that may be hazards as well as other pedestrians.
- **Target Horizontal Illuminance (± 10%):** 5 lux (0.5 footcandles) average on walkways.

DISCUSSION:

Lighting for housing and the surrounding areas should utilize low wattage light sources and fully shielded or \2\U0 /2/ luminaires to light the building surfaces, prevent glare, and provide a high level of visibility with the minimum light level necessary. When wall mounted luminaires light the wall surface, a soft ambient light is provided without the harsh glare of unshielded floodlights. Avoiding this glare controls contrast while people and objects stand out in silhouette.

Pedestrian poles with fully shielded or \2\ U1 /2/ light paths and walkways with a minimum amount of glare, light trespass, and light pollution. Light trespass in bedroom windows increases the chance of circadian cycle disruption. Well-designed reflectors still provide adequate vertical illuminance to light individuals and possible hazards.

PEDESTRIAN AREAS
Walkways



Low brightness luminaires reduce direct glare and provide adequate vertical illuminance while minimizing light pollution and trespass.

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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Pole mounted, \2\ U0 or shielded /2/ pedestrian scale luminaire.*	*\2\ LED, induction, hight output compact fluorescent, or /2/ metal halide light source.*	*\2\ Control with photocell or timeclock. Bi-level switch or step dim with motion sensor./2/*
A ALT	*Bollard, (Typically, these luminaires provide poor facial lighting. Best used as indicators rather than for area or pedestrian lighting.)*	*\2\ LED or /2/ compact fluorescent light source\2\./2/*	*Control with \2\ photocell or timeclock. Bi-level switch or step dim with motion sensor./2/*

/1/

CRITICAL DESIGN ISSUES:

- **Appearance of Space and Luminaires:** Decorative pedestrian poles must match the aesthetic character of the adjacent buildings. If the luminaires are not decorative in nature, luminaires and poles should be painted a neutral color so that they are as inconspicuous as possible.
- **Color Appearance and Color Contrast:** White light sources, such as metal halide, fluorescent, \2\ LED /2/ and induction provide better color rendering than frequently used high or low pressure sodium sources.

- **Direct Glare:** Because the surroundings may be very dark at night, direct glare from luminaires and excessive contrast of surfaces must be considered. Luminaires should use low wattage light sources.
- **Light Pollution / Trespass:** The use of fully shielded or full-cutoff luminaires eliminates direct light above the horizontal plane. While all lighting contributes to light pollution, direct light has the largest contribution. Using \2\ fully shielded /2/ optics and low wattage light sources can minimize light pollution. Shielded luminaires minimize the chance of light trespass on a neighboring property or building.
- **Modeling of Faces or Objects:** By providing vertical illuminance from multiple directions, pedestrians' faces will be visible and accurately rendered.
- **Peripheral Detection:** Detecting hazards relies heavily on peripheral vision. Research shows that peripheral vision and detection are enhanced under white light. White light (as opposed to more orange light produced by high pressure sodium) renders objects sharper and provides excellent peripheral detection compared to high pressure sodium.
- **Reflected Glare:** Consider the potential for reflected glare based on luminaire location and surface characteristics.
- **Shadows:** Luminaires should be located to eliminate shadows that could hide potential hazards.
- **Vertical Illuminance:** Adequate vertical illuminance lights possible hazards as well as other pedestrians.
- **Target Horizontal Illuminance (± 10%):** 5 lux (0.5 footcandles) average.

DISCUSSION:

Pedestrian walkways utilizing a pedestrian scale poles allow for adequate vertical illuminance to light individuals and their faces. If the luminaires are decorative, a lens or louver should shield the light source, prevent direct glare, and minimize the possibility of light trespass. Eliminating glare and providing uniformity provides the best security lighting. Low wattage light sources and shielded or cut-off luminaires minimize light pollution.

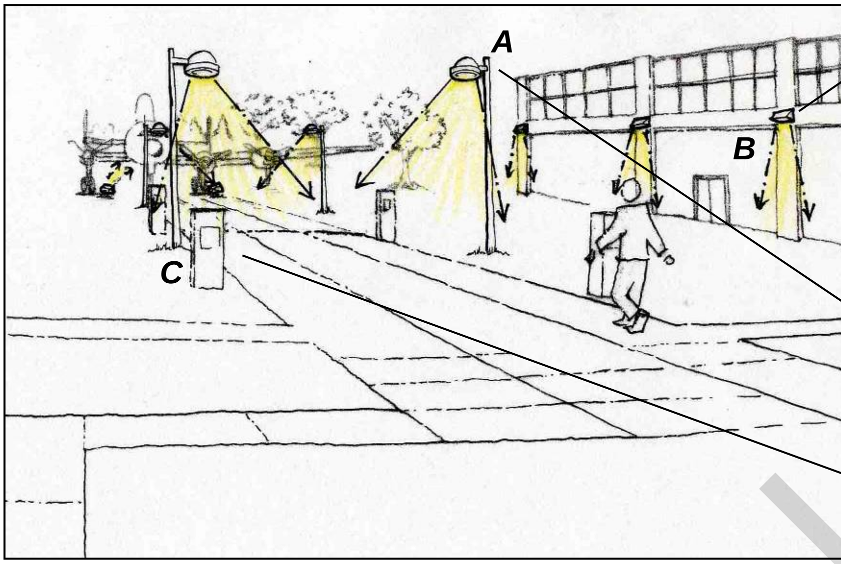
Locate poles in paved areas when possible to avoid blocking irrigation spray heads. When luminaires are positioned in planting areas, locate in shrub rather than lawn areas to avoid damage from mowing and edging.

RULES OF THUMB:

- Mounting height: Use 3.0 – 4.3m (10' – 14') poles for pedestrian luminaires.

- Spacing to mounting height: When beginning a design, start with an 8:1 spacing to mounting height ratio and modify accordingly to meet critical design issues.
- Locate poles at intersections and nodes. Consider the visual layout of equipment rather than a strict adherence to spacing criteria.

PEDESTRIAN AREAS — Plazas



Building lighting illuminates the perimeter of the plaza and helps to define the exterior "space". This perimeter lighting also provides a sense of security.

Low brightness pedestrian poles reduce direct glare and provide adequate vertical illuminance.

Feature accent lighting highlights focal points of the plaza.

\1\

EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Pole mounted, U1 or shielded, pedestrian scale luminaire.*	*\2\ LED, induction, high output compact fluorescent or coated metal halide light source. /2/*	*\2\ Control with photocell/ timclock. Bi-level switch or step dim with motion sensor./2/*
A ALT	*Bollard, (Typically, these luminaires provide poor facial lighting. Best used as indicators rather than for area or pedestrian lighting.)*	*\2\ LED or /2/ compact fluorescent light source. \2\/2/*	*Control with \2\ photocell or timeclock. Bi-level switch or step dim with motion sensor./2/*
B	*Building mounted fully shielded downlight / wallwasher.*	*\2\ LED or /2/ compact fluorescent.*	*\2\ Control with photocell or timclock./2/*
C	*Accent light.*	*\2\ LED or /2/ compact fluorescent.*	*\2\ Control with photocell or timclock./2/*

/1/

CRITICAL DESIGN ISSUES:

- **Color Appearance and Color Contrast:** White light sources, such as metal halide, fluorescent, SSL and induction provide better color rendering than frequently used high pressure sodium sources.
- **Direct Glare:** Because the surroundings may be very dark at night, direct glare from luminaires and excessive contrast of surfaces must be considered. Luminaires should use shielded, low wattage light sources.
- **Light Pollution / Trespass:** The use of fully shielded \2\ U0 or U1 /2/ luminaires eliminates direct light above the horizontal plane. While all lighting contributes to light pollution, direct light has the largest contribution. Using shielded and low \2\ lumen light sources /2/ can

minimize light pollution. Shielded luminaires minimize the chance of light trespass on a neighboring property or building.

- **Modeling of Faces or Objects:** By providing vertical illuminance from multiple directions, pedestrians' faces will be visible and accurately rendered.
- **Peripheral Detection:** Detecting hazards relies heavily on peripheral vision. Research shows that peripheral vision and detection are enhanced under white light. White light (as opposed to more orange light produced by high pressure sodium) renders objects sharper and provides excellent peripheral detection compared to high pressure sodium. Lighting the facades of surrounding buildings with low glare lighting silhouettes objects and improves peripheral detection.
- **Reflected Glare:** Consider the potential for reflected glare based on luminaire location and surface characteristics.
- **Shadows:** Luminaires should be located to eliminate shadows that could hide potential hazards.
- **Vertical Illuminance:** Adequate vertical illuminance lights possible hazards as well as other pedestrians.
- **Target Horizontal Illuminance (± 10%):** 5 lux (0.5 footcandles) average.

DISCUSSION:

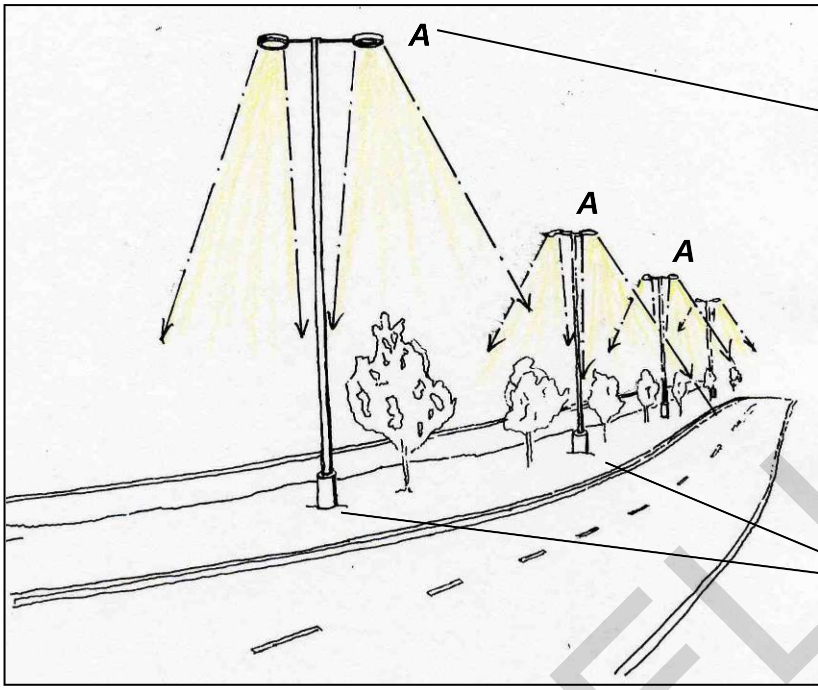
Plazas utilizing pedestrian scale poles provide adequate vertical illuminance to light individuals and their faces. If the luminaires are decorative, a lens or louver should shield the light source, prevent direct glare, and minimize the possibility of light trespass. \2\ Low lumen light sources /2/ and shielded \2\ or U1 /2/ luminaires minimize light pollution.

Selectively lighting the facades of surrounding buildings helps to create the sense of an exterior space. By silhouetting objects, this technique increases visibility and improves peripheral detection.

Features to accent light must be selected carefully, considering viewing angles, glare, and light pollution and trespass. Low \2\ lumen light sources /2/ and the controlled downlighting of surfaces provide the best opportunities. If uplight cannot be avoided, control the light so that the luminaires are lighting the feature only, minimizing spill. Shield the luminaires to prevent glare and light trespass and minimize light pollution. Consider using the lighting only at specific times or for special occasions.

Locate poles in paved areas when possible to avoid blocking irrigation spray heads. When luminaires are positioned in planting areas, locate in shrub rather than lawn areas to avoid damage from mowing and edging.

VEHICLE TRAFFIC AREAS — Roadways and Streets



Fully shielded or \2\ U0 /2/ luminaires control glare and reduce light pollution and trespass.

Spacing luminaires 4-5 times the mounting height provides uniform horizontal illuminance.

\1\

EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Pole mounted fully shielded or \2\ U0 /2/ roadway luminaire.*	*LED, induction, or metal halide.*	*\2\ Control with photocell on/off. Bi-level switch or step dim with timeclock or network control./2/*

/1/

CRITICAL DESIGN ISSUES:

- **Appearance of Space and Luminaires:** Luminaires and poles should be painted a neutral color so that they are as inconspicuous as possible.
- **Direct Glare:** Fully shielded or \2\ U0 /2/ luminaires conceal the light source and minimize the direct glare from the luminaire. Because the eye adjusts to the brightest source in the field of view, eliminating glare is the highest priority in designing for nighttime driving.
- **Light Distribution on Surfaces:** More important than light level, uniform light distribution provides high visibility and a comfortable nighttime driving environment.
- **Light Pollution / Trespass:** Fully shielded or \2\ U0 /2/ luminaires prevent any direct light from leaving the luminaire above horizontal. This direct light is the largest contributor to light pollution and light trespass.

- **Peripheral Detection:** Detecting hazards while driving relies heavily on peripheral vision. Research shows that peripheral vision and detection are enhanced under white light. White light (as opposed to more orange light produced by high pressure sodium) renders objects sharper and provides excellent peripheral detection compared to high pressure sodium.
- **Reflected Glare:** Wet surfaces often provide a surface that has the potential for reflected glare. Luminaires need to be selected and located to minimize this as much as possible.
- **Shadows:** Luminaires should be located to eliminate shadows that could hide potential hazards.
- **Source / Task / Eye Geometry:** Consider the angles between the driver, the luminaires, and the tasks. The tasks may be just the roadway or it may be pedestrians in a crosswalk or other cars at an intersection.
- **Vertical Illuminance:** Vertical illuminance serves to light objects that may be hazards as well as pedestrians that may be near a roadway or in an intersection. See IES RP-8-00 “Roadway Lighting”.
- **Small Target Visibility (STV):** Varies, based on application. See IES RP-8-00 “Roadway Lighting”.
- **Luminance:** Varies, based on application. See IES RP-8-00 “Roadway Lighting”.

DISCUSSION:

The visual environment needs along the roadway can be described in terms of pavement illuminance and luminance, uniformity and direct glare produced by the light sources. \2\ (IES 10th Edition Chapter 26 – Lighting for Exteriors)./2/

There are three calculation methods available for roadway design: small target visibility, luminance and illuminance. Since Roadway lighting is a specialized design area, refer to *IES RP-8-00 Roadway Lighting* for specific design criteria.

Small target visibility (STV) is the preferred method since it best accounts for identifying an object or pedestrian crossing the roadway. In order to achieve a high STV, luminaire placement and arrangement is critical. For example, median mounted poles or poles lined up opposite each other produce the highest STV values. A staggered pole arrangement produces the lowest STV values. If safety is a concern, then the preferred method is small target visibility.

Luminance method calculates the pavement brightness as seen by a motorist. The glare potential from the roadway luminaires is taken into account with the veiling luminance calculation. The Luminance method is an excellent alternative method since it realistically models the pavement brightness and its uniformity.

The Illuminance method is not recommended since it usually produces poor STV results. Traditionally, the illuminance method was used in roadway calculations since it is simple to calculate and obtain field measurements.

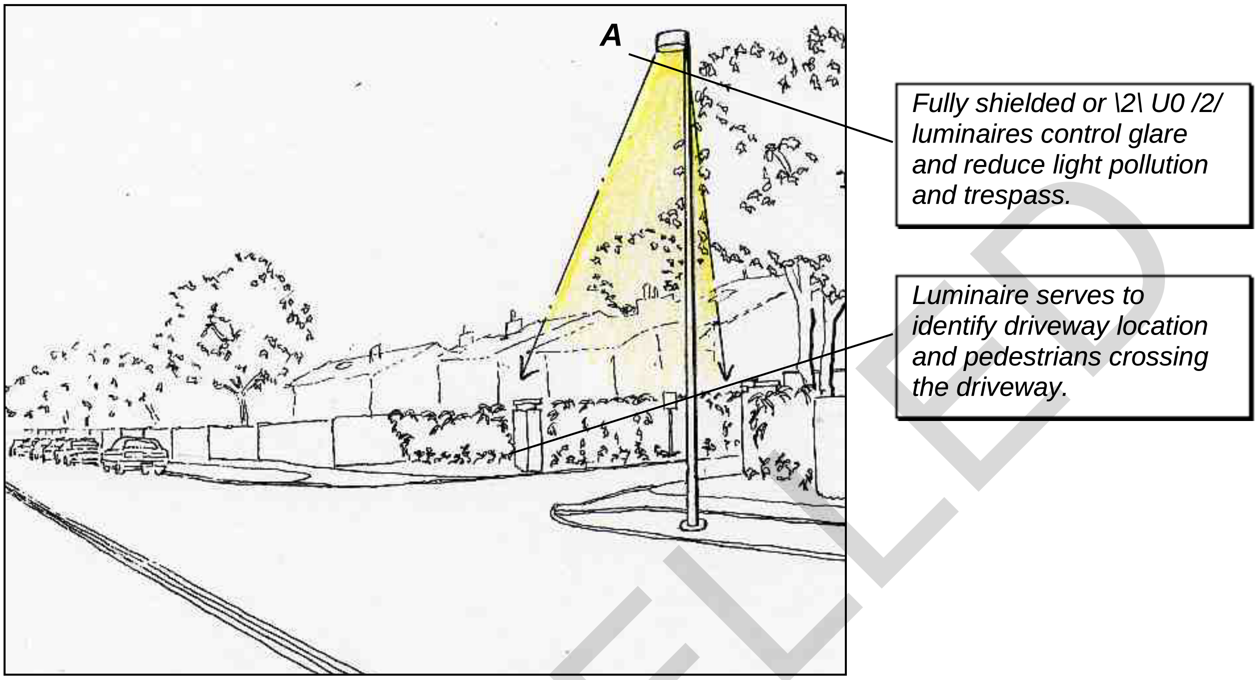
The recommendation is to use STV first and luminance method as a final check for roadway lighting quality.

For roadway lighting applications where peripheral vision is important such as detecting pedestrians or potential off axis activity, white light as produced by a metal halide, fluorescent, or induction light source is recommended. In addition to providing better visibility, this has an energy impact as well. \1\/1/

RULES OF THUMB:

- Spacing to mounting height: When beginning a design, start with a 5:1 spacing to mounting height ratio and modify accordingly to meet critical design issues.

VEHICLE TRAFFIC AREAS — Driveways



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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Pole mounted fully shielded \2\ or U0 /2/ roadway luminaire.*	*LED, induction, or metal halide.*	*Control with photocell. \2\ Bi-level switch or step dim with timeclock or network controls./2/*

/1/

CRITICAL DESIGN ISSUES:

- **Direct Glare:** \2\ Fully shielded or U0 /2/ luminaires conceal the light source and minimize the direct glare from the luminaire. Because the eye adjusts to the brightest source in the field of view, eliminating glare is the highest priority in designing for nighttime driving.
- **Light Pollution / Trespass:** Fully shielded or \2\ U0 /2/ luminaires prevent any direct light from leaving the luminaire above horizontal. This direct light is the largest contributor to light pollution and light trespass.
- **Modeling of Faces or Objects:** Luminaires need to provide adequate vertical illuminance to light people and their faces. By locating the pole ahead of the cross walk, it provides vertical light on pedestrians crossing the street.

- **Peripheral Detection:** Detecting hazards while driving relies heavily on peripheral vision. \1\/1/
- **Shadows:** Locate and select luminaires to provide a uniform illuminance on the ground and eliminate dark spots and shadows. Such dark spots can be distracting to drivers and also may conceal hazards.
- **Vertical Illuminance:** Pole location, height, and luminaire selection all contribute to adequate vertical illuminance.
- **Target Horizontal Illuminance (± 10%):** Varies with type of surrounding environment.

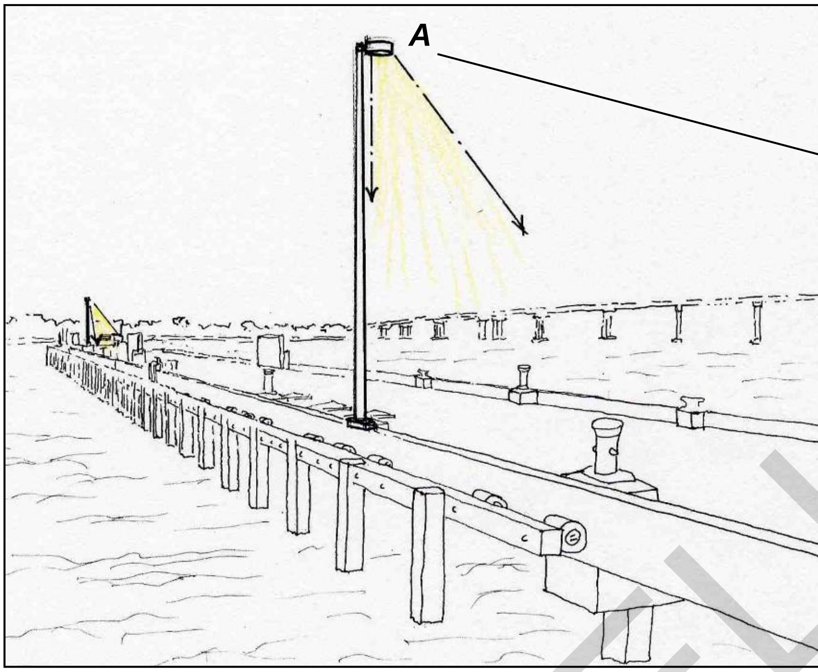
DISCUSSION:

Research shows that peripheral vision and detection are enhanced under white light. White light (as opposed to more orange light produced by high pressure sodium) renders objects sharper and provides excellent peripheral detection compared to high pressure sodium. This peripheral detection is critical at points where other vehicles may be entering a roadway and pedestrians may be crossing the street.

\1\/1/

Luminaires should utilize shielded sources with cutoff reflectors to minimize light pollution and light trespass.

MARINAS



Fully shielded or \2\ U0 /2/ luminaires control glare and reduce light pollution and trespass.

\1\

EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Pole mounted.*	*LED, induction, or coated metal halide. Use low pressure sodium light sources \2\or approved monochromatic LEDs for sensitive environments such as wildlife habitat or nesting areas./2/*	*Control with photocell. \2\ Bi-level switching / step dim with timeclock, or network controls./2/*

/1/

CRITICAL DESIGN ISSUES:

- **Direct Glare:** Fully shielded or \2\ U0 /2/, flat-lens luminaires conceal the light source and minimize the direct glare from the luminaire. Because the eye adjusts to the brightest source in the field of view, eliminating glare is the highest priority in designing for nighttime, exterior tasks.
- **Light Pollution / Trespass:** The use of fully shielded or \2\ U0 /2/ luminaires eliminates direct light above the horizontal plane. Using \2\ fully shielded /2/ optics and low wattage light sources can minimize light pollution. Shielded luminaires minimize the chance of light trespass on a neighboring property or building.

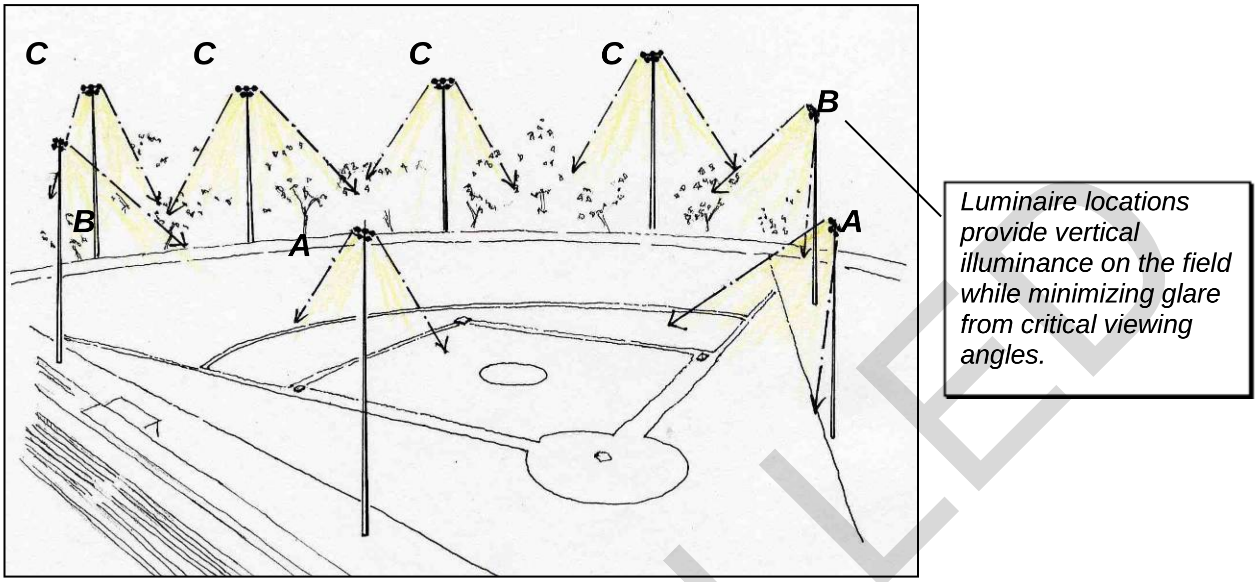
- **Modeling of Faces or Objects:** By providing light from multiple directions, objects and people are accurately rendered and modeled.
- **Reflected Glare:** Wet surfaces often provide a surface that has the potential for reflected glare. Luminaires need to be selected and located and surface finishes chosen to minimize this as much as possible.
- **Shadows:** Poles should be located and spaced for maximum uniformity and so that the light from the luminaires minimizes shadows that could conceal potential hazards.
- **Source / Task / Eye Geometry:** Luminaire locations and pole heights need to be determined while considering the location and viewing angles of typical tasks. Light sources should be kept out of the field of view as much as possible.
- **Target Horizontal Illuminance (± 10%):** \2\ 5 lux (0.5 footcandles) average. /2/

DISCUSSION:

The use of fully shielded \2\ or U0 /2/ luminaires with flat lenses, in addition to the lowest wattage light source that will adequately meet light level requirements, minimizes light pollution and the chance of direct glare. Research shows that peripheral vision and detection are enhanced under white light. White light (as opposed to more orange light produced by high pressure sodium) renders objects sharper and provides excellent peripheral detection compared to high pressure sodium.

\2\Monochromatic LEDs may be used in place of LPS for sensitive environments such as wildlife habitat, observatories, wildlife nesting, or to meet dark sky requirements. LED luminaires used in special environmental applications shall be products approved by the appropriate state and local governing authority. For marine applications, incorporate Fish and Wildlife, state and local governing authority recommendations for lighting systems design and installation. The lighting manufacturer is responsible for obtaining any applicable certifications for their products. /2/

EXTERIOR RECREATIONAL AREAS Baseball & Softball Fields



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EQUIPMENT REQUIREMENTS: /1/

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Pole mounted modular rack of adjustable floodlights. Distribution types 2, 3, and 4 with internal and external shielding.*	*Metal halide.*	*Manual on/off.*
B	*Pole mounted modular rack of adjustable floodlights. Distribution types 2, 3, 4, and 5 with internal and external shielding.*	*Metal halide.*	*Manual on/off.*
C	*Pole mounted modular rack of adjustable floodlights. Distribution types 4, 5, and 6 with internal and external.*	*Metal halide.*	*Manual on/off.*

CRITICAL DESIGN ISSUES:

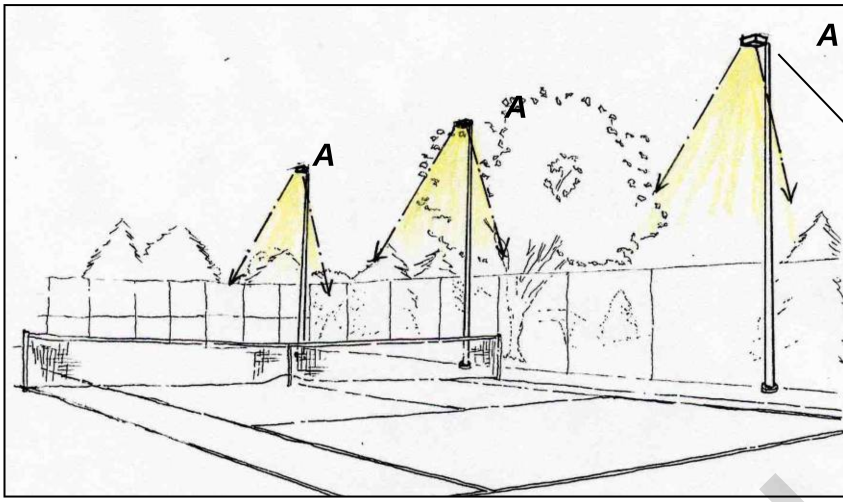
- **Direct Glare:** In a game where the ball is traveling at high speeds and all possible angles, glare needs to be minimized to provide adequate visibility. *IES RP-6-01 Sports and Recreational Area Lighting* outlines critical glare zones where poles should not be located. This way, when a player follows the ball, they will not look directly into a floodlight.
- **Light Distribution on Task Plane (Uniformity):** Floodlight locations and distribution provide uniform illuminance on the field. The uniformity and elimination of dark spots improves visibility and minimizes distractions.

- **Target Horizontal Illuminance:** For various classes of play and illuminance recommendations see IES Lighting Handbook, Figure 20-2 and *IES RP-6-01, Sports and Recreational Area Lighting*.

DISCUSSION:

The lighting for baseball and softball fields should illuminate the field uniformly and also from multiple angles to eliminate dark spots and model the ball accurately. The poles should not be located in zones where luminaire glare would be critical. *IES RP-6-01 Sports and Recreational Area Lighting* outlines these zones where players may follow the ball's path and look directly into a luminaire. This glare impairs visibility, as the ball may be lost from sight. All floodlights should have internal and external shielding to increase player visibility and decrease light trespass. Lighting templates with pole and luminaire data are readily available from sports lighting manufacturers.

EXTERIOR RECREATIONAL AREAS Tennis Courts



\1\

EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Pole mounted, fully shielded \2\U0/2/ area luminaire.*	*LED, induction, or coated metal halide.*	*Timer switch, motion sensor, or manual on/off with a timer.*

/1/

CRITICAL DESIGN ISSUES:

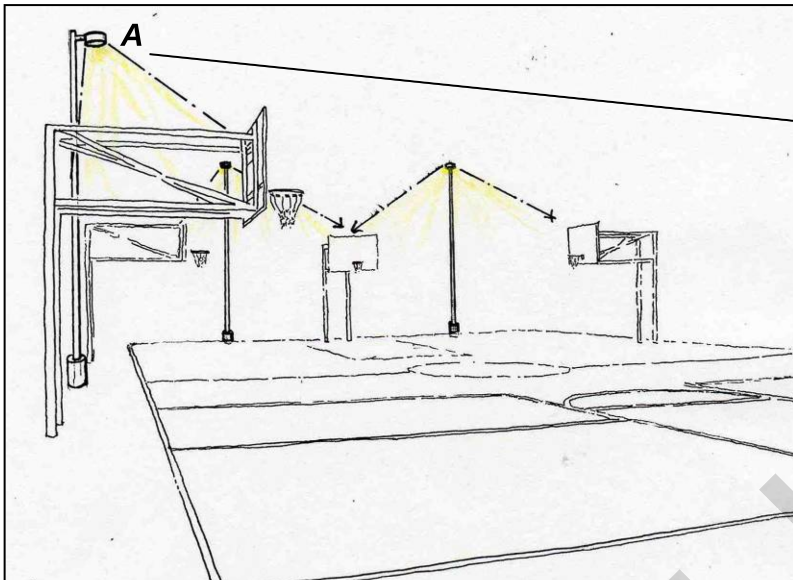
- **Direct Glare:** Luminaires should be located parallel to the direction of play to minimize the chance of looking up into the luminaires. Flat lensed and fully shielded or \2\ U0 /2/ luminaires also reduce luminaire brightness and direct glare.
- **Flicker (and Strobe):** Specify electronic ballasts to prevent flicker and stroboscopic effects.
- **Light Distribution on Task Plane:** Luminaires should be spaced appropriately to provide a uniform distribution of light on the court.
- **Modeling of Faces or Objects:** Light should come from multiple directions to accurately render the ball and other players.
- **Vertical Illuminance:** Adequate vertical illuminance is necessary to see the ball at all angles.
- **Target Horizontal Illuminance:** For various classes of play and illuminance recommendations see IES Lighting Handbook, Figure 20-2 and *IES RP-6-01, Sports and Recreational Area Lighting*.

DISCUSSION:

Tennis courts should be illuminated from the sides of the court. This will minimize the chance of players looking directly into a luminaire during play. Uniform horizontal and vertical illuminance is important to accurately model a ball at high speed. Lighting templates with pole and luminaire data are readily available from sports lighting manufacturers.

The lighting system should be controlled by a time clock or from an office location if the facility is part of a fitness center. Approximately one half of the luminaires should remain on per timeclock settings. The other half of the luminaires can have local control, perhaps on a timer. \1\ As an alternate control strategy, use bi-level switching with luminaires on the low level throughout operating hours of darkness. An occupancy sensor raises them to the high level when triggered. A timer returns them to the low level after a period of undetected motion. /1/

EXTERIOR RECREATIONAL AREAS — Basketball Courts



Pole mounted luminaires are spaced to provide uniform illuminance and minimize direct glare.

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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Pole mounted, fully shielded or \2\ U0 /2/ area luminaire.*	*LED, induction, or coated metal halide.*	*Control with photocell, timeclock, or motion sensor (induction light source and LED only).*

/1/

CRITICAL DESIGN ISSUES:

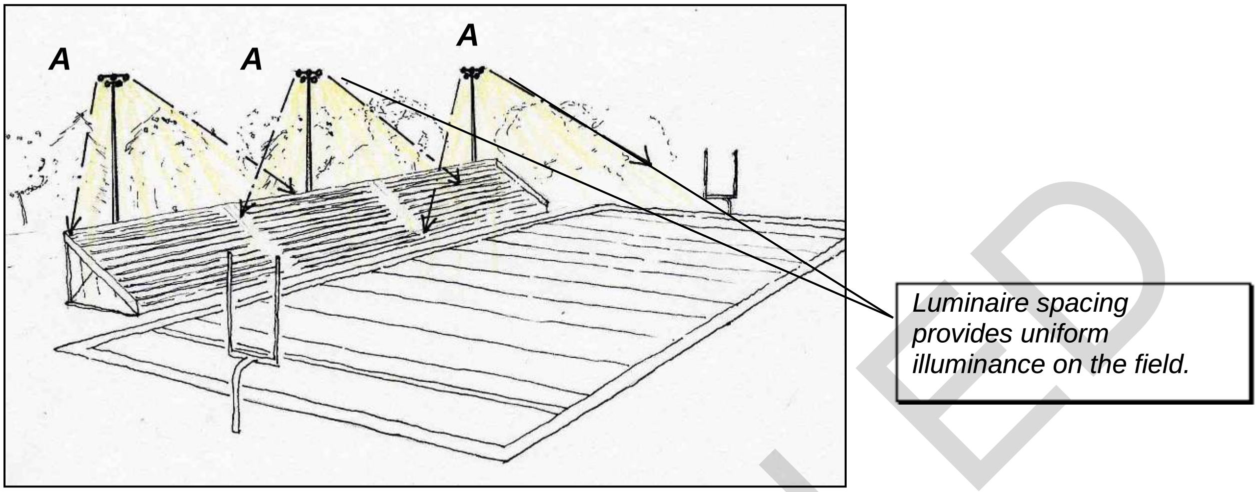
- **Direct Glare:** Pole mounted luminaires located around a court must be spaced to minimized direct glare when looking at the basket. Flat lensed and fully shielded or \2\ U0 /2/ luminaires also reduce luminaire brightness and direct glare.
- **Light Distribution on Task Plane (Uniformity):** Luminaires should be spaced appropriately to provide a uniform distribution of light on the court. By locating luminaires around the court, the uniformity can be achieved while avoiding direct glare and still lighting the basket from multiple angles.
- **Target Horizontal Illuminance:** For various classes of play and illuminance recommendations see IES Lighting Handbook, Figure 20-2 and *IES RP-6-01, Sports and Recreational Area Lighting*.

DISCUSSION:

No matter where poles are located along the boundary of the court, there is the chance of direct glare due to the variety of angles that players view the baskets. This can be minimized by not locating poles directly behind the basket. If poles flank the basket, there is less of a chance of looking into the luminaire when shooting. By locating luminaires around the court, the basket will be illuminated from multiple angles. Lighting templates with pole and luminaire data are readily available from sports lighting manufacturers.

The lighting system should be controlled by a time clock or from an office location if the facility is part of a fitness center. Approximately one half of the luminaires should remain on per timeclock settings. The other half of the luminaires can have local control, perhaps on a timer. \1\ As an alternate control strategy, use bi-level switching with luminaires on the low level throughout operating hours of darkness. An occupancy sensor raises them to the high level when triggered. A timer returns them to the low level after a period of undetected motion. /1/

EXTERIOR RECREATIONAL AREAS Football Fields



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EQUIPMENT REQUIREMENTS: /1/

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Pole mounted modular rack of adjustable floodlights with internal and external shielding.*	*Metal halide.*	*Manual on/off.*

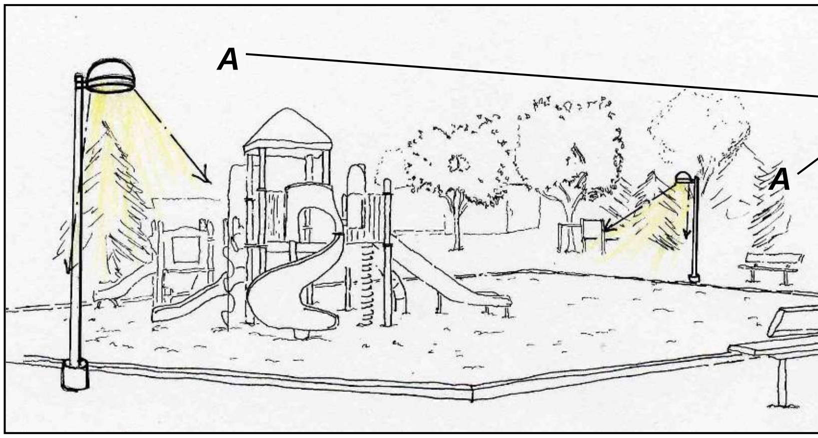
CRITICAL DESIGN ISSUES:

- **Direct Glare:** By locating the light poles along the sides of the field and parallel to the general direction of play, the field is illuminated from multiple angles while minimizing the chance of looking directly into a luminaire. Such direct glare needs to be minimized to enhance visibility.
- **Light Distribution on Task Plane (Uniformity):** Luminaire locations and distribution provide uniform illuminance on the field. The uniformity and elimination of dark spots improves visibility and minimizes distractions.
- **Target Horizontal Illuminance:** For various classes of play and illuminance recommendations see IES Lighting Handbook, Figure 20-2 and *IES RP-6-01, Sports and Recreational Area Lighting*.

DISCUSSION:

The lighting for football fields should illuminate the field uniformly and also from multiple angles to eliminate dark spots and model the ball and players accurately. The poles, located parallel to the direction of play, minimize the direct glare. Pole quantity depends on the setback distance from the field, with fewer poles required when they are further away. Refer to *IES RP-6-01* for more details. Lighting templates with pole and luminaire data are readily available from sports lighting manufacturers.

EXTERIOR RECREATIONAL AREAS Playgrounds



Pedestrian poles around the playground uniformly illuminate the area.

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EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Pole mounted, shielded \2\ /2/ pedestrian scale luminaire.*	*Induction, LED, compact fluorescent, or coated metal halide.*	*Control with photocell, timeclock, or motion sensor (\2\ LED /2/, induction, and compact fluorescent light sources only).*

/1/

CRITICAL DESIGN ISSUES:

- **Light Distribution on Task Plane (Uniformity):** Pedestrian poles should be selected and located to uniformly illuminate the area.
- **Shadows:** Luminaires should be located and spaced to eliminate shadows that could hide potential hazards. Light from multiple angles will provide adequate visibility on the playground equipment.
- **Target Horizontal Illuminance (± 10%):** 50 lux (5 footcandles) average.

DISCUSSION:

Playgrounds should be illuminated with security as the intent. They typically will not be used at night so the equipment does not need to be illuminated. The lighting should be located to eliminate shadows or dark areas. Placement must also avoid all playground equipment safety zones, as defined by the playground equipment manufacturer.

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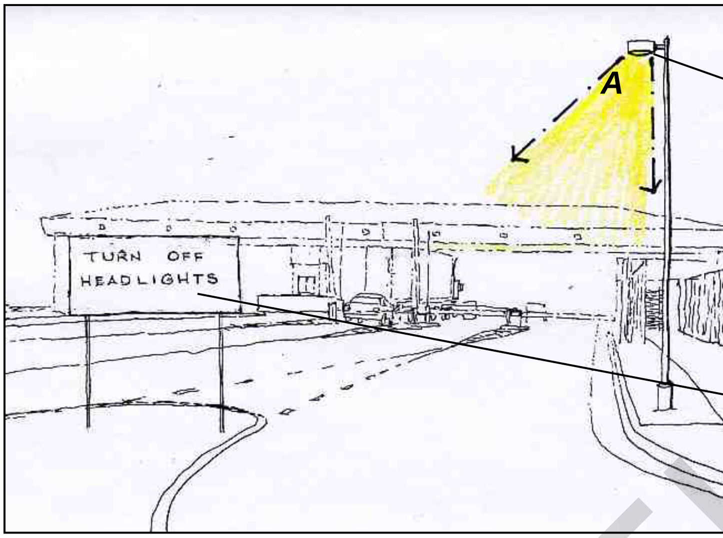
SECURITY LIGHTING — Entry Control Facility

Access Control Points – Approach Zone



Fully \2\ shielded or U0 /2/ luminaire reduces glare for approaching drivers and for security personnel. Increase light level at approach zone to provide transition to the higher level at the access control point.

Post signs that instruct motorists to turn off headlights when approaching the access control zone.

EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Pole mounted, fully shield \2\ or U0 /2/ roadway luminaire.*	*LED, induction, or metal halide.*	*Photocell on/off. Use bi-level \2\ switch / step dimming /2/ or zone switching (alternate poles) so that lighting energy consumption can be reduced during closure.*

CRITICAL DESIGN ISSUES:

- **Color Appearance:** Lighting should accurately render approaching vehicles for the security personnel on duty. At times, they may need to report vehicle color and type.
- **Direct Glare:** \2\ Fully shielded or U0 /2/ luminaires conceal the light source and minimize the direct glare from the luminaire to the driver. Because the eye adjusts to the brightest source in the field of view, eliminating glare is the highest priority in designing for nighttime driving. Signs should also instruct motorists to turn off headlights when approaching the access control zone. This will eliminate glare for the security personnel. Additional signs in the response zone should remind drivers to turn their headlights back on.

- **Light Distribution on Surfaces:** More important than light level, uniform light distribution provides high visibility and a comfortable nighttime driving environment.
- **Light Pollution / Trespass:** Fully shielded \2\ or U0 /2/ luminaires prevent any direct light from leaving the luminaire above horizontal. This direct light is the largest contributor to light pollution and light trespass. Make sure that all lighting is oriented to a horizontal plane to minimize both light pollution and trespass.
- **Peripheral Detection:** Detecting hazards while driving relies heavily on peripheral vision. Research shows that peripheral vision and detection are enhanced under white light. White light (as opposed to more orange light produced by high pressure sodium) renders objects sharper and provides excellent peripheral detection compared to high pressure sodium.
- **Point of Emphasis:** By increasing the brightness at the guardhouse and attending personnel, motorists are directed through to the access control zone.
- **Reflected Glare:** Wet surfaces often provide a surface that has the potential for reflected glare. Full cutoff or fully shielded luminaires will minimize this effect and limit the viewing angles where reflected glare becomes a problem. Also be aware of reflective surfaces (on the canopy structure, signage, etc.) that may become sources of reflected glare.
- **Shadows:** Luminaires should be located to eliminate shadows that could hide potential hazards or aggressors.
- **Backup Power:** Coordinate lighting system with emergency, backup power availability. Consider interim lighting for sources with a restrike time such as metal halide. Induction and SSL are instant-on with no re-strike time. Refer to service specific guidance regarding facilities and equipment authorized backup power.

Target Horizontal Illuminance (± 10%): 30 lux (3 footcandle) average on roadway surface. Maintain 10:1 maximum to minimum uniformity.

DISCUSSION:

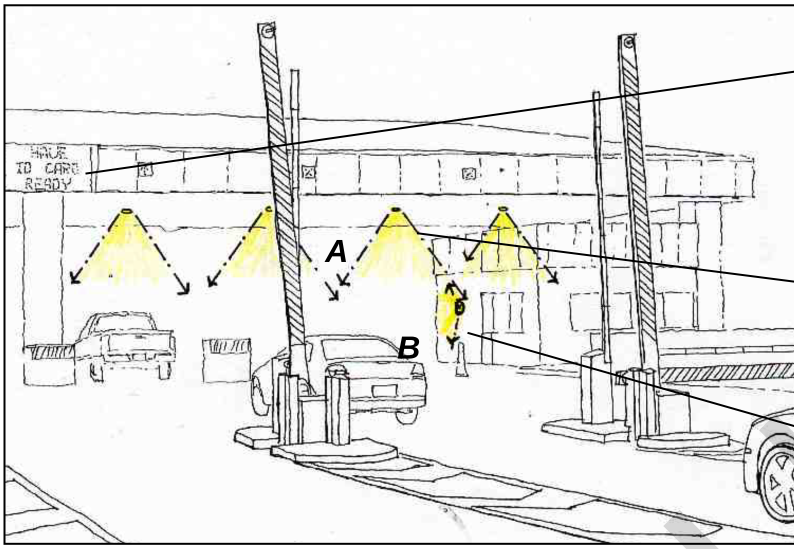
By keeping the light levels relatively low in the approach and response zones, the security personnel and the access control point will become a brighter focal point. This will direct approaching vehicles and also serve to alert motorists to the guard station.

Additionally in both the approach and response zones, signage should direct motorists to turn off headlights and then turn them back on respectively. This will prevent glare for the security personnel and minimize the adaptation problems that may be caused by viewing both bright headlights as well as much lower luminance levels.

Light levels should gradually be increased (closer pole spacing) to the recommended target illuminance as the motorist approaches the ECF. This will minimize an abrupt transition from dark to light. See Response Zone and UFC 4-022-01 Exterior lighting for additional information on transition lighting.

SECURITY LIGHTING — Entry Control Facility

Access Control Points – Access Zone



Do not backlight illuminated signage. This will reduce contrast of sign.

Recessed or surface mounted downlights eliminate glare for approaching drivers.

Low brightness luminaire behind and to side of inspection personnel to light the approaching vehicle and driver.

EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Recessed or surface mounted \2\ U0 /2/ downlights in canopy.*	*LED, induction, compact or linear \2\ T8/T5HO /2/ fluorescent, or metal halide.*	*Photocell on/off with manual override. Use bi-level switching \2\ / step dimming /2/: low level when ECP is closed and high level when open.*
A ALT	*Indirect uplights and \2\ U0 /2/ downlights for open canopy.*	*LED, compact or linear \2\ T8/T5HO /2/ fluorescent or metal halide.*	*Photocell on/off with manual override. Use bi-level switching \2\ / step dimming/2/: low level when ECP is closed and high level when open.*
B	*Surface mounted low brightness luminaire.*	*Compact fluorescent or LED.*	*On / off switch located in the guardhouse. Use bi-level switching \2\/ step dimming/2/: low level when ECP is closed and high level when open.*

CRITICAL DESIGN ISSUES:

- **Color Appearance:** Lighting must accurately render vehicles and people for both identification and reporting purposes. Sources with high color rendering properties should be used throughout the approach, control, and response zones.

- **Direct Glare:** Recessed downlights in the canopy will minimize direct glare under normal viewing conditions. The brightness of wall mounted luminaires must be low or shielded to avoid direct glare from these sources. Additionally, signs should instruct approaching motorists to turn off headlights.
- **Light Distribution on Surfaces:** Adequate vertical illuminance on any adjacent surfaces will increase the brightness in the guard's field of view. This will allow detection of movement in the form of silhouettes and reduce shadows and potential hiding areas.
- **Light Pollution / Trespass:** Fully shielded or \2\ U0 /2/ luminaires prevent any direct light from leaving the luminaire above horizontal. This direct light is the largest contributor to light pollution and light trespass. Direct light can be easily contained within the structure (canopy) of the access control point by using recessed and surface mounted lighting.
- **Identification of Faces or Objects:** Lighting should come from multiple directions to accurately model individuals, vehicles, and cargo. For example, it may be directed down from overhead lighting and also come from luminaires mounted on the guardhouse.
- **Peripheral Detection:** Detecting hazards while driving relies heavily on peripheral vision. Research shows that peripheral vision and detection are enhanced under white light. White light (such as metal halide, \2\ LED, /2/induction, or fluorescent) renders objects sharper and provides excellent peripheral detection compared to high pressure sodium.
- **Point of Emphasis:** By increasing the brightness at the guardhouse and attending personnel, motorists are directed through the access control zone.
- **Reflected Glare:** Wet surfaces often provide a surface that has the potential for reflected glare. Recessed downlights and \2\fully shielded or U02/ luminaires will minimize this potential.
- **Shadows:** Luminaires should be located to eliminate shadows that could hide potential hazards or aggressors.
- **Surface Characteristics:** By using light-colored, reflective finish colors for the structures surrounding the access control point, more light will be reflected and individuals will be more visible against lighter backgrounds.
- **Backup Power:** Coordinate lighting system with emergency, backup power availability. Consider interim lighting for sources with a restrike time such as metal halide. \1\ Induction and SSL are instant-on with no restrike time. /1/ Refer to service specific guidance regarding facilities and equipment authorized backup power.
- **Signage:** Internally lighted signage provides a good contrast ratio that provides clear and readable messages. Refer to UFC 4-022-01 Security

Engineering: Entry Control Facilities / Access Control Points for additional criteria on signage.

- **Target Horizontal Illuminance (± 10%):** \1\ 30 lux (3 footcandle) /1/ average on roadway surface. Maintain 10:1 maximum to minimum uniformity.

DISCUSSION:

Recessed downlights at the access control point will illuminate the vehicles during inspection. They will also help to light inside vehicles and the backs of trucks. Recessing the lights will conceal the light source and minimize glare for both the attendant and the motorist. If using open downlights, specify a matte or semi-specular reflector to further minimize glare. If using a lensed downlight, use a flat, clear lens.

In some projects, an open structure may cover the Access Control Zone. In such cases, downlights should still be used. However, they should be \2\ U0 /2/ \1\ or fully shielded /1/ surface or suspended-mounted cylinders attached directly to the structure.

Locate low brightness luminaire behind and to side of inspection personnel to light the approaching vehicle and driver. This will also eliminate glare for the guard.

EQUIPMENT REQUIREMENTS

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Surface mounted low brightness luminaire.*	*Compact fluorescent \2\ or LED. /2/*	*On / off switch located in the guardhouse.*

CRITICAL DESIGN ISSUES:

- **Color Appearance:** Lighting should accurately render approaching vehicles for the security personnel on duty. At times, they may need to report vehicle color and type.
- **Direct Glare:** Signs for approaching vehicles should direct motorists to turn off their headlights. This will eliminate direct glare from vehicles. Wall mounted luminaires must be low brightness (less than 3500 initial light source lumens) or shielded to eliminate glare from these sources.
- **Light Distribution on Surfaces:** Adequate vertical illuminance must be maintained to illuminate both the exterior and the interior of the vehicle.
- **Identification of Faces or Objects:** The same vertical illuminance from multiple sources will light and accurately render faces and objects in the vehicle.
- **Peripheral Detection:** Detecting hazards while driving relies heavily on peripheral vision. Research shows that peripheral vision and detection are enhanced under white light. White light (as opposed to more orange light produced by high pressure sodium) renders objects sharper and provides excellent peripheral detection compared to high pressure sodium. Peripheral detection is especially important for drivers approaching an

access control point where pedestrians and security personnel are present.

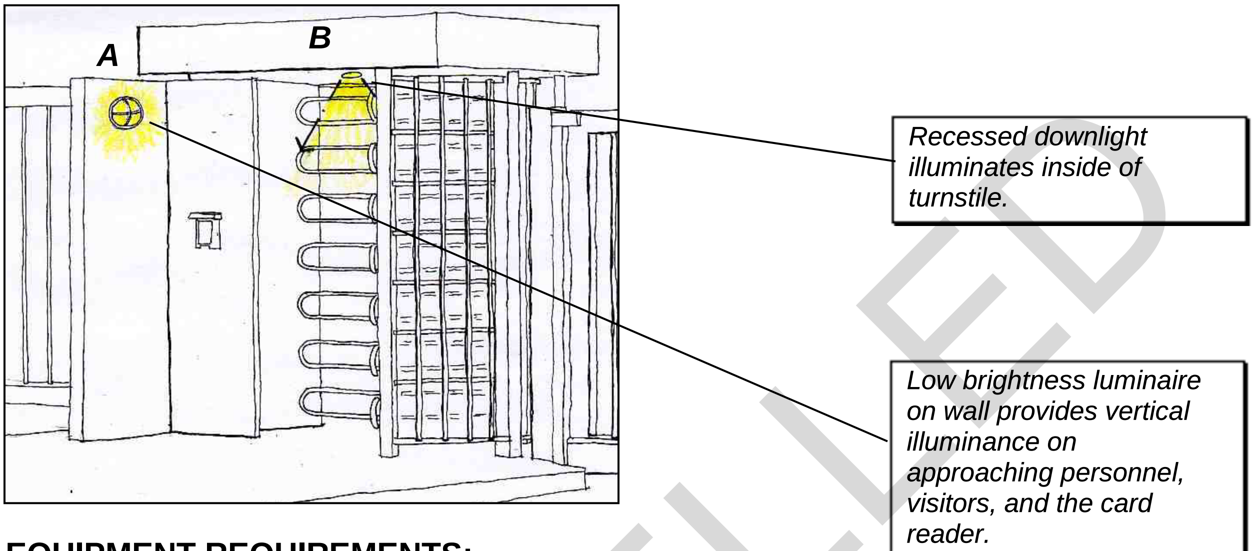
- **Reflected Glare:** Wet surfaces often provide a surface that has the potential for reflected glare. Luminaires need to be selected and located to minimize this as much as possible. It will most likely not be a problem for attendants if approaching vehicles turn off headlights.
- **Shadows:** Luminaires should be located to eliminate shadows that could hide potential hazards or aggressors. Locations will also allow for suitable inspection of vehicles.
- **Specific Task Lighting:** Low brightness task lighting should come from behind the security officer and light both the driver's face and the interior of the vehicle.
- **Target Horizontal Illuminance (± 10%):** 200 lux (20 footcandles) average.

DISCUSSION:

To help in the inspection and identification tasks required at the access control point, lighting should come from several sources. Overhead lighting will illuminate vehicles and their occupants, but if used in isolation will also cast sharp shadows on both objects and people. This will make identification more difficult and can potentially hide objects. Low brightness lighting located on the guard house, will better model the faces of motorists and wash out sharp shadows that may be created by the overhead downlight. If the lighting is coming from behind or the side of the attendant, it will light the side of the vehicle, the occupants inside, and not become a source of glare.

SECURITY LIGHTING — Entry Control Facility

Access Control Points – Pedestrian Entry



EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Surface mounted low brightness luminaire.*	*Compact fluorescent or LED.*	*Photocell on/off with manual override. Use bi-level switching\2\ / step dimming/2/ : low level when ECP is closed and high level when open.*
B	*Recessed \2\ U0 /2/ downlight*	*Compact fluorescent or LED.*	*Photocell on/off with manual override. Use bi-level switching\2\ / step dimming /2/: low level when ECP is closed and high level when open.*

CRITICAL DESIGN ISSUES:

- **Color Appearance:** Light sources with a color rendering index value of 80+ will provide accurate color appearance. This is essential for accurate identification, reporting, and CCTV recording of individuals at the entry.
- **Direct Glare:** The luminaire must provide adequate light to illuminate the person at the entry, but not so much that it becomes a source of glare. Not only will glare be an annoyance but it will also decrease visibility of the card reader. Wall mounted luminaires must be low brightness (less than 3500 initial light source lumens) or shielded to eliminate glare from these sources.

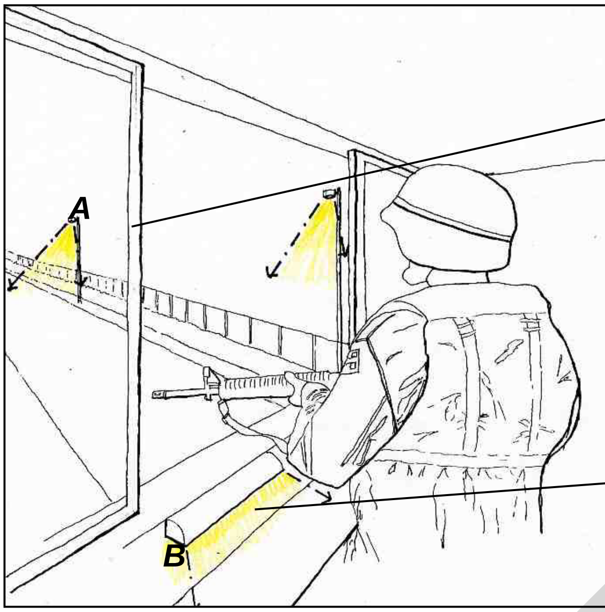
- **Light Distribution on Surfaces:** Adequate vertical illuminance on any adjacent surfaces will increase the brightness in the guard's field of view. This will allow detection of movement in the form of silhouettes and reduce shadows and potential hiding areas.
- **Identification of Faces or Objects:** Vertical illuminance will help to accurately model individuals.
- **Point of Emphasis:** A luminaire with some brightness will help to identify the entry.
- **Shadows:** Luminaires should be located to eliminate shadows that could hide potential hazards or aggressors.
- **Surface Characteristics:** By using light, reflective finish colors for the structures surrounding the access control point, more light will be reflected and individuals will be more visible against lighter backgrounds.
- **Signage:** Internally lighted signage provides a good contrast ratio that provides clear and readable messages. Refer to UFC 4-022-01 Security Engineering: Entry Control Facilities / Access Control Points for additional criteria on signage.
- **Target Horizontal Illuminance (± 10%):** \1\ 30 lux (3 footcandles) /1/ average.

DISCUSSION:

In most cases, the roadway lighting for the approach and response zones will provide plenty of light for an adjacent pedestrian entrance. The design shown above is applicable for those configurations where the pedestrian entrance must be separately lighted. While a wall mounted luminaire provides benefits such as vertical illuminance and entry identification, it must be a low brightness, low glare source. Depending on the surrounding brightness, the light source at an entry location may only be an 18 or 26 watt compact fluorescent. In cold climates, specify low temperature ballasts for reliable starting and brightness.

SECURITY LIGHTING — Entry Control Facility

Access Control Points – Response Zone



EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Pole mounted,\2\ fully shielded, U0 /2/ roadway luminaire with shielding toward the overwatch position if necessary.*	*LED, induction, or metal halide.*	*Photocell on/off.*
B	*Surface mounted task light.*	*LED, compact or linear T8/T5 fluorescent. \2\ Use red LED s to improve dark adaptation./2/*	*Manual on/off dimming.*

CRITICAL DESIGN ISSUES:

- **Color Appearance:** Good color rending is essential for guards to identify and report people or objects.
- **Direct Glare:** The roadway luminaires through the access response zone must be located either below eye level of the overwatch position or high enough above it to avoid direct glare. The guard's field of view must not contain the light source brightness. If necessary, add additional shielding on the luminaire toward the overwatch position to eliminate direct glare.
- **Light Distribution on Surfaces:** Adequate vertical illuminance on any adjacent surfaces will increase the brightness in the guard's field of view. This will allow detection of movement in the form of silhouettes and reduce shadows and potential hiding areas.

- **Identification of Faces or Objects:** Lighting must provide adequate vertical illuminance and modeling to identify and report people or objects.
- **Peripheral Detection:** Detecting potential aggressors relies heavily on peripheral vision. Movement is typically detected by this component of our eyesight. Research shows that peripheral vision and detection are enhanced under white light. White light (as opposed to more orange light produced by high pressure sodium) renders objects sharper and provides excellent peripheral detection compared to high pressure sodium.
- **Reflected Glare:** Wet surfaces often provide a surface that has the potential for reflected glare. This is especially important to personnel in an overwatch position who will be watching the road through the access control point and response zone. Luminaires need to be selected and located to minimize this as much as possible.
- **Shadows:** Luminaires should be located to eliminate shadows that could hide potential hazards or aggressors.
- **Backup Power:** Coordinate lighting system with emergency, backup power availability. Consider interim lighting for sources with a restrike time such as metal halide. Induction and SSL are instant-on with no restrike time. Refer to service specific guidance regarding facilities and equipment authorized backup power.
- **Target Horizontal Illuminance (± 10%):** \1\ 30 lux (3 footcandle) /1/ average on roadway surface. Maintain 10:1 maximum to minimum uniformity. 100 – 200 lux (10 – 20 footcandles) average task illuminance only if necessary in an overwatch position.

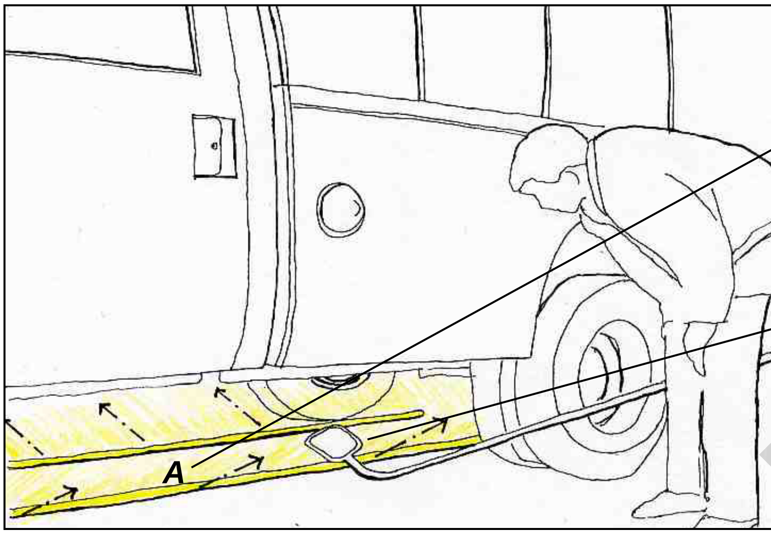
DISCUSSION:

As in the approach zone, the response zone must address the transition between a high brightness zone and a low brightness zone. Roadway lighting must continue past the access control and slowly reduce intensity. Illumination levels should be reduced by 50 percent within the average distance traveled in 15 seconds in order to create proper transitional lighting. As an example, at an ECF with a speed limit of 40 km/ph (25 mph) where the illumination level is 4 foot-candles, the illumination level should be 2 foot-candles at 168 m (550 ft) and 10 lux (1 footcandle) at 334 m (1,100 ft). Additionally signs must be posted reminding motorists to turn headlights back on.

The roadway luminaires that light the response zone must be appropriately mounted, aimed, and shielded to eliminate any glare that may be visible from an overwatch position. By first locating the luminaires on the sides of the road rather than the median, a clear view will be maintained through the entire access control area. The mounting height should not be high enough above the level of the overwatch position that the luminaire becomes a source of glare. If the light source can be seen, it should be re-aimed or shielded to eliminate the glare. By lighting the roadway uniformly and to an appropriate illuminance level, the security personnel in the overwatch position will have a comfortable view of the access control point and adjacent zones.

Additionally, lighting inside the overwatch position must be carefully located and controlled. Bright overhead lighting at night will illuminate the guards inside and make them visible. If there is any overhead lighting in the space, it must be controlled separately from task lighting located at desk height. Dimmable task lighting will enable the guard to write notes on a low desk and not be illuminated.

SECURITY LIGHTING Under Vehicle Inspection



EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Ground mounted uplight.*	*LED or fiber optic.*	*Control with on/off dimming switch in guard house.*
A ALT	*Airfield omni-directional, semi-flush taxiway luminaire.*	*LED.*	*Control with on/off dimming switch in guard house.*

CRITICAL DESIGN ISSUES:

- **Color and Contrast:** Lighting should accurately render the underside of a vehicle to show color and contrast between all components. While yellow SSL typically are less expensive than white, the color rendering for yellow is very poor.
- **Direct Glare:** The luminaire brightness must be kept at a low level because the inspector will be looking directly at the light source. Looking directly at the source must be comfortable and not a cause of adaptation problems.
- **Light Distribution on Surfaces:** The underside of the vehicle must be uniformly illuminated to eliminate shadows and allow for accurate inspection. The length of the SSL or fiber optic uplight must match the vehicle length.
- **Identification of Faces and Objects:** Good color rendering and uniform distribution of lighting will aid security personnel in the inspection process.
- **Shadows:** The light should be distributed evenly to eliminate shadows under the vehicle which may conceal objects.

- **Target Horizontal Illuminance (± 10%):** 50 – 100 lux (5 – 10 footcandles) average. Measured on a horizontal plane 12” above the ground, facing downward.

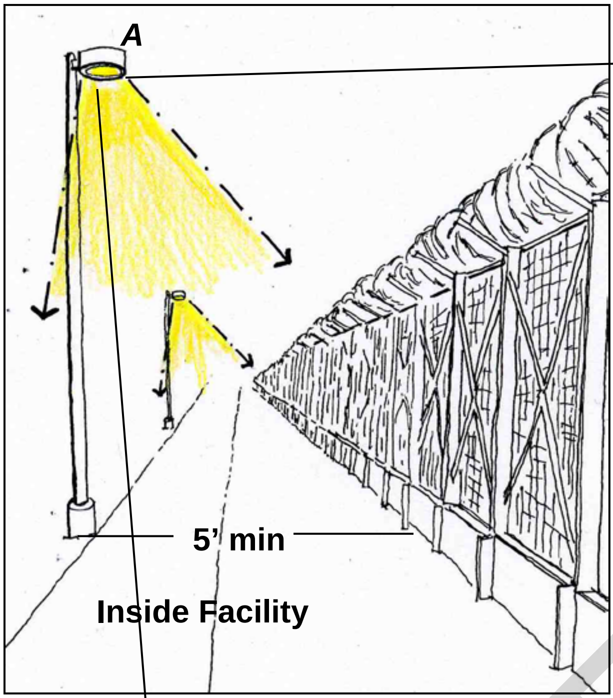
DISCUSSION:

While flashlights can be used, under vehicle inspections benefit from uplighting located below the vehicle. However, this location inherently becomes a potential source of glare. By using a low wattage light source, a distributed linear source, and even dimming control, the inspection personnel can use a handheld, angled mirror to view the underside of the vehicle without an overly bright light source in the field of view.

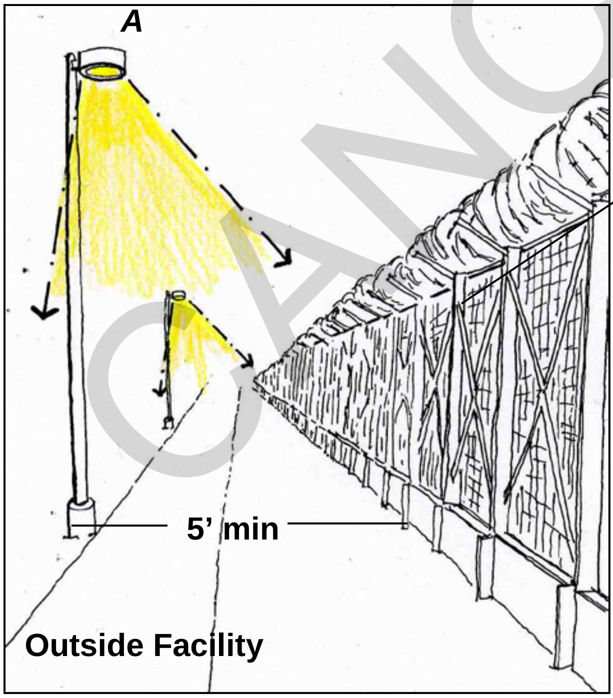
Other lighting products which may be used include fiber optic or SSL strips attached to a handheld illuminator. This allows an even source of light to be used in hard to reach places and even containers.

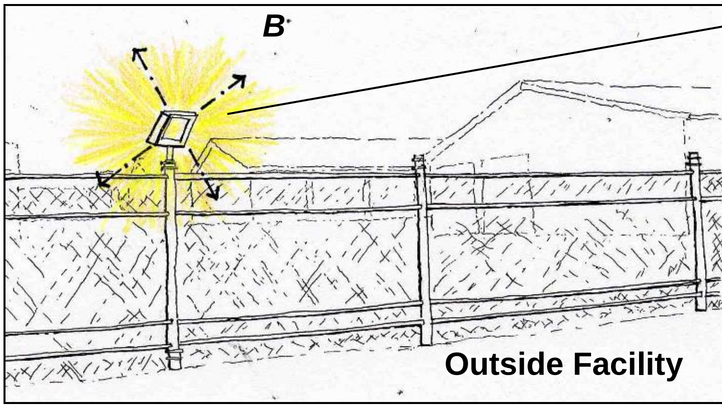
SECURITY LIGHTING — Controlled Perimeters

Pole mounted, \2\ fully shielded or U0 /2/ luminaires provide uniform illuminance and limit glare and light trespass.



Increasing the brightness on the outside of the fence permits vision through for someone on the inside, but limits it for those on the outside.





In high threat areas or expeditionary locations, glare projection strategies may be used. In these situations, aim luminaires away from the perimeter to illuminate approaching intruders and limit visibility into the protected area.

EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Pole mounted, \2\ fully shielded or U0 /2/ area luminaire located opposite the fencing or incorporated into the fence with break-away connections. (This connection in a pole will not support the weight of a person and will cause the pole to collapse if climbed.)*	*LED, induction, or metal halide.*	*Control with photocell on, time switch off. Consider motion sensors for appropriate applications (possible for induction and LED only.)*
B	*Pole mounted, floodlight aimed away from the perimeter.*	*LED, induction, or metal halide.*	*Control with photocell on, time switch off.*

CRITICAL DESIGN ISSUES:

- **Direct Glare:** \2\ Fully shielded or U0 /2/ luminaires conceal the light source and minimize the direct glare from the luminaire to the guard or patrol. Because the eye adjusts to the brightest source in the field of view, eliminating glare is the highest priority when designing for nighttime visibility.
- **Light Distribution on Surfaces:** More important than light level, uniform light distribution avoids adaptation problems when the eye must adjust between bright and dim areas. By uniformly lighting the outside of the fence, silhouettes can easily be seen. Additionally, an aggressor on the outside will only be able to see the brighter fence and will not be able to see through it.
- **Light Pollution / Light Trespass:** Fully shielded \2\ or U0 /2/ luminaires prevent any direct light from leaving the luminaire above horizontal. This direct light is the largest contributor to light pollution and light trespass.
- **Identification of Faces or Objects:** Good color rendering, uniform light distribution, and adequate vertical illuminance will aid security personnel in the identification of individuals and objects.

- **Peripheral Detection:** Detecting potential aggressors at a perimeter relies heavily on peripheral vision. White light (as opposed to more orange light produced by high pressure sodium) renders objects sharper and provides excellent peripheral detection compared to high pressure sodium.
- **Reflected Glare:** Wet surfaces often provide a surface that has the potential for reflected glare. This will only be a concern when the fence borders a paved surface that will be regularly patrolled.
- **Shadows:** Uniform distribution of lighting will minimize shadows along the perimeter and eliminate potential hiding places.
- **Backup Power:** Coordinate lighting system with emergency, backup power availability. Consider interim lighting for sources with a restrike time such as metal halide. Induction and SSL are instant-on with no restrike time. Refer to service specific guidance regarding facilities and equipment authorized backup power.
- **Target Horizontal Illuminance (± 10%):** 2 – 40 lux (0.2 – 4 footcandles) average see Table 6-1.

DISCUSSION:

Perimeter security lighting is primarily for the detection and assessment of penetrations into secured areas. Additionally, fence lines often mark the property line and adjacent properties may not allow light trespass or the location of poles. In this typical case, locate luminaires inside the property. Make sure that the poles are a minimum of 5' away from the fence so that they cannot be used to scale the fence. Locating the poles inside the perimeter will also mitigate the possibility of sabotage or vandalism.

If possible, illuminate the outside rather than the inside of the fence. In this case, an aggressor will have to pass through the lighted area to get to the fence. Additionally, the aggressor will not be able to see past a brightly lit fence to a darker area. However, a guard on the inside of the fence will have suitable visibility through it to the brightly lit perimeter.

In extreme applications where high levels of protection are required or other unusual circumstances, glare projection may be used to light the perimeter. In these applications, aim floodlight luminaires away from the fenced area. The high level of glare produced in one direction will make intruders more visible while making individuals and objects within the perimeter less visible.

When locating pole-mounted luminaires in a perimeter fence lighting application, the luminaires must not provide access to the fence. This prevents an aggressor from using the pole to climb over the fence. An exception to this restriction may be made if the luminaire is mounted with a breakaway connection. Such a connection is designed where the luminaire mounts to the top of the pole. Breakaway connections will support normal wind loads but not the added stress of a person climbing the pole.

If the perimeter uses an opaque fence, light the side that will be patrolled so that activity will be visible. Be sure and consider potential shadowing created by the opaque barrier. Shadows will provide areas for aggressors to hide.

SECURITY LIGHTING Restricted Area

Use wall mounted luminaires when possible to minimize equipment cost.

Pole mounted luminaires provide uniform illuminance and minimize shadows.

EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Pole mounted, \2\ fully shielded or U0 /2/ area luminaire.*	*LED, induction, or metal halide.*	*Control with photocell on, time switch off. Consider motion sensors in some applications (possible for induction and LED only.) Use bi-level switching \2\ / step dimming/2/: low level for security and high level for operational requirements.*
B	*Wall mounted, \2\ fully shielded or U0 /2/ area luminaire.*	*LED, induction, metal halide, or compact fluorescent.*	*Control with photocell on, time switch off. Consider motion sensors in some applications (possible for induction, LED, and CFL only.) Use bi-level switching \2\ / step dimming /2/: low level for security and high level for operational requirements.*

CRITICAL DESIGN ISSUES:

- **Direct Glare:** \2\ Fully shielded or U0 /2/ luminaires conceal the light source and minimize the direct glare from the luminaire. Eliminating the glare prevents adaptation problems when changing view between brighter and darker areas of a depot.

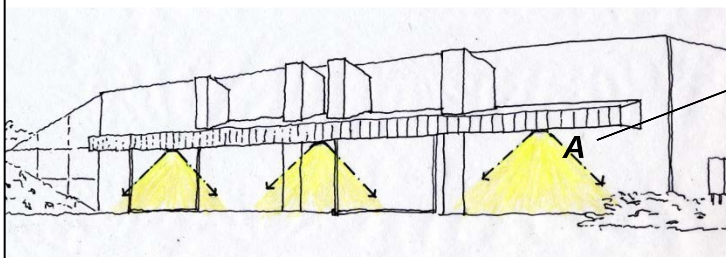
- **Light Distribution on Surfaces:** Adequate vertical illuminance on any surrounding building surfaces will increase the brightness in the guard's field of view. This will allow detection of movement in the form of silhouettes and reduce shadows and potential hiding areas.
- **Light Pollution / Trespass:** Fully shielded \2\ or U0 /2/ luminaires prevent any direct light from leaving the luminaire above horizontal. This direct light is the largest contributor to light pollution and light trespass
- **Peripheral Detection:** Detecting potential aggressors relies heavily on peripheral vision. White light (as opposed to more orange light produced by high pressure sodium) renders objects sharper and provides excellent peripheral detection compared to high pressure sodium.
- **Shadows:** Luminaires should be located to eliminate shadows that could hide potential hazards or aggressors.
- **Backup Power:** Coordinate lighting system with emergency, backup power availability. Consider interim lighting for sources with a restrike time such as metal halide. \1\ Induction and SSL are instant-on with no restrike time. /1/ Refer to service specific guidance regarding facilities and equipment authorized backup power.
- **Target Horizontal Illuminance (± 10%):** 2 – 50 lux (0.2 – 5 fc) average depending on level of protection. See Table 6-1.

DISCUSSION:

Restricted areas are designated with one of three levels of protection: medium, high, or very high. See section 6-2 for more detail on levels of protection.

By using adjacent buildings to mount lighting equipment, the number of poles can be reduced, saving both cost and space. Add pole mounted lighting to maintain lighting uniformity and eliminate shadows throughout the area.

SECURITY LIGHTING — Magazines



\2\ Fully shielded or U0 /2/ area luminaire mounted under canopy lights the door area while minimizing glare.

EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Canopy mounted, \2\ fully shielded or U0 /2/ area luminaire.*	*LED, induction, or metal halide.*	*Control with photocell on, time switch off. Consider motion sensors in some applications (possible for induction and LED only.) Use bi-level switching \2\ / step dimming/2/: low level for security and high level for operational requirements.*

CRITICAL DESIGN ISSUES:

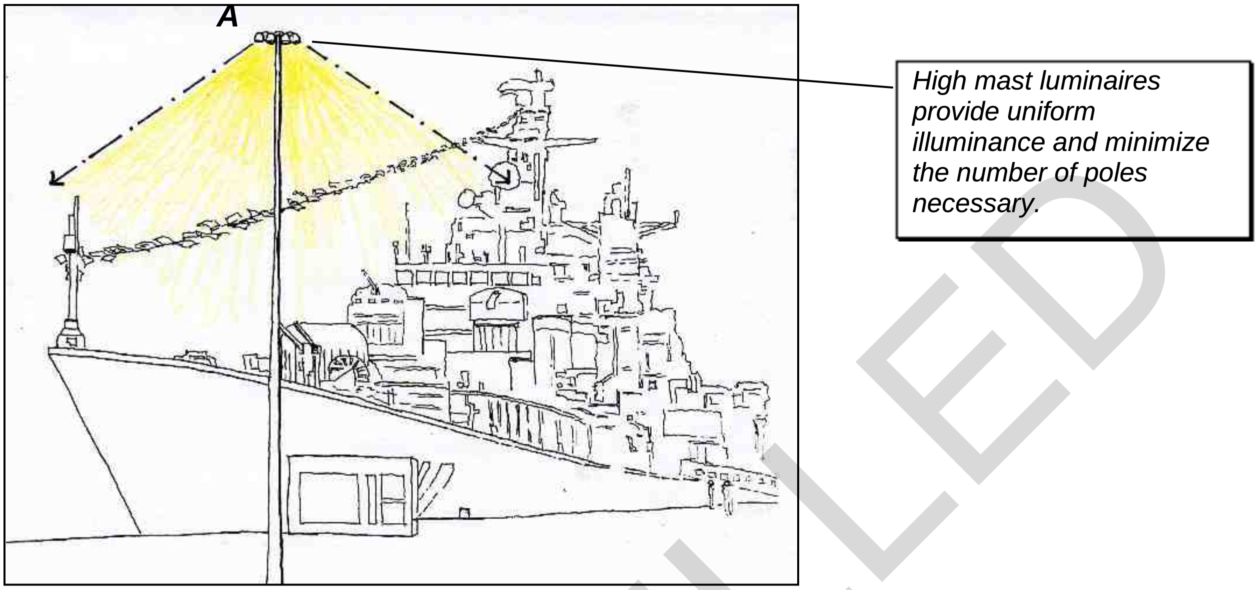
- **Direct Glare:** \2\ Fully shielded or U0 /2/ luminaires conceal the light source and minimize the direct glare from the luminaire. Eliminating the glare prevents adaptation problems when changing view between brighter and darker areas of a magazine.
- **Light Distribution on Surfaces:** Adequate vertical illuminance on the magazine building surface will increase the brightness in the field of view. This will allow detection of movement in the form of silhouettes and reduce shadows and potential hiding areas.
- **Light Pollution / Trespass:** Fully shielded \2\ or U0 /2/ luminaires prevent any direct light from leaving the luminaire above horizontal. This direct light is the largest contributor to light pollution and light trespass
- **Peripheral Detection:** Detecting potential aggressors relies heavily on peripheral vision. White light (as opposed to more orange light produced by high pressure sodium) renders objects sharper and provides excellent peripheral detection compared to high pressure sodium.

- **Backup Power:** Coordinate lighting system with emergency, backup power availability. Consider interim lighting for sources with a restrike time such as metal halide. \1\ Induction and SSL are instant-on with no restrike time. /1/ Refer to service specific guidance regarding facilities and equipment authorized backup power.
- **Target Horizontal Illuminance (± 10%):** 2 – 50 lux (0.2 – 5 fc) average depending on level of protection. See Table 6-1.

DISCUSSION:

For magazines which do not have a canopy over the doors, locate a wall mounted,\2\ fully shielded or U0 /2/ luminaire above the doors. The lighting shown for this application represents basic security lighting for the magazine. A second system (controlled separately) of area lighting will be required for operations near the magazine. This lighting equipment should be building mounted to the extent possible to minimize pole costs.

SECURITY LIGHTING Piers



EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*High mast fully shielded \2\ or U0 /2/ luminaire.*	*Metal halide.*	*Control with photocell on, timeclock off.*

CRITICAL DESIGN ISSUES:

- **Direct Glare: \2** Fully shielded \2\luminaires conceal the light source and minimize the direct glare from the luminaire. When in the immediate area of the high mast, the luminaire mounting height is sufficiently high that it is not in the field of view. However, high masts can be seen from a long distance and should be \2\ U0 /2/ \1\ or fully shielded /1/ to eliminate glare for all potential viewers.
- **Light Distribution on Surfaces:** More important than light level, uniform light distribution on the pier provides high visibility and comfort.
- **Light Pollution / Trespass:** Fully shielded or \2\ U0 /2/ luminaires prevent any direct light from leaving the luminaire above horizontal. This direct light is the largest contributor to light pollution and light trespass.
- **Peripheral Detection:** Piers may host a significant amount of activity with loading equipment, delivery vehicles, and personnel. Safety is improved with enhanced peripheral vision. White light (as opposed to more orange light produced by high pressure sodium) renders objects sharper and

provides excellent peripheral detection compared to high pressure sodium.

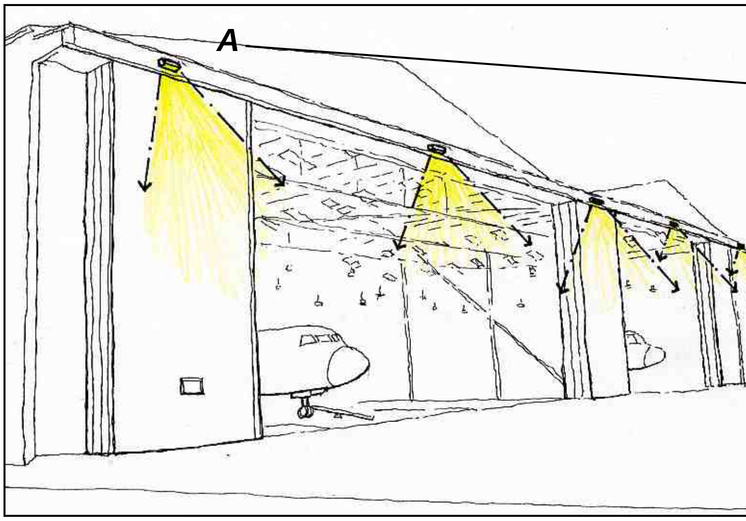
- **Reflected Glare:** Wet surfaces often provide a surface that has the potential for reflected glare. Luminaires need to be selected and located to minimize this as much as possible.
- **Shadows:** Uniform distribution of lighting will minimize shadows on the pier and eliminate potential hiding places and illuminate potential hazards.
- **Backup Power:** Coordinate lighting system with emergency, backup power availability. Consider interim lighting for sources with a restrike time such as metal halide. Refer to service specific guidance regarding facilities and equipment authorized backup power.
- **Target Horizontal Illuminance (± 10%):** \2\ Refer to UFC 4-152-01 for Pier and Wharf operational lighting requirements. /2/

DISCUSSION:

High mast lighting will minimize the obstructions on the pier and maintain clear paths for vehicles and equipment. The high mast lighting will also illuminate the ships and loading equipment in addition to the main pier.

Provide 3-5 foot-candles, average in active work areas. Provide 0.5 fc (5.4 lx) in all other areas including: pedestrian foot traffic areas, entrances, corners, vertical faces, and berth slip areas (600 ft [182.9 m] from face of pier) of piers. Utilize minimum number of high mast lighting poles and luminaires that will provide uniformity. Coordinate number, height, and location of poles with their associated concrete pedestals so as not to obstruct pier operations. Luminaires should be metal halide (MH) to provide better color rendering and nighttime visibility than HPS. Utilize luminaire shielding and \2\ fully shielded or U0/2/ features to provide the required lighting for the pier or wharf deck and waterside edges without blinding the ship's pilots during berthing operations. In sea turtle nesting areas use of low-pressure sodium (LPS) luminaires is required.

SECURITY LIGHTING — Airfields (Hangar)



Wall mounted, \2\ fully shielded or U0 /2/ area luminaires illuminate both the hanger walls and the adjacent area. The \2\ fully shielded or U0 /2/ characteristic eliminates glare for approaching aircraft.

EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Wall mounted, \2\ fully shielded or U0 /2/ area luminaire.*	*LED, induction, or metal halide.*	*On / off.*

CRITICAL DESIGN ISSUES:

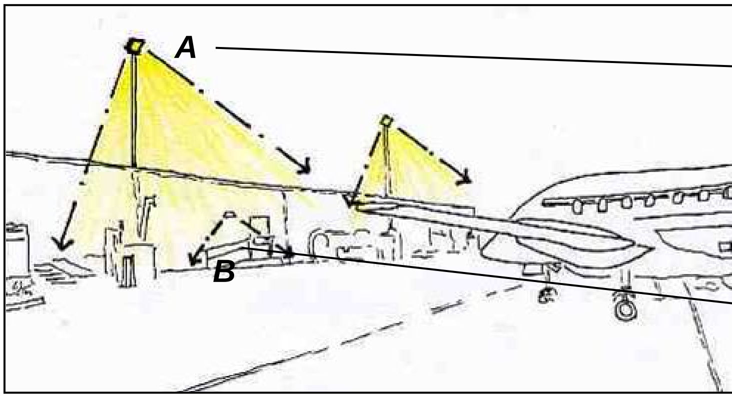
- **Direct Glare:** \2\ Fully shielded or U0 /2/ luminaires conceal the light source and minimize the direct glare from the luminaire to approaching pilots or maintenance staff.
- **Light Distribution on Surfaces:** More important than light level, uniform light distribution provides high visibility and a comfortable nighttime driving environment. Additionally, wall mounted lighting can uniformly light the exterior wall of the hangar. With this lighted background, people and objects will stand out as silhouettes.
- **Light Pollution / Trespass:** Fully shielded or \2\ U0 /2/ luminaires prevent any direct light from leaving the luminaire above horizontal. This direct light is the largest contributor to light pollution and light trespass.
- **Peripheral Detection:** Given the significant amount of activity that may occur around a hangar, peripheral detection of hazards is important. White light (as opposed to more orange light produced by high pressure sodium) renders objects sharper and provides excellent peripheral detection compared to high pressure sodium.
- **Reflected Glare:** Wet surfaces often provide a surface that has the potential for reflected glare. Wall mounted luminaires will minimize this possibility.

- **Shadows:** Luminaires should be located to eliminate shadows that could hide potential hazards or aggressors.
- **Backup Power:** Coordinate lighting system with emergency, backup power availability. Consider interim lighting for sources with a restrike time such as metal halide. Induction and SSL are instant-on with no restrike time. Refer to service specific guidance regarding facilities and equipment authorized backup power.
- **Target Horizontal Illuminance (± 10%):** 10 lux (1 footcandle) average.

DISCUSSION:

The use of wall mounted downlights will light the hangar itself as well as the surrounding area. Lighting vertical surfaces improves the security of an area by showing people and objects in silhouette. With a bright background, any movement is more visible.

SECURITY LIGHTING — Airfields (Apron)



EQUIPMENT REQUIREMENTS:

	LUMINAIRE	LIGHT SOURCE	CONTROLS
A	*Pole mounted adjustable apron luminaire with internal and external louvers.*	*Metal halide, LED, or induction.*	*Photocell on/off with manual override.*
B	*Wall mounted, \2\ fully shielded or U0 /2/ area light.*	*Metal halide, LED, or induction.*	*Photocell on/off.*

CRITICAL DESIGN ISSUES:

- **Direct Glare:** Standard apron lighting luminaires are typically aimed no more than 60 degrees above nadir toward the approaching planes. This has the potential to cause direct glare for the pilots. To minimize this glare, specify luminaires with internal louvers.
- **Light Distribution on Surfaces:** Lighting the vertical surfaces of the adjacent terminal or other buildings will increase the overall brightness of the area. This will reduce the contrast between the primary lighting and immediate surroundings.
- **Peripheral Detection:** Like hangars, a significant amount of activity may occur around the apron with the interaction of pedestrian, vehicles, and planes. White light (such as metal halide and induction) renders objects sharper and provides excellent peripheral detection compared to high pressure sodium.
- **Reflected Glare:** Wet surfaces often provide a surface that has the potential for reflected glare. This is quite possible when using a standard adjustable apron luminaire. Internal louvers on the luminaire will minimize reflected glare.

- **Shadows:** Luminaires should be located to eliminate shadows that could hide potential hazards or aggressors.
- **Backup Power:** Coordinate lighting system with emergency, backup power availability. Consider interim lighting for sources with a restrike time such as metal halide. \1\ Induction and SSL are instant-on with no restrike time. /1/ Refer to service specific guidance regarding facilities and equipment authorized backup power.
- **Target Horizontal Illuminance (± 10%):** 5-20 lux (0.5-2 footcandles) average.

DISCUSSION:

UFC 3-260-01, *Airfield and Heliport Planning and Design* specifically prohibits light emissions; either directly or indirectly (reflected), that may interfere with pilot vision in runway clear zones. Exterior lighting must meet all FAA and airfield operational regulations. These regulations restrict the height and location of poles located near airfields. Coordinate security lighting with installation's airfield safety officer and FAA regulations. Use fully shielded or \2\ U0 /2/ luminaires to reduce glare that may affect airfield operations.

Because apron lighting is typically aimed outward toward approaching planes, it is important to minimize direct glare with the use of internal louvers. The use of external louvers minimizes spill light and directs upward light (which would otherwise result in light pollution) back toward the ground. Additional luminaires may be installed on adjacent buildings to improve overall area lighting and also indicate entrance doors.

/1/

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APPENDIX B: PHYSIOLOGICAL ISSUES

B-1 Light quality and quantity can have profound physical and psychological effects. In addition to the eye fatigue that can be caused by direct and reflected glare, lighting also affects Seasonal Affective Disorder (SAD), sleep disorders, and jet lag.

B-1.1 Seasonal Affective Disorder (SAD) is a clinical condition brought about by the shorter days and less sunlight during fall and winter seasons. Symptoms include a loss of physical energy as well as emotional depression, increase in sleep requirements, and an increase in appetite. Light therapy has been used to treat SAD where patients are exposed to levels of light significantly higher than those typically provided indoors. The therapy depends more on the quantity of light, than the light source. Introducing daylight into interior spaces is the best architectural solution for SAD.

B-1.2 Sleep disorders. Because of the connection between light and sleep cycles, scientists expect that light therapy can be used to treat some sleep disorders. However, no recommendations have yet been developed for such therapy. Because circadian cycles depend on daylight during the day and darkness while sleeping, it is extremely important to expose people to daylight during the day and eliminate or minimize light in sleeping areas.

B-1.3 Jet lag results in a variety of symptoms ranging from sleep disruption to digestion problems. Similar to sleep disorders, scientists expect that light therapy can be used to overcome jet lag and its negative effects faster than the natural adjustment period.

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APPENDIX C: GLOSSARY OF LIGHTING TERMS [42]

Abbreviations and Acronyms:

ANSI – American National Standards Institute

ASHRAE – American Society of Heating, Refrigerating, and Air-Conditioning Engineers

CCT – Correlated Color Temperature

CRI – Color Rendering Index

DOE – Department of Energy

EPA – Environmental Protection Agency

FEMP – Federal Energy Management Program

HID – High-Intensity Discharge

HVAC – Heating, Ventilating, and Cooling

Hz – Hertz

IES – Illuminating Engineering Society of North America

kW – Kilowatts

kWh – Kilowatt Hours

LEC – Light Emitting Capacitor

LED – Light Emitting Diode

LLD – Lamp Lumen Depreciation

NEC – National Electric Code

NECA – National Electrical Contractors Association

NEMA – National Electrical Manufacturers Association

NESC – National Electrical Safety Code

NFPA – National Fire Protection Association

OCONUS – Outside Continental United States

O&M – Operations and Maintenance

RFI – Radio Frequency Interference

SAD – Seasonal Affective Disorder

SF – Square Foot

THD – Total Harmonic Distortion

[42] All definitions taken from “Glossary of Lighting Terminology”, *The IES Lighting Handbook*, Chapter G, Ninth Edition (New York: The Illuminating Engineering Society of North America, 2000), p. G-1.

UFGS – Unified Facilities Guide Specifications

UL – Underwriters Laboratories

V – Volt

W - Watts

Terms:

Adaptation – the process by which the retina becomes accustomed to more or less light than it was exposed to during an immediately preceding period. It results in a change in the sensitivity to light.

Altitude – the angular distance of a heavenly body measured on the great circle that passes perpendicular to the plane of the horizon, through the body and through the zenith. It is measure positively from the horizon to the zenith, from 0 degrees to 90 degrees.

Ambient Lighting – lighting throughout an area that produces general illumination

Area Lighting Luminaire – a complete lighting device consisting of a light source and ballast, where appropriate, together with its direct appurtenances such as globe, reflector, refractor, housing, and such support as is integral with the housing. The pole, post, or bracket is not considered part of the luminaire.

Average Luminance – luminance is a property of a geometric ray. Luminance as measured by conventional meters is averaged with respect to two independent variables, area and solid angle; both must be defined for a complete description of a luminance measurement.

Azimuth – the angular distance between the vertical plane containing a given line or celestial body and the plane of the meridian.

Baffle – a single opaque or translucent element to shield a source from direct view at certain angles, to absorb or block unwanted light, or to reflect and redirect light.

Ballast – a device used with an electric-discharge light source to obtain the necessary circuit conditions (voltage, current, and waveform) for starting and operating.

Ballast Factor – the fractional flux of a fluorescent light source operated on a ballast compared to the flux when operated on the standard (reference) ballast specified for rating light source lumens.

Bollard – luminaires having the appearance of a short, thick post, used for walkway and grounds lighting. The optical components are usually top-mounted.

Bowl – an open-top diffusing glass or plastic enclosure used to shield a light source from direct view and to redirect or scatter the light.

Bracket (mast arm) – an attachment to a light source post or pole from which a luminaire is suspended.

Candela, cd – the SI unit of luminous intensity, equal to one lumen per steradian (lm/sr).

Candlepower (cp), $I = d\phi/d\omega$ - luminous intensity expressed in candelas.

Clerestory – that part of a building that rises clear of the roofs or other parts and whose walls contain windows for lighting the interior.

Coefficient of Utilization (CU) – the ratio of luminous flux (lumens) calculated as received on the work plane to the total luminous flux (lumens) emitted by the light sources alone. It is equal to the product of room utilization factor and luminaire efficiency.

Color Matching – the action of making a color appear the same as a given color.

Color Rendering – a general expression for the effect of a light source on the color appearance of objects in conscious or subconscious comparison with their color appearance under a reference light source.

Color Rendering Index (of a light source) (CRI) – a measure of the degree of color shift objects undergo when illuminated by the light source as compared with those same objects when illuminated by a reference source of comparable color temperature.

Color Temperature (of a light source) – the absolute temperature of a blackbody radiator having a chromaticity equal to that of the light source. Refer to Correlated Color Temperature.

Contrast – *see luminance contrast.*

Correlated Color Temperature (of a light source) (CCT) – the absolute temperature of a blackbody whose chromaticity most nearly resembles that of the light source.

Daylight Availability – the luminous flux from the sun plus sky at a specific location, time, date, and sky condition.

Diffused Lighting – lighting provided on the work plane or on an object that is not incident predominantly from any particular direction.

Dimmer – a device used to control the intensity of light emitted by a luminaire by controlling the voltage or current available to it.

Direct Component – that portion of the light from a luminaire that arrives at the work plane without being reflected by room surfaces.

Direct Glare – glare resulting from high luminances or insufficiently shielded light sources in the field of view. It is usually associated with bright areas, such as luminaires, ceilings, and windows that are outside the visual task or region being viewed. A direct glare source can also affect performance by distracting attention.

Direct-Indirect Lighting – a variant of general diffuse lighting in which the luminaires emit little or no light at angles near the horizontal.

Direct Lighting – lighting involves luminaires that distribute 90 to 100% of the emitted light in the general direction of the surface to be illuminated. The term usually refers to light emitted in a downward direction.

Directional Lighting – lighting provided on the workplane or on an object. Light that is predominantly from a preferred direction.

Disability Glare – the effect of stray light in the eye whereby visibility and visual performance are reduced. A direct glare source that produces discomfort can also produce disability glare by introducing a measurable amount of stray light in the eye.

Discomfort Glare – glare that produces discomfort. It does not necessarily interfere with visual performance or visibility.

Downlight – a small direct lighting unit that directs the light downward and can be recessed, surface-mounted, or suspended.

Efficacy – See *luminous efficacy of a source of light.*

Efficiency – See *luminaire efficiency*.

Electroluminescence – the emission of light from a phosphor excited by an electromagnetic field.

Emergency Exit – a way out of the premises that is intended to be used only during an emergency.

Emergency Lighting – lighting designed to supply illumination essential to the safety of life and property in the event of a failure of the normal supply. The system must be capable of providing minimum required illuminance specified in NFPA 101, *Code for Safety to Life from Fire in Buildings and Structures*.

Exit sign – a graphic device including words or symbols that indicates or identifies an escape route or the location of, or direct to, an exit or emergency exit.

Floodlight – a projector designed for lighting a scene or object to a luminance considerably greater than it surroundings.

Fluorescent light source – a low pressure mercury electric-discharge light source in which a fluorescing coating (phosphor) transforms some of the UV energy generated by the discharge into light.

Flush-mounted or Recessed Luminaire – a luminaire that is mounted above the ceiling (or behind a wall or other surface) with the opening of the luminaire level with the surface.

Footcandle, fc – a unit of illuminance equal to 1 lm/ft^2.

Full Cutoff – the classification for a roadway luminaire where zero candela intensity occurs at an angle of 90 degrees above nadir, and at all greater angles from nadir. Additionally, the candela per 1000 light source lumens does not numerically exceed 100 (10%) at a vertical angle of 80 degrees above nadir. This applies to all lateral angles around the luminaire.

Fully Shielded – the classification for an exterior luminaire where all light emitted by the luminaire, either directly from the light source or a diffusing element, or indirectly by reflection or refraction from any part of the luminaire, is projected below the horizontal. (Definition from the International Dark Skies Association Outdoor Lighting Code

Handbook.)

Glare – the sensation produced by luminances within the visual field that are sufficiently greater than the luminance to which the eyes are adapted, which causes annoyance, discomfort, or loss in visual performance, and visibility.

Globe – a transparent or diffusing enclosure intended to protect a light source, to diffuse and redirect its light, or to change the color of the light.

High-Intensity discharge (HID) Light source – an electric-discharge light source in which the light-producing arc is stabilized by bulb wall temperature, and the arc tube has a bulb wall loading in excess of 3 W/cm². HID light sources include groups of light sources known as mercury, metal halide, and high pressure sodium.

High-Mast Lighting – illumination of a large area by means of a group of luminaires that are designed to be mounted in a fixed orientation at the top of a high mast, generally 20 m (65 ft.) or higher.

High-Pressure sodium (HPS) light source – a high intensity discharge (HID) light source in which light is produced by radiation from sodium vapor.

Illuminance – the areal density of the luminous flux incident at a point on a surface. Commonly measured in the horizontal or vertical plane

Illuminance (footcandle or lux) meter – an instrument for measuring illuminance on a plane. The instrument is comprised of some form of photodetector with or without a filter driving a digital or analog readout through appropriate circuitry.

Illumination – an alternative but deprecated term for illuminance.

Incandescent filament light source – a light source in which light is produced by a filament heated to incandescence by an electric current.

Indirect Component – the portion of the luminous flux from a luminaire that arrives at the workplane after being reflected by room surfaces.

Indirect lighting – lighting involving luminaires that distribute 90 to 100% of the emitted light upward.

Induction lighting – lighting technology that uses electric current to induce an electromagnetic field within the phosphor coated light source. No filaments are used. Its advantages include instant on/off operation, white light with good color rendering characteristics, and a long light source life of 100,000 hours.

Instant-start fluorescent light source – a fluorescent light source designed for starting by a high voltage without preheating of the electrodes.

Intensity (candlepower) distribution curve – a curve, often polar, that represents the variation of luminous intensity of a light source or luminaire in the plane through the light center.

Isolux (Isofootcandle) line – a line plotted on any appropriate set of coordinates to show all the points on a surface where the illuminance is the same.

Kelvin – the unit of temperature used to designate the color temperature of a light source.

Light source – a generic term for a source created to produce optical radiation.

Light source Lumen Depreciation (LLD) Factor – the fractional loss of light source lumens at rated operating conditions that progressively occurs during light source operation.

Lens – a glass or plastic element used in luminaires to change the direction and control the distribution of light rays.

Light – radiant energy that is capable of exciting the retina and producing a visual sensation.

Light-Emitting Diode (LED) - a p-n junction solid state diode whose radiated output is a function of its physical construction, material used, and exciting current.

Light Loss Factor (LLF) – formerly called maintenance factor. The ratio of illuminance (or exitance or luminance) for a given area to the value that would occur if light sources operated at their (initial) rated lumens and if no system variation or depreciation had occurred.

Light Meter – a common name for an illuminance meter.

Light Source Color – the color of the light emitted by a source.

Louver – a series of baffles used to shield a source from view at certain angles, to absorb or block unwanted light, or to reflect or redirect light.

Low-Bay Lighting – interior lighting where the roof trusses or ceiling height is approximately 7.6 m (25 ft.) or less above the floor.

Low-Pressure Mercury Vapor Light source – a discharge light source (with or without a phosphor coating) in which the partial pressure of mercury vapor does not exceed 100 Pa during operation.

Low-Pressure Sodium (LPS) Light source – a discharge light source in which light is produced by radiation from sodium vapor.

Lumen, lm – SI unit of luminous flux.

Lumen Depreciation – the decrease in lumen output that occurs as a lam pis operated, until failure.

Lumen (or flux) Method – a lighting design procedure used for predetermining the relation between the number and types of light sources or luminaires, the room characteristics, and the average illuminance on the workplane.

Luminaire (light fixture) – a complete lighting unit consisting of a light source or light sources and ballast(s) (when applicable) together with the parts designed to distribute the light, to position and protect the light sources, and to connect the light sources to the power supply.

Luminaire Dirt Depreciation (LDD) – the fractional loss of task illuminance due to luminaire dirt accumulation.

Luminaire Efficiency – the ratio of luminous flux (lumens) emitted by a luminaire to that emitted by the light source or light sources used therein.

Luminance Contrast – the relationship between the luminances of an object and its immediate background.

Luminance ratio – the ratio between the luminances any two areas in the visual field.

Luminous Efficacy of a Source of Light – the quotient of the total luminous flux emitted to the total light source power input. It is expressed in lumens per watt.

Matte Surface – a surface from which the reflection is predominantly diffuse, with or without a negligible specular component.

Means of Egress - an unobstructed and continuous way of exit from any point in a building or structure to a public way.

Mercury Light source - a high-intensity discharge (HID) light source in which the major portion of the light is produced by radiation from mercury operating at a partial pressure in excess of 10s Pa.

Mesopic Vision – vision with fully adapted eyes at luminance conditions between those of photopic and scotopic vision, that is, between about 3.4 and 0.034 cd/nr.

Metal Halide Light source – a high-intensity discharge (HID) light source 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.

Orientation – the relation of a building with respect to compass directions.

Overcast Sky – one that has 100% cloud cover; the sun is not visible.

Overhang – the distance between a vertical line passing through a specified point (often the photometric center) of a luminaire and the curb or edge of a roadway.

PAR Light source – See pressed reflector light source.

Partly Cloudy Sky – a sky that has 30 to 70% cloud cover.

Pendant luminaire – See suspended luminaire.

Peripheral Vision – the seeing of objects displaced from the primary line of sight and outside the central visual field.

Photometry – the measurement of quantities associated with light.

Photopic Vision – vision mediated essentially or exclusively by the cones. It is generally associated with adaptation to a luminance of at least 3.4 cd/m^2.

Point-by-Point Method – a method of lighting calculation, now called the point method.

Point Method – a lighting design procedure for predetermining the illuminance at various location in lighting installations by use of luminaire photometric data.

Point Source – a source of radiation, whose dimensions are sufficiently small, compared with the distance between the source and the irradiated surface, that these dimensions can be neglected in calculations and measurements.

Pole (roadway lighting) – a standard support generally used where overhead lighting distribution circuits are employed.

Programmed Rapid Start – a fluorescent starting method where the cathode is preheated before the light source is ignited. This softer ignition increases the number of starts over the life of the light source.

Quality of Lighting – pertains to the distribution of luminance in a visual environment. The term is used in a positive sense and implies that all luminances contribute favorably to visual performance, visual comfort, ease of seeing, safety, and aesthetics for the specific visual tasks involved.

Rapid-Start Fluorescent Light source – a fluorescent light source designed for operation with a ballast that provides a low-voltage winding for preheating the electrodes and initiating the arc without a starting switch or the application of high voltage.

Rated Light source Life – the life value assigned to a particular type light source. This is commonly a statistically determined estimate of average or of median operational life.

Reflected Glare – glare resulting from reflections of high luminances in polished or glossy surfaces in the field of view.

Reflection – a general term for the process by which the incident flux leaves a (stationary) surface or medium from the incident side without change in frequency.

Reflector – a device used to redirect the flux from a source by the process of reflection.

Scotopic Vision – vision mediated essentially or exclusively by the rods. It is generally associated with adaptation to a luminance below about 0.034 cd/m².

Self-Ballasted Light sources – any arc discharge light source of which the current limiting devices is an integral part.

Solid State Lighting – light sources that generate light through electroluminescence rather than filaments or gas discharge. SSL sources include light emitting diodes (LEDs), organic light emitting diodes (OLEDs), and polymer light emitting diodes (PLED).

Spacing – for roadway lighting, the distance between successive lighting units, measured along the centerline of the street.

Spacing-to-Mounting-Height Ratio – the ratio of the actual distance between luminaire centers to the mounting height above the work plane.

Sun Bearing – the angle measured in the plane of the horizon between a vertical plane at a right angle to the window wall and the position of this plane after it has been rotated to contain the sun.

Suspended (pendant) Luminaire – a luminaire that is hung from a ceiling by supports.

Table Lamp– a portable luminaire with a short stand, suitable for standing on furniture.

Torchiere – an indirect floor light source that sends all or nearly all of its light upward.

Translucent – transmitting light diffusely or imperfectly.

Transmission – a general term for the process by which incident flux leaves a surface or medium on a side other than the incident side, without change in frequency.

Transmittance – the ratio of the transmitted flux to the incident flux.

Transmittance, Visible(T_{vis}) – the percentage of the visible spectrum transmitted.

Transparent – having the property of transmitting rays of light through its substance so that bodies situated beyond or behind can be distinctly seen.

Troffer – a long recessed lighting unit usually installed with the opening flush with the ceiling.

Tungsten-Halogen Light source – a gas-filled tungsten filament incandescent light source containing a certain proportion of halogens in an inert gas whose pressure exceeds 3 atm.

Valance – a longitudinal shielding member mounted across the top of a window or along a wall (and is usually parallel to the wall) to conceal light sources, giving both upward and downward distributions.

Valance Lighting – lighting comprising light sources shielded by a panel parallel to the wall at the top of a window.

Veiling Reflection – regular reflections that are superimposed upon diffuse reflections from an object that partially or totally obscure the details to be seen by reducing the contrast.

Visibility – the quality or state of being perceivable by the eye.

Volt – the difference in electrical potential between two points in a circuit.

Watt – the unit of power (rate of doing work). In electrical calculation, one watt is the poser produced by a current of one ampere across a potential difference of one volt.

Workplane – the plane on which a visual task is usually done, and on which the illuminance is specified and measured.