The basics of proper security lighting, from terminology to application.

Lighting Technology for Security Practitioners

By David G. Aggleton, CPP

In the not-too-distant past, our forebears worked during the daylight hours, and activities at night were restricted by the illumination produced by fires, oil lamps and candles. Artificial lighting, developed from the application of electricity, now allows us to continue to perform occupations, sports and other activities at all times of day and night. Many of us, particularly urban dwellers, rely on lighting to be aware of our environment, and we use the quality of that light to gauge our level of security and safety. Lighting is important to the application of security for two primary reasons: it is well known as a deterrent to criminal activity, and it is essential for the optimum performance of security cameras.

To better understand security lighting applications, it is useful to look at basic lighting terminology and technology.

Lighting Definitions

The quantity of light emitted by a light source is measured in lumens. A typical household bulb rated at 100 watts may output about 1700 lumens. Illuminance, measured in lux (lumens per square meter) or footcandles (lumens per square foot), is the concentration of light over a particular area. A spotlight and a floodlight may output the same quantity of light, but the spot concentrates its output in a small area, whereas the flood disperses the light over a larger area. Since light spreads from its source, the farther away an object, the less the illuminance. When evaluating the amount of light needed to perceive a scene, it is the amount of light shining over the area of the eye (or the camera lens)—its illuminance—that is critical. We can gauge different light levels from our common experiences. Table 1 gives some examples.

In Table 1, the average Earth light levels are one-half of the natural light source levels. This is because, on average, the reflectance of most objects is approximately 50 percent. The measure of reflectance of an object is the ratio of the quantity of light falling on it to the light being reflected from it, expressed as a percentage. When we see an object, our eyes are sensing the light reflected from that object. The color of the surface also has an impact on reflectance; a light surface, such as a parking lot newly paved in concrete, will have higher reflectance than a dark surface—the same parking lot paved in asphalt or blacktop. Table 2 provides some rule-of-thumb measures for the reflectance of some common materials. Note that these are average values and the reflectance value, in particular for man-made objects, will depend on the materials and their age. Most CCTV camera manufacturers use an assumed reflectance of 75 percent or even 90 percent when describing the performance of their cameras in catalog data sheets.

Table 1: Natural & Visual Light Levels

LIGHT LEVEL (footcandles)	NATURAL LIGHT SOURCE	VISUAL EXPERIENCE LIGHT LEVELS
50,000		Upper Limit of Visual Tolerance
10,000	Direct Sunlight	Fresh Snow on a Clear Day
1,000	Full Daylight	Average Earth on a Clear Day
100	Overcast Day	Average Earth on a Cloudy Day
1	Twilight	White Paper 1ft from Standard Candle
0.1	Deep Twilight	
0.05		Snow in Full Moon
0.01	Full Moon	
0.005		Average Earth in Full Moon
0.001	Quarter Moon	
0.0001	Starlight	Snow in Starlight
0.00005		Grass in Starlight
0.00001	Overcast Night	
0.000001		Absolute Limit of Seeing

Table 2: Reflectance Measurements

(From "Lighting the Way to Security," Security Management, Terry McGhee & Charlie Pierce, Dec. 90)

MATERIAL		REFLECTANCE
Asphalt		5%
Concrete	(New)	40%
	(Old)	25%
Red Brick		25%
Grass		40%
Snow		95%

Color temperature is a measure of the warmth or coolness of a light. To understand color temperature, it helps to think of a piece of metal being heated in a furnace. When it starts to glow "red hot" it is at about 2700°K, "white hot" is at about 4100°K, and "blue hot" is at about 5000°K corresponding to daylight. We perceive red as a warm color and white and blue as being cool, despite the higher temperatures required to achieve them. The color temperature of a light source affects our mood and the ambiance of the surroundings. Table 3 summarizes the color temperatures of various types of lamps and their applications.

Security personnel and employees need the ability to accurately describe color. This is important in the apprehension and prosecution of those seen perpetrating crimes on secured property and is applicable to human vision and CCTV displays and recordings. The ability of a lamp to faithfully reproduce the colors seen in an object is a property known as color rendition and is measured as a Color Rendition Index (CRI) on a scale of 0 to 100. A CRI of 70 to 80 is considered good, above 80 is considered excellent, and 100 is considered daylight. Table 4 shows the CRI values of various lamps. Note that the high- and low-pressure sodium and mercury vapor light sources have very low CRI values and should not be used in conjunction with color camera applications or where color identification is critical. For example, under low-pressure sodium light, a green shirt will have a blue hue.

Table 3: Color Temperature

(Adapted from Lamp Specification and Application Guide, Philips Lighting Company, Jan. 99)

COLOR TEMPERATURE	WARM 3000ºK	NEUTRAL 3500ºK	COOL 4100ºK	DAYLIGHT 5000ºK
ASSOCIATED EFFECTS AND MOODS	Friendly Intimate Personal Exclusive	Friendly Inviting Non-threatening	Neat Clean Efficient	Bright Alert Exacting coloration
APPLICATIONS	Restaurants Hotel lobbies Boutiques Libraries Office areas Retail stores	Public reception areas Showrooms Bookstores Office areas	Conference rooms Classrooms Hospitals Office areas Mass merchandisers	Galleries Museums Jewelry stores Medical exam. areas Printing companies
LAMP TYPES	Fluorescent Incandescent Halogen	Fluorescent Mercury vapor	Fluorescent Mercury vapor Metal halide	Fluorescent Mercury vapor Metal halide

NOTE: *Color Temperature for low- & high-pressure sodium: 1750ºK & 2000ºK*

Table 4: Color Rendition Index

LAMP TYPE	INCANDESCENT	HALOGEN	FLUORESCENT	METAL HALIDE	MERCURY VAPOR	HIGH PRES. SODIUM	LOW PRES. SODIUM
CRI	100	100	75 – 100	70	50	20	5

Table 4: Color Rendition Index

LAMP TYPE	INCAN-DESCENT	HALOGEN	FLUOR-ESCENT	METAL HALIDE	MERCURY VAPOR	HIGH PRES. SODIUM	LOW PRES. SODIUM
CRI	100	100	75 – 100	70	50	20	5

In addition to security operations, high color rendering is important in retail, restaurants and precision manual work. A high CRI also increases visual clarity and creates higher morale and greater productivity. High CRI values in outdoor locations at night make pedestrians feel safer in that they can recognize and evaluate others at a greater distance and they have better depth perception.

A couple of more subjective terms are brightness and glare. Brightness is our perception of the amount of light that reaches our eyes. Glare is a term used to describe excessive brightness, and it has importance in security applications. Glare is hurtful to the eye and impacts the eye's efficiency; it creates excessive contrast with other objects, makes us turn our eyes away, and generally makes it difficult to see clearly. Glare can be used very effectively to deter unauthorized activity at a site perimeter. However, it has a negative effect on patrols and on response forces. Additionally, it may cause light trespass onto adjoining properties including sidewalks and roadways. Many communities set limits through zoning restrictions on the level of lighting and the amount of light that can "spill," or trespass, into neighboring areas. It is important that light trespass does not cause glare or excessive contrast to drivers or pedestrians either on your property or in adjacent areas.

Sometimes it is not possible to light an object directly. We can, however, see the object and its movements with relative clarity by its contrast with a well-lit background. This will be examined in more detail in later discussions on the applications of security to lighting.

Lighting Systems

A lighting system consists of a number of components, all of which are important to the effectiveness of a lighting application. Following is a list of the major components and their function.

• **Lamp** (also known as a light bulb) is the manufactured light source that includes the filament or an arc tube, its glass casing, and its electrical connectors. Lamp names (incandescent, mercury vapor, etc.) describe the technologies used to create the light.

• **Luminaire** (also known as fixture) is the complete lighting unit consisting of the lamp, its holder, and the reflectors and diffusers used to distribute and focus the light. Some lamps, like spots and floods, are designed with integral, shaped reflectors for the focus and distribution of the light. The luminaire will also contain the means of connecting to the power source and, depending on the lamp technology, will include ballasts (to generate the correct starting and operating voltage, current and waveform) and photo sensors (to control switching of lights based on ambient lighting conditions). The design of luminaires depends on aesthetics as well as performance characteristics.

• **Mounting hardware** such as a wall bracket or a light pole fixes the luminaire at the correct height and location.

• **Electrical power** operates the lamp, ballasts and photocells. Some lamp technologies are sensitive to reduced voltages, in particular the high-intensity discharge family of lamps (metal halide, mercury vapor and high-pressure sodium). These lamps require relatively stable voltage levels since they produce light from an arc discharge under high pressure; if the supply voltage is sufficiently reduced, the arc will be extinguished. Restart times are often lengthy (up to 20 minutes). Back-up batteries, generators and uninterruptable power supply (UPS) systems need to be considered for the lighting of high-security areas such as vaults, cash registers and paths of emergency egress and assembly.

Lighting Economics

The cost of lighting is a major factor in deciding the level of lighting to install for security and safety. Some lighting is mandated by code, like fire safety, retail banking, NRC-regulated facilities, and OSHA. Many times, however, security lighting is an elective cost that must be justified based on identifiable savings or quantifiable reduction in risk.

For a typical lighting installation the operating cost consists of capital items, energy and maintenance. Since the proportion of these costs is approximately eight percent capital items, four percent maintenance and 88 percent energy, the energy efficiency, or efficacy, measured by the lamp's output in lumens divided by the lamp's power draw in watts, is very important. The next highest cost is that of replacement lamps. This is a function of the lamp technology and the quality of the lamp. Table 5 shows typical levels of efficacy and lamp life. As a ready guide, there are 8,760 hours in a year. A lamp that is on for eight hours per day will burn for 2,920 hours per year.

Maintenance costs include the labor to replace lamps and to clean them. Cleaning cannot be ignored, since the lumen output of a lamp will reduce if dirt accumulates on the fixture. In a clean environment, such as a computer room or office area, the percentage output will reduce by approximately three to four percent per year and cleaning intervals of three years are recommended. In a very dirty environment, a luminaire could be emitting only 80 percent of its design output after only one year. Since the power consumption remains the same regardless of the amount of dirt accumulated on the luminaire, it makes sense to implement regular cleaning to maintain the designed light output. It should be noted that the performance of most lamps reduces with age. By the end of a lamp's rated life it may produce only 80 percent of its designed output even when clean.

The number of luminaires required is a function of the area to be covered, the light levels required, the height of the luminaires and their design, and the type of lighting technology used. It is expensive to achieve a uniform distribution of light, particularly outdoors. Some variation in light levels is considered acceptable and is measured as uniformity, the ratio between the average light level and the minimum light level. Typical uniformity ratios would be 1:0.7 for working environments, 4:1 on a pedestrian walkway and 10:1 on a roadway. Higher uniformity gives better depth perception and a greater perception of security to individuals in the area.

Starting And Re-strike

It was mentioned earlier that some lamps require time to re-light if they are switched off intentionally or due to either a full power failure or a brownout. Extended re-lighting time is typical of high-intensity discharge (HID) lamps, since they rely on an arc to produce light. The lamp tube must cool sufficiently before the arc can be re-struck. In addition, HID lamps (and to a much lesser extent fluorescent lamps) take time on starting from cold to reach their designed light output levels.

These functional limitations of lamps are of concern to the security practitioner since, although lamp switch-on times can be scheduled to allow for their start-up time, a full or partial power failure, however brief, can mean a loss of lighting for a considerable period. Table 6 shows typical starting and re-strike times for the different types of lamps.

Note that new technology and manufacturing methods seek to reduce these times. For example, some HID lamps are available with two tubes—only one is used at a time so that the other remains cool for a quick re-strike.

This article is not intended to make the reader an expert in lighting design, but rather to gain an understanding of the technology of lighting so as to better appreciate its application to security. The Web sites listed below may be useful to the reader who wishes to explore this topic in more detail.

- National Lighting Bureau – *www.nlb.org*
- Illuminating Engineers Society of North America – *www.iesna.org*
- National Council on Qualifications for the Lighting Professional – *www.ncqlp.org*
- National Association of Lighting Designers – *www.iald.org*
- Philips Lighting Company – *www.lighting.philips.com*
- GE Lighting – *www.gestpectrum.com*
- Sylvania Lighting – *www.sylvania.com*

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Table 5: Lamp Efficacy and Life

LAMP TYPE	INCAN-DESCENT	HALOGEN	FLUOR-ESCENT	METAL HALIDE	MERCURY VAPOR	HIGH PRES. SODIUM	LOW PRES. SODIUM
Efficacy (lumens per watt)	20	25	60-80	125	65	125	200
Life (hours)	1,000 – 4,000	10,000 –20,000	10,000 – 20,000	10,000 – 25,000	16,000 – 24,000	16,000 – 24,000	15,000 – 25,000

Table 6: Lamp Starting and Re-strike Times

LAMP TYPE	INCAN-DESCENT	HALOGEN	FLUOR-ESCENT	METAL HALIDE	MERCURY VAPOR	HIGH PRES. SODIUM	LOW PRES. SODIUM
Start Time (mins)	Instant	Instant	Instant*	5 – 8	5 – 8	2 – 5	5 – 8
Re-strike Time (mins)	Instant	Instant	Instant	10 – 20	10 – 20	1 – 20	0 – 8

* *Fluorescent lamps require time (especially in cold weather) to reach full output.*