Environmental Impact Of On-Premise Sign Lighting

Light Trespass
Sky Glow
Glare

UNITED STATES SIGN COUNCIL

RESEARCH CONCLUSIONS / PENNSYLVANIA STATE UNIVERSITY

ENVIRONMENTAL IMPACT OF ON-PREMISE IDENTIFICATION SIGN LIGHTING

With Respect To Potential
Light Trespass
Sky Glow
Glare

A Research Project Of The
UNITED STATES SIGN COUNCIL FOUNDATION

By
Philip M. Garvey
Of The
Pennsylvania Transportation Institute
The Pennsylvania State University
University Park, PA

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The United States Sign Council Foundation Inc.
211 Radcliffe Street, Bristol, PA 19007
215-785-1922 / Fax: 215-788-8395

EXECUTIVE SUMMARY

Objectives

The objective of this study was to evaluate the actual and perceived contribution to "light pollution" of on premises identification signs. The phrase "on premises identification sign" refers to a sign that is placed on a property where a permitted Zoning Use is located and activity is conducted; the sign refers to the Use or Activity on the property in question and no other. These signs have broad usage and can include signs at commercial retail businesses, professional offices, financial institutions, corporate headquarters, governmental agencies, and medical offices. Conversely, the phrase "off premises sign" typically refers to an advertising sign that displays the name of a business that is *not* located on the property. These types of signs are often referred to as "Billboards" or "Outdoor Advertising." The current study did not examine off premises signs.

The objective was achieved through a two-part research project. The first part consisted of a review of the relevant literature and standards on light pollution as they pertain to on premises sign lighting. The second part consisted of photometric measurements of light emitted by in-service on premises signs that were representative of the various sign illumination modes and sign designs used in the on premises sign industry today. The purpose of these measurements was to investigate the properties of on premises signs as they relate light pollution. While data were collected on both internally and externally illuminated signs, the emphasis of the research was on internally illuminated on premises identification signs.

Background

Light pollution, also known as obtrusive light and stray light, is a term used to broadly describe light that is either too bright for its intended purpose or "that shines where it is not needed or wanted." (RASC, 2003). The concept of light pollution has been around for over 25 years (IESNA, 2000a; Finch, 1978); however it is only recently that on premises identification sign lighting has been indicated as a contributing factor to light pollution. To date, there are no estimates on the effect of sign lighting on light pollution, but the supposition is that any form of outdoor lighting has the potential to produce obtrusive light.

There are three forms or components of light pollution that may pertain to sign illumination. These are sky glow (sky brightness caused by artificial light reflecting off the atmosphere), light trespass (light spilling out of the intended area), and glare (light shining in the eyes causing discomfort or disability).

While there are no current photometric measurement standards for on premises signs, sky glow and light trespass can be thought of as problems associated with light hitting or going beyond a certain plane, while glare is associated with sign brightness from the observer's perspective. The metric most often used to calculate light trespass is illuminance (light projected from a source that reaches a surface) while glare effects are measured by luminance: "the physical measure of the stimulus, which produces the sensation of brightness" (ILE, 2001).

Currently Recommended Photometric Levels to Prevent Light Pollution

Sky Glow Using Walker's Law, the International Dark Sky Association (IDA) states that "urban sky glow becomes a significant problem when [sky brightness due to artificial light] reaches 0.10, or 10% above the natural sky background."

Light Trespass Shaflik (1997) points out that San Diego County has developed limits of 0.21 lx horizontal and vertical measured 5 ft (1.5 meters) over private property lines and that Skokie, IL classifies 3.0 lx as a "public nuisance." Kosiorek (2000) stated, "Limit the exterior lighting originating on a property to a maximum of 0.5 horizontal foot candles [5.38 lx] at a distance of 25 feet [7.6 m] beyond the property lines." IESNA (2000c) recommended illuminance levels (Table 1) as a function of environmental zones (E1 to E4, from darkest to lightest environment).

Table 1. IESNA (2000c) recommended light trespass illuminance levels.

Environmental Zone	Illuminance (lx)
E1	1.0
E2	3.0
E3	8.0
E4	15.0

Glare The Institute of Lighting Engineers (ILE, 2001) recommended maximum luminance levels based on environmental zones and sign size (Table 2). For externally illuminated commercial signs the ILE recommended that the lighting be positioned so the source is not directly visible from any usual viewing angle. They suggested turning lights off when not in use, directing the light downward if possible, using cutoff lights or downward aiming, and the avoidance of "overlighting."

Table 2: ILE (2001) recommendations for maximum luminance (cd/m^2).

Illuminated area ft^2 (m^2)	**Zone E1**	**Zone E2**	**Zone E3**	**Zone E4**
up to 108 (10)	100	600	800	1000
over 108 (10)	n/a	300	600	600

Data Collection

Through a literature review and phone survey of lighting professionals, it was determined that measures of vertical illuminance and luminance would both be needed to fully describe the potential impact of on premises identification signs on light pollution. Luminance measurements were taken of all colors on each sign. These luminance measurements were then used to calculate average sign luminance and vertical illuminance from several distances.

Data on twenty-two signs were collected in the King of Prussia, PA area. Data on thirty-six signs were collected in the State College, PA area. A total of thirty-three internally illuminated signs, ten externally illuminated signs, seven channel letter signs, and eight neon signs were evaluated. Table 3 provides summary luminance data for all 58 signs.

Table 3. Mean luminance (cd/m^2) data for all signs by sign type.

Sign Type	Minimum Luminance	Maximum Luminance	Weighted Mean Luminance
Internally Illuminated	28.37	391.48	238.3
Externally Illuminated	5.16	62.85	24.15
Channel Letter	79.33	295.71	113.00
Neon	n/a	317.00	117.51

Table 4 provides summaries of calculated vertical illuminance for all signs at 16.4 foot (5 m) increments.

Table 4. Mean vertical illuminance (lx) for all signs by sign type.

Sign Type	Distance ft (m)									
	16.4 (5)	33 (10)	49 (15)	66 (20)	82 (25)	98 (30)	115 (35)	131 (40)	148 (45)	164 (50)
Internally Illuminated	16.78	4.19	1.86	1.05	0.67	0.47	0.34	0.26	0.21	0.17
Externally Illuminated	3.00	0.75	0.33	0.19	0.12	0.08	0.06	0.05	0.04	0.03
Channel Letter	9.79	2.45	1.09	0.61	0.39	0.27	0.20	0.15	0.12	0.10
Neon	7.75	1.94	0.86	0.48	0.31	0.22	0.16	0.12	0.10	0.08

Eleven of the internally illuminated signs were displayed in positive contrast (i.e., with copy in a lighter color than the background) and twenty-two were in negative contrast (i.e., with copy darker than background). Table 5 shows a comparison between the light emitted from positive and negative contrast signs.

Table 5. Mean data for internally illuminated signs by contrast orientation

Contrast Orientation	Minimum Luminance (cd/m^2)	Maximum Luminance (cd/m^2)	Weighted Mean Luminance (cd/m^2)	Luminous Intensity (cd)	Illuminance (lx)				
					Distance in feet (m)				
					33 (10)	66 (20)	98 (30)	131 (40)	164 (50)
Positive	19.40	388.09	117.47	214.71	2.15	0.54	0.24	0.13	0.09
Negative	32.85	393.18	298.71	521.76	5.22	1.30	0.58	0.33	0.21

Conclusions

Sky Glow There are no agreed upon objective methods for physically measuring overall sky glow and no metric to measure sky glow from a single light source. The IDA contends that a sky glow problem exists when sky brightness due to artificial light is ten percent above the natural sky brightness, however there are no universally agreed upon levels of acceptable or unacceptable sky glow. Furthermore, while contrast between celestial bodies and the ambient sky may provide useful visibility levels for astronomers, this measure is as dependent on atmospheric transmissivity as it is on light levels. And subjective evaluation of sky glow such as "star counting" is further dependent on an individual's visual acuity and contrast sensitivity. Given the current lack of guidance on measurement techniques and recommended lighting levels to avoid sky glow, it was not possible to establish the effect of on premises identification sign lighting on sky glow at the time this report was written.

Light Trespass As vertical illuminance is dependent on the distance from the sign to the measurement location (e.g., adjacent property or traffic); it is difficult to determine if the vertical illuminance levels of the signs tested in this study would be considered obtrusive. However, by 33 to 49 ft (10 to 15 m) all lighting designs measured in this study had mean vertical illuminance below 3.0 lx, a light level which has not been associated with light trespass (e.g., Kosiorek, 2000; Shaflik, 1997; IESNA, 2000c; and IESNA, 2001).

Glare While couched in scientific terms and equations, the concept of glare is somewhat nebulous and although disability glare (glare that reduces visual abilities) is directly measurable, discomfort glare is highly subjective (Mace, et al., 2001). The idea that internally illuminated on premises identification signs produce sufficient illumination to result in either kind of glare is debatable and could benefit greatly from additional research. The one existing document that evaluated the effects of commercial signs on discomfort glare (ILE, 2001), however did resulted in luminance recommendations to avoid glare effects (Table 2). Although there were a few particularly high luminance signs evaluated in the present research, both the average and the maximum luminance levels found for all lighting designs fell below the ILE recommendations for all but Zone E1 (i.e., "Areas with intrinsically dark landscapes: National Parks, Areas of outstanding natural beauty (where roads usually are unlit)."

Discussion

In discussing light pollution, IESNA (2000c) stated, "The realistic aim of an ordinance should be to control lighting that is "very objectionable."" However, what constitutes "very objectionable" lighting is at best subjective and dependent on the environment and the perceptions of the observer. In fact, IESNA (2000a) denounced attempts at applying a set recommended maximum for sign brightness or luminance, declaring "discomfort glare can be produced by most outdoor lighting equipment when it is observed against a dark background."

While the present study does not contend to be the final word on the impact of sign lighting on light pollution, or what should be included in lighting codes, what it does provide is an exploration of the complexity of the issues surrounding the concept of light pollution as it relates to outdoor signing and a representative sample of the light levels common to internally illuminated on premises identification signs. The cutoff points for defining obtrusive light are still under debate; however it is clear that the luminance and illuminance levels obtained from in-service signs tested in the present research fall below the levels currently associated with light pollution.

ON-PREMISES IDENTIFICATION SIGN LIGHTING

I OBJECTIVE

The objective of this study was to evaluate the actual and perceived contribution to "light pollution" of on premises identification signs. The phrase "on premises identification sign" refers to a sign that is placed on a property where a permitted Zoning Use is located and activity is conducted; the sign refers to the Use or Activity on the property in question and no other. These signs have broad usage and can include signs at commercial retail businesses, professional offices, financial institutions, corporate headquarters, governmental agencies, and medical offices. Conversely, the phrase "off premises sign" typically refers to an advertising sign that displays the name of a business that is *not* located on the property. These types of signs are often referred to as "Billboards" or "Outdoor Advertising." The current study did not examine off premises signs.

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II BACKGROUND

In a document that addressed the illumination of roadway signs (i.e., signs mounted along a road, street or highway that serve a guidance, warning, or regulatory traffic function), the Illuminating Engineering Society of North America (IESNA, 2001) wrote "well-designed sign lighting can aid the driver in rapid, accurate recognition and understanding of the sign's message. This serves to improve safety by reducing the possibility that motorists will stop or drastically reduce speed at signs that may otherwise be difficult to read." This same argument has been made for on premises signs, as they are also part of motorists' wayfinding system (Kuhn, Garvey, and Pietrucha, 1997).

The IESNA (2001) identified four critical elements associated with the visibility of roadway sign lighting: ambient luminance (i.e., adaptation luminance), sign luminance above ambient (i.e., external contrast), contrast between sign legend and background (i.e., internal contrast), and uniformity ratio. It has long been known that proper attention to these variables will ensure sign lighting that is visually effective, while lighting that falls below appropriate levels will result in signs that lack detectability and legibility (Garvey and Kuhn, 2003). It is only relatively recently, however that it has been suggested that sign lighting *above* appropriate levels can result in light pollution.

Light pollution, also known as obtrusive light and stray light, is a term used to broadly describe light that is either too bright for its intended purpose or “that shines where it is not needed or wanted.” (RASC, 2003). The concept of light pollution has been around for over 25 years (IESNA, 2000a; Finch, 1978); however it is only recently that on premises identification sign lighting has been indicated as a contributing factor to light pollution.

Shaflik (1997) reported estimates that 35 to 50 percent of light pollution is caused by roadway lighting while IESNA (2000a) stated “roadway lighting has been estimated to account for approximately 30 percent of sky glow and light trespass.” To date, there are no estimates on the effect of sign lighting on light pollution, but the supposition is that any form of outdoor lighting has the potential to produce obtrusive light.

There are three forms or components of light pollution that may pertain to sign illumination. These are sky glow, light trespass, and glare, with the following general definitions and usage:

a. Sky Glow

“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, “the added sky brightness caused by the scattering of electric light into the atmosphere, particularly from outdoor lighting in urban areas” IESNA (2000a). RASC (2003) defined sky glow as “the scattering of artificial light by water droplets and dust in the air” stating that it “obscures faint astronomical objects.” Sky glow can be caused by either “uplight,” light directed above the horizontal plane or by light reflected upward from surfaces.

b. Light Trespass

"Light that strays from the intended purpose and becomes an annoyance, a nuisance, or a detriment to visual performance…the encroachment of light causing annoyance, loss of privacy, or other nuisance" IESNA (2000a). IESNA also refers to light trespass as "obtrusive light" and associates it with certain "unfavorable features" such as "spill light, brightness, and glare."

c. Glare

"The sensation produced by luminance within the visual field that is sufficiently greater than the luminance to which the eyes are adapted causing annoyance, discomfort, or loss in visual performance and visibility...a severe form of light trespass" IESNA (2000a). RASC (2003) stated that glare is the "uncomfortable brightness of a light shining in your eyes, leaving you unable to see much of anything else." NEMA (2000) added "Glare occurs when a bright source causes the eye to continually be drawn toward the bright image or the brightness of the source prevents the viewer from adequately viewing the intended target." And that glare is "light that hinders or bothers the human eye," adding "the magnitude of the sensation of glare depends upon such factors as the size, position, luminance of the source, number of sources and the luminance to which the eyes are adapted."

III LIGHT CONTROL ORDINANCES

In the United States, the International Dark-Sky Association (IDA) has been active in drafting and promoting Model Light Control Ordinances since its incorporation in late 1987. Originally founded by a group of scientists and astronomers to help "bring back the night sky," IDA has evolved into a large membership-based organization (8,000 members currently) that consists of scientists, astronomers, lighting professionals, and planners. The organization says that it is devoted to improving outdoor lighting; making it more effective, with less spill-over; that it wants to help improve lighting design and construction to minimize and control nighttime lighting so that it can function, but have less impact on the night sky.

In Europe, the Institution of Lighting Engineers (ILE, 2001) has proposed recommendations that would regulate commercial sign brightness to avoid glare. The ILE is the UK's and Ireland's largest and most influential professional lighting association, dedicated to excellence in lighting.

Founded in 1924 as the Association of Public Lighting Engineers, the ILE has evolved to include lighting designers, architects, consultants and engineers amongst its 2,500 membership.

The ILE defines brightness as “the visual sensation associated with luminance, experienced by an observer” and asserts that brightness depends on four main factors: luminance, size, contrast, and the observer. Because, they state, the eye is drawn to and adapts to the brightest area of the sign, the ILE recommends putting limits on the maximum luminance rather than average luminance of commercial signs. Noting that the brightness of a sign is partly a function of the location in which it is mounted, the ILE suggests that a good ordinance should limit maximum luminance (a physical measure associated with the psychological perception of brightness) depending on the “form of the sign, its orientation and its location (zone).” They proposed using the CIE Zoning System (Schreuder, 1997) which includes four environmental zones:

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

IV LIGHT MEASUREMENT OF ON-PREMISES SIGNS

a. Sign Lighting

To understand on premises identification sign lighting it is important to recognize that there are two basic sign categories which may differentially impact light pollution and which have lighting designs that might require different measurement technique. These are defined by IESNA (2001) as follows:

- **Externally Lighted Signs:** signs on which a fixed message is illuminated by an external source of light.

- **Internally Lighted Signs**: signs in which the source of light is enclosed within the sign and the message becomes understandable because of the varying transmittance of the sign face.

While the present study evaluated both externally and internally illuminated on premises identification signs the emphasis is on internally illuminated signs.

b. Photometrics

To determine the potential impact of sign lighting on light pollution it is first necessary to understand how light is measured. With respect to sign lighting there are two basic measurements: illuminance and luminance.

Illuminance "The amount of light being transmitted upon a certain area" from any distance, lighting fixture array, or direction. The unit of measurement is lux (lx) and it is subject to the inverse square law; that is, illuminance diminishes with the square of the distance from the light source to the plane of measurement (Shaflik, 1997). NEMA (2000) defined illuminance as "a term that quantifies light striking a surface or plane at a point...the aerial density of the luminous flux incident at a point on a surface." When measuring illuminance, one measures the light that reaches a surface at some distance from the source. Cloudy moonlight is 0.25 lx, typical office lighting is 100 to 1,000 lx; a cloudy day is 10,000 lx, and a bright sunny day is 100,000 lx (IBM, 2003).

Luminance "The physical measure of the stimulus, which produces the sensation of brightness, measured by the luminous intensity of light emitted or reflected in a given direction from a surface element divided by the area of the element in the same direction" (ILE, 2001). The unit of measurement is candelas per square meter (cd/m^2). Luminance is a quality of the light source and, like wattage, is independent of distance. NEMA (2000) calls luminance "a term that quantifies directional brightness of a light source or of a surface that is illuminated or reflects light." Specifically addressing *sign* luminance, the ILE (2001) states that it "is a characteristic of the sign, dependent on the position of the observer, but [unlike brightness] independent of the surrounding conditions." When measuring luminance, one directly measures the object emitting or reflecting the light. The luminance of snow under a full moon is approximately 0.10 cd/m^2, average earth on a cloudy day is 350 cd/m^2; and fresh snow on a clear day is about 30,000 cd/m^2 (Grether and Baker, 1972).

c. Measurement Guidelines

A literature review and a phone survey of lighting professional organizations were conducted to determine if there were any existing guidelines for measuring on-premise identification sign luminance and illuminance with regard to their potential impact on light pollution. Discussions with members of IESNA's Outdoor Environmental Lighting Committee revealed that there are no current measurement standards for on premises signs, but an IESNA subcommittee was recently established to look into light pollution and the subcommittee is planning to write design guidelines for commercial sign illumination. As the committee had only recently been established, no guidelines had yet been written.

While the IESNA Lighting Handbook (IESNA, 2000b) contains a section titled "Lighting for Advertising," there is nothing in the handbook on the *measurement* of commercial sign lighting. It was suggested by members of the IESNA subcommittee that to measure the reflected or projected light from both externally and internally illuminated signs, illuminance measures should be taken with the meter held facing the sign. In addition, to measure the light hitting the sign face of externally lit signs, the meter should be held on the sign surface facing the light sources. To measure glare, a luminance meter should be aimed at the sign. In general, the recommendation was that measurements should be taken for both luminance and illuminance and that any measurement techniques used should be carefully documented.

The literature review revealed a few references that could be used to start developing a set of measures to evaluate on premises signs in relation to light pollution. In general, sky glow and light trespass are problems associated with light hitting or going beyond a certain plane, while glare is associated with sign brightness from the observer's perspective. The literature review basically supported the idea that the appropriate photometric measurement to describe the impact of on premises identification signs on sky glow and light trespass is illuminance, and glare effects should be measured via luminance. However the literature review revealed some issues that call into question the absolute nature of this distinction.

Sky Glow Although there are calculations to estimate sky glow over a geographical area using an estimated "lumens per capita," the population of the lighted area, and the distance from a given observation point (most notably “Walker’s Law” reported in Shaflik, 1997), and there are ways to evaluate a night sky with respect to sky glow (e.g., “star counts”), there are no generally agreed upon levels or objective methods for physically measuring overall sky glow (Schreuder, 1997) and no metric to measure sky glow from a single light source (e.g., a sign).

Light Trespass Shaflik (1997) reported that light trespass is “easily quantifiable as a measure of illuminance and easily measured in the field by a standard light meter.” However, IESNA (2000a) stated “horizontal illuminance limitations may not address the issue [of light trespass] as well as vertical illuminance and/or light source luminance limits,” going further to assert that limits on illuminance “do little to help those who are troubled by a bright luminaire that may be located blocks - even miles - away in an otherwise dark field of view.” Therefore, in addition to using an illuminance meter to measure horizontal and vertical lx at the property line (i.e., spill light), IESNA (2000c) discussed the possibility of using subjective measures to evaluate light trespass that would result in a ranking on a five point “objectionable rating” scale for a given luminaire or lighted area.

Glare Shaflik (1997) defined glare as “unwanted source luminance” which can be measured using a luminance meter. ILE (2001) recommended using a luminance meter with a measurement field of one degree or less. Readings should be taken at night and at right angles to the face of the sign from a distance of 6 to 16 ft (2 to 5 m), although readings taken from head height (even if the sign is 30 ft (10 m) higher) will not result in appreciable error.

IESNA (1998) provided useful information on the measurement of sign luminance that might be applicable to on premises signs. This document stated that one should take the readings from a normal driver point of view whenever possible and that the readings could be taken from any distance from the sign within reasonable angular displacements, as luminance is independent of distance. They recommended that average legend luminance and average background luminance be obtained and used to generate internal contrast ratios (legend-background/background).

d. Recommended Photometric Levels

In addition to recommended practices for commercial sign light *measurement*, the literature review revealed photometric levels or values believed to be associated with light pollution.

Sky Glow Using Walker's Law, the IDA states that "Urban sky glow becomes a significant problem when [sky brightness due to artificial light] reaches 0.10, or 10% above the natural sky background."

Light Trespass Shaflik (1997) pointed out that San Diego County has developed limits of 0.21 lx horizontal and vertical measured 5 ft (1.5 meters) over private property lines and that Skokie, IL classifies 3.0 lx as a "public nuisance." Kosiorek (2000) stated, "limit the exterior lighting originating on a property to a maximum of 0.5 horizontal foot candles [5.38 lx] at a distance of 25 feet [7.6 m] beyond the property lines." IESNA (2000c) recommended illuminance levels as a function of environmental zones to avoid light trespass (Table 1).

Table 1. IESNA (2000c) recommended light trespass illuminance levels.

Environmental Zone	Illuminance (lx)
E1	1.0
E2	3.0
E3	8.0
E4	15.0

Glare Shaflik (1997) stated that to avoid glare the "CA motor vehicle code limits the measured luminance of a light source within 10 degrees of a driver's line of sight to not more than 1,000 times the minimum measured ambient luminance in the field of view. This ordinance refers not only to roadway lighting but also to commercial signs adjacent to the road."

As discussed previously, in Europe the ILE (2001) made recommendations with regard to environmental zones to ensure that illuminated commercial signs have an "acceptable degree of subjective brightness." These suggested recommendations had not been adopted in the United States at the time of the present study. The ILE recommended that signs maintain luminance uniformity by having a 10:1 internal contrast ratio for large signs (greater than 16 ft^2 (1.5 m^2)) and 6:1 internal contrast ratio for smaller signs (less than 16 ft^2 (1.5 m^2)). For both internally and externally illuminated signs, the ILE recommended maximum luminance levels based on environmental zones and sign size (Table 2). For externally illuminated commercial signs the ILE (2001) added that the lighting be positioned so that the source is not directly visible from any usual viewing angle. They suggest turning lights off when not in use, directing the light downward if possible, and using cutoff lights or downward aiming, and the avoidance of "overlighting."

Table 2: ILE (2001) recommendations for maximum luminance (cd/m^2).

Illuminated area ft^2 (m^2)	**Zone E1**	**Zone E2**	**Zone E3**	**Zone E4**
up to 108 (10)	100	600	800	1000
over 108 (10)	n/a	300	600	600

V DATA COLLECTION

Through the literature review and phone survey it was determined that measures of vertical illuminance and luminance would both be needed to fully describe the potential impact of on premises identification signs on light pollution. Unfortunately, as the photocell of an illuminance meter is designed to measure all light sources incident to the plane of measurement, it is impracticable, if indeed not impossible, to fully isolate an individual sign in the open field (i.e., real world) in order to take illuminance measurements. On the other hand, through the use of an aperture and baffles, the design of luminance meters *would* allow the isolation of a single sign or part of a sign while functionally ignoring other light sources in the surrounding environment. The measure selected for use in the field data collection effort of the present project was, therefore luminance.

Through discussions with Illuminating Engineering faculty in the Architectural Engineering Department of the Pennsylvania State University and with concurrence from a former chairman of the IESNA Merchandise Lighting Design and Application committee, it was determined that a standard calculation could be employed to convert the field luminance measurements into vertical illuminance (i.e., light trespass) at any desired distance. The calculation was as follows:

$$E = (L*A)/d^2$$

Where:

E = Illuminance (lx)
L = Average Sign Luminance (cd/m^2)
A = Sign area (m^2)
d = Distance (m)

a. Closed Field (Test Track)

A closed-field photometric study was designed to test whether the conversion calculation would result in accurate predictions of vertical illuminance from field measures of average sign luminance. On October 2, 2003 measurements were taken of two internally illuminated advertising signs at the Pennsylvania Transportation Institute (PTI) test track (Figure 1).

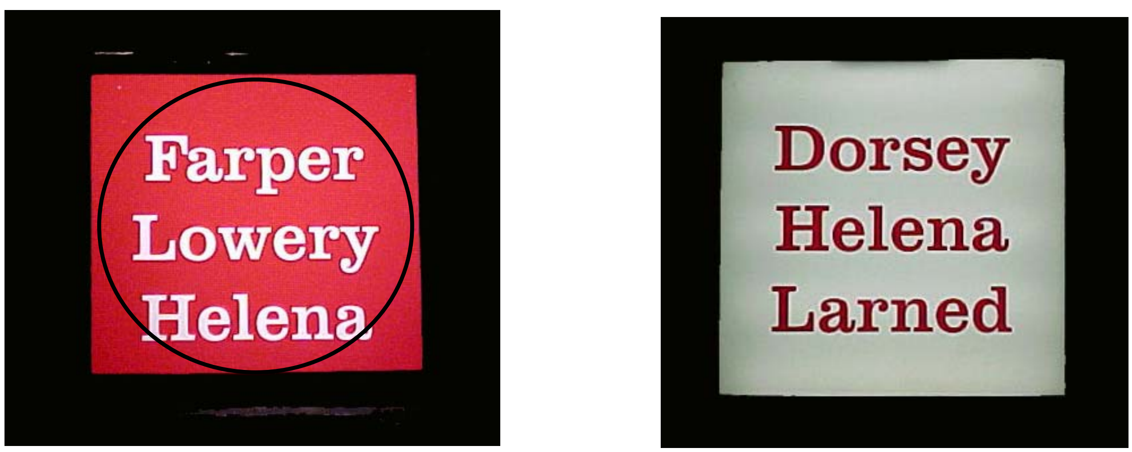

Figure 1. Signs used in test track evaluation.

These signs were designed and manufactured using lighting techniques and technologies common to on premises internally illuminated identification signs. Both sign faces were 3.5 ft by 3.5 ft squares with a surface area of 12.20 ft^2 (1.06 m x 1.06 m; 1.133 m^2). Luminance measures were taken of each sign at 550 ft (168 m). Using a 1/3° aperture luminance meter, nearly the entire sign was located within the aperture (Figure 1, left side). The results were as follows.

Measured Average Luminance:

Sign 1 = 160 cd/m^2
Sign 2 = 560 cd/m^2

The vertical illuminance at 16.4 ft (5 m) was then calculated by multiplying the measured average luminance by the measured sign area and dividing that product by the squared distance (82 ft (25 m)), with the following results.

Calculated Vertical Illuminance at 16.4 ft (5 m):

Sign 1 = 7.25 lx
Sign 2 = 25.38 lx

Vertical illuminance measurements were then taken at 16.4 ft (5.0 m) with the following results.

Measured Vertical Illuminance at 16.4 ft (5 m):

Sign 1 = 6.70 lx
Sign 2 = 25.00 lx

The measured vertical illuminance and the calculated vertical illuminance were essentially identical, it was determined that the proposed method of measuring average sign luminance for the open field data collection and calculating vertical illuminance was appropriate.

Equipment

The photometric equipment used to evaluate the signs in the closed field data collection effort are described by Minolta as follows:

- **Luminance Meter** "The Luminance Meter LS-110 is a compact, lightweight meter for measuring the luminance of light sources or reflective surfaces. The TTL (through-the-lens) viewing system enables accurate targeting of the subject. Measuring range: 0.01-999,900cd/m^2 Measurement angle: 1/3°"
- **Illuminance Meter** "Model T-1, with a metering range of 0.01 to 99.900 lux is ideal for measurements in most situations."

Both photometers were calibrated on September 29, 2003 with assistance from the Illuminating Engineering faculty of the Architectural Engineering Department of the Pennsylvania State University.

b. Open Field (Real World)

Data Collection Procedure Revision

Two general locations were selected for open field data collection: King of Prussia, PA and State College, PA. The data collection in King of Prussia took place on October 3, 2003. It was immediately apparent that the data collection technique described above, while so successful at the test track, would not be possible in the open field. Given the roadway geometries and the presence of other signs and roadway features, it was impossible to get far enough away from any given sign to take an average luminance measurement without there being some obstruction between the signs and the photometer. (With a 1/3°"aperture this distance is approximately 550 ft (168 m) for a 4 ft x 4 ft (1.22 m x 1.22 m) sign, and further for larger signs.)

It was decided, therefore that luminance measurements would be taken of all colors on each sign. The expectation was that an estimate of the percentage of the sign area illuminated by each color could be determined from the digital photographs taken of each sign. These percentages, in combination with the luminance measurements and the height and width measurements taken of each sign, would provide the information necessary to calculate the average sign luminance and the vertical illuminance from any sign at any distance using the following calculations:

Weighted Mean Luminance (WML) = L(1)*%A(1) + L(2)*%A(2) … + L(n)*%A(n)

Where:

L(#) = Luminance of a particular color
%A(#) = Percent of sign area in a particular color

and:

$$E = (WML*A)/d^2$$

Where:

E = Illuminance (lx)
WML = Weighted Mean Luminance (cd/m^2)
A = Sign area (m^2)
d = Distance (m)

This technique and calculation were evaluated at the test track using the same two signs used in the earlier test track study. Luminance measures were taken of both colors on both signs yielding the following average luminance readings for each color:

Measured Luminance of Colors on Sign 1:

White = 991 cd/m^2
Red = 62.5 cd/m^2

Measured Luminance of Colors on Sign 2:

White = 657.78 cd/m^2
Red = 82.67 cd/m^2

The percent of the sign area subtended by each color was established from digital photographs using the following procedure in Adobe Photoshop:

- The image of the sign was "Selected" from the original digital photograph
- Under "Image" "Histogram," the number of pixels in the selected sign image was obtained.
- Under "Select" "Color Range," areas of the sign in a given color were selected.
- Under "Image" "Histogram," the number of pixels in that color was obtained.
- The number of pixels in the color was divided by the total number of pixels in the sign to obtain the percent of the sign displaying that color.
- This was repeated for all sign colors.

Percent Sign Area per Color for Sign 1:

Red = 86%
White = 14%

Percent Sign Area per Color for Sign 2:

Red = 14%
White = 86%

The WML was calculated by multiplying the measured luminance of each sign color by its decimal percent sign area and adding the products.

Calculated Weighted Mean Luminance:

Sign 1: WML = (62.5 * 0.86) + (991 * 0.14) = 192.49
Sign 2: WML = (657.78 * 0.86) + (82.67 * 0.14) = 577.27

The vertical illuminance at 16.4 ft (5 m) was calculated by multiplying the WML and the overall sign area and dividing that product by the squared distance (82 ft (25m)).

Calculated Vertical Illuminance at 16.4 ft (5.0 m):

Sign 1 = (192.49 * 1.133)/25 = 8.72
Sign 2 = (577.27 * 1.133)/25 = 26.16

Measured Vertical Illuminance at 16.4 ft (5.0 m):

Sign 1 = 6.7 lx
Sign 2 = 25 lx

As the vertical illuminance readings and the calculated vertical illuminance were very close and the technique was amenable to field use, it was determined that the revised proposed method of measuring average sign luminance in the open field and calculating vertical illuminance would be satisfactory.

c. Final Open Field Procedures

For each sign a digital still photograph was taken as close to perpendicular to the sign face as possible (Appendix A). The height, width, and depth of the signs were measured using a tape measure. Multiple luminance measurements of each sign color were taken and an average luminance was established per sign color. The arithmetic procedures described above were then used to calculate average sign luminance and vertical illuminance.

While this general procedure was used for the majority of signs, there was some deviation between sign types and within sign types for specific cases. In developing sign areas for channel letter and neon signs an artificial "surround" was applied which tightly fit around the letters in a quadrangle (ILE, 2001). And with neon signs, as it was often not possible to get a clear measure from a distance that would allow a single letter to fit into the photometer's aperture, the luminance measurements were obtained by passing the photometer's aperture over the letters and taking a "peak" measurement.

d. Open Field Results

Data on twenty-two signs were collected in the King of Prussia, PA effort. Data on thirty-six signs were collected in the State College, PA area. There were thirty-three internally illuminated signs, ten externally illuminated signs, seven channel letter signs, and eight neon signs. Table 4 provides summary luminance data for all 58 signs. (The minimum luminances in Tables 3 and 5 do not include black areas of the signs.)

Table 3. Mean luminance (cd/m^2) data for all signs by sign type

Sign Type	Minimum Luminance	Maximum Luminance	Weighted Mean Luminance
Internally Illuminated	28.37	391.48	238.3
Externally Illuminated	5.16	62.85	24.15
Channel Letter	79.33	295.71	113.00
Neon	n/a	317.00	117.51

Table 4 provides summaries of calculated vertical illuminance data for all signs at 16.4 ft (5 m) increments. Appendix B contains detailed luminance, vertical illuminance, and luminous intensity data (illuminance at the sign face) for each sign. Appendix A contains photographs and detailed data from each sign.

Table 4. Mean vertical illuminance (lx) data for all signs by sign type

Sign Type	Distance ft (m)									
	16.4 (5)	33 (10)	49 (15)	66 (20)	82 (25)	98 (30)	115 (35)	131 (40)	148 (45)	164 (50)
Internally Illuminated	16.78	4.19	1.86	1.05	0.67	0.47	0.34	0.26	0.21	0.17
Externally Illuminated	3.00	0.75	0.33	0.19	0.12	0.08	0.06	0.05	0.04	0.03
Channel Letter	9.79	2.45	1.09	0.61	0.39	0.27	0.20	0.15	0.12	0.10
Neon	7.75	1.94	0.86	0.48	0.31	0.22	0.16	0.12	0.10	0.08

There were eleven internally illuminated signs displayed in positive contrast (i.e., with copy in a lighter color than the background) and twenty-two internally illuminated signs in negative contrast (i.e., with copy darker than background). Table 5 shows a comparison between the light emitted from internally illuminated positive and internally illuminated negative contrast signs.

Table 5. Mean data for internally illuminated signs by contrast orientation

Contrast Orientation	Minimum Luminance (cd/m^2)	Maximum Luminance (cd/m^2)	Weighted Mean Luminance (cd/m^2)	Luminous Intensity (cd)	Illuminance (lx)				
					Distance in feet (m)				
					33 (10)	66 (20)	98 (30)	131 (40)	164 (50)
Positive	19.40	388.09	117.47	214.71	2.15	0.54	0.24	0.13	0.09
Negative	32.85	393.18	298.71	521.76	5.22	1.30	0.58	0.33	0.21

VI CONCLUSIONS

a. Sky Glow

There are no agreed upon objective methods for physically measuring overall sky glow and no metric to measure sky glow from a single light source. The IDA contends that a sky glow problem exists when sky brightness due to artificial light is ten percent above the natural sky brightness, however there are no universally agreed upon levels of acceptable or unacceptable sky glow. Furthermore, while contrast between celestial bodies and the ambient sky may provide useful visibility levels for astronomers, this measure is as dependent on atmospheric transmissivity as it is on light levels. And subjective evaluation of sky glow such as “star counting” is further dependent on an individual’s visual acuity and contrast sensitivity. Given the current lack of guidance on measurement techniques and recommended lighting levels to avoid sky glow, it was not possible to establish the effect of on premises identification sign lighting on sky glow at the time this report was written.

b. Light Trespass

As vertical illuminance is dependent on the distance from the sign to the measurement location (e.g., adjacent property or traffic), it is difficult to determine if the vertical illuminance levels of the signs tested in this study would be considered obtrusive. However, by 33 to 49 ft (10 to 15 m) all lighting designs measured in this study had mean vertical illuminance below 3.0 lx, a light level which has not been associated with light trespass (e.g., Kosiorek, 2000; Shaflik, 1997; IESNA, 2000c; and IESNA, 2001).

c. Glare

While couched in scientific terms and equations, the concept of glare is somewhat nebulous and although disability glare (glare that reduces visual abilities) is directly measurable, discomfort glare is highly subjective (Mace, et al., 2001). The idea that internally illuminated on premises identification signs produce sufficient illumination to result in either kind of glare is debatable and could benefit greatly from additional research. The one existing document that evaluated the effects of commercial signs on discomfort glare (ILE, 2001), however did resulted in luminance recommendations to avoid glare effects (Table 2). Although there were a few particularly high luminance signs evaluated in the present research, both the average and the maximum luminance levels found for all lighting designs fell below the ILE recommendations for all but Zone E1 (i.e., "Areas with intrinsically dark landscapes: National Parks, Areas of outstanding natural beauty (where roads usually are unlit).”

VII DISCUSSION

In discussing light pollution, IESNA (2000c) stated, “The realistic aim of an ordinance should be to control lighting that is “very objectionable.”” However, what constitutes “very objectionable” lighting is at best subjective and dependent on the environment and the perceptions of the observer. In fact, IESNA (2000a) denounced attempts at applying a set recommended maximum for sign brightness or luminance, declaring “discomfort glare can be produced by most outdoor lighting equipment when it is observed against a dark background.” While the present study does not contend to be the final word on the impact of sign lighting on light pollution, or what should be included in lighting codes, what it does provide is an exploration of the complexity of the issues surrounding the concept of light pollution as it relates to outdoor signing and a representative sample of the light levels common to internally illuminated on premises identification signs. The cutoff points for defining obtrusive light are still under debate; however it is clear that the luminance and illuminance levels obtained from in-service signs tested in the present research fall below the levels currently associated with light pollution.

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Appendix A

Internally Illuminated Signs

Sign Size (in)
- Height - 36
- Width – 56
- Depth - 12

Sign Area (m^2) – 1.3

Sign Luminance (cd/m^2) / Percent of Sign Area
- **Blue – 3.5 / 47.23**
- White – 450 / 28.41
- White Letters – 115 / 14.75

Weighted Mean Luminance (cd/m^2) – 146.46

Luminous Intensity (cd) – 190.40

Sign Size (in)
- Height - 58
- Width – 73
- Depth - 14

Sign Area (m^2) – 2.732

Sign Luminance (cd/m^2) / Percent of Sign Area
- **Blue – 20 / 10**
- Red – 100 / 3
- White – 325 / 85

Weighted Mean Luminance (cd/m^2) – 281.25

Luminous Intensity (cd) – 768.38

Sign Size (in)
Height - 17
Width – 34
Depth - X

Sign Area (m^2) – 0.373

Sign Luminance (cd/m^2) / Percent of Sign Area
Red – 90 / 5.9
White – 700 / 81.5

Weighted Mean Luminance (cd/m^2) – 575.81

Luminous Intensity (cd) – 214.78

Sign Size (in)

Height - 33

Width – 58

Depth - 8

Sign Area (m^2) – 1.235

Sign Luminance (cd/m^2) / Percent of Sign Area

Blue – 120 / 3.71

White – 600 / 83.64

Weighted Mean Luminance (cd/m^2) – 506.29

Luminous Intensity (cd) – 625.27

Sign Size (in)

Height - 33

Width – 82

Depth - 10

Sign Area (m^2) – 1.746

Sign Luminance (cd/m^2) / Percent of Sign Area

Red – 30 / 11.5

White – 300 / 75.43

Weighted Mean Luminance (cd/m^2) – 229.74

Luminous Intensity (cd) – 401.13

Sign Size (in)

Height - 35

Width – 94

Depth - 9

Sign Area (m^2) – 2.123

Sign Luminance (cd/m^2) / Percent of Sign Area

Red – 40 / 9.1

White – 600 / 79.26

Weighted Mean Luminance (cd/m^2) – 479.20

Luminous Intensity (cd) – 1017.34

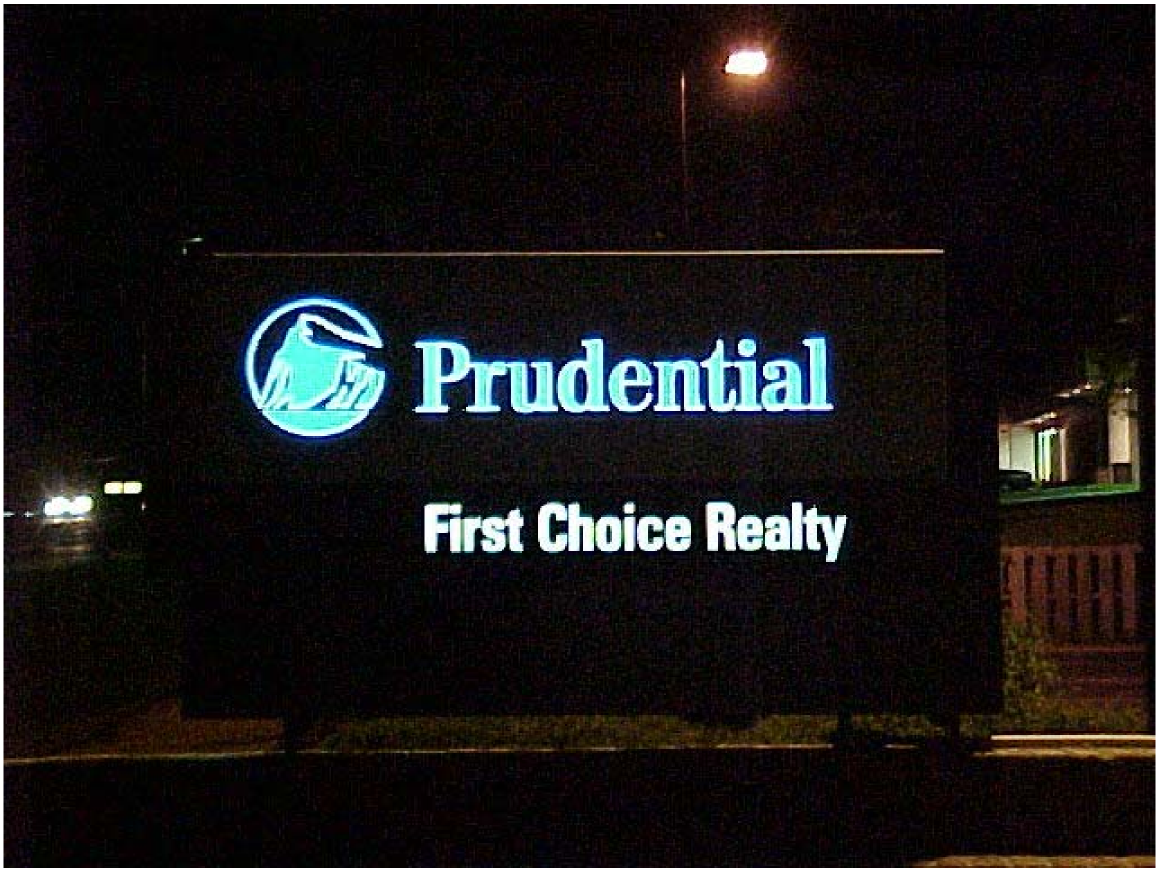
Sign Size (in)
Height - 45
Width – 69
Depth - 10

Sign Area (m^2) – 2.003

Sign Luminance (cd/m^2) / Percent of Sign Area
Red – 40 / 23.99
White – 300 / 70.34

Weighted Mean Luminance (cd/m^2) – 220.62

Luminous Intensity (cd) – 441.89



Sign Size (in)

Height - 24

Width – 55

Depth - 11

Sign Area (m^2) – 0.852

Sign Luminance (cd/m^2) / Percent of Sign Area

Blue – 20 / 73.23

White – 75 / 2.8

Weighted Mean Luminance (cd/m^2) – 16.75

Luminous Intensity (cd) – 14.27

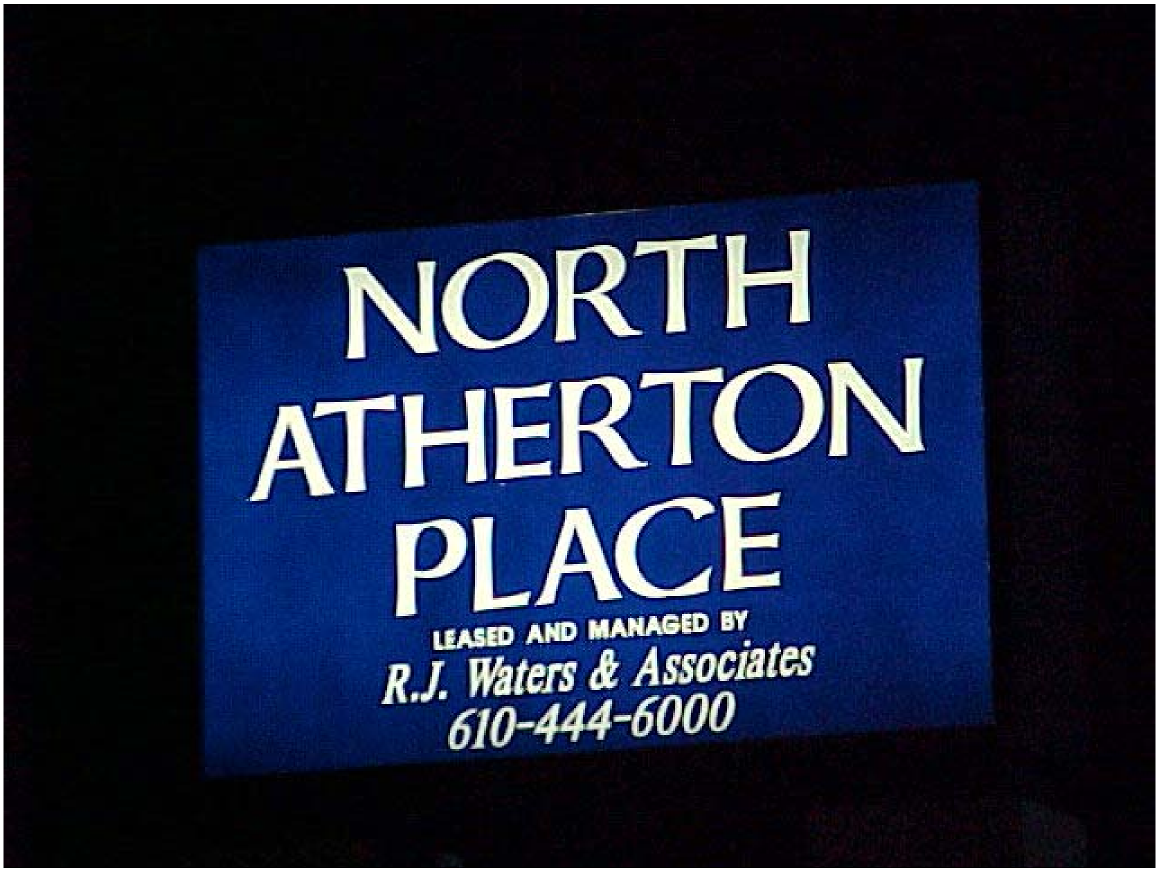
Sign Size (in)
- Height - 47
- Width – 58
- Depth – 5.5

Sign Area (m^2) – 1.759

Sign Luminance (cd/m^2) / Percent of Sign Area
- **Green – 100 / 4.07**
- **Blue – 150 / 16.51**
- Yellow – 550 / 12.4
- White – 600 / 67.02

Weighted Mean Luminance (cd/m^2) – 499.16

Luminous Intensity (cd) – 878.01



Sign Size (in)
Height - 45
Width – 68
Depth – 19

Sign Area (m^2) – 1.974

Sign Luminance (cd/m^2) / Percent of Sign Area
Blue – 1.5 / 83.83
White – 150 / 16.7

Weighted Mean Luminance (cd/m^2) – 26.31

Luminous Intensity (cd) – 51.93

Sign Size (in)

Height - 56

Width – 69

Depth – 12

Sign Area (m^2) – 2.493

Sign Luminance (cd/m^2) / Percent of Sign Area

Dark Green – 15 / 9.47

Light Green –30 / 8.78

Yellow – 40 / 10.45

White – 250 / 55.86

Weighted Mean Luminance (cd/m^2) – 147.89

Luminous Intensity (cd) – 368.68

Sign Size (in)
- Height - 32
- Width – 69
- Depth – 12

Sign Area (m^2) – 1.425

Sign Luminance (cd/m^2) / Percent of Sign Area
- Blue – 40 / 12.62
- White – 550 / 83.24

Weighted Mean Luminance (cd/m^2) – 462.87

Luminous Intensity (cd) – 659.59

Sign Size (in)
Height - 69
Width – 44
Depth – 10

Sign Area (m^2) – 1.959

Sign Luminance (cd/m^2) / Percent of Sign Area
Red – 30 / 9.47
White – 450 / 82.37

Weighted Mean Luminance (cd/m^2) – 373.51

Luminous Intensity (cd) – 731.70

Sign Size (in)
Height - 46
Width – 93
Depth – 11

Sign Area (m^2) – 2.76

Sign Luminance (cd/m^2) / Percent of Sign Area
Yellow – 300 / 69

Weighted Mean Luminance (cd/m^2) – 207.00

Luminous Intensity (cd) – 571.32

Sign Size (in)
- Height - 33
- Width – 92
- Depth – 9

Sign Area (m^2) – 1.959

Sign Luminance (cd/m^2) / Percent of Sign Area
- Red – 30 / 81.88
- White – 500 / 18.12

Weighted Mean Luminance (cd/m^2) – 115.16

Luminous Intensity (cd) – 225.60

Sign Size (in)

- Height - 43
- Width – 67
- Depth – 14

Sign Area (m^2) – 1.859

Sign Luminance (cd/m^2) / Percent of Sign Area

- Green – 30 / 37.72
- White – 350 / 62.28

Weighted Mean Luminance (cd/m^2) – 229.30

Luminous Intensity (cd) – 426.26

Sign Size (in)

- Height - 58
- Width – 53
- Depth – 15

Sign Area (m^2) – 1.983

Sign Luminance (cd/m^2) / Percent of Sign Area

- Red – 20 / 11.75
- Yellow – 200 / 4.28
- White – 480 / 17.51

Weighted Mean Luminance (cd/m^2) – 89.71

Luminous Intensity (cd) – 177.89

Sign Size (in)
Height - 34
Width – 69
Depth – 9

Sign Area (m^2) – 1.514

Sign Luminance (cd/m^2) / Percent of Sign Area
Green – 7 / 14.65
White – 250 / 74.04

Weighted Mean Luminance (cd/m^2) – 186.13

Luminous Intensity (cd) – 281.79

Sign Size (in)
- Height - 32
- Width – 56
- Depth – 12

Sign Area (m^2) – 1.156

Sign Luminance (cd/m^2) / Percent of Sign Area
- Blue – 15 / 9.43
- White – 500 / 60.74

Weighted Mean Luminance (cd/m^2) – 305.12

Luminous Intensity (cd) – 352.71

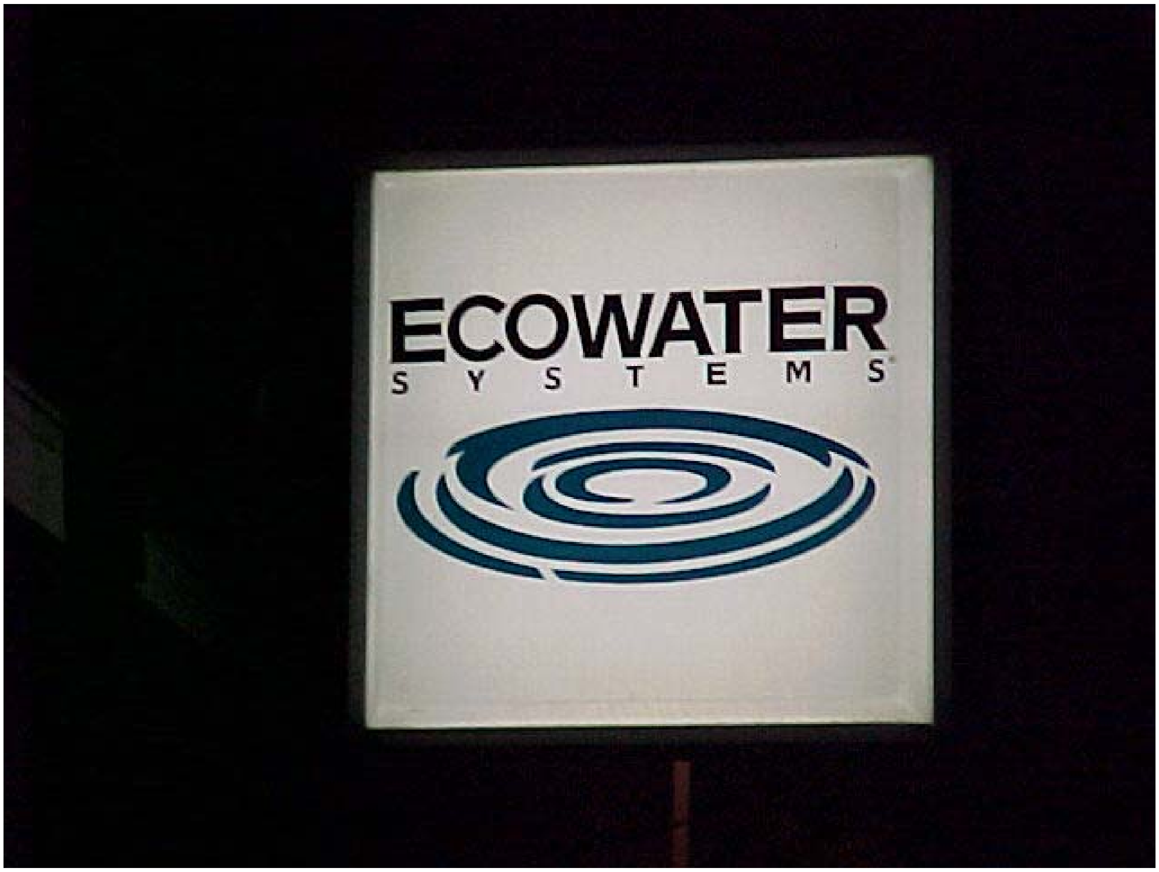
Sign Size (in)
- Height - 37
- Width – 45
- Depth – X

Sign Area (m^2) – 1.074

Sign Luminance (cd/m^2) / Percent of Sign Area
- Blue – 3 / 10.12
- Red – 8 / 26.38
- White – 140 / 63.5

Weighted Mean Luminance (cd/m^2) – 91.31

Luminous Intensity (cd) – 98.07



Sign Size (in)

Height - 47

Width – 47

Depth – 15

Sign Area (m^2) – 1.425

Sign Luminance (cd/m^2) / Percent of Sign Area

Blue – 12 / 8.19

White – 200 / 86.46

Weighted Mean Luminance (cd/m^2) – 173.90

Luminous Intensity (cd) – 247.81

Sign Size (in)

Height - 42

Width – 52.5

Depth – 12

Sign Area (m^2) – 1.423

Sign Luminance (cd/m^2) / Percent of Sign Area

Blue – 10 / 23.55

White – 310 / 60.16

Weighted Mean Luminance (cd/m^2) – 188.85

Luminous Intensity (cd) – 268.74

Sign Size (in)
Height - 21
Width – 117
Depth – 9

Sign Area (m^2) – 1.585

Sign Luminance (cd/m^2) / Percent of Sign Area
Yellow – 300 / 73

Weighted Mean Luminance (cd/m^2) – 219.00

Luminous Intensity (cd) – 347.12

Sign Size (in)

Height - 21

Width – 117

Depth – 18

Sign Area (m^2) – 1.585

Sign Luminance (cd/m^2) / Percent of Sign Area

Red – 11 / 82.7

White – 240 / 17.3

Weighted Mean Luminance (cd/m^2) – 50.62

Luminous Intensity (cd) – 80.23

Sign Size (in)

Height - 27

Width – 94

Depth – 6

Sign Area (m^2) – 1.637

Sign Luminance (cd/m^2) / Percent of Sign Area

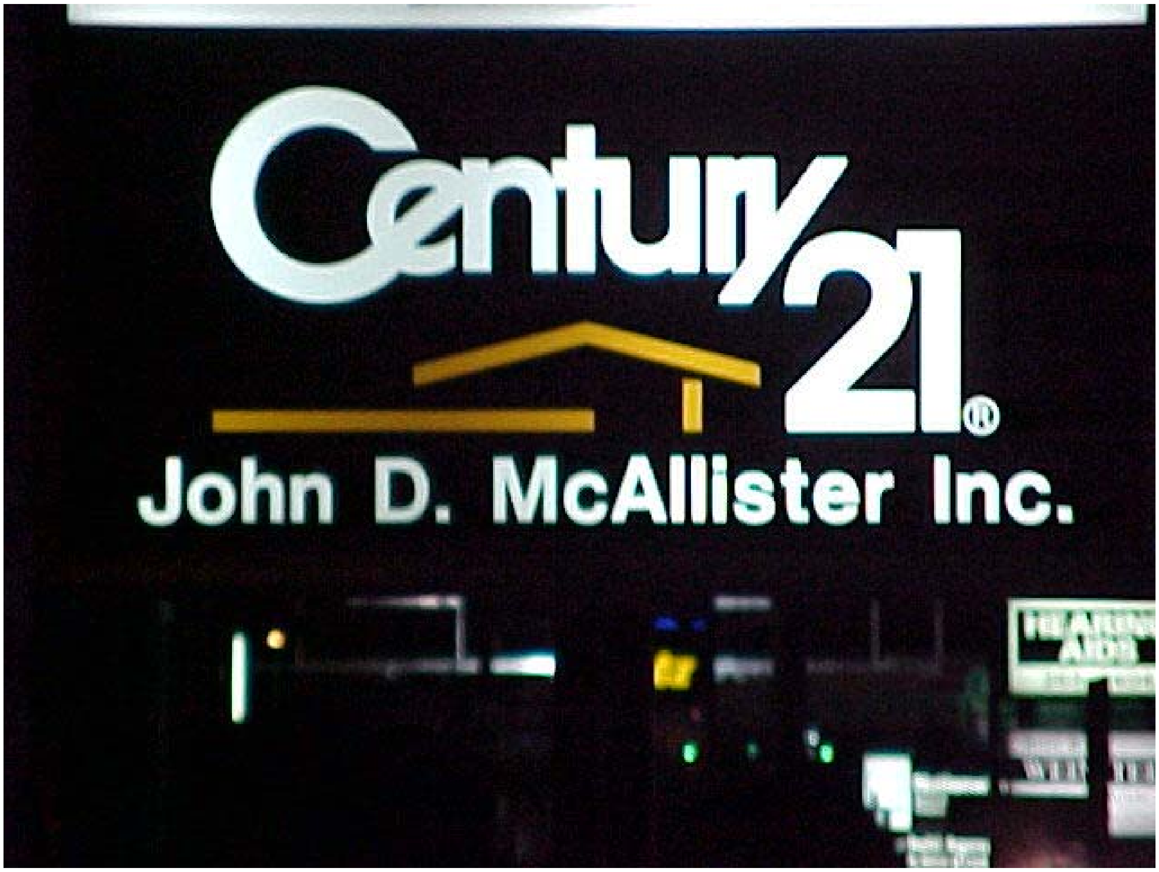
Blue – 10 / 19.2

Red – 70 / 6.07

White – 750 / 74.73

Weighted Mean Luminance (cd/m^2) – 566.64

Luminous Intensity (cd) – 927.60



Sign Size (in)
Height - 32
Width – 68
Depth – 14

Sign Area (m^2) – 1.404

Sign Luminance (cd/m^2) / Percent of Sign Area
Yellow – 1 / 4.11
White – 410 / 24.26

Weighted Mean Luminance (cd/m^2) – 99.51

Luminous Intensity (cd) – 139.71

Sign Size (in)

Height - 54

Width – 99

Depth – 19

Sign Area (m^2) – 3.449

Sign Luminance (cd/m^2) / Percent of Sign Area

Blue – 9 / 34.68

White – 315 / 65.34

Weighted Mean Luminance (cd/m^2) – 208.94

Luminous Intensity (cd) – 720.64

Sign Size (in)
- Height - 31
- Width – 69
- Depth – 10

Sign Area (m^2) – 1.38

Sign Luminance (cd/m^2) / Percent of Sign Area
- Blue – 11 / 14.59
- White – 100 / 85.41

Weighted Mean Luminance (cd/m^2) – 87.02

Luminous Intensity (cd) – 120.08

Sign Size (in)

Height - 94

Width – 82

Depth – 14

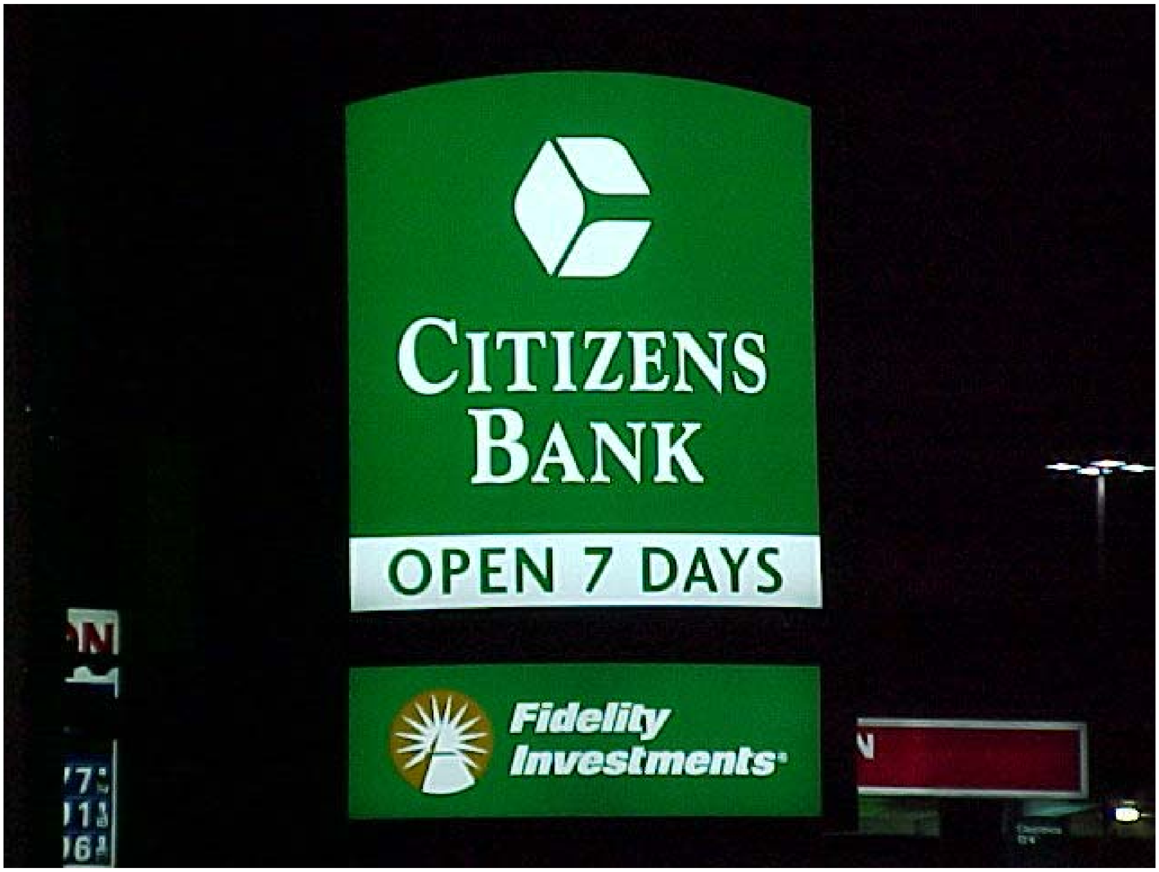
Sign Area (m^2) – 4.973

Sign Luminance (cd/m^2) / Percent of Sign Area

White – 400 / 62.02

Weighted Mean Luminance (cd/m^2) – 248.08

Luminous Intensity (cd) – 1233.70



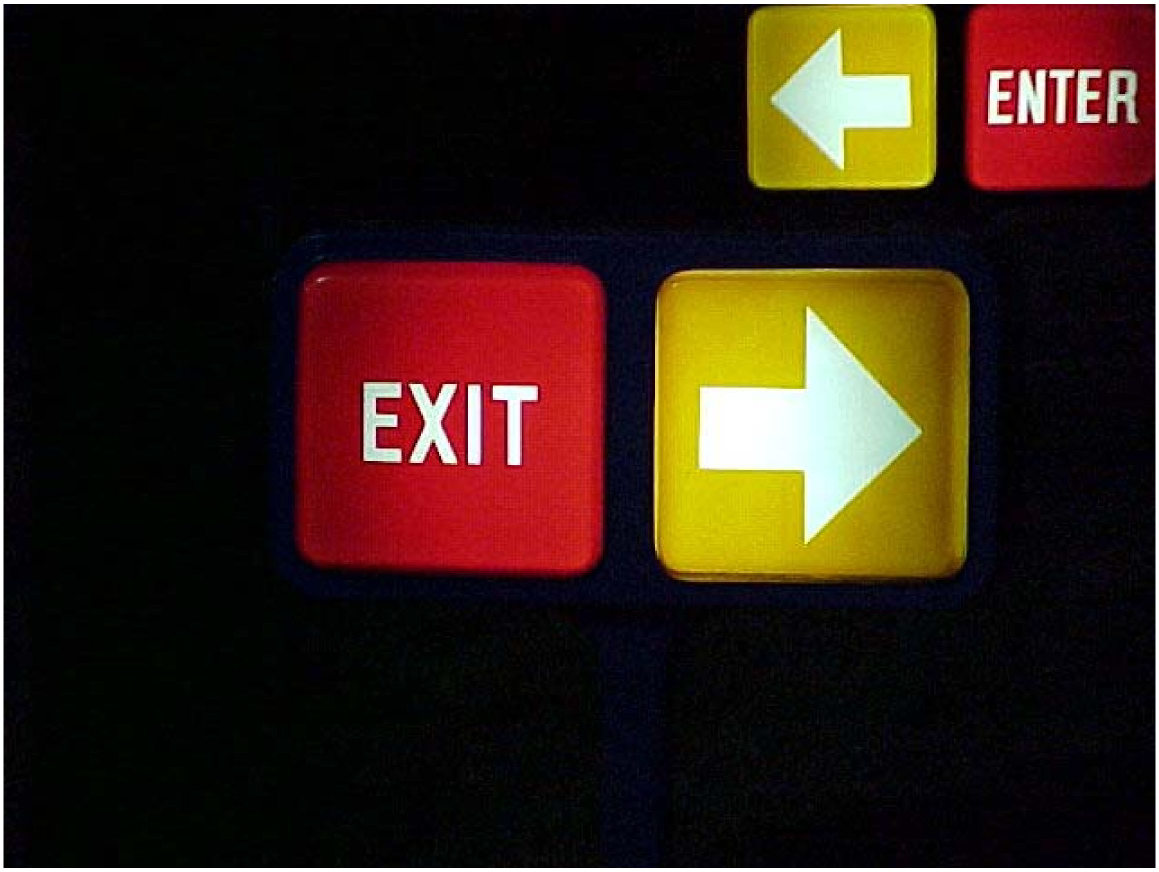
Sign Size (in)
- Height - 86
- Width – 55
- Depth – 16

Sign Area (m^2) – 3.052

Sign Luminance (cd/m^2) / Percent of Sign Area
- Green – 52 / 68.07
- White – 1022 / 22.38

Weighted Mean Luminance (cd/m^2) – 264.12

Luminous Intensity (cd) – 806.09



Sign Size (in)

Height - 18

Width – 35

Depth – 11

Sign Area (m^2) – 0.407

Sign Luminance (cd/m^2) / Percent of Sign Area

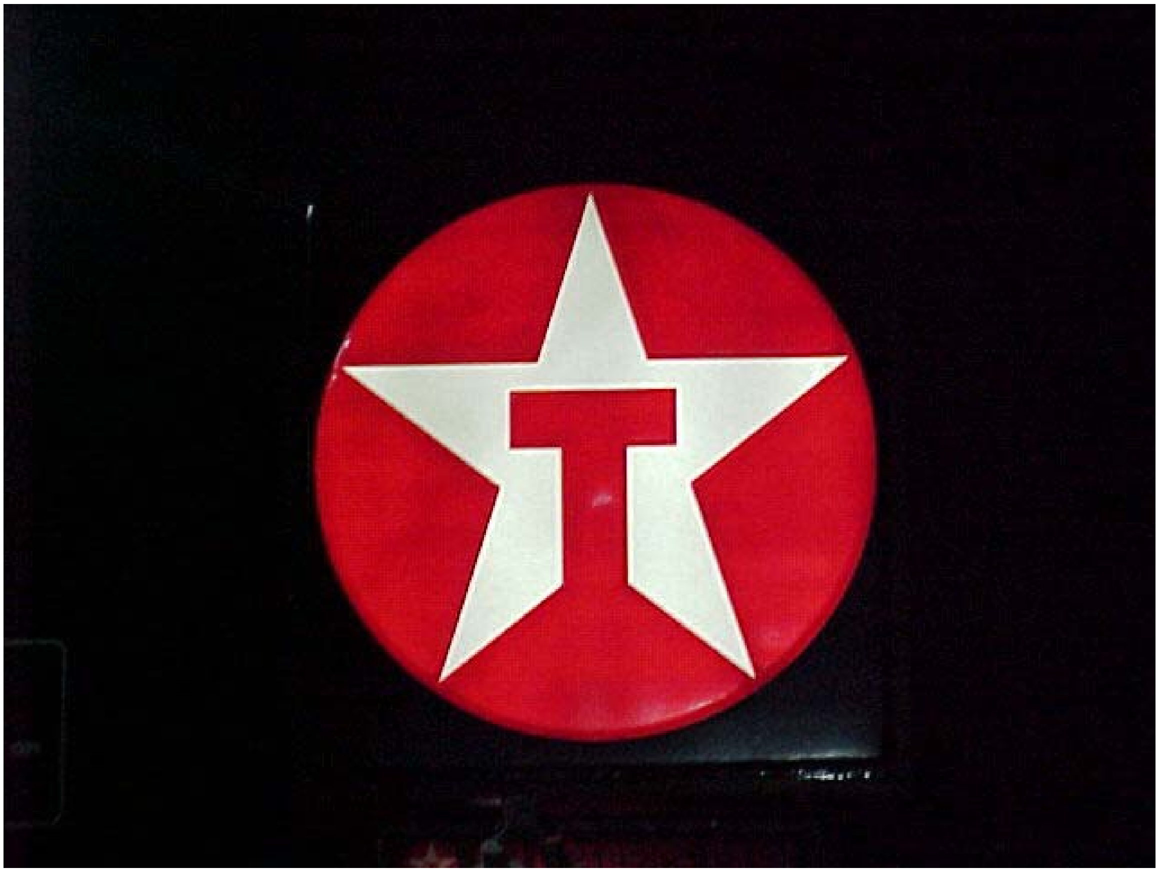
Yellow – 14 / 34.96

Red – 14 / 39.61

White – 234 / 15.66

Weighted Mean Luminance (cd/m^2) – 47.08

Luminous Intensity (cd) – 19.16



Sign Size (in)
- Height - 53
- Width – 53
- Depth – 10

Sign Area (m^2) – 1.423

Sign Luminance (cd/m^2) / Percent of Sign Area
- Red – 31 / 55.56
- White – 438 / 44.44

Weighted Mean Luminance (cd/m^2) – 217.43

Luminous Intensity (cd) – 309.40

Sign Size (in)
- Height - 15
- Width – 42
- Depth – 9

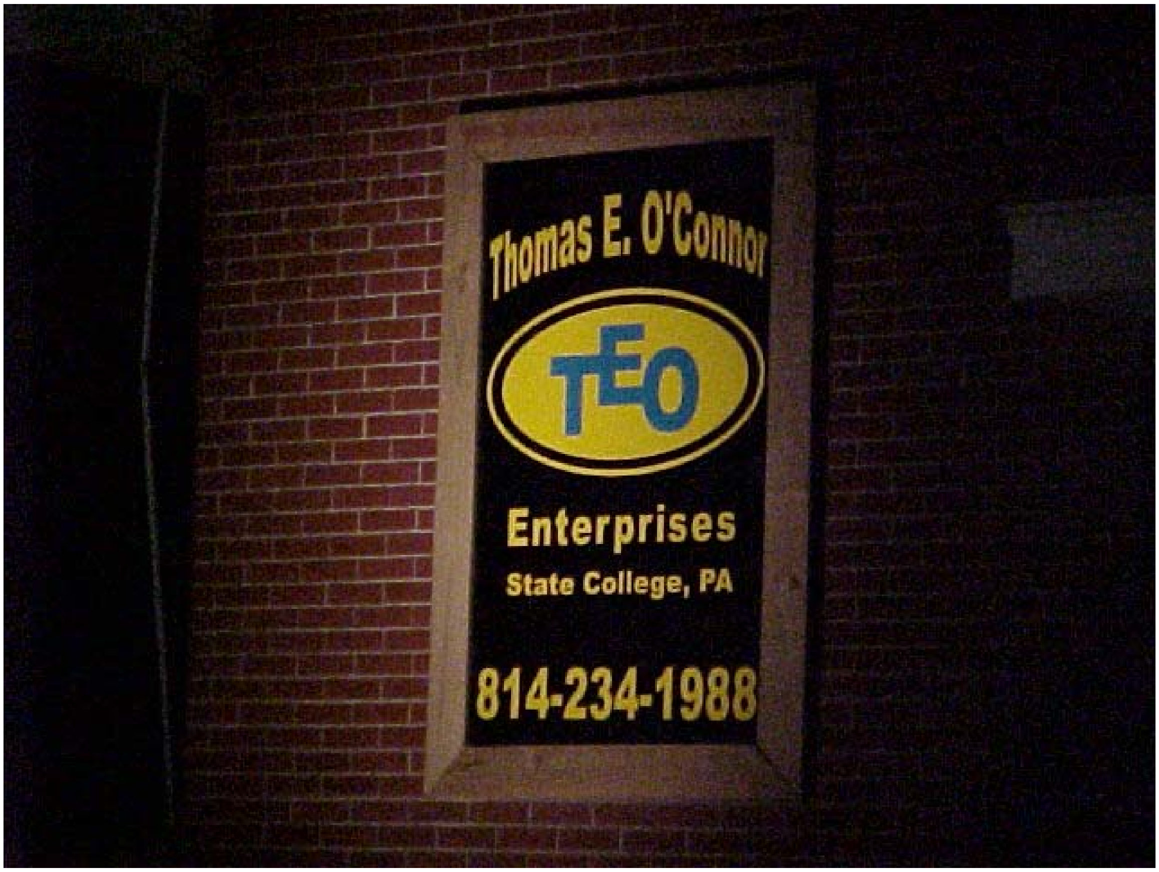
Sign Area (m^2) – 0.407

Sign Luminance (cd/m^2) / Percent of Sign Area
- Red – 25 / 17
- White – 360 / 83

Weighted Mean Luminance (cd/m^2) – 303.05

Luminous Intensity (cd) – 123.34

Externally Illuminated Signs



Sign Size (in)
Height - 63
Width – 40

Sign Area (m^2) – 1.626

Sign Luminance (cd/m^2) / Percent of Sign Area
Blue – 2 / 4.54
White – 10 / 36.57

Weighted Mean Luminance (cd/m^2) – 3.75

Luminous Intensity (cd) – 6.09

Sign Size (in)
Height - 42
Width – 42

Sign Area (m^2) – 1.138

Sign Luminance (cd/m^2) / Percent of Sign Area
Dark Green – 0.3 / 50.0
Green – 2.3 / 35.0
Gold – 6 / 15.0

Weighted Mean Luminance (cd/m^2) – 1.56

Luminous Intensity (cd) – 2.11

Sign Size (in)
Height - 33
Width – 80

Sign Area (m^2) – 1.703

Sign Luminance (cd/m^2) / Percent of Sign Area
Brown- 4.8 / 79.02
Silver – 34 / 20.98

Weighted Mean Luminance (cd/m^2) – 10.93

Luminous Intensity (cd) – 18.61

Sign Size (in)
Height - 36
Width – 72

Sign Area (m^2) – 1.672

Sign Luminance (cd/m^2) / Percent of Sign Area
Black- 12.8 / 88.25
Gold – 130 / 11.75

Weighted Mean Luminance (cd/m^2) – 26.57

Luminous Intensity (cd) – 44.43

Sign Size (in)

Height - 48

Width – 72

Sign Area (m^2) – 2.23

Sign Luminance (cd/m^2) / Percent of Sign Area

Brown- 4.3 / X

Orange – 18 / X

White – 49.5 / X

Weighted Mean Luminance (cd/m^2) - X

Luminous Intensity (cd) – X

Sign Size (in)
Height – 28
Middle Height - 39
Width – 58

Sign Area (m^2) – 1.305

Sign Luminance (cd/m^2) / Percent of Sign Area
Green- 2.4 / 78.24
White – 50 / 21.76

Weighted Mean Luminance (cd/m^2) – 12.76

Luminous Intensity (cd) – 16.65

Sign Size (in)
Height – 53
Width – 110

Sign Area (m^2) – 3.761

Sign Luminance (cd/m^2) / Percent of Sign Area
White – 155 / 85.5

Weighted Mean Luminance (cd/m^2) – 132.53

Luminous Intensity (cd) – 498.43

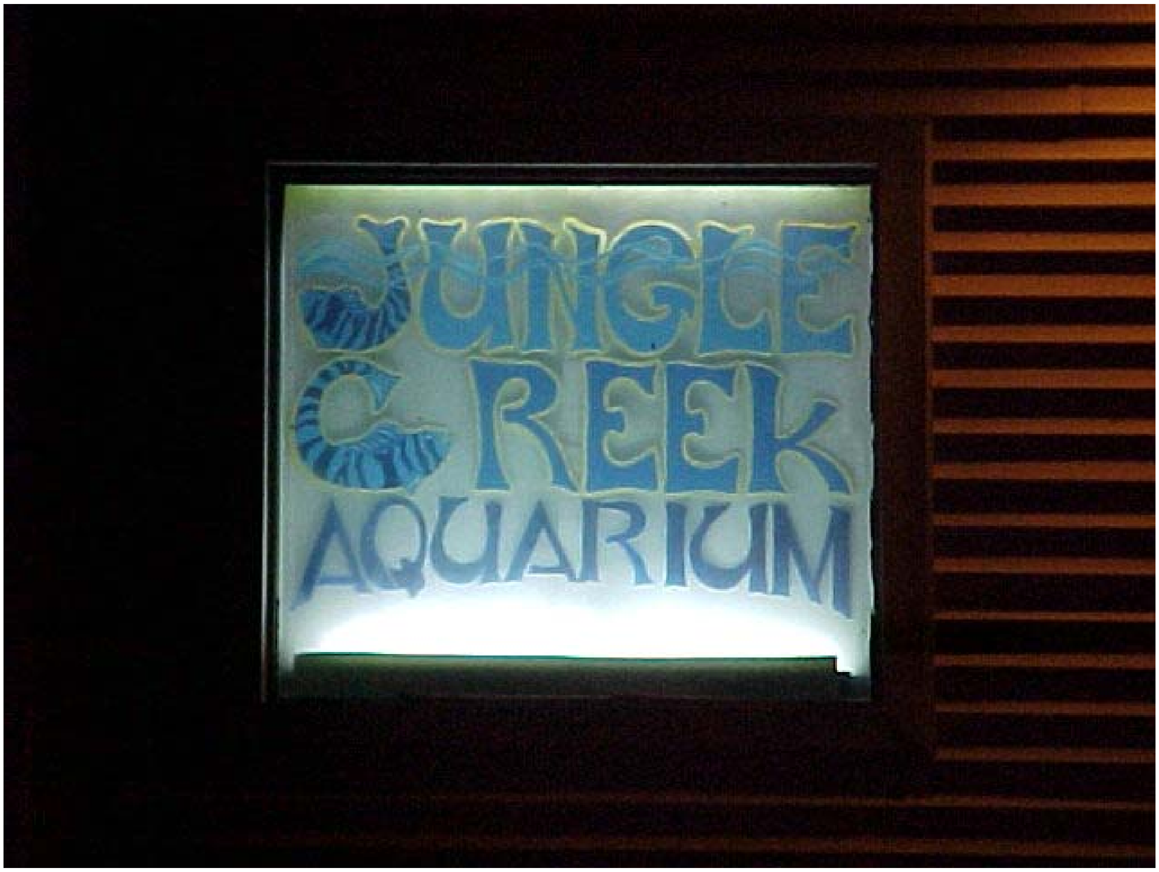
Sign Size (in)
- Height – 108
- Width – 59

Sign Area (m^2) – 4.242

Sign Luminance (cd/m^2) / Percent of Sign Area
- Green – 1.3 / 3.82
- White – 22 / 9.65

Weighted Mean Luminance (cd/m^2) – 2.17

Luminous Intensity (cd) – 9.22



Sign Size (in)
Height – 47
Width – 47

Sign Area (m^2) – 1.425

Sign Luminance (cd/m^2) / Percent of Sign Area
Blue – 17 / X
White – 166 / X

Weighted Mean Luminance (cd/m^2) - X

Luminous Intensity (cd) – X

Sign Size (in)

Height – 41

Width – 67

Sign Area (m^2) – 1.772

Sign Luminance (cd/m^2)

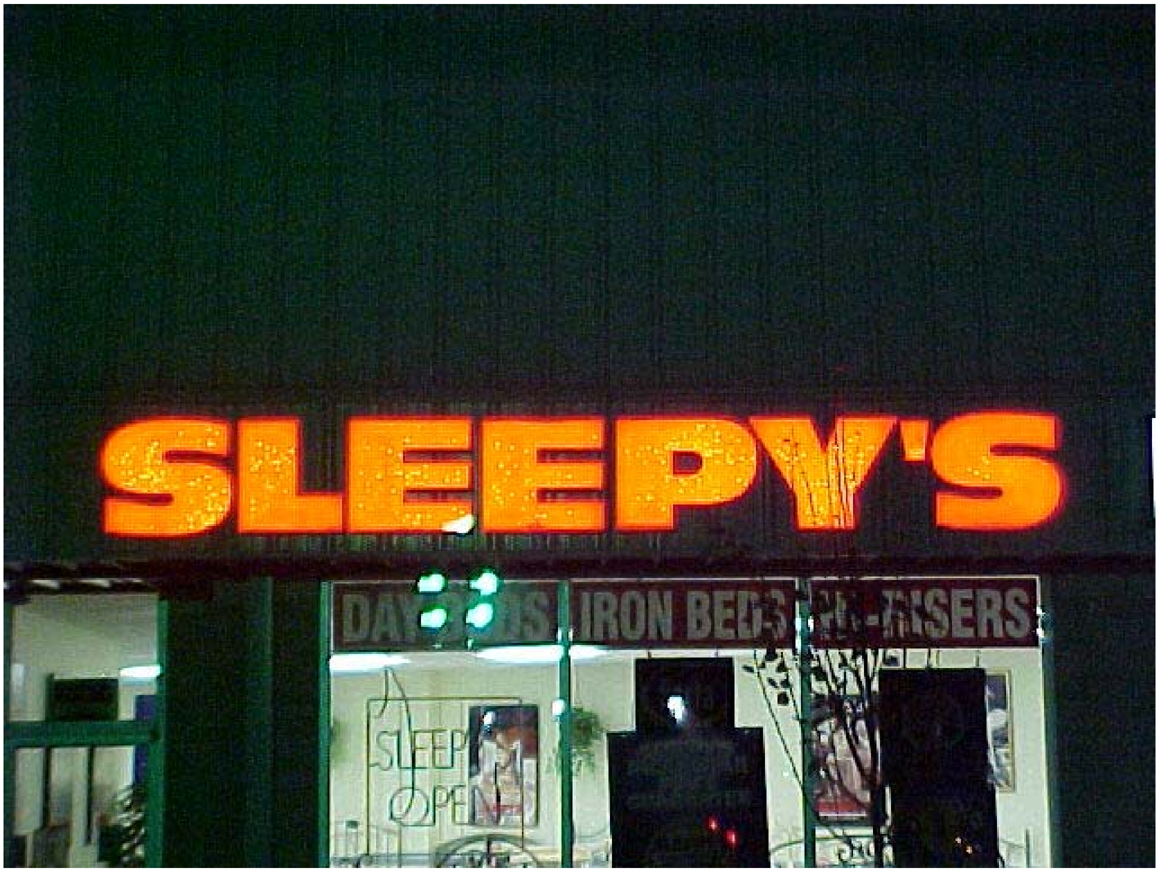
Green – 1.5 / 74.79

Gold – 6 / 25.21

Weighted Mean Luminance (cd/m^2) – 2.63

Luminous Intensity (cd) – 4.67

Channel Letter Signs



Letter Size (in) "E"

Letter Height – 24

Letter Width – 26

Letter Depth - 5.5

Sign Area (m^2) – 3.53

Sign Luminance (cd/m^2) / Percent of Sign Area

Orange – 185 / 79.38

Weighted Mean Luminance (cd/m^2) – 146.85

Luminous Intensity (cd) – 518.39

Letter Size (in)
Letter Height – 19.5 "U"/ 14 "O"
Letter Width – 13 "U"/ 11 "O"
Letter Depth - 5.25

Sign Area (m^2) – 1.419

Sign Luminance (cd/m^2) / Percent of Sign Area
Blue – 7 / 8.46
Orange – 150 / 15.81

Weighted Mean Luminance (cd/m^2) – 24.31

Luminous Intensity (cd) – 34.49

Letter Size (in)

Letter Height – 9 "E"/ 12 "O"

Letter Width – 7.75 "E"/ 13 "O"

Letter Depth - 5.25

Sign Area (m^2) – 3.992

Sign Luminance (cd/m^2) / Percent of Sign Area

Red – 81 / 14.0

White – 250 / 20.85

Weighted Mean Luminance (cd/m^2) – 63.47

Luminous Intensity (cd) – 253.35

Letter Size (in)

Letter Height – 15.5 “R”/ 23 “B”

Letter Width – 16 “R”/ 23.5 “B”

Letter Depth - 5.25

Sign Area (m^2) – 3.116

Sign Luminance (cd/m^2) / Percent of Sign Area

Blue – 150 / 40.83

Red – 295 / 3.6

Weighted Mean Luminance (cd/m^2) – 71.87

Luminous Intensity (cd) – 223.93

Letter Size (in) “O”

Letter Height – 19

Letter Width – 11

Letter Depth - 8.25

Sign Area (m^2) – 2.484

Sign Luminance (cd/m^2) / Percent of Sign Area

Orange – 150 / 31.61

Weighted Mean Luminance (cd/m^2) – 47.42

Luminous Intensity (cd) – 117.78

Letter Size (in) “

Letter Height – X

Letter Width – X

Letter Depth - X

Sign Area (m^2) –

Sign Luminance (cd/m^2) / Percent of Sign Area

White – 870 / 37.87

Weighted Mean Luminance (cd/m^2) – 329.47

Luminous Intensity (cd) – X

Letter Size (in) "O"

Letter Height – 21

Letter Width – 11

Letter Depth - 6

Sign Area (m^2) – 2.98

Sign Luminance (cd/m^2) / Percent of Sign Area

Orange – 170 / 63.3

Weighted Mean Luminance (cd/m^2) – 107.61

Luminous Intensity (cd) – 320.68

Neon Signs

Letter Size (in)

Letter Height – X

Letter Width – X

Letter Depth - X

Sign Area (m^2) – X

Sign Luminance (cd/m^2) / Percent of Sign Area

Green – 106 / 18.74

Weighted Mean Luminance (cd/m^2) – 19.86

Luminous Intensity (cd) – X

Letter Size (in) "E"

Letter Height – 5.5

Letter Width – 3.5

Letter Depth - X

Sign Area (m^2) – 0.168

Sign Luminance (cd/m^2) / Percent of Sign Area

Blue – 318 / 17.98

Weighted Mean Luminance (cd/m^2) – 57.18

Luminous Intensity (cd) – 9.61

Letter Size (in) “S”
- Letter Height – 5.5
- Letter Width – 3.5
- Letter Depth - X

Sign Area (m^2) – 0.465

Sign Luminance (cd/m^2) / Percent of Sign Area
- White – 394 / 17.22

Weighted Mean Luminance (cd/m^2) – 67.85

Luminous Intensity (cd) – 31.55

Letter Size (in) "S"
Letter Height – 5.5
Letter Width – 3.5
Letter Depth - X

Sign Area (m^2) – 0.186

Sign Luminance (cd/m^2) / Percent of Sign Area
Orange – 388 / 49.59

Weighted Mean Luminance (cd/m^2) – 192.41

Luminous Intensity (cd) – 35.79

Sign Size (in)
Height – 61.5
Width – 156
Depth - X

Sign Area (m^2) – 6.19

Sign Luminance (cd/m^2) / Percent of Sign Area
Orange – 280 / 48.64
White – X / 2.21

Weighted Mean Luminance (cd/m^2) – 136.12

Luminous Intensity (cd) – 843.03

Sign Size (in)
- Height – 48
- Width – 96
- Depth - X

Sign Area (m^2) – 2.973

Sign Luminance (cd/m^2) / Percent of Sign Area
- Dark Squares – 5 / 46.25
- Light Squares – 7 / 46.25
- Letters – 150 / 7.51

Weighted Mean Luminance (cd/m^2) – 16.82

Luminous Intensity (cd) – 49.22

Sign Size (in)
- Height – X
- Width – X
- Depth - X

Sign Area (m^2) – X

Sign Luminance (cd/m^2) / Percent of Sign Area
- Red – 560 / 39.64

Weighted Mean Luminance (cd/m^2) – 221.98

Luminous Intensity (cd) – X

Sign Size (in)

Height – X

Width – X

Depth - X

Sign Area (m^2) – X

Sign Luminance (cd/m^2) / Percent of Sign Area

Neon Orange– 340 / 67

Channel - 300

Weighted Mean Luminance (cd/m^2) – 227.80

Luminous Intensity (cd) – X

Appendix B