White Paper - Final Draft

Athletic Field Lighting and Control of Obtrusive Light Pollution

Fairfax County Park Authority

July 2010

Athletic Field Lighting and Control of Obtrusive Light Pollution

White Paper Project Team

Hal Strickland, Park Authority Board
Frank Crandall, Environmental Quality Advisory Council
Bob McLaren, Environmental Quality Advisory Council
Jack Reale, Department of Planning and Zoning
Lorrie Kirst, Department of Planning and Zoning
John Lehman, Fairfax County Park Authority
Sandy Stallman, Fairfax County Park Authority
Timothy Scott, Fairfax County Park Authority
Isabel Villarroel, Fairfax County Park Authority

Consultants

Ray Shaffer, SWSG, P. C.
Don McLean, DMD Associates Ltd.
Dr. Ian Lewin, Lighting Sciences, Inc.

White Paper - Final Draft

Athletic Field Lighting and Control of Obtrusive Light Pollution

TABLE OF CONTENTS

Introduction

In 2003 Fairfax County issued a new Outdoor Lighting Ordinance as a sub-section of its Zoning Ordinance. In their 2003 Annual Report on the Environment, the Environmental Quality Advisory Council recommended that the Board of Supervisors ensure that "…the Fairfax County Park Authority fully comply with the new ordinance and consistently follow the recommendations of the Illuminating Engineering Society of North America." As a result of significant advancements in athletic field lighting technology, the Park Authority commissioned a study to analyze the issues related to athletic field lighting. This study resulted in the development of the Park Authority's Performance Outline Specifications for Athletic Field Lighting Systems that were implemented in November 2006. In their 2007 Annual Report on the Environment, EQAC commented that the issue of glare was not adequately addressed in the specifications. In response to EQAC's recommendations, the Park Authority commissioned a "White Paper" to clarify issues and limitations related to the measurement and control of glare. The Fairfax County's Board of Supervisors requested the Park Authority to work with EQAC and the Department of Planning and Zoning (DPZ) to clarify this issue.

The following discussions of the "Response of the Human Eye to Light," and "Issues and Problems Controlling Light Pollution" has been prepared in cooperation with the Fairfax County Environmental Quality Council (EQAC); the Fairfax County Department of Planning and Zoning (DPZ); and input from DMD Associates Ltd., Consulting Engineers; Dr. Ian Lewin, President, Lighting Sciences, Inc.; and SWSG, PC, Consulting Engineers.

Overview

Light pollution is a general term used to describe light output, primarily from exterior (outdoor) sources, that is excessive in amount and/or that causes harmful glare to be directed into residential neighborhoods or into the path of vehicular or pedestrian travel. Light pollution is thus both a safety issue and a quality of life issue. With the increasing urbanization of Fairfax County, outdoor lighting and light pollution in its many forms have become pressing issues to our communities. In the past, Fairfax County had some regulations regarding exterior lighting, but they were minimal and out of date. A major effort was undertaken in 2002 to write a totally new and modern Outdoor Lighting Zoning Ordinance Standard that took into account the numerous advances that had been made in lighting technology in recent years. This highly successful effort utilized a number of workshops, in which several county agencies, EQAC, and local experts participated, and came to fruition in the summer of 2003 with the adoption of the new Zoning Ordinance Outdoor Lighting Standards. The new standards are regarded by experts in the outdoor lighting community as being one of the best in the mid-Atlantic region and has been cited and largely copied by localities in Connecticut, New York, Illinois and California.

However, there were a few technical areas at that time that could not be adequately addressed by the new standards, since suitable standards and convenient measurement technology were not available. This report will focus on these areas.

The Fairfax County Park Authority and the Fairfax County Public Schools are the two largest providers of lighted recreational facilities and sports fields in the county. Parks and schools by their very nature are usually located in the midst of residential communities where the outdoor lighting, if inadequately designed, can have a serious impact on the surrounding residents. Schools, particularly high schools, often have sports practice sessions extending into the early evening hours and games that begin after the dinner hour and run into the later evening hours. In addition, schools of all categories often have "security" lights that burn from dusk to dawn, although they could perhaps be better served by motion-detector activated lights. Our park and school systems, faced with increasing demand for team athletic facilities, will necessarily have to turn to synthetic turf and lighting during the evening to enable greater utilization of its existing fields. It is the responsibility of both organizations to utilize the best designs and equipment in addressing the increased demand. It is the vision of the Park Authority to enhance our community's quality of life. To do less would un-necessarily and unfairly impact the surrounding neighborhoods and diminish both property values and quality of life.

Definitions and Terminology

In order to clarify the concepts and information presented in this document, we must repeat much of the lighting terminology and definitions from the original 2005 *Athletic Field Lighting Technical Report*. In some cases the information has been simplified to better explain the definitions. Definitions and terminology are listed below.

Lumens

An electric lamp produces radiant energy (luminous flux) in the form of light. This "luminous flux" is expressed in lumens (lm). The lumen is the unit that quantifies the total amount of light emitted by a source. This unit is typically used to rate the light output of lamps. For example, the flame of a candle generates about 12 lumens. A standard 60 Watt incandescent lamp is rated at 890 lumens. A typical 1500 Watt lamp used for sports lighting is rated at 155,000 lumens.

Luminous Intensity (Candela)

Sports lighting fixtures (and many other fixtures, as well) use reflectors to concentrate the luminous flux from a lamp in a specific direction. This concentration of the luminous flux in a given direction represents the fixture's intensity in that direction. Intensity is also commonly termed "candlepower". The candela (cd) is the unit used to measure the intensity of light at a given angle. The familiar candle flame generates one candela in all directions. The candle is actually the historical basis for defining the candela. Designers are able to describe the intensity of a light in a given direction by determining the candelas from standard test reports.

Illuminance

Illuminance is the amount of light falling on a given surface; the more lumens that fall on the surface, the higher the illuminance. The unit of illuminance is expressed in foot-candles (fc) or lux (lx). A foot-candle is defined as one lumen uniformly distributed over an area of one square foot whereas a Lux is one lumen over a square meter. Illuminance is inversely proportional to the square of the distance between the light source and the surface. That is, the farther the surface intercepting a beam of light is away from the light source, the lower the illuminance.

Luminance

Luminance is a measure of luminous intensity reflected towards the eye per unit area of a diffuse surface. What the eye sees is related to luminance, and is expressed in candela per meter squared (cd/m^2). For small sources at a large distance, however, the eye does not see luminance, but rather source appearance which is based on its intensity.

Brightness

The brightness of a source is the human subjective effect produced by its luminance. The term brightness is also used to describe the general or ambient perceived light level of an outdoor area.

The proper definition of "brightness" is "perceived luminance." That is, it is the luminance, or intensity per unit area, that creates a sensation on the retina. Actually, it is quite similar in meaning to luminance, but is affected by variables such as pupil size.

The area of a light source viewed at a reasonably short distance produces discomfort glare. However, when a small source is viewed from a considerable distance, its area has no effect on the eye; it is perceived as a point source and thus its area has no meaning. The perception of such sources therefore is by intensity only.

Source Intensity

This defines the intensity of the lighting source(s) and is measured in candelas. It is an effective method of both calculating and measuring off-site light trespass impact. The concept of source intensity is defined further in *CIE 150:2003 Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations*. Table 2.1 Environmental Lighting Zones and Tables 2.3 Maximum Values of Intensity of Luminaries give suggested values for source intensity.

Spill Light

Spill light is any amount of light that falls beyond the area that is being illuminated. Spill light is also known as light trespass. Spill light is measured and expressed in fc or lux, and is usually measured and calculated in the vertical plane at the edge of residential property lines at 5’ above grade or horizontally at 3’ above grade at the property line.

Glare

The IESNA defines glare as “the sensation produced by luminance 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. The magnitude of the sensation of glare depends on such factors as the size, position, and luminance of a source, the number of sources, and the luminance to which the eyes are adapted.” The IESNA definition does not take into account the source-to-background contrast ratio or the very recent discoveries of melanopsin and pupilary control mechanisms in the eye.

Response of the Human Eye to Light

To put other sections of this report in proper context and introduce some useful terminology, it is helpful to briefly review how the human eye perceives and reacts to light. The eye works very much like a camera with an iris diaphragm that controls the amount of light reaching the interior of the eye. The iris is followed by the lens that brings the light to a focus on the retina, which is the matrix of sensory cells that convert the light into electrical signals going to the brain. The various cells of the retina of the eye contain what are called visual pigments. These pigments, in the fully dark-adapted condition, are complex proteins consisting of two linked components. The pigments respond to light by “bleaching” (actually the dissociation of the two protein moieties). The brighter the light, the greater is the bleaching and the longer the regeneration time. The greater the bleaching, the lower is the sensitivity of the retinal cell. The retina contains three types of sensory cells:

- The rods are most numerous toward the periphery of the retina and contain the visual pigment rhodopsin. They are useful primarily in quite low light and provide monochromatic images (i.e., objects are perceived as dim in relatively dark shades of gray).

- Three types of cones, mostly concentrated in the central portion of the retina, provide color vision. They contain respectively photopsin I (erythrolabe), photopsin II (chlorolabe), and photopsin III (cyanolabe). Their peak sensitivities are in the red, green, and blue portions of the spectrum just like the sensor chip in a digital camera. (George Wald received the 1967 Nobel Prize in Medicine for his work on the three kinds of cone photopsins.)

- The spidery retinal ganglion cells contain the visual pigment melanopsin. These cells perform two different functions: (1) control of the size of the pupil of the eye in response to light, and (2) as the control that resets the body’s day-night cycle clock. Prolonged exposure of melanopsin to bright lights during normally dark periods of the evening can result in significant disturbances of the sleep-wake cycle. The pigment melanopsin was discovered in 1998 by Ignacio Provencio (now faculty at the University of Virginia). Soon thereafter exploratory work on the functions of this pigment was undertaken by David Berson and his graduate students at Brown University. Major findings announced in 2002 and 2005 showed that in addition to control of the constriction of the pupil in response to light the pigment of these cells is the sensor that controls the setting of the circadian clock which in turn regulates many of the physiological functions of the body. In addition to its importance in the vertebrate animals, melanopsin has now been found to have importance in a number of invertebrates, as well.

Issues and Problems in Controlling Light Pollution

The main issues and problems of light pollution resulting from athletic field lighting may be summarized as follows:

Light Trespass

Light trespass is a term of relatively recent origin and denotes (1) light that spills beyond the boundaries of one property onto the surfaces of another, thereby producing unwanted illumination of it, and (2) glare that is generated by sources on one property that lie within the normal field of view of the occupants of another property. Increasingly, such light intrusions are being regarded as trespass violations every bit as serious as physical trespass of a person onto the property of another. Problems of illumination encroaching on adjacent properties are nearly always due to poor design and/or control of outdoor lighting such that surfaces on the adjacent property are illuminated by unwanted light. This problem can be readily avoided by the selection of proper fixtures, intensity levels and the use of timers and various sensors/controllers.

When light crosses property lines it can detract from the property value and quality of life of those whose property it is improperly directed. It can be a particularly objectionable problem when obtrusive recreational or commercial lighting is immediately adjacent to residential neighborhoods (or when a homeowner uses inappropriate fixtures, light levels and lighting duration, often in the interest of "security").

Lighting engineers often refer to light that trespasses across property lines to illuminate parts of an adjacent property as "spill light".

Glare

Glare is generally understood as excessive brightness occurring in the normal field of view. This indicates that the perception of glare results from an individual facing toward the light source so that the light from it directly enters the eye. In this way glare differs from spill light where the individual is not directly facing the source but is seeing the illumination of objects receiving light from it. Thus, the same light source (bulb/lamp) can produce both spill light and glare but the perception depends on whether the light rays enter the eye directly or illuminate an object which is viewed.

Glare, as defined by the Illuminating Engineering Society of North America (IESNA), falls into three main categories, which represent a difference of degree rather than a difference of kind:

Nuisance or annoyance glare – Nuisance glare diverts one's attention away from the activity of interest to the intrusive light source and results in complaints such as, "The light is shining in my window."

Discomfort glare – Discomfort glare may not necessarily reduce the ability to see an object, but it produces a sensation of discomfort due to high contrast or non-uniform distribution of light in the field of view.

Disability glare – Disability glare (sometimes less accurately referred to as veiling luminance) is caused by an overly bright light source that shines directly into one's eyes and is dangerous because it is blinding (i.e., it totally overloads the eye's light sensor cells by causing excessive bleaching of the visual pigments which in turn causes very long regeneration times). Some of the new high intensity automobile headlamps are examples of this level of glare source.

Glare may be a significant problem that seriously impairs both safety and quality of life. Glare can be a serious safety hazard (for example for drivers and pedestrians) in that it demands attention since one's eyes are naturally attracted to bright light, and at night this destroys the eye's dark adaptation (i.e., the eye's sensitivity to lower light levels). Dark adaptation is due to restoration of the linkage of the two protein components of the visual pigments. Quality of life is adversely impacted by obtrusive lighting by commercial establishments; and selection of inappropriate fixtures for exterior residential lighting, and outdoor lighting at some public facilities, such as park and school recreation fields. High intensity lights and their placement as used to adequately illuminate recreational fields in parks and at school properties is a unique concern. Glare and excessive illumination (which, as noted above, are two separate problems) when cast into surrounding residential neighborhoods not only detract from the quality of life but can make it difficult for pedestrians and homeowners to see their surroundings. Recent installations of athletic field lighting in parks that use current lighting technology have vastly reduced the impact of glare and excessive illumination over older, non-cut-off lighting.

Both spill and glare may be present in a given situation. Illumination, that is, the amount of light energy falling on a surface, is readily measured by simple hand held instruments and is expressed in foot candles. The County's current Outdoor Lighting regulations do not provide for a maximum allowable footcandle standard at a property line, although the Park Authority uses a maximum of 0.5 footcandles as an acceptable maximum limit for illumination at the property lines that border their facilities. Recent lighting installations at our county parks are consistently meeting the standard for spill light and the design specifications which follow in this document ensure that this will continue to be the case. It is noted that prior to the adoption of the current Outdoor Lighting Standards, the County's Zoning Ordinance contained a provision that prohibited illumination in excess of 0.5 footcandles at the property line of a residentially zoned property. The recently adopted Outdoor Lighting Standards shift the focus of prevention/protection from illumination limits at a property line to the more pertinent, and complex issue of glare. The more recent standards for outdoor are geared toward preventing or reducing spill and glare, primarily by requiring that lighting fixtures incorporate appropriate shielding. These standards include a requirement that a Sports Illumination Plan (SIP) be submitted for all outdoor recreation facilities that include illuminated playing fields and/or courts that individually or cumulatively exceed 10,000 square feet in area, and/or have light poles that exceed 20 feet in height. The SIP submission requirement is designed to ensure that on-field and near-field lighting is maintained at appropriate levels and that all field/court lighting fixtures are either full cut-off or directionally shielded. The SIP also requires that on-site lighting fixtures that are not used for field/court lighting be full cutoff.

Glare or excessive brightness is a more complex and difficult-to-measure phenomenon. It is experienced when the light producing source (the bulb/lamp) is directly visible, but also depends on the luminance (brightness) of the source and on the contrast between that source and the surrounding background. For example, even a very bright light source viewed against a daytime sky doesn't seem particularly glaring or objectionable, but the same source viewed against a fully dark night sky is very objectionable and seems so bright as to be almost painful. One of the problems in addressing this kind of light trespass, or more properly glare trespass, is that there have not been good standards for acceptable limits, and instruments to measure this kind of glare are necessarily complex and difficult to operate.

Glare experienced from high-intensity sources, like those used to light athletic fields, is a result of the source-to-background contrast ratio. A typical field lighting fixture seen against a very dark sky seems very intense and intrusive, but if seen against a day time sky seems hardly noticeable. One can also readily see this by viewing a full moon at 2:00 or 3:00 a.m. when it appears as an intense disc so bright that it shows few features and will actually cast shadows. However, the same moon viewed at 9:00 or 10:00 a.m. is a very pale appearing disc with only slight contrast against the daylight sky and shows an extensive array of features. This effect is due to the great difference in contrast with the background against which it is viewed. The mathematical difference between the source and the background is known as the source-to-background contrast ratio. Unfortunately this is a fundamental law of nature over which there is no control.

Limits on Management and Control of Glare

Glare is recognized as a significant and pervasive problem, but one that for which there are very limited solutions. The Fairfax County Park Authority has attempted to address public demand for sports field availability by installing synthetic turf and lighting to increase the hours of availability of existing sports fields. Being aware that it bears a special responsibility to ensure that such lighting systems minimize adverse impact on adjacent residential neighborhoods it has continued to seek ways to avoid such impacts. It has been suggested that the problem of glare could be relatively easily solved by installing "full cut-off", i.e., fully shielded light fixtures, or in some cases using supplementary shielding panels, to prevent glare trespass onto adjacent residential properties. Indeed, the International Dark-Sky Association in its outdoor lighting handbook has colored illustrations of a field lighted with full cutoff fixtures that appear to minimize the glare problem, but a detailed engineering analysis shows that the pole placements required and the fact that most of our fields are multi-use and are located less than 300-500 feet from the property lines make this a non-viable solution for Fairfax County. However, in order to illuminate field surfaces adequately lights must be mounted on tall poles. This means that even when the sides of fixtures are shielded the light source is still visible through the bottom of the fixture when one is close to it. Glare impacts may still result when using full cut-off fixtures when athletic fields are in close proximity to neighboring houses. In some cases with aimable fixtures it is possible to place them on taller poles which permit steeper aiming angles and thereby reduce the distance at which the bulb is visible. On a baseball field near an adjacent neighborhood the Park Authority has had excellent results with this method.

Test results from a pair of rectangular fields outfitted with lights have been very informative. While the illumination of the surface of the first field is very good and light spillover illumination at the property line, which is only 70 feet from the field edge, meets the Park Authority's standard of 0.5 footcandle, the glare from the fully exposed, 1,500 watt lamps on 70 foot tall poles facing a residential neighborhood is intense (in the range of 12,000 lumens at 200 feet). An adjacent field outfitted with an advanced model of fixtures of the same type shows outstanding illumination of the field surface but no improvement in glare. The Park Authority's recently drafted specifications fully address the light spill problem but are unable to fully address the glare problem since it is primarily governed by fundamental laws of nature over which man has no real control. The ultimate consideration when glare becomes a pivotal issue is the decision for a particular site of "to light or not to light". Some additional measures that might well be considered as new modifications to the Outdoor Lighting Ordinance would include screening requirements, separation distances from property lines, pole heights, and field orientation as a test of whether a site is a good candidate for lighting. It should be noted, however, that field orientation during the initial master planning stage may make it possible to minimize glare problems, but this is unusual when retrofitting lights to existing fields.

Some of the problems with lighting that have resulted in the most frequent and strident complaints are lights left on after users have left the field or lights that are set to turn on automatically for scheduled activities but users have not shown up. These are operational and scheduling problems and not subject to engineering solutions. It is important to remember that a typical four pole rectangular field has lights that consume electrical power at the rate of 42 kilowatts. (Power consumption, i.e., what one is billed for, is measured in kilowatt-hours.) Thus, burning those lights incurs a considerable operating expense. Hence, rigorous control of scheduling and supervision of field usage is essential.

These same concerns apply equally to the Fairfax County Public Schools, which also use lighted sports fields and frequently have security lighting that remain on all night.

Engineering Considerations

In 2005, DMD and Associates Ltd and SWSG, PC co-authored the *Athletic Field Lighting Technical Report* for the Fairfax County Park Authority. The report focused on sports lighting standards and a review of various supplier's products. The report also discussed fundamental concepts and industry standards, reviewed the requirements of the Fairfax County Zoning Ordinance, and included analysis of various products and recommendations. The Park Authority is currently using the *Athletic Field Lighting Performance Specifications* that were developed in conjunction with the *Athletic Field Lighting Technical Report* and recommendations of EQAC. Performance standards for spill light and source intensity are specified for rectangular and diamond fields. Fairfax County Park Authority's *Athletic Field Lighting Performance Specifications* are comprehensive, aggressive and stringent specifications - when compared to other jurisdictions in the surrounding area and on the mid-Atlantic region. The Park Authority has installed nineteen fields using the established performance specifications. Measured source intensity and spill have been substantially reduced compared to previously installed systems. The Fairfax County Park Authority will continue to monitor the performance of our field lighting systems and will strive to improve our standards as lighting technology advances.

The Fairfax County Park Authority prepared this White Paper as a follow-up to the original 2005 report. The intent of this White Paper is to further explain the relationship between glare and source intensity and to document the limits that control of source intensity has on glare.

The initial scope of this White Paper was to discuss and elaborate further on the glare analysis method noted in the 2005 *Athletic Field Lighting Technical Report*. Upon further review it was determined that the design method noted in the 2005 Report as "glare analysis" was better defined by the use of term "source intensity" as it better represents the methods of analysis noted in that report. At this time no one has developed a viable method for fully controlling glare since it is dependent on the source-to-background contrast ratio over which we have no control.

Therefore the Park Authority's standards are directed at controlling the source intensity to minimize the effects of light trespass.

Source intensity is a published method of estimating the off-site impacts of a sports lighting system. The International Commission of Illumination (CIE) has also produced a document *CIE 150:2003 Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations* which defines limitations for source brightness (intensity) and spill light for outdoor lighting applications. IESNA *TM-11 Lighting Trespass: Research, Results and Recommendations* states, "Source brightness had been generally identified as being the principal characteristic [of athletic field lighting] to which persons object. Spill light was seen as a less significant effect. It was decided, therefore, to design experimentation to identify quantitatively the relationship between source brightness and the degree to which the light source was found objectionable."

Relationship Between Glare and Light Source Intensity

Though the term "glare" has been used in the 2005 *Athletic Field Lighting Technical Report* the term "source intensity" is a better representation of the methods noted in that report. Source intensity can be directly measured and is partially related to, but as explained earlier by no means equivalent to the perception of glare.

Source intensity applies to each sports lighting luminaire in the potentially obtrusive direction, outside of the area being lit. One can both calculate and measure light source intensity for any given sports lighting luminaire.

Unlike glare there are levels given in documents noted below which define allowable levels of source intensity for given types of areas. The basic principal here is the lower the light source intensity when viewed from a given specific point of interest, such as a residence, the less obtrusive the lighting will be.

Photograph 1.1 shows four different groups of sports lighting fixtures of the same beam type and wattage aimed at the same point on the field. This photo demonstrates how fixture optics can lead to different levels of source intensity when viewed from a defined location off the field. Aiming, wattage, supply voltage and other aspects of the demonstration shown in the photo have been verified to ensure an accurate comparison. Note the fixture intensity as captured (in the foreground) is a low wattage parking lot light. Each of the group of sports lights has different optics and shielding, which results in various levels of intensity. The intensity of light emitted from the fixtures, as observed in the photograph, varies greatly at this viewing angle.

Photograph 1.1

From the Park Authority's experience source intensity has been generally identified as being the principal characteristic to which residents object. We have found by reducing the source intensity residential concerns and issues are mitigated. We have found source intensity levels (when viewed off-site) to vary depending on the product, even though most products illuminate the playing fields to the required on-field lighting levels.

In Photograph 1.1, the third cluster of lights from the left is far less bright than the others. The third cluster of lights has superior spill and source intensity control optics and is less obtrusive than the others and demonstrates how the control and direct measurement of source intensity limits the perceived effects of glare.

The measurement of source intensity can be performed and is a simple way to evaluate sports lighting and at least partially limit its impacts. Though we agree a comprehensive glare calculation would be a better method of analysis than source intensity, there is not an agreed upon method for glare measurements nor is there research to define not-to-exceed levels.

Calculating Source Intensity

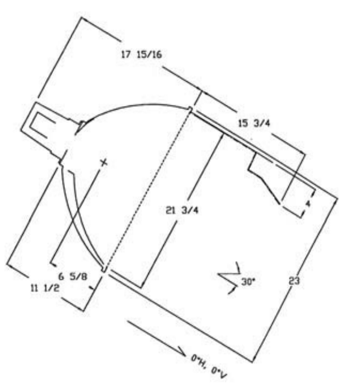
Laboratory photometric testing is used to establish the basis for performance and output of the proposed fixture. Photometric testing of a fixture involves gathering data that characterizes its intensity (or candlepower) distribution. Once the intensity values in all directions of emission are known, it is developed into photometric test reports. The measurement device used in a laboratory is a goniophotometer. Several different types of this instrument are used to rotate a photo-detector around the fixture, through both horizontal and vertical angles. Light readings are taken in fine angular steps at numerous points throughout the angular grid, so that the full lighting distribution is accurately quantified.

Data processing software reads the collected intensity array and produces test reports that provide the various required tables and graphs. Also produced is an electronic data file that stores the intensity (candela) array and other required information in a standard file format. This file (most common file format is that established by the IESNA) can be used as input data for computerized lighting design software performing the lighting design.

To assess the source intensity of a fixture one can simply review the sports lighting suppliers' photometric report, which can be obtained in PDF format from the sports lighting supplier. A sample photometric report is shown in the figure below.

The report below represents a typical sports lighting fixture from a supplier. The test report should be produced by a third-party testing agency for the supplier. Sports lighting fixture suppliers normally can provide such reports on any of their fixtures. These reports are the basis of the digital IESNA photometric files used for computerized lighting calculations.

CANDLEPOWER



DEG	HORIZ.	DEG	VERT.
76.0	0.	76.0	0.
68.0	90.	68.0	0.
60.0	490.	60.0	0.
52.0	1220.	52.0	0.
44.0	3930.	44.0	0.
36.0	14040.	36.0	820.
28.0	41740.	28.0	4510.
20.0	84960.	20.0	22940.
12.0	137470.	12.0	72900.
4.0	186390.	4.0	170170.
0.0	190240.	0.0	190240.
-4.0	186390.	-4.0	190450.
-12.0	137470.	-12.0	161780.
-20.0	84960.	-20.0	117750.
-28.0	41740.	-28.0	76380.
-36.0	14040.	-36.0	42390.
-44.0	3930.	-44.0	26210.
-52.0	1220.	-52.0	19250.
-60.0	490.	-60.0	10650.
-68.0	90.	-68.0	3890.
-76.0	0.	-76.0	1840.

Figure 1 - Example of Fixture Photometric File

Figure 1 above shows the various levels of intensity (candlepower) at various angles in both the vertical and horizontal planes. We have found intensities in the vertical plane to be the most significant and typically have the most impact on adjacent residences. From the photometric report one can see the most intense part of the vertical beam (190,240 cd) is at an angle of 0 degrees which is aimed to a defined location on the field. The most intense light is emitted at the (0, 0 angle) with the intensity decreasing as the angles (DEG) increase as shown in the table above. The positive vertical angles (DEG) define the upper part of the fixture beam and negative vertical angles (DEG) define the lower part of the fixture beam. The intensities at the upper (positive) vertical angles are typically the most visible when viewed from residences off site. As one can see, far less intensity is emitted from the upper angles than from the equivalent lower angles.

When undertaking lighting design, one must prepare lighting calculations to determine the on-field and off-field spill light levels. The designer selects a mounting height and aims the fixtures to various points on the field. The lighting design results should produce uniform illumination on the field. The fixture aiming points along with the fixture photometric files are a key to assessing off-site intensity (candlepower). This shall apply to all field types.

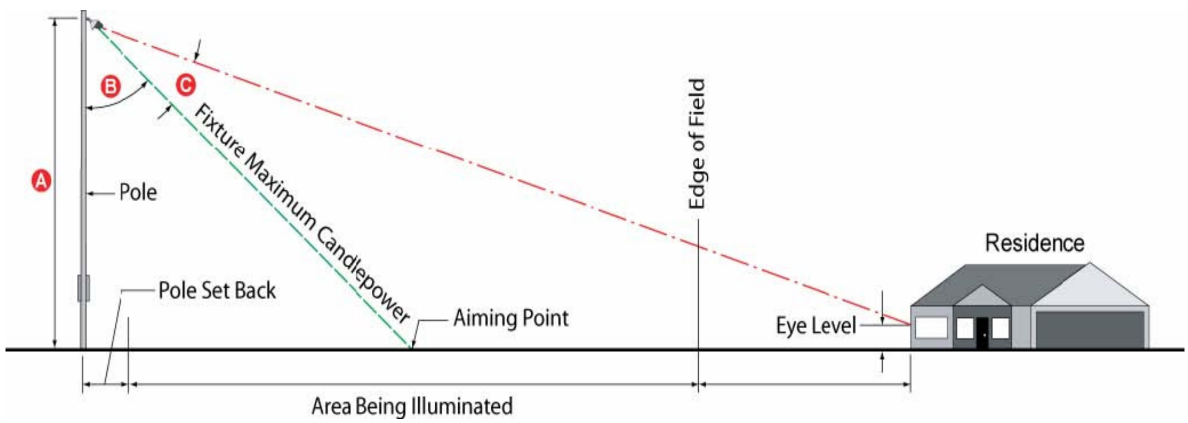


Figure 2 – Defining Source Intensity

To determine the source intensity of a given fixture when viewed from the point off site (as shown in Figure 2) one can undertake the following steps:

- Obtain fixture photometric report data files from supplier.
- Determine aiming angles from supplier or consultant for the computerized lighting calculations.
- The aiming angles (B) are based on the aiming point and fixture mounting height (A).
- The fixture aiming position will be the maximum candlepower at angle zero from the supplier's photometric report (see table on Figure 1).

- Determine the vertical angle (C) between the aiming point and the point 5 ft above grade at the residential property line. This angle is typically 20 to 30 degrees. If this angle was found to be 28 degrees, then based on the photometric report above the source intensity would be 4510 cd.

The intensity (candlepower) will be quite similar for various beam types from one supplier to another, in the lower and upper vertical angles range. Vast differences will be found from one supplier to another in 20 to 30 degree vertical ranges, which are the typical angles the fixtures will be seen from adjacent local residences.

As part of the fixture and mounting height selection process, it is recommended that the lighting designer should review the supplier's fixture candlepower curves and select the appropriate fixture mounting height and optical system so that from any given fixture no greater than 12,000 candlepower will be visible from the adjacent residential property lines.

This method of using the fixture supplier's candlepower curves to assess intensity (candlepower) is a common sense approach. The 12,000 cd level is the level recommended in the FCPA Lighting Specifications and was based on assessment, over the years, of products and public feedback from many sports lighting installations. Lower candlepower levels should be strived for as the lower the level the less the impact on the local residents. Care must be taken not to reduce the vertical light component too far, as it can be critical to sports such as baseball, which require vertical illumination to properly illuminate the ball.

Field Measurement of Source Intensity

Field photometric measurements are used to verify and monitor performance of the lighting system design. Similar types of photo-detectors, or photocells, are used for both laboratory and field measurements. Laboratory testing requires that the photo-detector be moved to many different positions around the fixture tested, so that its complete photometric distribution can be charted. However, field photometry measurements involve the use of a portable instrument known as a light meter with a photo-detector that can be placed at numerous locations around the field to assess the performance of the entire lighting system. The light meter measurements are given in foot-candle or lux.

Sports lighting calculations are typically performed using computer analysis with lighting design software and the fixture supplier's IESNA photometric files. The designs are undertaken via a trial and adjust process to meet the lighting criteria. Mounting height, number of poles, fixture wattage, number of fixtures, fixture aiming and fixture photometric files all have impact on the on-field and off-field lighting calculation results. Lighting calculations provide a fairly accurate representation of the anticipated on and off-field light levels. This method has traditionally been used to analyze and refine a sports lighting design.

Recommendations and Conclusions

- There is no readily available direct method to measure glare. It is a perceived effect that is dependent on the source-to-background contrast ratio and it also varies from observer to observer.
- Light source intensity is an easily measured quantifiable effect that is indirectly related to glare.
- The International Commission of Illumination (CIE) has issued guidelines for light source intensity.
- There are many ways to reduce source intensity as viewed by local residents and still meet the required on-field lighting requirements. Shielding, reflectors, wattages, beam types, mounting height and aiming angles all impact the source intensity and are key considerations in reducing glare.
- Consideration should be given to locating fields during the master planning process to take advantage of natural screening in order to reduce light trespass impacts. The location, alignment, and layout of fields with respect to reducing light trespass impacts will reduce potential spill and glare impacts.
- Problems related to illumination encroaching on adjacent properties can be reduced by the selection of proper fixtures, intensity levels and the use of timers and various sensors/controllers.
- Rigorous control of scheduling and supervision of field usage is essential in addressing complaints related to the operational and scheduling problems such as lights left burning before and/or after field use.
- In cases where properties are in close proximity to fields, and the location/layout of the fields can not be adjusted to reduce spill and glare, Park Authority Standards need to be examined and modified as needed to reduce impacts to neighboring residences.

References

- Illuminating Engineering Society of North America, IESNA Lighting Handbook (8th Edition), IESNA, New York, NY, 1993.
- lluminating Engineering Society of North America IESNA RP-33-00, Lighting for Exterior Environments, IESNA, New York, NY, 1999.
- Illuminating Engineering Society of North America, IESNA TM-11-00, Light Trespass: Research, Results and Recommendations, IESNA, New York, NY, 2000.
- CIE 150:2003 Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations, ISBN 3 901 906 19 3
- CIE112-1994 Glare Evaluation System for Use within Outdoor and Area Lighting