



White Paper on Outdoor Lighting Issues

Quality Lighting Applications

Prepared by the

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Introduction:

Providing quality outdoor lighting is a challenge to state and local policymakers. The need to balance safety and security while maintaining natural habitats are legitimate issues. This white paper is intended to educate and provide information related to outdoor lighting issues and quality lighting. This paper will identify specific lighting issues, explain the interaction of these lighting issues, define correct lighting terminology and provide straightforward technical guidance.

The NEMA Outdoor Lighting Task Force is a specific working group of the NEMA Luminaire Section. The Section is comprised of thirteen manufacturers representing some 90 percent of the lighting market, both in indoor and outdoor.

The National Electrical Manufacturers Association (NEMA) is the leading trade association in the United States representing the interests of electroindustry manufacturers. Founded in 1926 and headquartered near Washington, D.C., our 400 member companies manufacture products used in the generation, transmission and distribution, control, and end-use of electricity. Domestic shipments of electrical products within the NEMA scope exceed \$100 billion.

What Is Happening Around the States on Outdoor Lighting Issues?

Recommendations made by the NEMA Outdoor Lighting Task Force have been adopted by California in a rulemaking on outdoor lighting, as well as in Virginia and Rhode Island law. Many states and municipalities have, or are in the process of, developing outdoor lighting standards. When carefully constructed, these standards can help to reduce sky glow, light trespass onto adjacent properties, glare and energy consumption. However, myriad remedies including among others: full cutoff luminaire recommendations for specific lumen output; use of specific lamp source types or wattages; and, pole height limitations have been proposed. These well-intentioned remedies are not clearly defined and actually work to make outdoor lighting a greater problem. Poorly written codes can increase in energy usage resulting in greater air and light pollution; some requirements also make it very difficult to ensure a safe and secure environment.

What are the Fundamental Principles that Require Consideration?

Effective lighting design incorporates careful consideration of many variables including overall visibility, safety and security, energy efficiency, light trespass, and environmental concerns such as sky glow or impact on local wildlife. It is important to understand the interrelationship of the various factors that affect quality lighting before outdoor lighting codes are written. Moreover, outdoor lighting codes often try solutions that result in unintended consequences. These include, among others:

- Mandating the use of full cutoff luminaires will reduce light emitted directly from the luminaire into the night sky, but can increase sky glow from light reflected off ground surfaces. It may also require the use of more lighting equipment resulting in increased overall cost and energy consumption.
- Pole height limitations often result in poor lighting uniformity, increased costs, greater sky glow, and higher energy consumption. Pole height mandates typically increase the required number of poles and luminaires leading to increased costs and energy consumption. Excessively dark areas may compromise safety and security while excessively bright areas will increase sky glow due to light reflected from ground surfaces into the night sky.
- The use of Low Pressure Sodium lighting is often required in areas surrounding observatories because it can be easily filtered by observatory instrumentation. However, the characteristics of this source will result in a reduction in the ability to distinguish specific colors and contrast and as such, should be carefully considered for appropriate uses. Low Pressure Sodium lamps concentrate their output in the yellow portion of the visual spectrum. These types of lamps may cause color identification problems and may impact nighttime visibility.
- It is important to evaluate the effectiveness of scheduled outdoor lighting operation time frames. Reducing late-night light levels may be effective in some areas to reduce energy consumption and sky glow. However these schedules must be flexible and sensitive to safety and security issues.

What are the Most Effective Design Techniques?

Effective design techniques for outdoor lighting include:

- Defining lighting criteria based on the demographics for the area. There are distinct differences in the lighting requirements between urban and rural areas. Many codes and guidelines reference these areas as “environmental zones” or “lighting zones.” It is important to ensure that sufficient light levels accommodate the safety and security needs for the area. Retail or other areas with higher safety and security requirements may need to be addressed separately.
- The use of technically feasible and recommended lighting component devices that minimize unwanted light. These components include: using pole heights and spacing appropriate to the application; utilizing a shield that minimizes the component of light above horizontal and glare when luminaires need to be tilted or aimed (but avoiding tilting cutoff luminaires); control systems to reduce light levels during inactive periods or at predetermined times.
- IESNA recommended target illuminance guidelines for Security Lighting for People, Property and Public Spaces will provide adequate illuminance recommendations to ensure visibility for increased safety and security. Excessive illuminance levels may increase the likelihood of sky glow, light trespass and glare. Adaptation difficulties may exist when leaving a brightly lit area to the darker roadway. Use of excessive lamp wattage and/or illuminance wastes energy and contributes to glare and sky glow.

What Does the NEMA Outdoor Lighting Task Force Propose?

The Outdoor Lighting Task Force recommends legislative language that achieves effective light distribution while addressing energy consumption, sky glow, safety, security, operating costs and concerns. However, NEMA recommends language that does not mandate the use of full cut-off lighting. Such applications will restrict design flexibility, increase energy consumption, and may increase sky glow.

The Outdoor Lighting Task Force promotes technological solutions. Lighting professionals need a full range of options at their disposal to effectively address outdoor lighting concerns. The broad restriction of general product types will limit the use of new or emerging product technologies. Qualified lighting professionals recommend lighting that provides a minimum acceptable illuminance for a designated purpose (based on nationally recognized standards). Code requirements may also limit products to two percent (2%) upright above the horizontal plane of the luminaire for general area lighting such as parking lots or outdoor sales lots.

Finally, any language should allow exemptions for (among others): significant safety or security concerns; historic or residential areas that require special product aesthetics or vertical illuminance criteria (this exemption may be designed to limit the lamp lumens or wattage to control glare and light trespass); temporary lighting used for emergency or nighttime work; lighting used solely to enhance the beauty of an object; and special public events.

What are Further Sources of Recognized Information?

Input should be gathered from recognized lighting professionals or equipment manufacturers. These entities, and other industry organizations that can also provide useful information include:

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| • Illuminating Engineering Society of North America | (IESNA) |
| • International Association of Lighting Designers | (IALD) |
| • National Council on Qualifications for the Lighting Professions | (NCQLP) |
| • National Electrical Manufacturers Association | (NEMA) |

These organizations can help to identify the specific issues for your lighting needs, and understand the interrelationship of product and design criteria. In addition, the International Dark-Sky Association can provide information regarding outdoor lighting near or around observatories, or areas concerned with sky glow.

For further information regarding this white paper, please contact the National Electrical Manufacturers Association (NEMA) at 703-841-3200 or via our website at www.nema.org.

OUTDOOR LIGHTING ISSUES:

	What Is It?	What Causes It?	How Is Do I Minimize It?	Typical Code Issues
<p>Sky Glow</p> <p>- or -</p> <p>“Light Pollution”</p>	<p>Sky glow is the haze or “glow” of light that surrounds highly populated areas and reduces the ability to view the night time sky. Sky glow is of particular concern in areas near observatories. Light emitted or reflected into the sky interferes with the ability of the observatory and the public to view the sky in an unobstructed manner.</p>	<p>The sky glow phenomenon is a result of light reflected from atmospheric particles such as fog, dust, or smog. It results from light entering the sky from outdoor lighting in these two ways:</p> <ul style="list-style-type: none"> • Light emitted from a luminaire in a direction above the plane of the horizon. • Light emitted from a luminaire in a direction below the plane of the horizon but reflected from the surrounding surface, including the ground, towards the sky. The effect this has depends on the amount of light aimed to the reflective surface, the reflectivity of that surface and the angle of the light leaving the surface. 	<p>To minimize sky glow effects, appropriate lighting equipment and layout design should be utilized:</p> <ul style="list-style-type: none"> • Turn off non-critical lighting late at night; but roadway luminaires should remain lit at night. • Limit the use of non-cutoff luminaires. • Select luminaires emitting little to no light above the plane of the horizon. • Utilize internal or external shielding that minimizes the component of light above horizontal when luminaires need to be tilted or aimed. • Design to appropriate light levels and space poles such that illuminance on the ground is uniform. Excessive illuminance will increase the reflected component of light into the sky and affect visual adaptation especially when driving from one area to another. 	<p>Outdoor codes often mandate full cutoff luminaires. Such devices restrict design flexibility and can cause greater sky glow.</p> <p>Requirements for IESNA cutoff luminaires, when properly applied, can reduce uplight, but a better requirement to limit sky glow may be to limit uplight.</p> <p>Restrictions on pole heights often create more application problems, such as reduced uniformity or increased sky glow due to light reflected off ground surfaces.</p> <p>Curfews for lighting can create enforcement and regulatory burdens. When properly implemented for sensitive areas or specific applications such as sportlighting, curfews can reduce nuisance lighting and reduce energy consumption.</p> <p>Regulating lamps lumen per watt (high and low pressure sodium issues) can cause color identification issues and hinder lighting quality and visual acuity.</p>
<p>Light Trespass</p>	<p>Light trespass occurs when neighbors of an illuminated space are affected by the lighting system’s inability to contain its light within the intended area.</p> <p>The most common form of light trespass is spill light, illuminating objects beyond the property boundaries.</p> <p>Light trespass has become an increasing concern as residences and commercial developments are constructed closer to each other.</p> <p>Light trespass may be more obvious during late night hours.</p>	<p>Light trespass occurs when a luminaire emits too much light at high angles or projects light too far from where it is intended.</p> <p>A common cause of light trespass is the inappropriate selection, tilting or aiming of outdoor luminaires for the particular lighting task.</p> <p>Even luminaires that are designed to control their light output can be light trespass offenders when improperly applied within a lighting design.</p> <p>It is important to remember that all types of outdoor luminaires will emit some amount of light to an unwanted area.</p>	<p>Light trespass can be minimized through the:</p> <ul style="list-style-type: none"> • Careful selection of lamp wattage, luminaire type, and placement. • Appropriate reflector selection; aiming and shielding of the luminaires is critical to keep the projection of the light within property boundaries. <p>When using floodlights or wallpacks in areas close to adjacent properties, select products that utilize advanced optical techniques to minimize light trespass.</p> <p>Noncutoff luminaires will not have a significant impact on light trespass if the light does not project far from the luminaire location.</p>	<p>Codes will often require the following that don’t fully solve the problem or introduce unintended results:</p> <ul style="list-style-type: none"> • Optical cutoff luminaires; flat lenses are a requirement in some codes; • Product mandates that eliminate lighting choices thus limiting application flexibility • Maximum allowed lumens or “lumen caps” • Pole height limits • Civil and/or criminal penalties; clogs system • Trespass limits that are not technologically feasible

	What Is It?	What Causes It?	How Do I Minimize It?	Typical Code Issues
Glare	<p>Glare occurs when a bright source causes the eye to be continually drawn toward the bright image or source thus preventing and adequately viewed target; may create a loss of contrast or an afterimage on the retina of the eye reducing overall visibility.</p> <p>Two classifications of glare:</p> <ul style="list-style-type: none"> • Discomfort glare: does not necessarily keep the viewer from seeing an object but does cause a constant adaptation of the eye to the contrast of light levels that in turn may cause a sensation of discomfort. • Disability glare: occurs when the bright source causes stray light to scatter in the eye which causes the primary image on the retina to be obscured. It may prevent the viewer from seeing things of importance. 	<p>There are two distinct situations when glare occurs:</p> <ol style="list-style-type: none"> 1. When a spot in the field of view is significantly brighter in contrast to the rest of the field of view. An example is when a bright direct or reflected lamp image is visible. 2. When a significant difference in light levels exists between adjacent areas. An example is when a person leaves a brightly lit gas station and re-enters the roadway; it may take minutes for the eyes to adapt to the lower lighting levels. 	<p>Full cutoff and cutoff luminaires can help prevent the direct image of a bright source and lower the intensity of the light at high angles. Luminaires may be equipped with louvers and/or exterior visors to prevent viewing a bright source at lower angles.</p> <p>Use of quality prismatic or opaque lens materials can spread the bright image over a larger area and reduce the brightness of the source.</p> <p>Maximum mounting heights are required for proper aiming of floodlight luminaires to reduce glare in an adjacent, unintended, field of view.</p> <p>It is important to conform to ambient light levels based on the environment of proposed installation. Even lighting designs intended to comply with local codes or master store specifications may need to be adjusted to accommodate the specific surrounding environment.</p>	<p>Codes will often require the following that don't fully solve the problem or introduce unintended results:</p> <ul style="list-style-type: none"> • Full cutoff luminaires; flat lenses are a requirement in some codes; • Product mandates that eliminate lighting choices thus limiting application • Maximum allowed lumens or "lumen caps" • Pole height limits • Civil and/or criminal penalties; clogs system • Glare limits that are not technologically feasible <p>Codes designed to limit glare can specify various levels of optical cutoff for specific zones or specific limits on high angle brightness.</p>
Energy Use	<p>Outdoor lighting products use electrical energy to light a given area. Are there efficiencies that can be captured to gain greater energy cost savings?</p>	<p>Higher energy costs are associated with the excessive use of nonessential devices; these devices provide too much light or operate at the wrong hours, among other issues.</p>	<p>Energy costs can be reduced by ensuring that the proper design has been chosen for the given application, and that the lighting devices are operating at the right times.</p> <p>Moreover, the favorable use of lighting controls and reasonable, flexible curfews can be structured to achieve greater energy cost savings.</p>	<p>Code language that implements design mandates can use more energy. The arbitrary and inflexible use of a full cutoff luminaire in every lighting application combined with a lumen mandate may lead to more fixtures and greater energy and maintenance costs.</p> <p>Every use is unique: code language must allow for comprehensive quality lighting designs that factor lighting power densities, lamp types and control devices according to design/application criteria.</p>
Manage Safety and Security	<p>Outdoor lighting is often installed to discourage crime and vandalism and to promote a perception of safety. Public facilities utilize lighting to manage their liability responsibilities.</p>	<p>Inappropriate lighting (too much or too little) creates an imbalance. Specifically, too little light can cause poor uniformity and shadows leading to potential criminal activity. Too much light can result in glare reducing the ability to identify potential hazards or criminal activities.</p>	<p>Lighting professionals have established criteria for these and other issues in the IESNA G-1-03 document. This document specifies higher illuminance for safety concerns. Moreover, the IESNA guidelines provide for adequate vertical lighting and uniformity ratios.</p>	<p>Codes affect liability, safety and security and pedestrian safety; codes must allow for comprehensive quality lighting designs that account for design/application criteria to protect community movement, property, and safety and security concerns (e.g. anti-terror efforts to 24 hour public safety). IESNA safety and security guidelines or others established for crime prevention must be considered.</p>

	What Is It?	What Causes It?	How Do I Minimize It?	Typical Code Issues
Natural Habitat	Natural habitat such as sea turtles and birds utilize the moon and stars to guide them. Interference with the natural environment may cause detrimental impacts on hatching and migration patterns.	Excessive electrical light, especially light that contributes to glare, light trespass and sky glow can improperly direct young sea turtles away from the water. Excessive light can also misdirect bird migration due to negative impact on the bird's ability to see the stars.	In areas where natural habitat concerns exist, the lighting design should utilize lighting products that minimize glare, light trespass and sky glow. The spectral content of certain types of lamps may also minimize the impact on wildlife.	Outdoor codes often mandate full cutoff luminaires. Such devices restrict design flexibility and can cause greater sky glow. Codes should include requirements to protect natural habitat by defining those areas where there is a need to minimize the impact. Careful evaluation of the local conditions and identifying specific, enforceable criterion is necessary for a successful code. In many cases, using certain types of light sources such as high pressure sodium, restricting high angle brightness or enforcing curfews can result in the most effective results.
Lighting Quality	Lighting quality can mean various things to different stakeholders. Typically, this term is used to describe lighting that provides the right amount of light, to the right place at the right time. Lighting quality may also consider the materials used to manufacture a product or characteristics that relate to the maintenance of the system.	Superior lighting installations are achieved by careful evaluation of the requirements of the site (visibility, environmental issues, security, maintenance, etc.). Designs will often require a tradeoff among various these requirements. Quality lighting products generally include premium materials and precisely designed optical systems (reflectors, refractors, lenses).	Quality lighting applications can be compromised even when superior products are used. The lighting products and proper design techniques integrate together to achieve preferred results.	Codes often state objectives to maximize quality lighting. The tradeoffs required to address multiple lighting objectives generally cannot maximize a single criterion. To achieve quality lighting, specific requirements should to be defined and measurements for compliance should be identified. Vague statements about quality typically reduce the effectiveness of a code.
Visibility	Visibility for outdoor applications is depends on a several factors including the: amount of light; uniformity of light; spectral qualities of the light source; age of people conducting activities in that area; contrast of surfaces within the area; and importance and speed required to perform tasks within the area.	Visibility in a nighttime environment uses different photoreceptors in the human eye than for daytime visibility; they respond to light with more blue spectral content, but are less effective providing good visibility in the direct field of focus. Some research suggests that nighttime electrical lighting will make photoreceptors operable. Good visibility is generally created lighting designs provide uniform lighting, minimizes excessive high angle brightness (glare) and uses light sources with blue content in their spectral distribution.	Higher pole heights or lower wattage sources on lower poles can often reduce the brightness within the field of view. Visibility can be compromised when the lighting is not uniform or if there is excessive glare and improve visibility. Visibility can also be compromised when there is insufficient light in the blue-green portion of the spectrum, which also reduces the ability of a person to identify colors. The site layout can also affect visibility, especially when landscape or other structures interfere with the proper distribution of light from the electrical lighting system.	Codes often set objectives to maximize visibility. However, many codes include requirements or mandates that can have a negative impact on visibility such as: pole height limitations and lamp type or wattage mandates, among others. Addressing visibility in a code is typically best addressed with requirements for specific performance criteria such as illuminance levels, uniformity or glare.

DEFINITIONS:

Many existing codes utilize improper or inconsistent use of lighting terminology. The following definitions accurately describe lighting terminology often used in outdoor lighting codes. Where appropriate, a paraphrased definition is provided in plain English to supplement the technical definition.

Term	Paraphrased Definition	Technical Definition Based on IESNA
Candela (cd)	Unit describing the intensity of a light source in a specified direction. Sometimes incorrectly referred to as a "light ray".	The SI unit of luminous intensity, equal to one lumen per steradian (lm/sr).
Cutoff Full Cutoff	A light distribution where no light is permitted at or above a horizontal plane located at the bottom of a luminaire. There will be little to no light at the angles that are usually associated with glare. <i>See Figure 1.</i>	A luminaire light distribution 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 lamp lumens does not numerically exceed 100 (10 percent) at a vertical angle of 80 degrees above nadir.
Cutoff	A light distribution where a negligible amount of light is permitted at a horizontal plane located at the bottom of a luminaire. Light above the horizontal plane at the bottom of the luminaire is not limited, but cutoff luminaires usually have very little light above the luminaire. <i>See Figure 2.</i>	A luminaire light distribution where the candela per 1000 lamp lumens does not numerically exceed 25 (2.5 percent) at an angle of 90 degrees above nadir, and 100 (10 percent) at a vertical angle of 80 degrees above nadir.
Cutoff Semicutoff	A light distribution where slightly more light is permitted at a horizontal plane located at the bottom of a luminaire than the cutoff distribution. Like cutoff, light above the horizontal plane at the bottom of the luminaire is not limited, but the amount of light above the luminaire is relatively small. <i>See Figure 3.</i>	A luminaire light distribution where the candela per 1000 lamp lumens does not numerically exceed 50 (5 percent) at an angle of 90 degrees above nadir, and 200 (20 percent) at a vertical angle of 80 degrees above nadir.
Cutoff Noncutoff	A light distribution that can produce considerable light above the horizontal plane located at the bottom of a luminaire. <i>See Figure 4.</i>	A luminaire light distribution where there is no candela limitation in the zone above maximum candela.
Disability glare	Glare that is significant enough to keep a person from seeing adequately.	The effect of stray light in the eye whereby visibility and visual performance are reduced. A direct glare source that produces discomfort may also produce disability glare by introducing a measurable amount of stray light in the eye.
Discomfort glare	Glare that is bothersome to an individual.	Glare that produces discomfort. It does not necessarily interfere with visual performance or visibility.
Efficacy (Luminous Efficacy)	A measurement used to compare light output to power consumed. Efficacy is a ratio of lumens to watts and can be defined for bare lamps or for luminaires.	The quotient of total luminous flux emitted by the total power input.
Efficiency	A ratio of the light emitted from a luminaire to the light produced by the bare lamps.	The ratio of luminous flux (lumens) emitted by a luminaire to that emitted by the lamp or lamps used therein.
Glare (see also disability glare or discomfort glare)	Light that hinders or bothers the human eye.	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. Note: the magnitude of the sensation of glare depends upon such factors as the size, position, luminance of the source, number of sources and the luminance to which the eyes are adapted.
High Intensity Discharge (HID)	A family of electric-discharge light sources including Metal Halide, High Pressure Sodium, and Mercury Vapor lamps.	An electric-discharge lamp in which the light-producing arc is stabilized by wall temperature, and the arc tube has a bulb wall loading in excess of 3 W/cm ² . HID lamps include groups of lamps known as mercury, metal halide and high-pressure sodium.
High Pressure Sodium (HPS)	A HID light source that typically provides high efficacy, but poor color. Color rendering is better with HPS than LPS, but the source is still considered to be yellow by most people.	A high-intensity discharge (HID) lamp in which light is produced by radiation from sodium vapor operating at a partial pressure of about 1.33 x 10 ⁴ Pa (100 Torr).
Illuminance (footcandle or lux)	A term that quantifies light striking a surface or plane at a point. It is expressed either in lumens per square foot (footcandles/the English unit) or lumens per square meter (lux/the metric unit). 1 footcandle = 10.76 lux	The areal density of the luminous flux incident at a point on a surface.
Lamp	A light bulb.	A generic term for a source created to produce optical radiation. By extension, the term is also used to denote sources that radiate in regions of the spectrum adjacent to the visible.
Low Pressure Sodium (LPS)	Considered a single-color light source (appears to be yellow in color and causes most other colors to be seen as gray or brown).	A discharge lamp in which light is produced by radiation from sodium vapor operating at a partial pressure of 0.1-1.5 Pa (approximately 10 ⁻³ – 10 ⁻² Torr)
Luminaire (Light Fixture)	A complete lighting unit, often referred to as a "light fixture". A luminaire consists of the light source, optical reflector and housing, and electrical components for safely starting and operating the source.	A complete lighting unit consisting of a lamp or lamps and ballasting (when applicable) together with the parts designed to distribute the light, to position and protect the lamps and to connect the lamps to the power supply.

Lumen	The unit representing the quantity of light being produced by a lamp or emitted from a luminaire.	The luminous flux emitted within a unit solid angle (1 sr) by a point source having a uniform luminous intensity of 1 cd.
Luminance	A term that quantifies directional brightness of a light source or of a surface that is illuminated and reflects light. It is expressed as footlamberts (English units) or candelas/meters squared (Metric units). (Note: footlambert is no longer a recognized unit by the IESNA.)	The quotient of the luminous flux at an element of the surface surrounding the point, and propagated in directions defined by an elementary cone containing the given direction, by the product of the solid angle of the cone and the area of the orthogonal projection of the element of the surface on a plan perpendicular to the given direction.
Mercury (Mercury Vapor)	A HID light source that typically provides long lamp life, but poor color and low efficacy compared to other HID sources.	A high-intensity discharge (HID) lamp in which the major portion of the light is produced by a radiation from mercury operating at a partial pressure in excess of 10^5 Pa (approximately 1 atm).
Metal Halide	A HID light source that typically provides good color and high efficacy.	A high-intensity discharge (HID) lamp in which the major portion of light is produced by radiation of metal halides and their products of dissociation – possibly in combination with metallic vapors such as mercury.
Nadir	The point directly below the luminaire when the luminaire is pointed down (0-degree angle).	None.
Photo Control	The device that turns the luminaire on at dusk and off at dawn. Also called photo eye, photocell, and or control. Photo controls may contain a timer to turn luminaires off part way through the night.	None
Shielded, Partially Shielded or Fully Shielded	Sometimes used in reference to a luminaire that is provided with internal or external louvers, shields or visors to limit glare. Also used to refer to luminaires that are designed to control glare without the use of additional shields. “Shielded” and “Fully Shielded” are sometimes used in place of either “Cutoff” or “Full Cutoff”. “Partially Shielded” is sometimes used in place of “Semicutoff”. The cutoff classifications are the industry-accepted terminology.	None

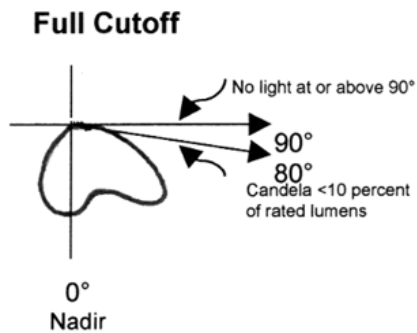


FIGURE 1

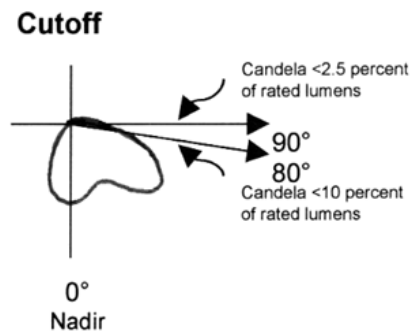


FIGURE 2

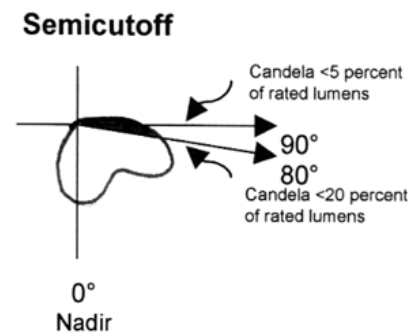


FIGURE 3

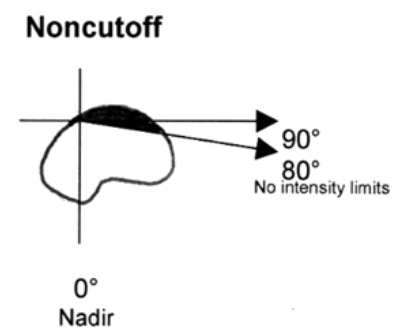


FIGURE 4

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