ON-PREMISE SIGN LIGHTING

Terms Definitions Measurement

UNITED STATES SIGN COUNCIL

USSC ON-PREMISE SIGNS / TECHNICAL INFORMATION

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Terms...Definitions...Measurement

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On-Premise Sign Illumination: Terms, Definitions, Measurement

Preface

Throughout the United States and the rest of the developed world, land use regulations are increasingly being enacted to control the nighttime use of outdoor artificial light, including light used to illuminate signs. On-premise signs identify businesses or services performed at the location of the sign and, although they produce a very small portion of the overall light in any given environment, they do require some lighting at night to be visible. However, signs differ from standard outdoor lighting fixtures and devices in that their light is not intended to provide task or ground illumination, but rather to enable them to convey their intended message at night. On-premise signs may nonetheless be subject to some regulation of illumination levels by a local zoning or lighting code.

It is the purpose of this document to:

1.) Examine the role and function of illuminated on-premise signs as a critical factor in motorist wayfinding systems,

2.) Present cohesive and comprehensive methods of measuring the light output of these signs with the aim of providing designers and regulators tools to achieve optimum levels of visibility, legibility, and traffic safety in any nighttime environment in which illuminated on-premise signs are used, and

3.) Define critical lighting terms.

To the extent possible, technical jargon or terms of art customarily used in the sign and lighting professions are avoided in this document, and when not possible, the terms are presented in bold type and defined as they arise, using everyday language. Further detailed definitions and descriptions are also provided in glossary form in Appendix A. In addition, the glossary includes a number of key words, terms, and names of organizations that do not appear in the document text, but might be useful to anyone engaged in the design of sign illumination or sign lighting standards.

Overview

Since 2004, The United States Sign Council (USSC), through its research entity The United States Sign Council Foundation (USSCF), has funded extensive research into on-premise sign illumination. The four distinct USSCF university level studies published to date are now widely regarded as a definitive basis for a full understanding of the unique environmental and safety factors involved in both the design and use of on-premise sign illumination in the nighttime environment.

These USSCF sign lighting studies, conducted by the Thomas D. Larson Pennsylvania Transportation Institute at the Pennsylvania State University, are:

1. Environmental impact of on-premise sign lighting, with respect to potential light trespass, sky glow, and glare. 2004[1]
2. Relative visibility of internally and externally illuminated on-premise signs. 2004[2]
3. Internally illuminated sign lighting, effects on visibility and traffic safety. 2009[3]
4. Internal vs. external on-premise sign lighting. 2009[4]

Using this research base, lighting techniques and lighting levels designed to optimize viewer comfort and safety while minimizing environmental impact can be calculated as a function of on-premise sign usage in specific environments.

Purpose of On-Premise Sign Illumination

On-premise signs serve a variety of communication, advertising, and wayfinding functions, principal among which is the placemarking of the location or building on which they are installed[5]. Simply stated, on-premise signs tell people where something is located in the landscape. In high speed or congested traffic environments particularly, this placemarking (or situational wayfinding) function of on-premise signs can be a critical component in providing motorists and viewers in general with a precise and unequivocal awareness of the location of places and points of interest in the environment through which they are traveling.

Although significant advances have been made with in-vehicle navigation technology through GPS and other systems, it is still the on-premise sign alone that provides motorists' situational awareness with absolute precision, certainty, and reliability, while requiring only the normal visual scan of roadside cues familiar to every motorist.

This critical function of the on-premise sign, of course, must be met not only in daylight, but after dark as well. It is for this reason that on-premise signs are illuminated. On-premise signs require illumination that is as effective and as efficient as possible, because artificial light, even when optimized, is unable to provide equal visibility and legibility attainable under ordinary daylight conditions[2,3,4]. Yet the need for the roadside information transmitted by on-premise signs increases substantially in the more challenging nighttime driving environment.

Types of On-Premise Sign Illumination and their Impact on Driver Safety

Signs are visible in the daytime because sunlight reflects from the face of the sign. At night, for signs to be bright enough to be detected and read, they must be artificially illuminated. This can be done either internally or externally (Figure 1). As the name suggests, **internally illuminated signs** are lit from the inside, with light sources mounted within the sign cabinet itself back-projecting light onto the sign face. This is mainly accomplished using **fluorescent** bulbs, **neon** tubes, or light emitting diodes (**LEDs)**. **Externally illuminated signs** are lit from outside the sign, usually by flood lamps mounted above or below the sign face.

Figure 1. a. Internally illuminated sign. b. Externally illuminated signs lit from bottom and top.

Research has shown conclusively that internally illuminated on-premise signs are read from a much greater distance than externally illuminated signs[2,4]. This was first demonstrated on a test track where 40 to 60 percent longer reading distances were found with internally illuminated signs[2]. This improvement was found even though the lights for the externally illuminated signs were bright, new, and carefully placed and aimed. Because many externally illuminated signs in the real world are under-lit, poorly aimed, and dirty, a second study on real roads was conducted[4]. The result was that when externally illuminated signs in the real world were switched to identical signs that used internal illumination, on average people read the internally illuminated signs 70 percent further away and in some cases at more than twice the distance.

These research findings have significant traffic safety implications. Within relatively high speed urban and suburban driving environments, in which on-premise signs provide motorists with wayfinding and situational awareness information, the time required to process that information is critical. Referenced in the USSC research literature as Viewer Reaction Time (VRT), this represents the time interval required for a motorist to view and read a sign and then to perform the various driving maneuvers necessary to react to the sign and enter the destination at which it is located. These include such actions as signaling, deceleration, lane changing, and others necessary to maintain vehicular control and spacing within the traffic stream. These maneuvers, along with the time required to simply read and understand the message displayed by a sign, typically have been shown to require from six to as much as twelve or more seconds depending on the road conditions. Traffic safety issues can arise whenever the VRT is less than that required for a motorist to fully complete the sequence of events from sign detection to location arrival. These may include erratic glance behaviors and/or driving maneuvers that can be the prelude to a crash. Conditions that allow for an increase in VRT, such as the ability of a sign to be more quickly detected and read further up road because of better illumination, placement, size, or height, have the ability to enhance traffic safety and reduce the likelihood of crashes, particularly in the nighttime environment, when many visual cues are otherwise obscured. The research cited above shows that the method of sign illumination can have a marked effect on VRT, as a 70 percent improvement with internally illuminated signs over externally illuminated signs can give the driver an additional four seconds.

Light that Signs Generate

Luminance

There are two basic sign lighting concepts. The first relates to the brightness of the sign itself. In this sense, brightness is created either by light that is back projected onto the face of an internally illuminated sign or light that shines on the front face of an externally illuminated sign. In light measurement terms, this idea of brightness is called **luminance**. Because luminance describes a characteristic of the sign, it is not affected by distance. In other words, it doesn't matter if an observer is two inches from a sign or a mile away (or is not there at all), the sign has the same luminance, just as it has the same color and size.

Illuminance

The second sign lighting concept addresses the question of how much of the light that shines from a sign face reaches some point in the distance. This is technically referred to as **illuminance**, which is simply a projection of the light from the sign into surrounding space, such as light cast by a reading lamp on a book, or a street light on the road surface. Illuminance diminishes rapidly with distance, and this reduction in light is measurable at any point from the sign at a rate equal to the square of the distance from the sign.

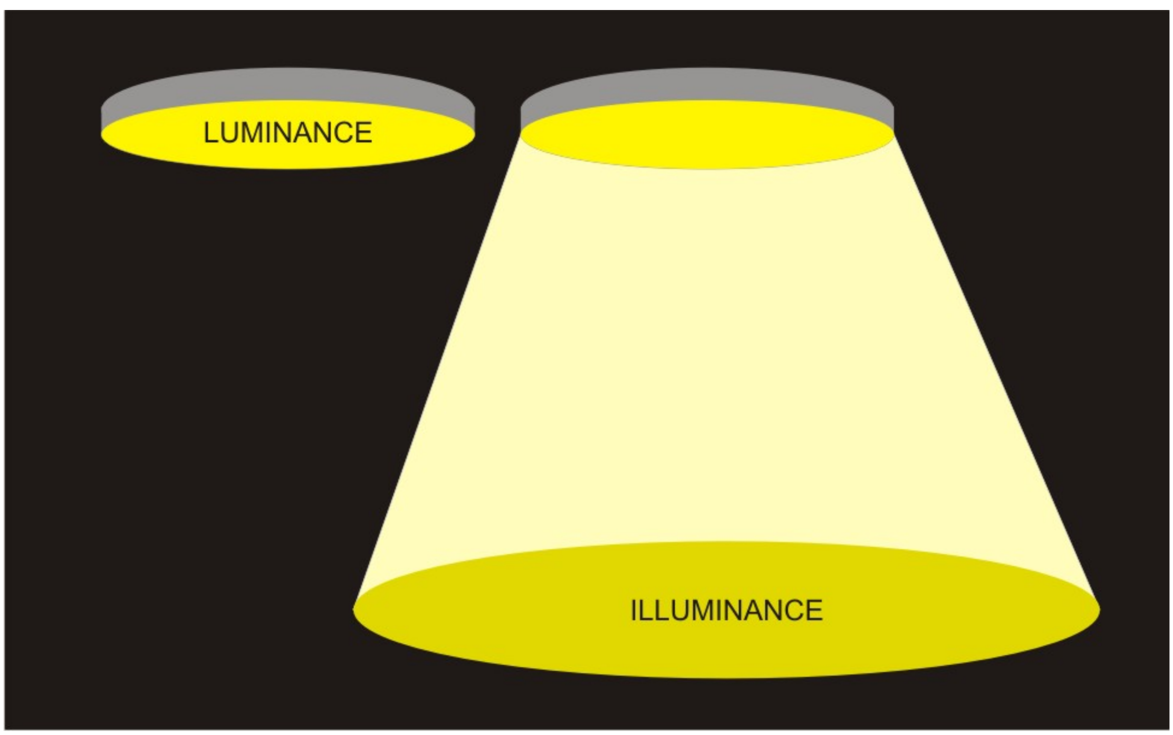

Figure 2. Luminance and illuminance.

Luminance and illuminance are related to each other through **reflection**. When a beam of light (illuminance) hits an object, the object lights up (luminance). Depending on the reflectance of that object, it appears more or less bright. A black object has low reflectance and so it absorbs more light than it reflects, and it appears dark. The absorbed light is converted into heat which explains why a black car sitting in the sun is hotter than a white car right next to it. Higher reflectance is also why the white car is brighter and in general easier to see.

In summary, sign luminance is simply a measure of the light at the surface of the sign while sign illuminance is a measure of the light cast by the sign into surrounding space.

The importance of distinguishing between sign luminance and illuminance

A well designed sign with the proper amount of luminance gives approaching motorists sufficient Viewer Reaction Time to allow for a comfortable period of detection, legibility, and driving maneuver in response to the sign at its particular location. On the other hand, even otherwise well designed signs can have a pronounced negative effect on VRT if they have insufficient luminance.

Research has shown that if a sign is too dim, it will be difficult to find because it will not differ enough in brightness from its surroundings[6]; this is know as **external contrast**. A dim sign will also not be readable because there is not enough difference between the sign copy and the sign face background[3]; this is called the sign's **internal contrast**. Alternatively, research also confirms that if the luminance of an internally illuminated sign is increased to abnormally high levels, although the sign becomes brighter and therefore more detectable, no advantage in legibility is gained, and, in fact, some legibility may be lost[3]. This, of course, underscores the need to keep sign luminance within ranges that will optimize legibility.

Illuminance, or the amount of light that shines from a light source onto other objects, has only an indirect relevance to on-premise signs. Since on-premise signs are not designed to cast light on other objects or spaces, their illuminance only becomes relevant in terms of its possible relationship to an environmental concept called **light trespass**.

The **Illuminating Engineering Society** (IESNA) describes light trespass as “light that strays from the intended purpose and becomes an annoyance, a nuisance, or a detriment to visual performance.”[7] It is light that shines where it is not wanted. Light trespass can result in **glare** if it is shining in someone’s eyes, or it can simply and annoyingly light up an area it is not supposed to, like when a street light or a car’s headlamps shine into a bedroom window. Because internally illuminated signs have low initial light levels that fall off rapidly with distance, these signs have virtually no significant light trespass[1]. It is mainly a problem with badly aimed lighting of externally illuminated signs, in particular when spot or flood lights spill over the edges of the sign or are so poorly aimed that they miss the sign altogether. Nonetheless, in addition to their other provisions, sign codes may address the issue of light trespass by requiring that the illuminance of signs at the property lines be restricted to a specific level.

The Measurement of Light – Photometry and Human Visual Perception

The measurement of light is known as photometry. Technically speaking, light is the very small range of electromagnetic radiation that humans can see. The normal human eye sees light as the familiar red, orange, yellow, green, blue, indigo, and violet of the rainbow or some combination of these basic colors. Light can be described by its wavelengths, which are shorter than radio, television, and infrared waves, and longer than ultraviolet, x-rays and gamma rays (Figure 3). In the daytime, yellow light is easier for people to see than red or blue. At night, best vision shifts toward the blue and away from the red (the so-called Purkinje shift), but still remains in the yellow/green range. Photometric equipment takes these sensitivities into consideration, however it does not account for dark adaptation.

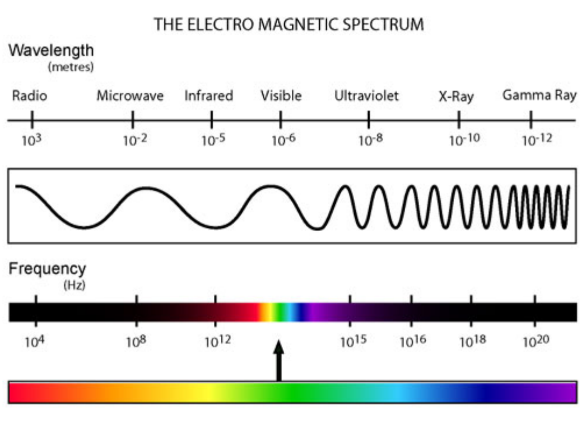

Figure 3. The Electro Magnetic Spectrum[8].

Although of course people cannot see in the complete absence of light, between the mechanical opening and closing of our pupils and the chemical reactions that take place within our rods and cones in the retina, we are capable of seeing in extremely bright and extremely dim conditions through what is generally know of as **dark adaptation**. While this ability is very useful, it creates a gap between measured light levels and what people call bright or dim. An illuminated sign will have the same luminance whether you measure it on a country road or on the well lit streets of Atlantic City. However, because of dark adaptation the sign in the rural area will appear very bright and perhaps even glary, while when viewed in the city it may be too dim to read or even find. It is the same phenomenon that makes you shield your eyes from the sunlight when exiting a movie theatre in the daytime.

This concept of dark adaptation has relevance to on-premise sign illumination because codes regulating sign lighting may take the brightness of the general area where the sign is located (the **ambient light level**), into account, by allowing the sign to be brighter as the ambient light level increases. Lighting for four **environmental zones** was first identified by the **International Commission on Illumination (CIE)** in 1997[9] in response to complaints from the international astronomical community (professional and amateur) about the reduction of night sky visibility due to light pollution in the form of **sky glow**. Although these zones have not been adopted as a "national" standard or concept in the United States, they have gained increasing acceptance by professionals in the field and provide a conceptual framework to consider lighting levels in varying outdoor environments. Zone 1 is established as the darkest environment and Zone 4 the brightest. While there are many ways to describe environmental zones, they all generally follow the lead of the CIE Zoning System as follows[7]:

- **Zone 1:** Areas with intrinsically dark landscapes: National Parks, or areas of outstanding natural beauty where roads are usually unlit.
- **Zone 2:** Areas of low brightness: outer urban and rural residential areas where roads are intermittently lit to residential standards.
- **Zone 3:** Areas of medium brightness: generally urban residential areas where roads are lit to traffic route standards.
- **Zone 4:** Areas of high district brightness: generally urban areas having mixed residential and commercial land use with high night-time activity.

Photometric Terms and the Dual Systems of Measurement

Photometric terms can be confusing. In addition to the similarity of the two basic terms: luminance and illuminance; the issue is further confounded by the use of both **SI** (**metric)** and English units of measurement. The difficulty with this dual system in the United States particularly is that some code requirements use metric measurements, others English measurements, and, in some cases, an ill-conceived code may use measurements from both systems. It is critical to understand the two systems and their terminology and measurement conversions, because the difference between them can be as much as a factor of ten. Meaning simply, that if the English and SI (metric) terms become mixed or transposed, a sign could be either ten times brighter or ten times dimmer than the code requires (see Table 1).

One key to unlocking the mystery between the English and SI (metric) system is the term for the basic building block of photometric measurement. In English units this is the **candle** and in SI (metric) units the **candela**. A simple way to remember which is which is that the word candle is an English word while the word candela is not. So any photometric term with the English word candle in it is in English units. These are **candle**, **foot candle** (fc), and **candlepower**. Any photometric term with the Latin word candela in it is in SI (metric) units. These are **candela** and **candela per meter squared** or candela per square meter (mainly written as **cd/m^2**).

The next step is untangling the photometric units used to measure and describe luminance from those used with illuminance:

- **Luminance:** The SI (metric) unit is candelas per square meter or **cd/m^2** and the English unit is **foot lamberts** (or candles per square foot, cd/ft^2). One foot lambert is equal to 3.43 candelas per square meter (cd/m^2.) To add to the confusion, sometimes cd/m^2 is referred to as a **nit**, which is neither an SI (metric) nor an English term.
- **Illuminance:** The SI (metric) unit is **lux** (lx) and the English unit is **foot candles**. One foot candle is equal to ten lux. Table 1 provides conversion factors from one system to the other.

Table 1. English and SI (metric) terms for luminance and illuminance and conversions.

	English	Conversion to SI (metric)	SI (metric)
Luminance	foot lambert (fL or ft-L)	x 3.43	cd/m^2
Illuminance	foot candle (fc)	x 10	lux (lx)
	SI (metric)	**Conversion to English**	**English**
Luminance	cd/m^2	X 0.29	fL or ft-L
Illuminance	lux (lx)	x 0.1	fc

Complying with Outdoor Lighting Codes

Outdoor lighting code language can be confusing to sign designers and owners of business establishments who are trying to comply with them. Assuming that these outdoor lighting codes are intended to apply to signs, then basically all the codes are trying to do is to prevent signs from being so bright that they result in glare or light trespass. There are two basic ways that lighting codes attempt to do this. First, they place physical restrictions on sign lighting designs, and second, they place photometric restrictions on the light levels that the signs produce. The first is fairly easy to comply with, as the codes state, for example, what lighting type, **wattage**, lamp type, or **cutoff angles** are allowed. The second requires that either photometric measurements be taken or some form of "look-up tables" be established to ensure that the lighting levels are within code stipulations.

Sample code terms

- **EAVG –** E is the symbol for illuminance; this term means average illuminance.
- **EAVG VERT –** This is the average illuminance taken with the illuminance meter receptor directly pointed at the sign face, held straight up and down (i.e., vertically).
- **Photopic Lumens –** Light as seen by the human eye in the daytime. Standard illuminance meters automatically measure this way.
- **Lumens per square foot –** A measure of illuminance in English terms also known as foot candles (fc). If it were lumens per square meter (i.e., lux) the code would be looking for illuminance in SI (metric).
- **Cosine Corrector –** Most professional illuminance meters have this built in (for example, the Minolta T-10).

Sample code language

Some codes are very specific in their lighting restrictions. For example, Lincoln, Nebraska's code states: "Signs may be illuminated…provided that the surface/face illumination of any sign shall not exceed the levels shown in Figure 1 below for different conditions of ambient light." (see Figure 4)

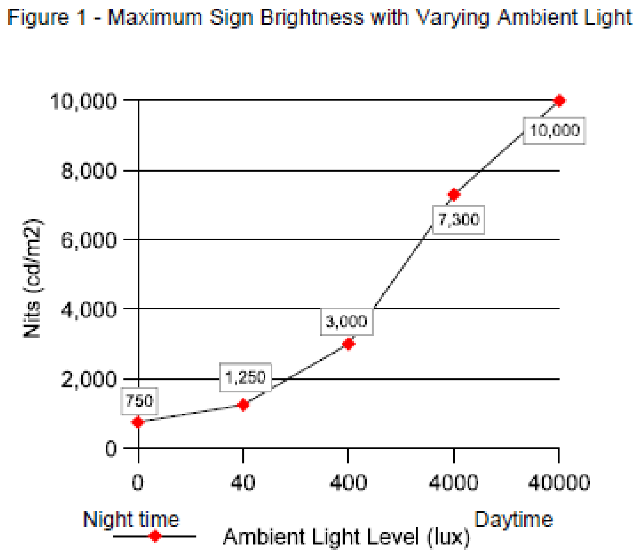

Figure 4. Maximum sign brightness with varying ambient light.

This code requires one to measure the sign and to determine what the lighting is around the sign so that the sign conforms to that ambient level. This is similar to the concept of using environmental zones, but more specific to the actual location of the sign. As the figure indicates, one would need to measure the ambient light level with an illuminance meter using SI (metric) units (lux) and then match that with luminance measurements of the sign also using SI (metric) units (cd/m^2). That the code requires the sign be measured in luminance means that they are concerned more about glare than they are about light trespass.

When the lighting code does not make sense to you, you will need to ask the authority for clarification. For example, a particular code may state, "The average illumination on the face or vertical surface of any sign shall not exceed 1 foot-candle." This code would require an illuminance measure to be taken in English units (foot candles) on the face of the sign. However, with externally illuminated signs, 1.0 fc of illumination cast on the sign will not be sufficient to light the sign to any reasonable level. [By comparison, a more realistic code might state, “Illuminance of the sign face by ground mounted light fixtures shall not exceed 50 foot-candles.”] If the first code is intended for internally illuminated signs, then it does not make sense to take an illuminance measure on the face, as that kind of measure has to be taken at some distance in front of the sign. [An example of a better way of stating this would be a code that reads something like, “lighting shall not cast light [illuminance] at the joint property line of adjacent residential use of more than 0.5 footcandles.”]

Measurement Methods

Measurement of either the luminance or illuminance of a given sign can be easily accomplished through the use of a luminance and/or an illuminance meter (sometimes called a lux meter) specifically designed for the measurement of light output.

The meters, which are precision instruments, require some expenditure of cost, currently in the range of $3,000 US for a luminance meter and $1,000 US for an illuminance meter similar to the Minolta manufactured units pictured in Figure 5. It is possible, however to save costs and measurement time by just measuring either luminance or illuminance and then doing some simple calculations (described below) to determine the other value.

Figure 5. a. Minolta LS-100 Luminance Meter; b. Minolta T-10 Illuminance Meter.

How and where to take the measurements

Photometric measurements can be taken indoors or outdoors. However, if they are taken outdoors after the sign has been installed in the built environment, there are many other light sources that might interfere with the readings. It is best, therefore if at all possible to take the sign photometric measurements in the sign workshop where all other lights can be turned off. If there is no choice but to take the measurements after the sign is installed, one of two things can be done: 1. the photometer can be shielded from extraneous light sources, or 2. the measurements can be taken with the sign on and with the sign off subtracting out the light measured with the sign turned off.

Photometers vary by make and model and their specific instructions should be followed carefully, however taking the measurements is relatively straightforward and generally follows these procedures:

Luminance: Stand at any convenient distance in front of the sign, aim the photometer, and take the reading. With the exception of when there is an extremely bright light source very close to the photometer's aperture, other light sources will not interfere with your measurements as the luminance meter is designed to only measure the specific target area. All the sign colors will need to be measured as they will produce different readings. An estimate of the percentage of the sign that the various colors cover should be made and a weighted average of the luminances taken. For example, if the sign has white copy measured at 100 cd/m^2 and a blue background measured at 10 cd/m^2, and the copy takes up about 25 percent of the sign face, then the average sign luminance will be ((100 x 75) + (10 x 25))/100 = 77.5 cd/m^2.

Illuminance: The illuminance meter is held upright (vertical) with the receptor directly facing the sign. As a rule of thumb, place the meter at a distance equal to or greater than twice the largest sign dimension; e.g., if the sign is ten feet wide and four feet high, take the measurement at 20 feet. Measure the distance accurately as that number will be needed to calculate illuminance at various distances that might be required by codes (for example, at the proposed property line).

To avoid having to take numerous illuminance measurements, you can calculate illuminance at any distance using the general equation:

$$\mathbf{Ed_2 = \frac{Ed_1}{(d_2/d_1)^2}}$$

Where E is illuminance; d_1 is the first distance (in meters or feet) and d_2 is the second distance. For example, if the reading was 500 fc at 20 ft (Ed_1) and you are interested in the illuminance at the proposed property line of 175 ft (Ed_2), you simply divide 175 by 20 (d_2/d_1) which gives you

8.75, then square that number (i.e., multiply 8.75 x 8.75) and that gives you 76.56. When 500 is divided by 76.56 you get 6.53 fc at the property line (Ed_2). This works exactly the same way regardless of whether SI (metric) or English units are used. Alternately, you can simply measure the illuminance at all the distances of interest using your illuminance meter as described above.

Converting between Illuminance and Luminance

Sign luminance is sign intensity divided by the *area* of the sign. Sign intensity is expressed as candles or candelas "cd." In English units, luminance is expressed as cd/ft^2 (known as foot lamberts) and in SI (metric) units as cd/m^2 (sometimes called nits). The ft^2 and m^2 are simply referring to the sign *area* (nominally height x width) in either feet or meters

Sign illuminance is sign intensity divided by the *distance* away from the sign. Like sign luminance, the units for sign illuminance in English are cd/ft^2 (this time called foot candles) and in SI (metric) cd/m^2 (lux), but this time the ft^2 and m^2 represent the *distance* from the sign where the measurement is taken.

The common element between luminance and illuminance is the "cd." If you know that you can determine the luminance by just knowing the illuminance, and the illuminance by just knowing the luminance[1]. Here is an example in English and roughly equivalent SI (metric) terms:

From Illuminance to Luminance (Illuminance x Distance-to-Sign^2/Sign Area)

English Units:

1. Illuminance = 150 fc
2. Measurement distance = 6 ft (6 x 6 = 36 ft^2)
3. Sign area = 16 ft^2
4. Luminance = (150 x 36)/16 = 337.5 ft-L

$$\textbf{Luminance} = \frac{\textbf{Illuminance x Distance Squared}}{\textbf{Sign Area}}$$

SI (metric) Units:

1. Illuminance = 1,500 lx
2. Measurement distance = 2 m (2 x 2 = 4 m^2)
3. Sign Area = 1.5 m^2
4. Luminance = (1500 x 4)/1.5 = 4,000 cd/m^2

From Luminance to Illuminance (Luminance x Sign Area/Distance-to-Sign^2)

English Units:

1. Luminance = 337.5 ft-L
2. Sign area = 16 ft^2
3. Measurement Distance #1 = 6 ft (6 x 6 = 36 ft^2)
4. Illuminance = (337.5 x 16) / 36 = 150 fc
5. *Measurement Distance #2 = 20 ft (20 x 20 = 400 ft^2)*
6. *Illuminance = (337.5 x 16) / 400 = 13.5 fc*

$$\textbf{Illuminance} = \frac{\textbf{Luminance x Sign Area}}{\textbf{Distance Squared}}$$

SI (metric) Units:

1. Luminance = 4,000 cd/m^2
2. Sign Area = 1.5 m^2
3. Measurement Distance #1 = 2 m (2 x 2 = 4 m^2)
4. Illuminance = (4,000 x 1.5) / 4 = 1,500 lx
5. *Measurement Distance #2 = 15 m (15 x 15 = 225 m^2)*
6. *Illuminance = (4,000 x 1.5) / 225 = 26.67 lx*

Look-up Tables

It is impossible to measure, and difficult to guess, what a sign's luminance and illuminance will be prior to its fabrication. After the installation of a sign, it is expensive and time consuming to take the measurements and do the calculations detailed in the above sections. It would be useful, therefore to have a way of estimating the likely luminance and illuminance of any on-premise sign given its size, color, and the distance of interest. Research sponsored by the United States Sign Council Foundation[1,3] has made it possible to take a first step toward this. "Look-up Tables" (2 and 3) provide luminance levels for various color combinations of internally illuminated signs, lit to "industry standard" using, for example, four Sylvania Daylight 60 watt fluorescent tubes evenly spaced in the cabinet. The tables also estimate the illuminance levels that these signs will generate at various distances. The values in Tables 2 and 3 represent measurements taken perpendicular to the sign and are therefore the brightest estimates. When viewed from any other angle, the signs will likely have a lower luminance and will certainly have a lower illuminance.

How to use the tables. Tables 2 and 3 were developed from measurements taken of internally illuminated test signs that were four feet by four feet squares, with an area of 16 ft^2 (1.133m^2). Since luminance is independent of the area of the sign, the luminance values shown in the tables would be the same (as an approximate rule of thumb) for any similarly illuminated sign regardless of its size or dimensions. The illuminance values in Tables 2 and 3, on the other hand, which depend on the square area of the sign, cannot be used if your sign differs from 16 ft^2 without a mathematical adjustment to account for the size of your sign. This however can be accomplished simply by dividing the area of your sign by 16 and multiplying the illuminance levels in the tables by the result (i.e., quotient)[11]. For example (highlighted in Table 2), a 10ft x 10ft (100ft^2) white sign with black letters at 30 ft would be about 194 fc (100/16 = 6.25; 6.25 x 31.11 = 194).

Table 2. "Look-up Table" luminance levels, and illuminance levels at four distances, for standard illuminated 16 ft^2 internally illuminated signs (English measurement units).

Color (Copy/Background)	Weighted Mean Luminance (ft-L)	Illuminance (fc)			
		30 ft	60 ft	90 ft	120 ft
Black/White	175	31.11	7.78	3.46	0.19
Black/Yellow	120	21.33	5.33	2.37	0.13
Black/Green	20	3.56	0.89	0.40	0.02
Black/Red	15	2.67	0.67	0.30	0.02
White/Black	30	5.33	1.33	0.59	0.03
White/Yellow	150	26.67	6.67	2.96	0.17
White/Green	50	8.89	2.22	0.99	0.06
White/Red	50	8.89	2.22	0.99	0.06
Yellow/Black	20	3.56	0.89	0.40	0.02
Yellow/White	180	32.00	8.00	3.56	0.20
Yellow/Green	40	7.11	1.78	0.79	0.04
Yellow/Red	40	7.11	1.78	0.79	0.04
Green/Black	3	0.53	0.13	0.06	0.00
Green/White	170	30.22	7.56	3.36	0.19
Green/Yellow	115	20.44	5.11	2.27	0.13
Green/Red	15	2.67	0.67	0.30	0.02
Red/White	170	30.22	7.56	3.36	0.19
Red/Yellow	115	20.44	5.11	2.27	0.13
Red/Green	20	3.56	0.89	0.40	0.02
Red/Black	3	0.53	0.13	0.06	0.00

Table 3. "Look-up Table" luminance levels, and illuminance levels at four distances, for standard illuminated 1.133 m^2 internally illuminated signs (SI (metric) measurement units).

Color (Copy/Background)	Weighted Mean Luminance (cd/m^2)	Illuminance (lx)			
		10 m	20 m	30 m	40 m
Black/White	600	6.80	1.70	0.76	0.42
Black/Yellow	400	4.53	1.13	0.50	0.28
Black/Green	60	0.68	0.17	0.08	0.04
Black/Red	50	0.57	0.14	0.06	0.04
White/Black	100	1.13	0.28	0.13	0.07
White/Yellow	500	5.67	1.42	0.63	0.35
White/Green	150	1.70	0.42	0.19	0.11
White/Red	150	1.70	0.42	0.19	0.11
Yellow/Black	65	0.74	0.18	0.08	0.05
Yellow/White	625	7.08	1.77	0.79	0.44
Yellow/Green	125	1.42	0.35	0.16	0.09
Yellow/Red	120	1.36	0.34	0.15	0.08
Green/Black	10	0.11	0.03	0.01	0.01
Green/White	575	6.51	1.63	0.72	0.41
Green/Yellow	400	4.53	1.13	0.50	0.28
Green/Red	60	0.68	0.17	0.08	0.04
Red/White	575	6.51	1.63	0.72	0.41
Red/Yellow	400	4.53	1.13	0.50	0.28
Red/Green	70	0.79	0.20	0.09	0.05
Red/Black	10	0.11	0.03	0.01	0.01

Conclusion

The objective of this document is to help designers and fabricators of on-premise commercial sign and the owners of business establishments reach an understanding with city planners and organizations who craft outdoor lighting codes or zoning codes that contain regulations on sign lighting. To do this, the document provides information that should give these groups an improved understanding of how to best light these signs from a driver safety and sign visibility perspective, a better understanding of the language of sign lighting and its measurement; and relatively easy to understand and implement methods to comply with codes. This document should give anyone who is interested in understanding sign lighting a handle on the basic issues involved. It should also supply enough information so that an interested person would be able to comply with codes, including sign photometric measurement.

Text References

[1]Garvey, P.M. (2005). On-premise commercial sign lighting and light pollution. Leukos: The Journal of the Illuminating Society of North America. Vol. 1(3), 7-18.

[2]Garvey, P.M., Ramaswamy, C., Ghebrial, R., De la Riva, M., and Pietrucha, MT. (2004). Relative visibility of internally and externally illuminated on-premise signs. Report to the United States Sign Council Foundation.

[3]Garvey, P.M., Pietrucha, M.T., and Cruzado, I. (2008). The effect of internally illuminated on-premise sign brightness on nighttime sign visibility and traffic safety. United States Sign Council (USSC) Research Project, Final Report.

[4]Garvey, P.M., Pietrucha, M.T., Damin, S.J., and Deptuch, D. (February, 2009). Internal vs. External On-Premise Sign Lighting: Visibility and Safety in the Real World. Final Report to the United States Sign Council Foundation.

[5]Garvey, P.M., Thompson-Kuhn, B. and Pietrucha, M.T. (1995). Sign visibility literature review. United States Sign Council (USSC) Research Project, Final Report.

[6]Mace, D.M., Garvey, P.M., and Heckard, R.F. (1994). Relative visibility of increased legend size vs. brighter materials for traffic signs. Publication No. FHWA-RD-94-035.

[7]Illuminating Engineering Society of North America. (2000a). IESNA Technical memorandum addressing obtrusive light (urban sky glow and light trespass) in conjunctions with roadway lighting. New York: Illuminating Engineering Society of North America Technical Manual TM-10–00. 7 p.

[8]Color Therapy Healing: The electromagnetic spectrum. www.colourtherapyhealing.com/colour/electromagnetic_spectrum.php

[9]CIE (1997). Guidelines for minimizing sky glow. CIE126-1997.

[10]Schreuder DA. 1997. Bilateral agreements on limits to outdoor lighting: The new CIE Recommendations, their origins and implications. Presented at the XXIIIrd General Assembly International Astronomical Union. Kyoto (Japan http://www.eplioan.gr/LP/artic3.htm

[11] Lewin, I. (2009). Electronic message center sign luminance. Report to International Sign Association.

Glossary References

Journal Articles:

Ashdown, I. (2002). Photometry and Radiometry: A Tour Guide for Computer Graphics Enthusiasts From: Radiosity: A Programmer's Perspective by Heart Consultants Limited. (Originally published by John Wiley & Sons in 1994.)

[ILE] Institution of Lighting Engineers. 2001. Brightness of illuminated advertisements. 3rd edition. Rubgy (England): Institution of Lighting Engineers.

Internet Resources:

American National Standards Institute. http://www.ansi.org/

Merriam-Webster Online Dictionary and Thesaurus. http://www.merriam-webster.com

Illuminating Engineering Society. http://www.ies.org

LDPI Technical Information on Fluorescent, Incandescent and HID Lamps http://www.ldpi-inc.com/main-site/technical/lamps.html

California Energy Commission. http://www.energy.ca.gov/

The Unit of Luminous Intensity: Candela (cd). http://www.electro-optical.com/

Rensselaer Polytechnic Institute, Lighting Research Center. http://www.lrc.rpi.edu/

Lighting Catalog. http://www.lightingcatalog.com/

International Dark Sky Association. http://www.darksky.org

Wikipedia. http://en.wikipedia.org

About.com – Inventors. http://inventors.about.com

National Electrical Manufacturers Association. http://www.nema.org/

AF Florence Manufacturing Company. http://www.florencemailboxes.com/

Underwriters Laboratories Incorporated. http://www.ul.com/

The National Institute of Standards and Technology. http://physics.nist.gov/

International Organization for Standardization. http://www.iso.org/

ACP Noxtat. http://www.noxtat.com

Helios 32 – Radiosity Rendering for Architecture and Lighting Design http://www.helios32.com

Philips – Lighting.com. http://www.lighting.com

Appendix A: Glossary of Terms

GLOSSARY

American National Standards Institute (ANSI) – Established in 1918, ANSI is a nonprofit organization that promotes and facilitates the use, assessment, and integrity of voluntary standards, norms, and guidelines that directly impact businesses. ANSI is the official U.S. representative to the International Organization for Standardization (ISO).

Ballast – An electrical device used to provide the starting voltage and to stabilize the current in fluorescent, mercury, or other electric-discharge lamps.

- **Ballast Efficiency Factor –** A measure of the energy efficiency of a ballast/lamp combination. The higher the BEF, the more energy efficient the ballast
- **Electronic Ballast –** A high-energy efficiency ballast that uses semi-conductor components.
- **Electronic Dimming Ballast –** A ballast that allows the user to adjust the brightness of a fluorescent lamp, like a rheostat or "dimmer switch" for an incandescent lamp.
- **Energy-Saving Ballast –** A type of magnetic ballast designed so the components operate more efficiently, cooler, and longer than a "standard magnetic" ballast. By U.S. law, standard magnetic ballasts can no longer be manufactured.

Blinding Glare – Glare so intense that while the light source is present and for an appreciable length of time after it has been removed, no object can be seen.

Brightness – The visual sensation experienced by an observer that is associated with the photometric concept of luminance. The level of brightness experienced depends on the luminance, size, and contrast of the object and characteristics of the observer's vision such as their level of dark adaptation. Brightness is a psycho-physiological phenomenon that cannot be measured directly. The term "photometric brightness" was at one time used to refer to luminance. However, it is no longer used for scientific or engineering purposes.

California Energy Commission (CEC) – Created in 1974 and located in Sacramento, the CEC is California's primary energy policy and planning agency. It has an impact on on-premise signs because it sets the state's standards on energy efficiency for signs and it works with local government to enforce those standards.

Candela – The basic unit in the measurement of light in SI (metric) units. It enables you to calculate how much light is cast on a surface no matter where the surface is.

Candela per square meter (cd/m^2) – The SI (metric) unit used to describe the luminance of a light source or of an illuminated surface that reflects light.

Candle or candlepower – Synonymous with candela, but in English terms.

Color Temperature – A description of the color of light in terms of temperature. As the temperature increases from colder to warmer, the color appearance shifts from red to blue. This is somewhat confusing as reds and oranges are typically considered "warm" colors while blues are said to be "cool." For example yellowish high or low pressure sodium lamps put out a temperature of about 2,000 degrees kelvin while white light metal halide lamps have a color temperature of about 5,000 degrees kelvin.

Contrast – There are three types of sign contrast: external luminance contrast, internal luminance contrast, and color contrast.

- **External contrast** affects the distance at which a sign can first be seen, it is defined as the relation between the sign's luminance and the luminance of the area directly surrounding the sign.
- **Internal contrast** affects the distance at which a sign can first be read and is defined as the relation between the luminance of a sign's copy and the luminance of the sign face.
- **Color contrast** is the relation between the color of sign copy and the color of the sign face.

Cut-Off Angle – The angle of light distribution from a luminaire, measured upward from nadir, between the vertical axis and the first line at which the bare source (lamp) is not visible.

Dark Adaptation – The ability of the eye to adapt to various levels of illumination

Downlight – Light aimed in a downward direction, or a type of lighting fixture where most of the light is directed downward.

Efficacy – The power or ability to produce an effect.

Energy-Saving Lamp – A lower wattage lamp, generally producing fewer lumens.

Environmental Zones – Outdoor lighting standards are often based on how bright the surrounding conditions are, with the highest lighting levels being allowed in the brightest surrounding conditions. While there are many ways to describe environmental zones, they all generally follow the lead of the International Commission on Illumination (CIE) Zoning System as follows:

- Zone E1: Areas with intrinsically dark landscapes: National Parks, Areas of outstanding natural beauty (where roads usually are unlit).
- Zone E2: Areas of "low district brightness": outer urban and rural residential areas (where roads are lit to residential road standard).
- Zone E3: Areas of "medium district brightness": generally urban residential areas (where roads are lit to traffic route standards).
- Zone E4: Areas of "high district brightness": generally urban areas having mixed residential and commercial land use with high night-time activity.

Flood Light – A lighting unit that projects a comparatively uniform broad beam of light over a large area.

Foot Candle (fc) – An English unit of measurement of the amount of light hitting a surface (illuminance). One foot candle is equal to one lumen per square foot. For many purposes it is quite sufficient to think of one foot-candle as about ten lux. Therefore, it is commonplace to simply state 1 fc = 10 lux. A foot-candle is equivalent to one lumen per square foot (where a lumen is a measure of the luminous flux, or quantity of light). A wax candle flame has a luminous intensity (or equivalently, candlepower) of approximately one candela. If you hold the candle one foot away from a surface, the illuminance of the surface at this distance due to the light from the candle will be approximately one foot-candle. It will be 1/4 fc at two feet, 1/9 fc at three feet, and so on in accordance with the inverse square law for point light sources.

Foot Lambert – An English unit of measurement of the amount of light emitted by or reflecting off a surface (luminance) equivalent to 3.4262591 candelas per square meter.

Fluorescent Lamp – A light source consisting of a tube filled with argon, along with krypton or other inert gas. When electrical current is applied, the resulting arc emits ultraviolet radiation that excites the phosphors inside the lamp wall, causing them to radiate visible light.

Glare – According to IESNA, glare is the sensation produced by luminance that is sufficiently greater than the luminance to which the eyes are adapted to cause annoyance, discomfort, or loss in visual performance and visibility. Stated informally, it is uncomfortably bright light shining in your eyes, sometimes making it difficult to see anything other than the glare source itself.

- **Discomfort Glare –** Discomfort glare causes our pupils to contract severely, forcing us to turn away or move or shield our eyes to avoid pain.
- **Disability Glare –** Glare that makes it more difficult to see other object.
- **Veiling Reflection –** Also known as veiling glare or veiling luminance, this is a form of disability glare where light reflects off the visual task into the viewer's eyes in a way that overwhelms the task's contrast, effectively "throwing a veil" over the task. An example is the veiling glare on the windshield that can occur when driving at night with the interior dome light on.
- **Direct Glare –** Glare resulting straight from a high brightness light source.
- **Indirect Glare –** Otherwise known as reflected glare, it is glare resulting from light bouncing off a reflective surface.

Gooseneck – Any mechanical device shaped like a goose's neck, such as a flexible rod for supporting a lamp

Halogen Lamp – Also known as a Tungsten Halogen Lamp or a Quartz Lamp, it is a gas-filled tungsten filament incandescent lamp with an envelope made of quartz to withstand the resulting high temperature. This lamp contains some chemicals known as halogens (iodine, chlorine, bromine, and fluorine), which slow the evaporation of the tungsten.

High Intensity Discharge (HID) – Generic term describing mercury vapor, metal halide, high pressure sodium, and (informally) low pressure sodium light sources.

High Output (HO) – A lamp or ballast designed to operate at higher currents and produce more light.

High Power Factor – A ballast with a 0.9 or higher rated power factor, which is achieved by using a capacitor.

High Pressure Sodium Lamp – A high-intensity discharge lamp that uses sodium under high pressure as the primary light-producing element.

Institution of Lighting Engineers (ILE) – Founded in 1924 as a non-profit group, the ILE is the United Kingdom and Ireland's largest and most influential professional lighting association comparable to North America's Illuminating Engineering Society.

Illuminance – Commonly called "light level" or "illumination," luminance is the amount of light hitting a real or imaginary surface. Illuminance is measured in foot candles (lumens/square foot) in the English system and lux (lumens/square meter) in the SI system. One foot candle equals 10.76 lux, although for convenience the IESNA uses 10 lux as the equivalent. The further away from the source, the lower the illuminance (inverse square rule).

Illuminating Engineering Society of North America (IES) – Founded in 1906, the IESNA is the recognized U.S. technical authority on illumination. Its objective is to communicate information on all aspects of good lighting practice to its members, the lighting community, and consumers, through a variety of programs, publications, and services.

International Dark Sky Association (IDA) – Founded in 1988 as a non-profit organization, the goal of the IDA is to reduce light pollution by promoting good outdoor lighting practices and educating the public.

International Organization for Standardization (ISO) – Founded in 1947, the ISO is the world's largest developer and publisher of International Standards. ISO is a network of the national standards institutes of 159 countries, one member per country, with a Central Secretariat in Geneva, Switzerland, that coordinates the system.

Lambert – An English unit of measurement of the amount of light on the surface of an object (luminance). It is equivalent to 3,182 cd/m^2, the SI equivalent.

Light Emitting Diode (LED) – A very small light source used in electronics including electronic signs, LED's are electronic light sources based on the semiconductor diode. They have the benefits of a lower energy consumption, longer lifetime, smaller size, and faster switching than traditional light sources.

Legibility Distance – The longest distance at which a person can accurately read sign copy. For commercial signs, this represents a scenario where a motorist does not know the exact name of a business establishment he is looking for and so has to read the content of each sign to try to find it.

Lens – A transparent or translucent medium that alters the directional characteristics of light passing through it. It is typically made of glass or acrylic.

Light Trespass – A form of light pollution, IESNA defines light trespass as light that strays from the intended purpose and becomes an annoyance, a nuisance, or a detriment to visual performance. It is light that shines where it is not needed or wanted.

Low Power Factor – Essentially, a ballast power factor of less than 0.9.

Low-Pressure Sodium – A lamp in which light is produced by radiation from sodium vapor. Most colors look gray under this type of lamp.

Low-Voltage Lamp – Typically a compact halogen lamp that provides both high brightness and good color. They operate at 12 volts and require the use of a transformer. Popular lamps are MR11, MR16, and PAR36.

Lumen (lm) – A Lumen is a quantity of light, the same kind of unit as a watt, but measured in such a way that takes into account the sensitivity of the eye. Lumens are measured as the entire output, regardless of direction. It is the SI (metric) unit for term call "luminous flux."

Luminaire – Also called a fixture, a luminaire is the complete lighting unit, including the light source, any reflectors or lenses, anything used to position or protect the lamp, as well as any connection to the power supply.

Luminaire Efficiency – The ratio of the measured light output of a luminaire to its active power, expressed in lumens per watt (LPW).

Luminance – The photometric quantity most closely related with the perception of brightness, it can refer to either the light that is emitted by or reflected from a surface. Luminance is measured in units of luminous intensity (candelas) per unit area (square feet or square meters). In English units it is expressed as foot lamberts (fL) and in SI units as cd/m^2.

Luminous Flux – The time rate of flow of light, measured in lumens.

Luminous Intensity – Expressed in candelas (cd), luminous intensity is a description of a light source itself and is, therefore, independent of distance. That is, no matter how far away an observer is from a lamp, that lamp always has the same intensity. Luminous intensity is the photometric measurement most often specified by lamp and LED manufacturers.

Lux (lx) – The SI (metric) unit for illuminance, or how much light falls on a surface. One lux is equal to one lumen per square meter. One lux equals 0.093 foot candles

Mercury Vapor Lamp – A high-intensity discharge lamp that uses mercury and several halide additives as light-producing elements.

Meter Lambert – Another measurement term for luminance.

Metric System – The **metric system** is an international decimalised system of measurement, first adopted by France in 1791, that is the common system of measuring units used by most of the world. It exists in several variations, with different choices of fundamental units, though the choice of base units does not affect its day-to-day use. Over the last two centuries, different variants have been considered *the* metric system. Since the 1960s the International System of Units ("*Système International d'Unités*" in French, hence "SI") has been the internationally recognized standard metric system.

Nadir – Directly below a luminaire, "straight down," 0 degree angle.

Neon – Hollow glass tubes are shaped by heating the glass with lit gas and forced air. Argon or neon is back filled into the tube and sealed off. Red is the color neon gas produces. Almost every color other than red is produced using argon, mercury, and phosphor. Neon tubes informally refer to all positive-column discharge lamps, regardless of the gas filling.

National Electrical Manufacturers Association (NEMA) – Founded in 1926, NEMA is the trade association for the electrical manufacturing industry. NEMA provides a forum for the development of technical standards that are in the best interests of the industry and users, advocacy of industry policies on legislative and regulatory matters, and collection, analysis, and dissemination of industry data.

Nit – A non-SI, non-English photometric unit that is believed to come from the Latin word *nitere* meaning "to shine." A nit is unit of measurement that refers to luminance. One nit is equal to 1 cd/m^2.

Normal Power Factor (NPF) – A ballast/lamp combination in which no components like capacitors have been added to correct the power factor.

Par Lamp – A parabolic (U-Shaped) aluminized reflector lamp. An incandescent, metal halide, or compact fluorescent lamp used to redirect light from the source using a parabolic reflector. They are available with flood or spot distributions.

Photocell – A light sensing device used to control luminaires and dimmers in response to detected light levels. Photocells allow signs to be dimmed or brightened automatically in response to changing ambient light conditions.

Photometric Report – Data from laboratory testing describing the light distribution, efficiency, and output of a luminaire.

Phot (ph) – A non-SI, non-English photometric unit of illuminance equal to 10 kilolux (1 ph = 10,000 lx).

Power Factor – The ratio of AC volts x amps through a device to AC wattage of the device. A device such as a ballast that measures 120 volts, 1 amp, and 60 watts has a power factor of 50 percent (volts x amps = 120 VA, therefore 60 watts/120 VA = 0.5). Some utilities charge customers for low power factor systems.

Recognition Distance – The longest distance at which a person can identify a word they are looking for on a sign. For commercial signs, this represents a scenario where a motorist knows the name of the business establishment he is looking for and merely has to distinguish that word from words on other on-premises signs.

Reflectance – Illuminance divided by luminance, it describes the proportion of light that is absorbed and the proportion that bounces off a surface.

SI (International System of Units) – The modern metric system of measurement; abbreviated SI for the French term "Le Système International d'Unités."

Sign Copy – The physical sign message including any words, letters, numbers, pictures, and symbols.

Sky Glow – A form of light pollution that IESNA describes as “The brightening of the night sky that results from the reflection of radiation scattered from the constituents of the atmosphere in the direction of the observer.” Or less technically, sky brightness caused by the scattering of artificial light particularly in urban areas that makes it difficult to see stars and planets. Sky-glow can be caused by either light directed upward or by light reflected upward from surfaces.

Spot Light – A lighting unit that projects a comparatively uniform narrow beam of light over a small area.

T12 Lamp – Industry standard for a fluorescent lamp. The “T” refers to the diameter of the glass envelope of the lamp in eighths of an inch. Therefore, a T1 lamp (if it existed) would be 1/8 inch in diameter. A T12 lamp is one and one-half inches in diameter

Underwriters' Laboratories (UL) – Established in 1894, UL is an independent product safety certification organization that tests products and writes safety standards.

Very High Output (VHO) – A fluorescent lamp that operates at a "very high" current, producing more light output than “high output” or “standard output” lamps.

Volt or Voltage – The standard unit of measurement for electrical potential. It defines the "force" or "pressure" of electricity.

Watt – The unit for measuring electrical power. It is often incorrectly associated with light output. It defines the rate of energy consumption by an electrical device when it is in operation. The energy cost of operating an electrical device is calculated as its wattage times the hours of use.

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