Submitted by ESF to RoHS Exemption Stakeholder Consultation 4 September 2012, concerning Ex. No. 9. Stakeholder states that "This document shows the USA has a very similar situation, as is technology. On page 8-25 you can find description of the arguments of ISA, our counterpart organisation". Part 1

Interstate Mercury Education & Reduction Clearinghouse

APPLICATION FOR EXEMPTION TO MERCURY-ADDED PRODUCT PHASE-OUT

For IMERC use only
Date rec'd
Date data entry
Exemption #

IMPORTANT NOTES:

- Please type or print using black ink to complete this application.
- All applications must be submitted in hard copy with an original signature — NO faxes or electronic submissions will be accepted.

Date: July , 2008

I. TYPE OF APPLICATION (PLEASE CHECK):

X New Application

X $200 Application Fee Sent to Rhode Island Department of Environmental Management

___ Renewal Application

___ Update to Previous Application

Note: If this is an application for a renewal of an approved exemption to the states' mercury-added product phase-out requirements, please complete Sections II and IX, only.

II. APPLICANT'S FULL LEGAL NAME, ADDRESS, & CONTACT INFORMATION:

Name/Organization: International Sign Association

Mailing Address: 1001 N. Fairfax Street, Suite 301

City/Town: Alexandria State: VA

Zip Code: 22314 Telephone #: (703) 836-4012

Website: http://www.signs.org

Contact Person: Bill Dundas Telephone #:(703)836-4012

Mailing Address: SAME AS ABOVE

City/Town: ___ State: ___

Zip Code: ___ E-mail address: Bill.Dundas@signs.org

Please check one of the lines below to indicate your relationship to the product manufacturer:

___ Product Manufacturer ___ Importer ___ Distributor

___ Product User x Representative of Product Manufacturer

III. PRODUCT MANUFACTURERS' NAME, ADDRESS, & CONTACT INFORMATION (IF DIFFERENT FROM ABOVE)

Name/Organization: ____

Mailing Address: ____

City/Town: ____ State: _________

Zip Code: ____________________ Telephone #: ________________________

Website: ____

Contact Person: ______________________________ Telephone #: ______________

Mailing Address: ____

City/Town: ____ State: _________

Zip Code: ______________ E-mail address: ______________________________

IV. PRODUCT INFORMATION

Describe the mercury-added product or product component for which you seek an exemption and the uses of the product:

Mercury-Added Neon Signs

____

Briefly describe the purpose of the mercury in the product:

Mercury is necessary to generate short-wave ultraviolet light within certain wavelengths which interacts with phosphors to generate colors other than in the red spectrum. Mercury is also critical to the high intensity and visibility of neon signs.

V. MERCURY-ADDED REPLACEMENT PARTS

Are you seeking this exemption for the sole purpose of allowing the sale of replacement parts in a larger product? Yes ___ No X___

If no, proceed to Section VI. If yes, please answer the following additional questions before proceeding to Section VI.

- When was the larger product placed in service?
  - ☐ Before July 1, 2006
  - ☐ On or after July 1, 2006 but before January 1, 2007
  - ☐ On or after January 1, 2007 but before July 1, 2007
  - ☐ On or after July 1, 2007

- Is the larger product used in manufacturing? Y ____   N ____

If yes, describe the function of the larger product in the manufacturing process and identify the product manufacturer:

____
____
____

VI. Basis for Mercury-added Product Exemption Request. Indicate the basis for your exemption application by checking the appropriate line below.

1. __X______ There are no technically feasible non-mercury alternatives available at a reasonable cost.

2. ________ The use of mercury in the product is mandated by a state or federal law or requirement.

3. ________ There are technically feasible non-mercury alternatives, but the mercury-added product is more beneficial to the environment, public health or public safety.

VII. Required Supporting Information. The following information must be submitted with your Application:

1. An IMERC Mercury-added Product Notification Form approval letter for the most recent triennial filing period (i.e., 2004, 2007, 2010).

2. If you checked Section VI (1) as the basis for your exemption request, attach a narrative and supporting data that, at a minimum:

   - Describes why the product or component must use mercury;
   - Describes in detail the potential non-mercury alternative products or components and why they are not technically feasible;
   - Describes the current status of the industry efforts to find a non-mercury substitution;
   - Describes the process by which you researched available non-mercury alternative products or components and made a determination that they are not feasible, including discussions with outside unbiased experts;
   - If there are technically feasible non-mercury alternatives but you are claiming that their costs are unreasonable, include data documenting your claim.

3. If you checked Section VI (2) as the basis of your exemption request, provide a citation to the federal or state law or other requirement:

   ____

   Also provide a copy of the law and highlight the specific provision that requires the use of mercury.

4. If you checked Section VI (3) as the basis of your exemption request, attach a narrative and supporting data that:

- Describes the specific benefit to the environment and public health and safety that you are claiming;
- Explains how the claimed benefit differs from the benefits afforded by available non-mercury alternatives to the mercury-added product;
- Estimates amount of mercury that will be placed in commerce annually if the exemption is granted; and
- List the steps, if any, that will be taken, through product design or otherwise, to ensure that the mercury in the product is not released during use and disposal.

VIII. COLLECTION PLAN. If you meet the criteria for the states' product phase-out exemptions as outlined above in Sections VI and VII, you also need to include a description of the proposed or existing system for ensuring that the mercury-added product will be properly collected, transported, and processed when the user is done with it. If you waive the Illinois completeness review in Section X, you do not need to submit a collection plan until all other sections of this application are adequately addressed. Attach a narrative and supporting data that, at a minimum:

- Describes how the system will work and who will run it;
- Includes an estimate of the number of units of the product expected to be available for collection each year and the number of these units or percentage that the collection system can reasonably be expected to capture;
- Includes the performance measures to be used to demonstrate that the collection system is meeting the capture rate target;
- Describes a public education program, including implementation dates, which will inform the relevant portions of the public and private sector about the mercury-added products, the purpose of the collection system program, and how they may participate;
- Proposes the frequency and method for disposal/recycling for the items that are collected;
- Demonstrates the financing for the implementation of the proposed collection system;
- Describes the recordkeeping protocol that the manufacturer or company other than the manufacturer will maintain to assure compliance with this Plan; and
- Includes documentation of the readiness of all necessary parties to perform as intended in the collection and recycling or disposal system.

IX. RENEWAL APPLICATION If you are requesting the renewal of an exemption previously granted by one or more IMERC-member states, please attach a detailed narrative describing your efforts to eliminate the use of mercury in the product or replace the product with one that does not require the use of mercury.

X. ILLINOIS WAIVER OF COMPLETENESS REVIEW Exemption applications for mercury switches and relays must be reviewed by the Illinois Environmental Protection Agency (IL EPA) within 10 days of receipt of the application to determine whether an application is complete.

This deadline may be waived by the applicant in writing. Waiving this deadline will facilitate a coordinated review of your application among the IMERC states, reducing burden on you.

__x__ I waive the deadline for the IL EPA's completeness review as set forth in 35 Illinois Administrative Code, Section 182.206(a).

Waiving the completeness review allows Illinois to review an exemption application without the collection plan to determine whether the application meets the other criteria for approval of a Phase-out Exemption request. If Illinois finds that the Applicant has satisfied the state's other criteria for approval of an Exemption Application, they will contact the applicant to request a collection plan that provides the information requested in Section VIII.

XI. CERTIFICATION

As the applicant for this exemption, I have personally examined and am familiar with the information submitted in this document and all attachments thereto, and I certify that based on reasonable investigation, including my inquiry of the individuals responsible for obtaining the information, the submitted information is true, accurate, and complete to the best of my knowledge and belief. I certify that this application is on a complete and accurate Form as prescribed by the member states of the Interstate Mercury Education Reduction Clearinghouse Committee (IMERC) without alteration of text. I understand that a false statement in the submitted information may be punishable as a criminal offense, in accordance with the applicable IMERC members' state laws.

______________________________ July , 2008

Signature (of an Authorized Senior Management Official or designee) Date

Richard Gottwald, Education and Technical Initiatives Vice President

Print or Type Name and Title of the Authorized Senior Management Official, or designee

For Applicants to Rhode Island:

____

Notary Signature Commission Expires

XII. MANUFACTURER'S DESIGNATED INDUSTRIAL TRADE GROUP REGISTRATION

Pursuant to discussions with Adam Wienert of IMERC, Original Manufacturer's Designated Industrial Trade Group Registration for each ISA member seeking an exemption are being collected during the initial review of this application. They will be made available before final review of the application.

MANUFACTURER'S CERTIFICATION OF DESIGNATED INDUSTRIAL TRADE GROUP REGISTRATION:

Pursuant to discussions with Adam Wienert of IMERC, Original Manufacturer's Designated Industrial Trade Group Registration for each ISA member seeking an exemption are being collected during the initial review of this application. They will be made available before final review of the application.

Writer's Direct Access
Jean-Cyril Walker
(202) 434-4181
walker@khlaw.com

July 7, 2008

Via Overnight Mail

Adam Wienert
IMERC
c/o NEWMOA
129 Portland Street, Suite 602
Boston, MA 02114

Re: Request for Exemption From Mercury Limits or Bans Applicable to Mercury-Added Neon Signs

Dear Mr. Wienert:

This letter constitutes the narrative and supporting documentation of our client, the International Sign Association ("ISA" or "the Association"), as required by Section VII (2) of the Interstate Mercury Education and Reduction Clearinghouse ("IMERC") Application for Exemption to Mercury-Added Product Phase-Out form. As indicated on the attached form, the ISA requests an exemption from mercury phase-outs and a product ban applicable to neon signs in Connecticut, Louisiana, Rhode Island, and Vermont, respectively.[1] The ISA respectfully submits that this request should be granted because it meets the statutory criteria for an exemption set out by these states. Original requests have been submitted to each state with a copy for coordination to IMERC.[2]

In many ways, the predominantly artisan-based neon sign industry defies description or categorization, and further complicates the task of fashioning an exemption that is protective of both the environment and an industry comprised primarily of small and home businesses. While recognizing these difficulties, the ISA nevertheless submits that a creative and flexible approach to regulating mercury use within the neon sign industry is achievable and warranted. To this end, the ISA seeks an exemption only for those neon signs manufactured by its members that have submitted or subsequently submit mercury notifications in accordance with the

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[1] *See* CONN. GEN. STAT. § 22a-618; LA. REV. STAT. ANN. § 30:2576(F); R.I. GEN. LAWS § 23-24.9-7(g); VT. STAT. ANN. tit. 10, § 7105(h).

[2] Pursuant to our discussion last week, Original Manufacturer's Designated Industrial Trade Group Registration for each ISA member seeking an exemption are being collected during the initial review of this application. They will be made available before final review of the application.

requirements of the various IMERC states.[3] A list of members and the most recent industry notification approval are included at **Attachments A-1** and **A-2**, respectively. In turn, the ISA and its members commit to: (1) significantly reduce the use of mercury in neon signs; (2) implement educational measures to inform and educate the remainder of the neon sign industry about mercury issues and concerns; and (3) implement a system to ensure the proper collection, transportation, and processing of neon signs at their end-of-life.

We first provide some background on the ISA, the neon sign industry and the neon sign manufacturing process. The specific narratives required under Section VII(2) of the attached IMERC form are provided in Sections II through VI of this letter. These discussions make clear that technically feasible alternatives to the use of mercury in neon sign applications are not currently available.[4]

I. Background

The International Sign Association is a 2,600-member organization comprised of manufacturers, users and suppliers of on-premise signs and sign products from the 50 U.S. states and 54 additional countries.[5] ISA exists to support, promote and improve the sign industry, which sustains the nation's retail industry. This is accomplished through a number of programs and services, including government advocacy, education and training programs, technical resources, and communications outreach and industry events.[6]

ISA member companies manufacture neon signs and decorative neon artwork that are employed in a wide variety of commercial and artistic settings. The specific manufacturers on whose behalf ISA is seeking an exemption from the IMERC limits are identified in Section IV of the IMERC application form. Many of these petitioners and other ISA member companies also use or manufacture light-emitting diode (LED), fiber optic lighting, and other alternatives to neon signs or neon sign components. While these alternatives are suitable in certain applications, mercury and neon technology remain necessary to produce certain colors of the spectrum, achieve certain lighting intensity and efficiency, and to produce complex sign configurations and designs.

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[3] *See* CONN. GEN. STAT. § 22a-615; LA. REV. STAT. ANN. § 30:2574; R.I. GEN. LAWS § 23-24.9-5; VT. STAT. ANN. tit. 10, § 7104.

[4] *See* CONN. GEN. STAT. § 22a-618(e); LA. REV. STAT. ANN. § 30:2576(F); R.I. GEN. LAWS § 23-24.9-7(g); VT. STAT. ANN. tit. 10, § 7105(h)(4)(B)(ii).

[5] *See* http://www.signs.org.

[6] For more information on ISA educational and professional development programs, please see http://www.signs.org/education/.

Neon signs constitute a unique and important sector of the sign industry generally, and more broadly constitute an important segment of American cultural and artistic heritage. ISA and its members also recognize the importance of decreasing the amount of mercury present in the environment, and propose concrete steps both to educate the industry and the public regarding reductions in mercury usage, and to reduce the collective environmental footprint of the ISA's neon sign manufacturing members with respect to mercury.

A. The Neon Sign Industry

Neon signs have been utilized in the United States for commercial and artistic purposes since at least the early 1920s.[7] With few exceptions, each sign is unique and must be custom-made to fit the desired display within the confines of the available space. While certain components of neon signs are mass-produced, virtually all neon lamps used in such signs are hand-made by skilled glassblowers.[8] Indeed, neon sign fabrication is as much an art as it is a production process.

In most cases, a glass tube is first cleaned and its interior coated with phosphors unless certain specific red or blue colored lighting is required. Depending on the sign's configuration, the glass tube may be heated until it becomes malleable so that it may be bent into the desired shape. An electrode is heated and fused or welded onto each end of the glass tube. The tube assembly is then attached to a manifold and, by use of a vacuum pump, evacuated of all air until a near vacuum is created inside. During evacuation, a high current is forced through the tube via the wires protruding from each electrode (in a process known as "bombarding") to eliminate any residual moisture.

Thereafter, the evacuated tubing is filled with one or more noble gases, such as neon or argon. If a color is needed other than certain shades of red or orange, a small amount of mercury will be injected into the tube. In the alternative, electrodes pre-dosed with a set quantity of mercury may be used. As a last step, a transformer is connected to the finished glass piece(s) and the completed neon tube is installed in its appropriate fixture.[9]

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[7] *Neon Techniques, Handbook of Neon Sign and Cold Cathode Lighting* 5 (Wayne Strattman ed., ST Publications, Inc., 4th Ed. 2001); *see also* Dean and Michael Blazek, *Neon: The Next Generation* 12 (ST Publications, Inc. 1995).

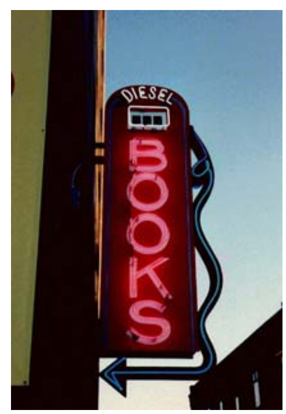
[8] *See, e.g.,* Marcus Thielen, *Learning the Trade – Becoming a Neon Signmaker in a Way That Works for You*, SIGNS OF THE TIMES (Feb. 10, 2006), available at **Attachment B-1**.

[9] *See*, *e.g.,* Marcus Thielen, *Neon 101 – A Simple Approach to Neon Basics*, SIGNS OF THE TIMES (Feb. 13, 2006), available at **Attachment B-2**

B. Neon Sign Attributes

A neon sign is a lighting display comprised chiefly of neon lamps—glass tubes filled with an inert gas (typically neon, krypton or argon) and shaped into letters, logos or other decorative designs.[10] Neon signs can be as simple as a small exit sign, or as complex as a multi-story facade on a building such as the marquee at Radio City Music Hall in New York City depicted at right. Neon signs and lamps are used both indoors and outdoors and come in a variety of styles and configurations. Outdoor neon sign configurations include:

Channel Letters–Three-dimensional letters that typically incorporate neon or LED lighting. In an open-channel letter, the light source may be exposed (only if neon is used). The light source (neon or LED) may also be placed behind a translucent plastic "face" that is fabricated to the contours of the letter. Backlighting for channel letters is one of the most widespread applications of neon in the sign industry.



Projecting Signs—Neon tubes are shaped into text or images and then affixed to one or both sides of a metal sign box that projects out from a building or other structure

Fascia Signs (or wall signs)—Neon tubes are shaped into text or images and designed to lie flat against a building façade;

[10] *See* NEON TECHNIQUES, *supra* note 6, at Ch. 3.

Outline Borders—Long neon tubes used to outline the edges of buildings, canopies, facades or other structures, often to match other neon signs; and

Marquees—Theater-type display, typically mounted on a special iron structure that projects over a sidewalk or entryway.

These configurations often can be combined; for example, the Radio City Music Hall sign mentioned above combines a marquee with a projecting sign. In addition, lighted neon tubes can be used to provide backlighting for signs constructed out of plastic sheeting, such as those discussed in Section IIIA. A wide variety of indoor neon sign configurations also are available:

Skeleton Sign—Continuous neon tube shaped into text and typically equipped with a framework of metal, glass, or solid plastic backing for mounting, reinforcement, and stability;

Indoor Box Sign—Neon tubes are mounted on supports with the electrodes insulated by small housings. The entire assembly, including the transformer, is packaged inside a small metal box, which is suitable for mounting on walls; and

Window Outlining—Long neon tubes similar to skeleton signs used to outline window borders, typically with colors designed to match other neon signs.

When used in neon lamps, mercury provides several unique performance characteristics that are unavailable with other lighting products. First, mercury-added neon lighting achieves a distinct character and intensity of light not available with fluorescent, LED or other light sources.[11] Mercury is also critical to the large palette of colors produced by neon lamps. The three major suppliers of neon sign tubing in the United States are able to produce approximately 50 colors (including up to 14 shades of white) with their products. For example, see the Color Chart from the EGL Company, Berkeley Heights, NJ, included as **Attachment C**.[12] Of these, less than 10% do not require mercury, in order to produce various shades of red, orange and pink. In contrast, the color palette that can be produced through the use of LED technology appears currently to be extremely limited. As the photograph to the left indicates, as well as a review of any website offering LED sign lighting alternative, the technology appears currently to be restricted to primary colors with some minor variations. For example, the photo at left illustrates the limited range of colors available from one of the principal manufacturers of LED tubing. In addition, LED products can only provide a choice of 4 shades in the critical white spectrum.

The availability of a wide spectrum of white shading is critical for several reasons. A broad range of white shades, which correspond to color temperature values, is necessary to properly render various colors. This is particularly important for those customers needing to complement or match existing signs or logos, or to comply with trademark or other intellectual property-related specifications. In the case of skeletal neon signs, a large range of whites is important for the same reasons a large palette of colors is important – it allows for greater artistic expression, flexibility, and product differentiation. When used as backlighting for channel

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[11] *See, e.g.*, Bill Dundas, *Lamps and Lighting: Understanding Specifications and Capabilities is Crucial for Effective Identity*, SIGNS OF THE TIMES (Apr. 1997), at **Attachment B-3**.

[12] *See also* color charts from Voltarc Industries, Waterbury, Connecticut, http://www.voltarc.com/NeonTubingStdColors.htm, *and* Tecnolux, Inc., Brooklyn, NY, http://www.tecnolux.com/index.php?option=com_content&task=category&sectionid=7&id=94&Itemid=72.

letters, the color temperature and phosphor composition of the white tube can dramatically affect the illuminated appearance of the diffuser material used – making, for example, for better matching of Pantone colors.[13] As a result, the color rendering capabilities of LED alternatives are significantly constricted when compared to neon sign products.

Fiber optic cables are used as a substitute for neon only in limited, specialty applications. These products do not approach the luminous intensity of neon, and the color palette ordinarily is restricted to a small number of primary colors that can be produced by filtering the light source through a color wheel.

Finally, unlike fiber optic cables or tubes internally illuminated by LEDs, neon lighting allows for the creation of shapes that require sharp bends and severe angles. LED and fiber optic products cannot be similarly formed without disrupting the light transmission, thus creating dark areas at the bends. It is neon's flexibility of color and shape, coupled with the high brightness and visibility benefits, which makes this lighting technology the preferred choice in a host of marketing, architectural and other uses.

C. Cultural and Historical Significance

Neon signs have long held a recognized place in American art, architecture and culture. The architectural and cultural importance of neon signage is increasingly being reaffirmed through various governmental and privately-funded efforts to protect, save, and restore neon signage of particular cultural and historical significance. For instance, the Nevada Historical Society has established a permanent exhibit entitled "Neon Nights" which highlights the history of neon signage in the state, beginning "just after the first interstate highways were built."[14] The Portland, Oregon Development Commission is proposing the creation of a Neon Sign District along Interstate Avenue to protect freestanding neon signs of historical significance which currently do not conform to sign code regulations (and thus could be torn down during future development).[15] And, the New Mexico Route 66 Association, in cooperation with the New Mexico Historic Preservation Division and the National Park Service Route 66 Corridor Preservation Office, has restored ten different vintage Route 66 neon signs as of 2003. *See* **Attachment D**.

One prominent example of neon art and architecture can be viewed at Chicago's O'Hare International Airport. The 1987 sculpture "Sky's the Limit" by Michael Hayden consists of over

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[13] *See, e.g.*, Dundas, *supra* note 11.

[14] The Nevada Historical Society exhibit consists of a fixed display at the Reno museum, as well as an online tour at http://dmla.clan.lib.nv.us/docs/museums/reno/exneon/neontext.htm.

[15] *See* Tyler Graf, *Bright Lights, Big Avenue*, DAILY JOURNAL OF COMMERCE (Portland, OR) (Apr. 14, 2008), at **Attachment B-4**.

23,000 square feet of mirrors reflecting over one mile of neon tubes.[16] This piece and many other examples of neon art, are on display throughout the world.[17] As discussed further below, the performance characteristics of neon lighting, which form the basis of this exemption request—the wide range of colors, superior light intensity, and the ability to create complex shapes—are critical to the creation of the works discussed above. From the foregoing, the importance of neon lighting as a medium for artistic and free expression is incontrovertible.

EXEMPTION REQUEST SUPPORT

The ISA requests an exemption from the use of mercury in neon sign applications on grounds that no technically feasible alternatives currently exist for such uses. Vermont's mercury reduction statute does not define what constitutes a "mercury-added neon type sign" for purposes of the state's ban.[18] State law, however, does define a "sign," in relevant part, as:

> …any structure, display, device or representation, either temporary or permanent, portable or ground-mounted, which is designed or used to advertise or call attention to any thing, person, business, activity or place and is visible from any highway or other right-of-way...[19]

The term "neon" is generally used to describe a specific sub-group of cold cathode low-pressure mercury discharge lamps.[20] The cold cathode family includes lamps that are used for diverse applications, including small lamps used as backlight for liquid crystal displays and neon tubes. There appears to be some confusion over the use of the terms "cold cathode" and "neon." Common industry practice is to refer as "Cold Cathode," larger-diameter mercury discharge tubes measuring between 18 and 25 millimeters (mm), and used primarily in architectural lighting applications such as cove lighting. While the electrodes used these tubes appear different those used in "neon" tubes, their operating characteristics are identical. "Neon" typically refers to the smaller-diameter mercury discharge tubes, measuring between 8 and 15 mm, and that are used for signs or skeleton tube lighting (building perimeters, etc.). In contrast, standard fluorescent lamps used for overhead lighting are classified as "hot cathode," low pressure, mercury discharge lamps.

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[16] *See Thinking Lightly Inc.*, *Michael Hayden Portfolio*, available at http://www.thinkinglightly.com/portfolio.cgi?item=HA07.

[17] For more examples and information on neon art, please visit the webpage of the Museum of Neon Art in Los Angeles, at http://www.neonmona.org.

[18] VT. STAT. ANN. tit. 10, § 7105(e)(1)(J).

[19] VT. STAT. ANN. tit. 10, § 481(6).

[20] *See, e.g.*, W. ELANBAS, LIGHT SOURCES, at 101 (Crane, Russak & Company, Inc., New York 1972).

Given the plain language of the Vermont "sign" definition, the ISA has significant question as to whether an indoor, cold cathode architectural or decorative neon sign that is not "visible from any highway or other right-of-way," is subject to the ban against "mercury-added neon type signs." Another question arises where a sign manufacturer uses a hot cathode or fluorescent lamp (which also contains mercury) to backlight a sign. It is unclear whether such a sign, which is not typically considered a "neon sign," would be a mercury-added "neon type" sign under Vermont's ban. In addition, novelty products such as clear phones that may incorporate mercury-added neon lighting also are not "mercury-added neon-type signs" under the Vermont statute. As mercury content restrictions in Connecticut, Louisiana and Rhode Island, however, apply more broadly to include all cold and hot cathode lamps, with limited exceptions, this ISA petition seeks an exemption solely for cold cathode, low-pressure mercury discharge lamps or tubes used in the sign categories set out in Section IB above.[21]

Obviously, the propriety of regulating commercial signs should be evaluated under First Amendment jurisprudence establishing a less stringent standard of review for commercial speech. Conversely, the broad mercury phase-outs and bans in these four states also necessarily govern the artistic and expressive use of neon lighting that is subject to the full panoply of protections afforded by the First Amendment.[22] This exemption request provides a less restrictive approach that is fully protective of both the environmental, health and safety concerns of the various state legislatures and the rights to artistic and free expression of neon lighting users.

II. Mercury is Essential to the Functioning and Utility of Neon Signs

"Neon" and cold cathode tubes used in neon signs are technically classified as low-pressure mercury discharge lamps, which are known to provide the most energy efficient forms of lighting currently available.[23] Common fluorescent lamps, amongst others, also belong to the low-pressure, mercury discharge class, but use a hot cathode. These lamps share one characteristic in common—they generally have fluorescent coatings (phosphors) on the inside of the tube that convert short-wave ultraviolet light into visible light of different colors. For all three types of lamps, the essential ultraviolet light is generated via the interaction of electrons

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[21] For example, Connecticut imposes a 100 milligram mercury content limit on all mercury-added products, except for specialized lighting used in the entertainment industry such as metal halide lights, and mercury containing lamps used for backlighting that are not easily removed by a purchaser. CONN. GEN. STAT. § 22a-617(a).

[22] *See, e.g., Mastrovincenzo v. City of New York*, 435 F.3d 78 (2d Cir. 2006).

[23] *See, e.g.*, Derek Phillips, *Daylighting: Natural Light in Architecture*, pg. 39,. Architecture Press, 2004.

with mercury species inside the lamp.[24] The major wavelength generated under normal conditions is the 254 nm mercury line, and most phosphors are developed for "excitement" (caused to emit light visible to the human eye) by this wavelength. Indeed, the only difference between "cold cathode" (neon sign type) lamps and "hot cathode" (standard fluorescent) lamps is the method used to introduce the electrons into the discharge. In all other aspects the manner in which they produce visible light is identical.

It is important to note that the use of neon gas alone only allows for production of light in shades of red and orange; this is because electrified neon gas produces a bright red light, which phosphors can only augment to certain shades of red and orange.[25] Thus, mercury is needed to produce the essential short-wave ultra violet radiation that excites the phosphors and results in colors outside the red to orange spectrum. Under discharge conditions, mercury will also produce visible light, mostly in the blue and blue/green range of the spectrum.

III. Technical Constraints Preclude the Use of Non-Mercury Alternatives

Non-mercury substitutes for neon signs can be divided into lighted and non-lighted alternatives. The various state statutes are silent on the extent to which billboards, wooden and other non-lighted alternatives must be considered and evaluated for purposes of this exemption. Clearly, one significant limitation of non-lighted signs is their limited visibility, particularly at night. Sign options may also be limited by custom or local ordinances enacted to preserve the historical or cultural identity of a local area. Signs illuminated via spotlights or other external forms of illumination do not provide visibility comparable to neon signs. In addition, neon tubes can be formed into the shapes of letters and logos, making the entire message a light source. As a result, neon signs are significantly brighter and more visible than any non-lighted signs. Moreover, neon lighting exhibits a penetrating characteristic that projects light over greater distances in a variety of atmospheric and weather conditions than incandescent or other forms of lighting.[26]

It is difficult to ascertain the extent to which conventional, fluorescent lighting, which contains mercury but is already exempted under relevant IMERC statutes, should be considered as alternatives in neon sign applications. The ISA notes, that a significant percentage of all electric signs are illuminated via standard, linear, fluorescent lamps. The vast majority of all electric signs are "cabinet signs" that incorporate a metal box inside which fluorescent lamps are

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[24] *See, e.g.*, W. Elanbas, Light Sources, Chapters 4 & 5 (Crane, Russak & Company, Inc., New York 1972)

[25] NEON TECHNIQUES, *supra* note 7, at 11-12, 20-26, 41; *see also* MICHAEL WEBB, THE MAGIC OF NEON viii (Gibbs M. Smith, Inc. 1984).

[26] *See Analysis – FAA/DOT Publications, Heliport Lighting for the Next Millennium, Results of FAA/DOT Research 1991-1998*, 12-17 (Litebeams May 2000), at **Attachment B-5**

placed to back-light plastic sign faces.[27] Although the ISA cannot readily provide numerical comparisons, the ISA estimate fluorescent usage to be double that of neon (*e.g.*, 30% neon, 60% fluorescent, 10% other types). Notwithstanding the wider use of fluorescent lighting in signs, neon lamps possess certain advantages which dictate their use in certain sign applications:

- Neon is a malleable light source whereas linear fluorescents are not;
- Neon can be used in exposed applications (i.e., where the light source is visible), whereas fluorescent lighting strictly is used in internal signs or where the lamps are shielded from direct view;
- Neon light sources produce a wide range of colors whereas fluorescent lamps are limited to various white shades plus a small number of other colors (*e.g.*, bug lamps, plant-grow lamps, black-lights);
- Neon lamps are dimmable and have the capability to be controlled by flasher devices (for special lighting effects), whereas fluorescent lamps do not;
- Neon lamps last much longer than fluorescent ones.

With regard to non-mercury alternatives, it is worth noting that signage decisions are the province of the sign purchaser (necessarily implicating thorny issues of free expression and artistic considerations) and not the neon sign manufacturer. Thus, to the extent that non-mercury alternatives are to be considered, we assume that for purposes of this exemption application they may be limited to those lighted sign technologies that impart the “look and feel” of neon signs. The ISA and the sign industry have identified only two non-mercury lighting technologies—fiber optic and light-emitting diodes (LEDs)—that are potentially viable as alternatives to neon technology. These technologies, however, lag behind mercury-added neon lighting in the three performance criteria that are most critical to neon sign users.

First, it is the discharge of mercury which produces the ultraviolet light needed to interact with the various phosphor coatings to create the broad spectrum of colors available to neon sign manufacturers.[28] Indeed, as many as 40 different colors and hues are available in mercury-added neon products.[29] Mercury use is also critical to shades beyond the 40 that are standard in the industry, which are on occasion produced for special effect by skilled sign makers using non-conventional combinations of glass, gas and phosphor coating.

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[27] A “face” is the plastic cover used in a channel sign.

[28] *See, e.g.,* NEON TECHNIQUES, *supra* note 7, at 20-24. The reasons for choosing certain gases over others in manufacturing neon lighting are mainly related to striking and running voltages and the environment in which the sign or lamp is designed to operate.

[29] *See* Section I.B, *supra* and **Attachment C**.

Second, brightness or luminance is a crucial factor in determining product performance and quality in the lighted sign industry.[30] For this reason, technologies such as fiber optics and LEDs are not considered acceptable as substitutes in a variety of applications.[31] It is axiomatic that as the brightness of an illuminated sign increases, so does its visibility. Thus, mercury is also critical in obtaining maximum brightness and visibility in lighted signs.[32] Indeed, following testing of next-generation heliport lighting systems by the Federal Aviation Administration and the U.S. Department of Transportation, the U.S. Park Police selected a mercury-based cold cathode heliport lighting system for its heliport.[33] The FAA and DOT analogized the cold cathode lights tested to neon signs and concluded that this mercury-based technology was a better replacement for incandescent lighting than lasers, LEDs, or fiber optics, for purposes of visibility at long distances, illumination, and color.

Third, while LED and fiber optic alternatives also allow for the formation of certain complex shapes and configurations, issues have arisen with regards to sharpness and consistency of illumination and brightness along the shape. We discuss each alternative in greater detail below.

A. Light Emitting Diodes (LEDs)

LEDs already are being used in a variety of traditional neon sign applications, including channel letter, outline border, skeleton, and indoor box signs. Manufacturers of these products generally attempt to replicate the uniformity and consistent look and feel of neon either by stringing several together and mounting them in a semi-opaque plastic flexible tube, or as part of a "module" of one or several individual LEDs mounted on a circuit board, plastic or other

[30] *See, e.g.*, Bernard Diffin, Ph.D., *Technology Advances in Neon Result in Bright, Efficient Light*, IMAGEMAKERS (July/Aug. 2006), at 48-51, **Attachment B-6**.

[31] *Id.*; *see also* Ventex Technology, Inc., *Ventex Powered Neon Outperforms Leading LED in Energy Efficiency and Light Output*, at **Attachment B-7**. The U.S. Department of Energy, in conducting testing on commercially available LED and other solid-state lighting (SSL) products, found major discrepancies between marketing claims and the actual performance of these products. U.S. Department of Energy, *DOE Solid State Lighting Commercial Product Testing Program, Summary of Results: Round 2 of Product Testing* (August 2007), 6-7, 13 (2007), available at **Attachment B-8**.

[32] *See, e.g.*, Kenny Greenberg, *A Channel-Letter Comparison*, SIGNS OF THE TIMES (May 2002), at **Attachment B-9**; Marcus Thielen, *Neon Visibility – Understanding the Basics of Light and Color Creates Satisfied Clients*, SIGNS OF THE TIMES (Feb. 8, 2006), at **Attachment B-10**; and Marcus Thielen, *LED or Neon? A Scientific Comparison*, SIGNS OF THE TIMES (Feb. 10, 2006), compiled at **Attachment B-11**.

[33] *See* **Attachment B-5** at 14, 16 n.2.

material. As discussed further in this section, however, LEDs in many instances cannot provide the flexibility, brightness, range of color and other options, and low cost available with mercury-added neon lighting.[34] There also is a need for the industry to standardize LED products, as the current variability of products from manufacturer to manufacturer makes it difficult for the industry to adopt LED technology.[35]

For example, a wide range of available light source colors is often very important when manufacturing or repairing channel letters for customers with logo or color specifications. While matching pantone colors in illuminated form is often difficult, the vast number of combinations of neon tube, colored semi-opaque diffuser material and translucent vinyl make near matches possible. In short, the diffuser material and translucent vinyl act as broad band filters that only allow certain light wavelengths to pass through for viewing.[36] Because the light emitted from phosphored mercury-containing tubes consists of several wavelength, (sometimes as very broad bands in the case of some whites), a large range of colors can be achieved.

Comparable color options are not attainable with the limited color palette of LEDs, and indeed, may be exacerbated when non-white LEDs are used. As all non-white LEDs are virtually monochromatic, emitting light in a very narrow band, the range of color and amount of light that the filtering materials allow through will be very limited, resulting in very low brightness and hence visibility. White LEDs, which usually contain a blue emitting diode with a yellow emitting phosphor, can as a result radiate across a fairly broad band in the green/yellow region plus a large narrow peak in the blue region. These can be used for backlighting colored plastics and vinyl, but this is not a very efficient process since much of light generated by the white LED is filtered out. Because LED channel letter modules contain discrete LED sources, they can create “hot spots” giving the letter or design a “patchy” or unevenly lit appearance. Thus manufacturers of LED products limit the types of vinyl/plastic rated by the lists of compatible LED vinyl / plastic combination published by some LED companies

We also note that LEDs provide only limited replacement for neon in the white spectrum. White neon tubes are available in color temperatures ranging from 2,400K to 8,100K.[37] In

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[34] *See* J.P. Freyssinier et al., *Evaluation of Light Emitting Diodes for Signage Applications,* Lighting Research Center, Rensselaer Polytechnic Institute, 4-7, 10 (2004), at **Attachment B-12**.

[35] Pacific Gas and Electric Company, *Codes and Standards Enhancement (CASE) Initiative, Draft Report: Requirements for Signs*, 14 (2007), at **Attachment B-13**.

[36] *See* Cyro Industries, *Acrylite GP, Acrylite FF: Light Transmission and Reflectance Technical Data Sheet*, p. 4, at **Attachment E**.

[37] EGL Neon Facts, *White and Colored Neon now 25 to 300% Brighter* at **Attachment B-14**.

contrast commercially available, white LEDs range from 6,000K to 7,000K.[38] White colors and shades are relevant when the neon tubing is visible, but also are important when the neon lamps are used as backlighting for plastic-face signs. As discussed above, sign designers do not have the same range of options with LEDs (in terms of matching sign-face colors with the light source) as they do when using neon. Variations in color temperature also are critical, however, in allowing lighted sign products to simulate the full spectrum of natural light, which permits desired lighting effects such as warmer "soft and fuzzy" lighted images or cooler, clinical, "corporate" styles.[39]

Industry tests have found similar or greater performance differentials when LEDs are compared to mercury-added neon lighting.[40] Industry testing suggests that neon is a substantially more efficient light source in terms of lumens per watt than LEDs in all other color spectrums outside the red.[41]

LEDs also are widely used in letters too small or narrow to house neon tubes and their associated connections. In some cases, LEDs are being used strictly to reduce maintenance costs (even in cases where efficiency or brightness may be inferior to neon). There is some question, however, as to whether LEDs in fact provide a lower maintenance alternative to cold cathode fluorescent lighting, in general, or neon, in particular. Although not directly on point, DOE testing of LED luminaires and other applications suggests that the life expectancy of these new products is generally unknown, but found that several factors could result in lumens depreciation over time, with significant decreases beginning after 5,000 hours.[42] In contrast, test data and long-term experience demonstrate that neon lighting will provide 20,000 to 30,000 hours of useful life, with anecdotal evidence of neon tubes lasting as long as 80,000 hours.[43] For example, the "open" sign at left was sold in 1992 (note date of manufacture), and as the ISA member who sold it indicates,

[38] We understand that some companies are now marketing "warmer," lower K white LEDs. Nevertheless, there are only two, possibly three color temperatures available, and does not compare to the up to 14 available for mercury-added neon lamps.

[39] *See, e.g.,* Dundas, *supra* note 11; *see also* Greenberg, *supra* note 32, at 2.

[40] *See* notes 30-32, *supra*.

[41] *See generally* EGL Neon News, *Dispelling the "Inefficient Neon" Myth* (Spring 2006) at **Attachment B-15.**

[42] *See* U.S. Department of Energy, *DOE Solid-State Lighting CALiPER Program: Summary of Results: Round 5 of Product Testing*, 20-23 (May 2008), at **Attachment B-16**.

[43] *See, e.g.,* Thielen, *Neon Visibility*, supra note 32; Thielen, *LED or Neon?,* supra note 32.

"it is still running strong:"

Even where LEDs provides a reasonable alternative to neon signs, the cost of the technology can be prohibitive, particularly for small companies. The Chart at **Attachment F-1** presents a cost comparison for a Budweiser sign one ISA member manufactured in Neon and LED neon "look alike." As the data shows, the actual unit costs for the signs were fairly comparable, with the neon sign slightly lower. The problem is that many business signs are not mass manufactured and require individual tooling for each sign. As the attachment illustrates, the LED Neon sign had to be injection molded at a significant tooling cost of $40,000. **Attachments F-2** through **F-4** provide other cost comparisons of neon and LED products by ISA members that sell both technologies.

B. Fiber Optic Technology

With respect to fiber optic lighting technologies, both fiber optic and neon units employ a colored light source that can be molded to a variety of custom shapes and forms. Given the basic differences between neon and fiber optics, the vast market for malleable lighting displays indicates that there may be many instances where fiber optic technology represents a sensible and desirable alternative to neon. However, fiber optic technology also presents several distinct drawbacks at the present time that hinder its ability to function as a complete substitute for all neon sign applications.

Most importantly, fiber optic cables, whether end-lit or side-lit type, cannot generate levels of light output comparable to neon. This relates to the basic difference in how light is generated by each technology. Fiber optic cable is strictly a transmitter of light from a remote source (typically a high-intensity bulb), whereas a neon unit itself constitutes the lamp and light source. For this reason, fiber optic cables are not suitable in applications where significant, ambient daylighting is present. This makes fiber optic cables primarily useful for interior applications or strictly for nighttime uses.

Both end-lit and side-lit fiber optic cables are utilized in signage and accent lighting applications. For example, smaller enclosed channel letters can be illuminated with end-lit cables installed through the letter backings, and larger channel letters and plastic-faced signs can be illuminated internally with side-lit cables arranged in rows. Side-lit cables can also be used in place of neon border tubing for cove lighting, or to accent or highlight buildings or other structures. End-lit cables are also used in exposed applications to form letters, or to create star-field displays. In addition, illuminated fiber optic cable are suitable for many applications where neon may not be possible or desirable, such as applications where a neon glass tube might face risk of breaking (e.g., under or near water, outdoor accent lighting that may be exposed to severe weather). None of these applications, however, offers light output or visual impact comparable to neon. For this reason, fiber optics continues to represent a very small percentage of all malleable lighting technologies currently in the marketplace.[44]

IV. Neon Sign Industry Efforts to Find Substitutes

Until fairly recently, the neon sign manufacturing industry was primarily a cottage industry made up mostly of businesses operated by one of two individuals. Over the past ___years, however, the industry has begun shifting towards larger, wholesale fabrication shops. This development portends a significant increase in research and development to address not only the environmental footprint of neon products, but also improvements in energy efficiency and other performance characteristics.

As discussed in the preceding section, LED and fiber optic technology are either being implemented or show some promise, but not in applications where color variation, light intensity, energy efficiency (non-red colors), and high-angle bends are critical performance requirements. As there currently appears to be no practical replacement for mercury in these applications, the industry is focusing on reducing the mercury concentration or "dose" used in each neon lamp. Two technologies show promise in this regard.

A. Hotfil Technology

As discussed above, neon lamps are examples of cold cathode tubes. This group of lamps is distinguished from the more common "hot cathode" tubes found in typical fluorescent lamps in that they are heated to incandescence during operation, which allows them to utilize less voltage than their cold cathode tube counterparts.[45] A hybrid product developed recently in Europe known as Hotfil (short for "hot filament," which describes the type of electrode used) attempts to combine the advantages of custom-made neon tubes with the operating characteristics typically seen in ordinary fluorescent lamps.[46]

We understand that early research suggests that Hotfil may in the future offer several key improvements over existing neon sign technology. Hotfil operates at a higher electrical current and offers amounts of brightness four to five times higher than neon lamps and signs. Importantly, because Hotfil also has a higher operating temperature than neon, it can employ marginally less mercury than a standard mercury-added neon tube product. Hotfil's substantially

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[44] *See* Bill Dundas, *Fiber Optics in the Sign Industry*, SIGNS OF THE TIMES (Mar. 1998), *available at* **Attachment B-17**.

[45] *See* NEON TECHNIQUES, *supra* note 7, at 26-27. Higher voltage levels are required in cold cathode tube products in order to attract enough electrons sufficient to trigger ionization within the tube; without ionization, no current will flow and no light will appear. *Id.* at 8.

[46] *See generally* http://hotfil.com/.

greater brightness raises some questions in terms of the specific applications where it might be an acceptable substitute for cold cathode neon. There also appear to be limitations to the length of tube that could be utilized in neon lamp applications. According to the Hotfil website, the maximum tube length for a 15 mm tube is 3.3 ft, which would severely limit the number of bends in a tube, and hence the complexity of shapes that are achievable.[47]

The ISA understands that the current cost for a Hotfil unit is 15-20% higher than its neon counterparts. There are other issues to consider. Standard hot cathode lamp manufacturers have been able to decease the quantity of mercury in their lamps mainly by the use of barrier coats on glass and/or phosphors. Such treatments are difficult to replicate in neon sign tubing, which is usually subject to high heat before bending. It is also the many bends in the average neon sign tube that can result in potential "cold spots" and "gravity traps" where liquid mercury can accumulate. As Hotfil uses hot cathodes, they are also very susceptible to early failure if not operated at a specific lamp current. In addition, Hotfil is in the early development stages, and whether it will in fact perform better than neon has yet to be determined. As a result, while initial indications appear promising, Hotfil technology is not yet at a point where it can be viewed as an adequate substitute for the vast majority of neon sign applications.

B. Pre-Dosed Electrodes

The EGL Company in Berkeley Heights, New Jersey and Eurocom Inc., in Irving, Texas manufacture and sell electrodes that incorporate mercury capsules containing pre-measured mercury doses.[48] The electrodes and tube are processed in the usual manner and the section is removed from the processing equipment. The capsule containing the mercury dose is then ruptured using a high frequency heating coil, releasing the mercury into the tube. Use of these products ensures an accurate, precise dose of mercury on every occasion and eliminates the need for any open form of elemental mercury in the sign shop. They also remove the risk of mercury contamination of the manufacturers' manifold and vacuum system.

Electrobits International (Quebec, Canada) also offers a similar product, but in the form of a capsule that is inserted into a side stem of the glass tubulation that connects the sign tube to the vacuum manifold.[49] After processing, the tube is removed from the pumping system in the usual manner, and the mercury capsule is ruptured. The mercury is rolled into the tube and the operator seals off and removes the section of tabulation containing the spent capsule. This spent capsule is intended to be disposed of in accordance with applicable disposal regulations.

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[47] http://hotfil.com/products.htm.

[48] *See* http://www.egl-neon.com/documents/merplus.pdf; http://www.eurocom-inc.com/Eurocom/HG+.html.

[49] *See* http://www.electrobits.com/index.asp?id=159.

We understand that there remain some lingering concerns over the use of these products in climates capable of reaching very cold temperatures. Issues surrounding cold weather performance, however, are not principally related to the use of pre-dosed capsules per se, but rather to the mercury concentration in the dose.[50] The determination of the minimum mercury dose needed is very complex and factors influencing the proper dose include: how well the sign has been processed (how clean it is); the size (MA-rating) of the electrode; the tube's diameter; running current; type of phosphors; gas fill pressure; and gas mix; among other contributors.

V. Mercury Dose Reduction

Historically, the neon sign industry had not developed a standard mercury dosing level for neon signs generally, nor dosing levels for signs destined for outdoor versus indoor usage. This circumstance can be attributed to a number of factors, including the historical inaccuracy of mercury injection methods and the conglomeration of small assembly shops. Despite these limitations, the industry long has sought to employ the minimum amount of mercury necessary to achieve the desired end product.[51] Thanks to improvements in the accuracy of mercury injection equipment, the advent of pre-dosed electrodes that obviate the need for mercury injection altogether, and the increasing prevalence of large sign fabricators entering the neon sign market, the neon sign industry as a whole is far better equipped to implement a comprehensive mercury reduction program than it would have been as recently as fifteen (15) years ago.

Through this exemption request process, the ISA proposes to establish and implement via its members an industry standard/certification program to ensure that neon sign products: (1) contain minimum amounts of mercury, not to exceed 100 mg per tube; and (2) are manufactured in accordance with a series of exacting best management practices currently under development.

While the industry recognizes that certain technologies may allow for lower mercury concentrations, several practical considerations prescribe the 100 mg limit. First, although large fabrication shops may be able to manufacture lamps and neon products with lower mercury concentrations, it is unrealistic to expect smaller shops to achieve these restrictions within the foreseeable future. Second, there are serious antitrust implications should the ISA recommend or advocate on behalf of a single technology or company. Third, commercial realities require that the industry not depend on a single or a few sources of supply.

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[50] Marcus Thielen, *Too Cold For Neon? How to Avoid Winter Dimming of Neon Signs* (2006), available at **Attachment B-18**.

[51] *See* NEON TECHNIQUES, supra note 7, at 162-63 (suggesting a range of mercury dosage from 50 mg to as high as 600 mg for a given neon sign application).

Accordingly, under this approach, a maximum mercury concentration of 100 mg per tube would be achieved either through the use of pre-dosed electrodes, state-of-the-art mercury injectors, or other recognized methodology. Such products would bear a certification label or other marking administered through a third-party certification organization. The ISA would initially develop the certification for implementation by an independent, third-party certifying body. Implementation may be initially funded by the ISA, but ultimately self-funding through certification costs. ISA's notion is that only certified neon products could be sold in the relevant IMERC states. Through its outreach and education efforts, IMERC would disseminate information about the hazards from improper disposal of mercury, IMERC requirements, and the growing number of states implementing these requirements. These outreach efforts would also educate industry members on the feasibility of making neon products with 100 mg of mercury.

The intent of this program would be to make certification affordable and open to all industry members, including non-ISA members, provided they comply with the maximum mercury limit, manufacture their products in accordance with best management practices, and otherwise comply with any condition of this exemption, including participation in end-of-life product collection and disposal of spent neon tubes. The ISA has begun to investigate how best to implement such a program and will provide information to IMERC as it becomes available.

VI. End-of-Life Collection and Disposal Systems for Spent Neon Signs

ISA understands that pursuant to IMERC review procedures, it may choose to develop and submit a collection plan after having been notified whether its application meets the other criteria for approval of the exemption request. In the interest of fully informing IMERC discussions on this application, however, ISA submits the following summary proposal.

It is important to remember that the neon signs under consideration in this request overwhelmingly are installed and removed by trained sign professionals. These professionals are subject to and familiar with hazardous and other waste disposal requirements associated with neon sign products. As neon signs break down and need to be serviced or replaced, the same technician or similarly qualified individuals who perform the installation generally are called on to remove the units. The removed signs are not immediately disposed of, but rather are taken back by the manufacturer who dismantles and recycles much of the components.

Until recently, neon tubes were not recycled at their end of life, but rather were disposed of as universal waste and in accordance with local regulations. The ISA has retained Veolia Environmental Services to begin developing a national program for collecting and recycling neon and other signs to the greatest extent possible. The Veolia proposal is included as **Attachment G**. The ISA intends that the greatest amount of mercury will be recycled rather than disposed of.[52] A second phase of this development process will conduct a broad survey of sign companies in New England to identify practical considerations and assist in developing a cost structure for this take back program.

VII. Conclusion

Neon signs offer several unique characteristics unavailable in other comparable lighted sign products. In addition, the neon sign industry is ready and willing to implement best management practices that would significantly lower the dosages of mercury in those neon signs requiring mercury usage, and no feasible alternatives to mercury-added neon signs are yet available as reasonable substitutes. No countervailing public policy reason exists to deny the Association's request, and doing so would unduly deprive consumers and the general public of a distinct type of artistry and decoration not found in any other comparable technology. Accordingly, for these and the remaining reasons stated above, the ISA requests that its Request for Exemption be granted on behalf of its industry members identified at **Attachment A-1**.

Should you have any questions concerning the ISA's Request for Exemption, please do not hesitate to contact me.

Sincerely,

Jean-Cyril Walker

Enclosures

cc: Rich Gottwald, ISA
Bill Dundas, ISA

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[52] *See* Veolia Environmental Services, *Proposal for Recycling of Fluorescent Light Bulbs, Ballasts and Associated Materials*, 16-17, 22-23 (2008).

ATTACHMENT A

INDUSTRY INFORMATION

A-1

ISA Member Companies for Which Mercury Exemption is Sought

ISA Member Companies—Mercury-added Product Notifications

1.) Barlo Signs International, Inc., 158 Greeley Street, Hudson, NH 03051
2.) Charles Signs Inc., 7856 Goguen Drive, Liverpool, NY 13090
3.) Clinton Signs, Inc., 1407 Empire Blvd., Webster, NY 14580
4.) Federal Heath, 2300 N. Highway 121, Euless, TX 76039
5.) ImagePoint, 445 S. Gay Street, Suite 100, Knoxville, TN 37902
6.) Kieffer & Company, Inc., 3322 Washington Avenue, Sheboygan, WI 53081
7.) National Signs, Ltd., 2611 El Camino Street, Houston, TX 77054
8.) North American Signs, Inc., 3601 W. Lathrop, South Bend, IN 46624
9.) Persona, Inc., 700 21^{st} Street S.W., Watertown, SD 57201
10.) Poyant Signs Inc., 125 Samuel Barnet Blvd., New Bedford, MA 02745
11.) Ruggles Sign Company, 308 Crossfield Drive, Versailles, KY 40383
12.) Thomas Sign & Awning Co., Inc., 4590 – 118^{th} Ave N., Clearwater, FL 33762
13.) Twin State Signs, 14 Gauthier Drive, Essex Junction, VT 05452
14.) Magellan Sign Corporation, 10 Cummings Park, Woburn, MA 01801
15.) Acme Sign & Plastics, P.O. Box 2977, Abilene, TX 79601
16.) Bee Seen Signs, Inc., 507 Babe Ruth Drive, Jefferson City, MO 65109
17.) Phantom Neon, 100 E. North St., Crawfordsville, IN 47933
18.) Hupp Neon LLC, P.O. Box 7730, Chico, CA 95927
19.) Green Sign Company, Inc., 1045 E. Freeland Rd., Greensburg, IN 47240
20.) Quality Sign Company, 5160 Sunbeam Rd., Jacksonville, FL 32257
21.) Tube Art Displays, Inc., 1705 – 4^{th} Avenue S., Seattle, WA 98134-1514
22.) North Shore Sign Company, 1925 Industrial Drive, Libertyville, IL 60048
23.) SignArt, Inc., 5757 East Cork Street, Kalamazoo, MI 49048
24.) Victory Sign Industries, Ltd., 2109 Lafayette Rd., Fort Oglethorpe, GA 30742
25.) Huron Sign Company, P.O. Box 980423, Ypsilanti, MI 48198-0423

A-2

Mercury Notification Approval

November 30, 2007

Mr. Bill Dundas
International Sign Association
707 North Saint Asaph Street
Alexandria, VA 22314-1911

Subject: Mercury-added Product Notification Form Approval

Dear Mr. Dundas,

Environmental agency representatives from Maine, Massachusetts, New Hampshire, and New York (the States) have reviewed the materials you submitted under the Mercury-added Product Notification requirements. This review was facilitated by the Interstate Mercury Education and Reduction Clearinghouse (IMERC). The information provided in your Notification Form, **dated October 10, 2007**, for International Sign Association satisfies the States' Mercury-added Product Notification requirements.

This approval covers the following companies:

- Barlo Signs International, Inc.
- Charles Signs, Inc.
- Clinton Signs, Inc.
- Federal Heath
- Imagepoint
- Kieffer & Co, Inc.
- National Signs, Ltd.
- North American Signs, Inc.
- Persona, Inc.
- Poyant Signs, Inc.
- Ruggles Sign Company
- Thomas Sign & Awning Co., Inc.
- Twin State Signs
- Fallon Luminous Products Corporation
- Fallon Neon Shanghai

As stated to ISA earlier, in order to most accurately submit total mercury information in future Triennial reporting years, the States request that you inform all companies filing through ISA to track elemental mercury use by weighing bottles of elemental mercury used to dose their neon lamps at the beginning and end of the reporting year. The weight difference should be submitted to ISA as their total mercury use for the year.

Currently, the states of Vermont, Rhode Island, and Connecticut prohibit the sale of neon signs as described in your Mercury-added Product Notification Form. For instructions on submitting an Exemption Application, please visit: **http://www.newmoa.org/prevention/mercury/imerc/phaseoutforms.cfm**

Please note that you are required to submit an updated Mercury-added Product Notification Form if there is a change in the information provided, or a Triennial Notification by April 1, 2008, if no changes occur before then. Information on total mercury in products sold during 2007 will be due as part of the Triennial Notification.

In the next few months, IMERC will be adding the data from your Mercury-added Product Notification Form to its "Mercury-added Products Database." IMERC will send you an email or letter asking for your review of the data prior to publishing it on the internet version of the database.

Thank you for complying with the States' Mercury-added Product Notification requirements. Please contact Adam Wienert at (617) 367-8558 x307 or awienert@newmoa.org if you have any questions.

Sincerely,

Lori Segall

Lori Segall, Massachusetts Dept. of Environmental Protection
IMERC Vice-Chairperson

cc: Enid Mitnik, ME DEP
Peter Pettit, NYS DEC
Stephanie D'Agostino, NH DES

Attachment B

Reference Articles

B-1

Marcus Thielen, *Learning the Trade – Becoming a Neon Signmaker in a Way That Works for You*, SIGNS OF THE TIMES (Feb. 10, 2006)

Learning the Trade

Becoming a neon signmaker in a way that works for you

By [Marcus Thielen] (02-10-2006)

Neon signs can't be machine-made. Thus, they will be handcrafted well into the future. Because it's quite labor-intensive, the neon trade has traditionally benefitted from recessions, which forced jobless individuals to seek new opportunities.

This month, I'll discuss ways to get started in the neon trade and pitfalls to avoid. But keep in mind, there's no right way to learn the neon trade. Because every situation is different, such learning techniques can't be generalized.

Many skills are needed

Neon signs come in various shapes, sizes and styles. Therefore, their fabrication requires different skills. In a small, neon signshop -- consisting of one to a few signmakers -- each person is generally skilled in all areas to complete multiple job tasks. In contrast, if you're a glassbender in a high-volume wholesale shop, your sole job may require repetitively bending the "e" in the word "beer" all day, every day.

In either case, your skills need to perfectly match the various job patterns in the neon-sign business. Because of the trade's variety, it's impossible to pinpoint, beforehand, the skills and education you'll require in your business setting.

Fig. 1: Sign service isn't a white-collar job. Here's an easily accessible roof sign comprising 8-ft. letters.

Small signshops typically divide their tasks into making neon tubes, and assembling and installing neon-sign components. Because special skills and expensive equipment are required, many small shops outsource their neon-tube fabrication and/or buy the tubing wholesale.

To learn the neon trade, you can take either the theoretical or practical approach. Taking the practical approach to training, a sign technician and service person must invest in training time and work with experienced people. However, an even better approach is to become an apprentice and learn the trade from a master sign electrician.

Anyone who's interested in starting an electric-sign business must observe the National Electric Code's (NEC) special regulations regarding neon installations (i.e. transformers according to UL 2161, see ST, *March 2002, page 56*), as well as consider the physical principles that apply to each job (see ST, *June 1999, page 22*), which are different from the principles associated with an average powerline or household electrician **(Fig. 2)**.

Building a neon sign (including metal and electrical work) requires familiarity with many materials and techniques. However, planning the construction, design and sale of a safe, working neon sign requires more know-how (see ST, *May 2001, page 24*). But keep in mind that you can't master every neon area at once. Learning this industry's ropes takes time.

Fig. 2: Sign electricians work on high-voltage circuits -- which are sometimes energized -- in awkward locations. Shown here is an electrician working from a 160-ft. elevation, bucket truck

Learning to make neon tubes

In the early days, neon glassmaking remained a closed society -- knowledge was passed down from father to son. But this changed after World War II, when the demand for neon signs exceeded the industry's capacity and the first, commercial, government-sponsored neon schools opened (see ST, *December 2001, page 20*).

Today, many commercial neon schools offer various classes, from three-day crash courses to six-month, intensive-training programs (see ST's *2002 Buyers' Guide, page 140*).

Contrary to the Old World **(Fig. 3)**, in the United States, no official document certifies a neon glassworker's skill. As private papers, neon-school certificates don't represent a common standard. Consequently, a person who applies for a neon-glassworker position typically must prove his/her ability and speed via a test given by a potential employer.

In the United States, it's common to scale glassbenders' payment based on speed -- measured in the number of bends per minute and pattern variations for a given number of bends.

It's not wise to establish your own neon shop before learning the craft. Even if you're an experienced neon tradesperson, setting up your own shop can present many possible pitfalls, such as insufficient ceiling height, insufficient electrical supply or the inability to set up a draft-free workspace (see ST, *October 1999, page 60*).

Fig. 3: A master neon glassblower attaches electrodes to a 25mm-diameter, cold-cathode tube spiral. The single tube's total length measures 27 ft.

Another way to learn the craft is through books and videos. However, without any assistance from an experienced glassworker, it's easy to improperly train yourself. Further, a neon school that claims it can train you to become a professional neon glassworker in only three weeks shouldn't be taken seriously. In this short time, you'll only learn the basics.

I suggest first taking a basic class in a neon school. Then, practice for several months on your own and return to school to attend an advanced class to correct mistakes and get up to speed.

In most neon schools, vacuum-tube processing isn't a major part of the curriculum. Learning to properly process a tube of any shape and size requires the development of feeling and an instinct for vacuum techniques -- intuition that can't be learned theoretically or from attempting a few times. Proper tube processing contributes to customer satisfaction because a neon sign's appearance and lifetime depend on its tubes' processing quality.

To learn proper tube processing for a variety of work coming in, start with a standard procedure (as demonstrated in the International Sign Assn.'s tube-processing video, available from ST Books, $75) and then vary slightly from case to case to see how your product and equipment react.

Neon signmaking requires participants to be knowledgeable in many fields. If you're interested in starting a neon business at ground level, it's probably best to start slowly by producing metal signage and outsourcing all glass and electrical work. In the meantime, keep learning about other neon areas on the job so you can handle all tasks later.

Several, new, small neon businesses have gone bankrupt because they started with all the niceties but had no experience in neon to run a company successfully

What Samuel C. Miller stated in his book, Neon Signs, nearly 70 years ago, still applies today, "Five things a good neon worker needs: Good materials, good tools, practice, practice -- and practice."

B-2

Marcus Thielen, *Neon 101 – A Simple Approach to Neon Basics*, SIGNS OF THE TIMES (Feb. 13, 2006)

Neon 101
A simple approach to neon basics

By **Marcus Thielen** (02-13-2006)

While waiting for a flight home from the International Sign Assn. tradeshow in Orlando, FL, I browsed the contents of a nearby bookstore, which stocked a series of Dummies books, including Computers for Dummies, Gardening for Dummies and more. With their simple, step-by-step instructions for learning various tasks, these books are quite popular. Thus, seeing that people generally favor quick and easy learning curves, this month, I'll provide a simple approach for readers with little or no neon-sign or lighting experience.

What is neon?

Precisely, neon is a gas. But to signmakers, neon refers to a custom-made, electric lamp that comprises gas-filled tubing. Some electric lamps -- those giving different shades of red light -- are often filled with neon gas. Thus, "neon signage" is the name given to such signs.

Excluding a few artistic exceptions, electric lamps, which are typically tubular-shaped glass bodies, are also called neon tubes. But why use glass? Glass and artificial lighting have been linked since the Middle Ages, and today, glass serves as the only material physically and economically capable of keeping neon gas pure inside a tube throughout its operational lifetime.

Fig. 1a: Letter-shaped neon tubes with electrical connections (electrodes) at the ends.

Fig. 1b: Here are the same tubes lit. The electrode parts, which are approximately 2 in. long, will not illuminate.

Because glass tubes for making neon are available in different sizes (from 8mm to 25mm diameter), various widths of the operating lamp's light line can be chosen to accommodate the application.

As in every electric lamp, the neon tube must also have two connecting wires to create a closed electrical circuit. The connections (also known as electrodes) between the electrical cables and gas inside the lamp are usually attached at the ends of the neon lamp's glass tube **(Figs. 1a and 1b)**. Only the shortest path between the neon tube's electrodes will be lit, so a neon lamp must have no "dead" sidearm. Consequently, a neon lamp must be made from a continuous piece of tubing.

Unlimited shapes

In contrast to off-the-shelf fluorescent lamps -- which are mostly straight and only available in a few standardized lengths and diameters -- the custom-made neon tube lamp can be shaped according to an application's constraints. Due to the continuity requirement, rendering complex logos or lettering in neon tubes can result in rather complex glass shapes **(Fig. 2)**. Note that, oftentimes, a neon tube lamp isn't flat, but rather, three-dimensional.

Tube shapes derived from a sign's design are given to a glassblower as a blueprint (i.e. glass pattern). Creating shapes from a straight glass tube requires skill and constant training. To shape glass, tubing must be heated to an almost liquid state. For lighting purposes, the maximum tube size is approximately 16 ft. long and 25mm in diameter.

Fig. 2: A typical window neon sign. The series of stars was made from a single glass tube; the connecting parts, which are dark, were painted black after the glass fabrication.

How a neon lamp is used

Because it can be custom made to suit an application, a tubular neon lamp has many uses. Although they pose a few technical limits, neon lamps offer the broadest range of colors (approximately 110 standard colors are available) and a very long lifetime (approximately 30,000 to 80,000 hours).

Similarly, neon generates more light for a given amount of power than incandescnet lamps or LEDs. Only fluorescent lamps surpass neon. Further, unlike incandescent or fluorescent lamps, neon tubes can be switched on and off continually, or dimmed, without affecting the lifetime.

Neon operates somewhat like bottled lightning as there's no metallic conductor (such as tungsten) between the tube ends, only gas. Just like atmospheric air needs a storm cloud's high voltage to break through and become conductive (so the lightning bolt can carry the electricity), a neon tube needs high voltage to start and operate.

Neon tubes can't operate directly from the 120V main line. A special neon transformer, which generates high voltage and limits power to the neon tube, prevents destructive effects. This special transformer (like the electronic type commonly used today) safely starts and operates the lamp.

A neon lamp itself shouldn't require maintenance during its lifetime. However, if damaged, the glass can be fixed and refilled with pure gas for a new lifetime of 30,000 to 80,000 hours. As every electric sign, a neon application needs periodic maintenance, especially when mounted outdoors. Dirt, dust and debris should be removed, and the electrical parts and connections require at least annual inspection by an authorized and experienced neon-sign electrician.

NEVER attempt to service a high-voltage electrical installation yourself, even if it's only a small, portable "beer sign".

How a neon lamp is installed

With the previous caveat in mind, a non-neon signmaker might create all structural parts and prepare a display for the required approval by a test institute or electrical inspector.

If all parts aren't listed by a nationally recognized testing laboratory (e.g. UL, ETL, CSA, etc.), field-installed neon tubing must be field inspected by the local authority having jurisdiction (AHJ), which is usually the electrical inspector in town, prior to operation.

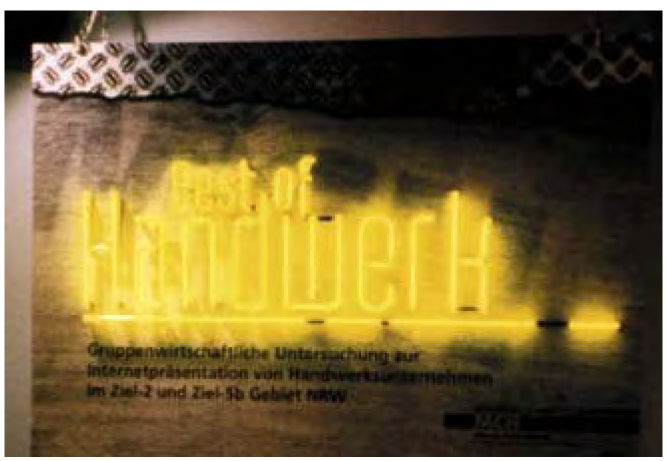


Fig. 3a: In these typical box signs, the electrodes protrude from the front mounting surface.

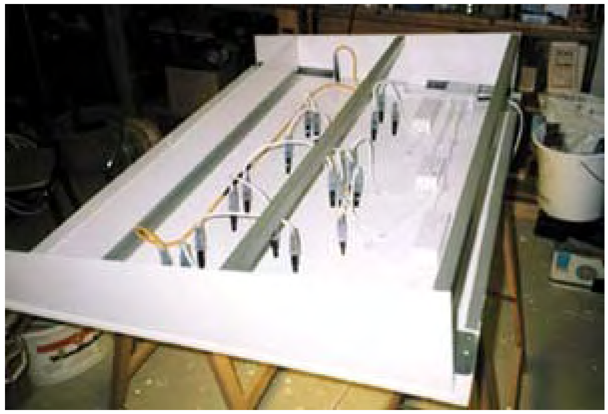


Fig. 3b: A backside view of the same sign in Fig. 3a. Notice the open box and electrical connections behind the front plate.

Neon-tube installations will vary due to design and intended use. In one common lamp form installed in front of a surface **(Figs. 3a and 3b)**, all electrical connections are made behind the surface. Special feed-through connectors, also called "housings," provide electrical contact for the tube and electrodes, and protect high voltage wires from accidental exposure to the user **(Fig.4).**

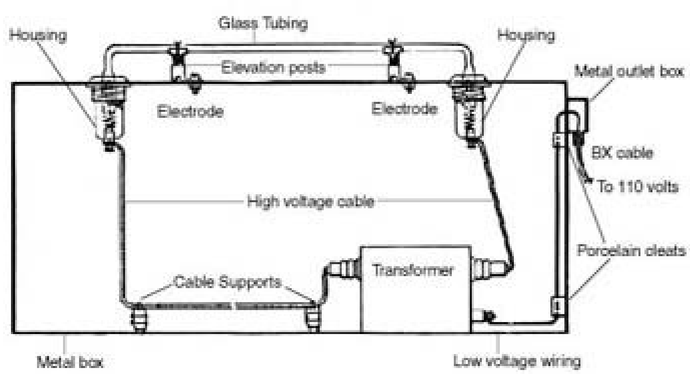
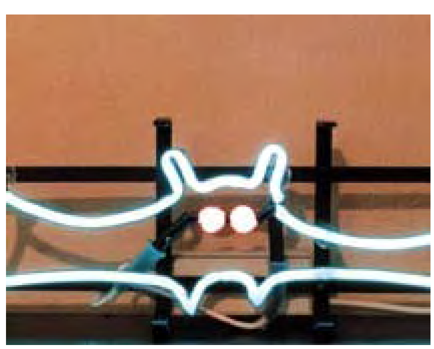


Fig. 4:A sketch of a common U.S. housing installation.

Finally, another installation technique is to install the electrical connections behind the visible plane of the neon tube; the high-voltage wire is twisted to the electrode leads. Further, a cap/cup of glass or plastic insulation material prevents accidental contact with exposed, high-voltage parts (Fig. 5).

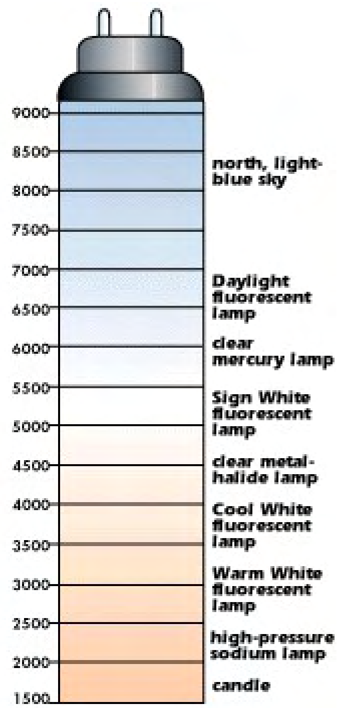


B-3

B. Dundas, *Lamps and Lighting: Understanding Specifications and Capabilities is Crucial for Effective Identity*, SIGNS OF THE TIMES (Apr. 1997)

Lamps and Lighting
The role of lamp color in sign illumination

By Bill Dundas (02-08-2006)



Cruising down Main St. after dark, you notice how different various signs appear, but you may not be aware that these variations have as much to do with the lighting source as they do with the color and type of translucent material. Lamp coloration is a vital component of the illuminated image. Not surprisingly, sign specifiers are quite particular about the lamp characteristics they select for major identity programs.

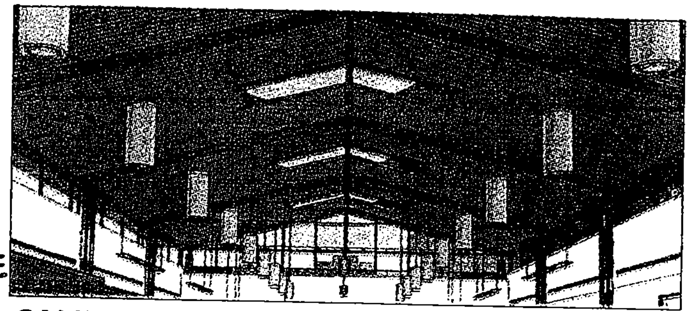
Specifications vary depending on the lighting effect the customer desires. Some users prefer a warmer, "soft and fuzzy" image, while others choose the cool, clinical, "corporate" look. The terms "warm" and "cool" describe the first major color characteristic of light - color temperature. The color temperature scale for lighting (see accompanying figure) is based on the color assumed by a piece of metal (technically called a "blackbody radiator") when heated to a given number of Kelvin (K) degrees. These colors correspond to the full spectrum of natural light, ranging from orange/red at the cool end of the scale to blue/white at the hot end.

Confusion arises because a lamp that appears "warm" emits light registering at the cool end of the color temperature scale. By contrast, "cooler" lamp colors register higher on the scale. This is because the "warm" and "cool" designations refer to the subjective way in which humans perceive these colors and their psychological effect, not the color temperature.

B-4

Tyler Graf, *Bright Lights, Big Avenue*,
DAILY JOURNAL OF COMMERCE (Portland, OR) (Apr. 14, 2008)

DJC



ON THE BOARDS

Fletcher Farr Ayotte is designing a new 30,000-square-foot Justice Center for the city of Lebanon. **Page 3**

THE DAILY JOURNAL OF COMMERCE, PORTLAND, OREGON

Bright lights, big avenue

The city proposes protective measure to keep Interstate Avenue's neon flickering

BY TYLER GRAF
tyler.graf@djcOregon.com

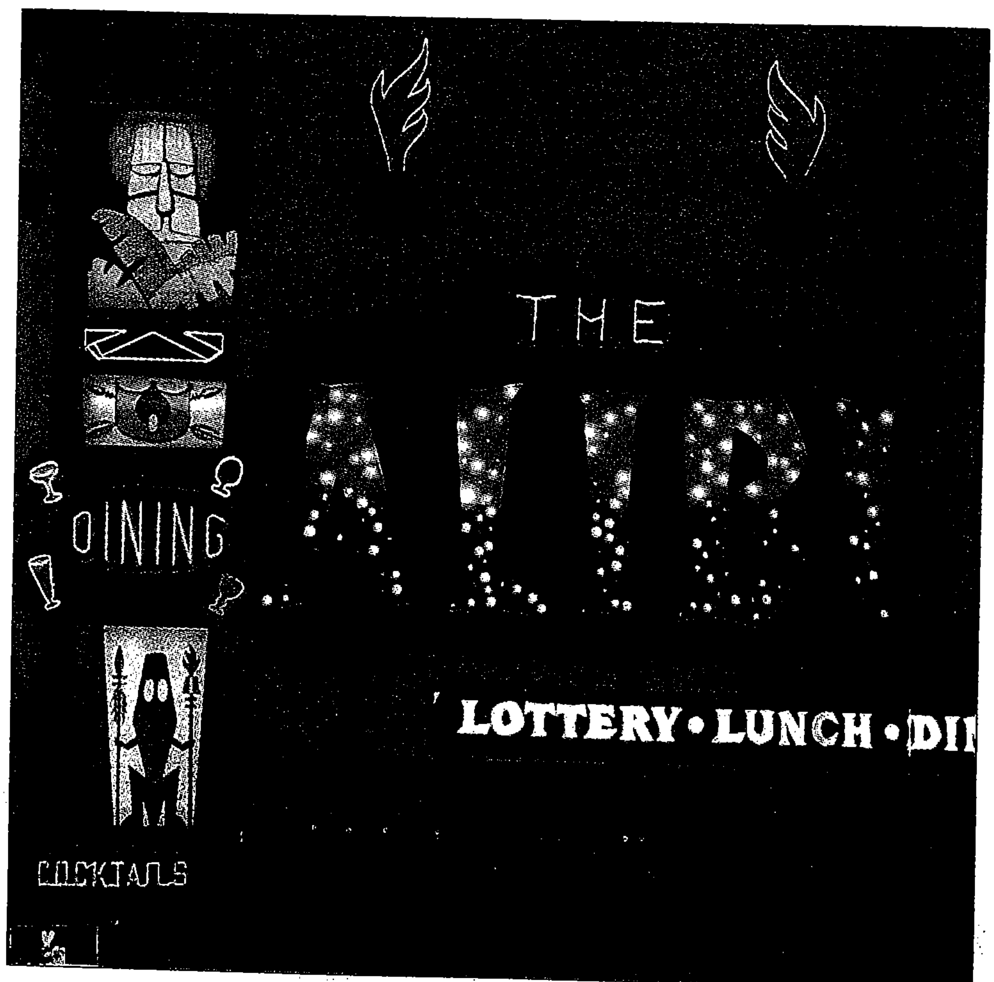
The night the lights go out on Interstate won't be anytime soon, if the city of Portland follows through with plans to create a Neon Sign District along Interstate Avenue – a corridor renowned for its mid-century luminescence.

The city is plush into its rezoning efforts along the avenue, which was once the main arterial north to Vancouver. The rezoning is intended to allow denser, mixed-use development along the corridor.

And, the Portland Development Commission says, the rezoning may even protect the area's plethora of colorful neon signs, such as the one that once adorned the Crown Motel, which came down recently and was placed in storage when the motel was razed.

As envisioned by the PDC, the Neon Sign District would stretch from the Overlook to Kenton light rail stations. A provision would be added to the zoning ordinance protecting the freestanding neon signs, which cur-

See NEON, Page 3



Dan Carter/DJC

The city is proposing the creation of a "Neon Sign District" along Interstate Avenue, which would help protect such neon luminaries as The Alibi's tiki-kitsch rooftop sign. Many of the signs don't conform to the corridor's codes.

Neon: Signs threatened by new and restrictive codes

Continued from Page 1

"When I-5 came around, that was a shockingly bad thing to do to a neighborhood. North Portland has always been the poor stepsister to the city."

– Sandy Duffy
Overlook resident

rently do not conform to sign-code regulations but continue to exist due to their "grandfathered" status.

Unless sign code regulations are changed, the renewed development along the corridor may threaten the signs' existence because the current code does not allow their removal and replacement.

Kevin Cronin, a project manager with the Portland Development Commission, says feedback on the sign preservation effort has been positive. And the PDC continues to recognize the need not only to protect the signs, but to allow them to prosper.

The sign atop the Crown Motel – having flickered and flashed its kitsch-level resplendence for generations – was saved earlier in the year by a group of enterprising retro enthusiasts called the Atomic Alliance, now known as the Mid-Century Modern League. The sign was going to be destroyed along with the motel, which was demolished to make room for new development.

Much of the energy expended to protect the rest of Interstate's signs has come from the organization and its vice president Alyssa Starelli, a Portland real estate agent.

Starelli says this isn't merely about saving "crappy signs" on "crappy motels," it's about keeping a part of Portland's history alive. The motels, restaurants and bars that line Interstate Avenue haven't changed much over the years, as the times have changed around them, but that's the way Starelli and her group like it.

With the right kind of development, she says, the avenue's motels could be turned into boutiques, citing the Palms and the Super Value Inn as prime examples.

"You just have to look at the Pearl District," Starelli said. "So much stuff went in there because big money decided it was the place to build."

For Sandy Duffy, a Multnomah County land-use attorney who grew up in the Overlook neighborhood, the neon signs represent a connection to the past – to a time before Interstate 5 redirected north-south traffic to the freeway system.

"When I-5 came around, that was a shockingly bad thing to do to a neighborhood," Duffy says. "North Portland has always been the poor stepsister to the city."

But after the freeway was built, she says, the neighborhood began to degenerate. It no longer thrived on vehicular traffic. Businesses left. People moved, including her in 1964. Prostitutes and drug dealers began to hole up in the motels and congregate outside the restaurants.

The neon began being associated with vice, she says.

Tod Swormstedt, of the American Sign Museum in Cincinnati, Ohio, says the roots-up support for sign preservation happens in communities across the nation, but he has never heard of a city enacting a Neon Sign District.

"There are numerous examples of historic neon signs being preserved when threatened by new and more restrictive sign codes," Swormstedt said. "Many times, there is a grassroots movement to preserve a local neon sign icon when city officials want to remove it."

Though the PDC says most residents are in favor of allowing the signs to thrive, a few neighbors have expressed dissatisfaction with the plan. One resident commented by saying it was inappropriate to glorify the energy inefficiency of the past by preserving the neon signs today.

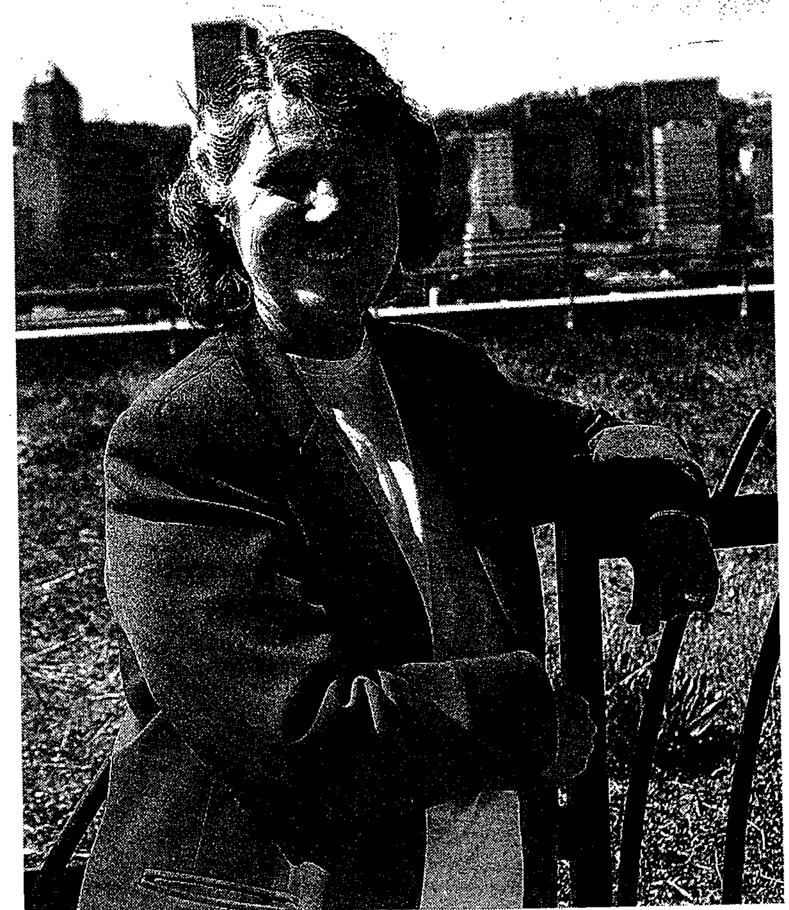
But Michael Mintz, who co-owns Portland-based sign company Neon It's a Gas, says the fear of neon, from an environmental perspective, is much ado about nothing.

"The newer electronic neon transformers use considerably less energy than the traditional, old-school core-and-coil (ones), due to increased resistance of copper windings," Mintz said.

He says solar-powered neon is in its early stages of development, and he's looking into whether it would be a viable option for Portland.

For Starelli, who professes to dislike any "modern" architecture, the aesthetic and historical value of the signs are worth their atomic weight in gold.

"They are just really incredibly awesome signs," Starelli said. "They are such a part of our American culture and part of Portland's history."



Dan Carter/DJC

Sandy Duffy has fond memories of growing up near Interstate Avenue in the 1960s. Once Interstate 5 was built, she says, the avenue fell on hard times, having lost its purpose as a north-south arterial.

B-5

Analysis – FAA/DOT Publications, Heliport Lighting for the Next Millennium, Results of FAA/DOT Research 1991-1998 **(Litebeams May 2000)**

ANALYSIS - FAA / DOT PUBLICATIONS

HELIPORT LIGHTING FOR THE NEXT MILLENIUM

RESULTS OF FAA / DOT RESEARCH 1991-1998

Introduction

Between 1996-1998 the U.S. Federal Aviation Administration, funded by a Congressional grant, sponsored a series of research studies to identify the newest and best lighting technologies for landing helicopters in the next millenium. Newer commercial helicopter designs feature larger aircraft with significantly increased load capacity, requiring changes in traditional heliport design to accommodate the new take off and landing capabilities heretofore available only to military customers.

Invitations were extended to multiple manufacturers, both within and outside of the U.S., to provide the newest lighting technologies for study, with the goal of improving and/or replacing existing incandescent landing lights for heliports.

Many research studies have been published by the FAA with regard to helicopter pilot activities during night landing operations. The definitive studies of the newest lighting technologies for use during helicopter night landing operations were published in a series of research papers published in 1998.

Summarized below are the results of the seminal research papers on this topic, as well as additional information that has since become available as the result of continuing research and development by Litebeams Corporation.

1. Guidelines for Integrating Helicopter Assets into Emergency Planning, DOT/FAA/RD-90/11, July, 1991, NTIS No. AD-A241479. (FAA Vertical Flight Program ARD-30)

During the decade 1980-1990, the use of helicopters in civilian and commercial operations expanded rapidly. One of the new uses for the helicopters was a greatly expanded Emergency Medical Services [EMS] base, nationwide. This guideline was the first coordinated attempt to consider all aspects of helicopter operations when responding to emergency situations. These guidelines contain "recommendations on how to best integrate helicopters into existing emergency planning in order to provide maximum protection and life saving services in the community."

On p.43 of the Guidelines, the subject of lighting is addressed. The subject, while of utmost importance, was given little attention. The entire statement regarding lighting is as follows:

"Lighting systems are necessary to support night operations, but they are usually only practical to install at permanent heliports. Portable lighting systems are commercially available and can be used at temporary facilities. Flares, vehicle lights, and other light sources are acceptable field expedients as long as they are deployed by trained personnel."

Comments

While extensive descriptions regarding the administrative and practical aspects of responding to an emergency with helicopter support are explored thoroughly, little or nothing is said regarding lighting requirements for night landing operations. A key statement used in this guideline is the permission granted, by this FAA sponsored study, to use "expedient" light sources, all of which have been used for many years. Use of "expedient" light sources, all of which contain a "point source" of light, are capable of inducing spatial disorientation in the pilot. This fact was not scientifically studied prior to 1991. Litebeams, Inc., through its R&D activities first introduced this concept to the Vertical Flight Program of the FAA in 1993-1994.

Additionally, the statement that "portable lighting systems are commercially available," while well-intended, did not mention that none of these lighting sources meet any reasonable standard for landing light effectiveness or safety. The primary reason for this lack of information was due to the fact definitive studies on helicopter landing lights had never been attempted. No information was available, and the researchers had no new information to report, other than what was being used, and had been used by helicopter operators, fire and police departments, etc., for many years.

2. Integrating Helicopter and Tiltrotor Assets Into Disaster Relief Planning, AC No. 00-59, November 13, 1998. (FAA Vertical Flight Program AND-710)

Due to the continuing increase in the use of helicopters in the U.S. and the introduction of the tiltrotor models, the FAA once again visited the subject of integration of the helicopter into emergency situations. The use of the helicopter, including larger aircraft with longer flight capabilities, significantly increased load capacities, improved take off and landing capabilities, and the ability to service multiple communities from a single location, made the updating and reissuing of these guidelines necessary.

The stated purpose of the new AC, "provides general guidance on integrating helicopters and tiltrotor aircraft into disaster relief planning efforts" is basically unchanged from the previous guidelines issued in 1991. There are many more additions to the original paper, presenting multiple administrative and management tools, including guidelines for community involvement.

In Chapter 5, Helicopter and Tiltrotor Landing Areas, Section 51 b. Safety Perspective, the statement is made "Safety is Paramount." Included in this chapter is Section 50 i, "Lighting." Once again the paragraph addressing this key issue is brief, however, it now contains a significant shift from the FAA's previous position as stated in the 1991 report above. The new statement is as follows:

"Lighting systems are necessary to support night operations, but usually, the installation of permanent lighting systems is only practical at permanent landing sites. Portable lighting systems are commercially available and can be used at temporary facilities. Flares, vehicle lights, and other light sources may be acceptable field expedients if trained personnel deploy them under very carefully controlled circumstances. To avoid the temporary destruction of the pilot's "night vision," special care must be taken in the placement and orientation of lighting."

Comments

The FAA, acting under newly published scientific information[1], for the first time has accepted the concept that a pilot's "night vision" can and will be affected by flares, vehicle lights and "other light sources." Current research has verified the fact that a "point source" of light, which emanates from a single intense origin such as an incandescent filament or a road flare, will physiologically affect the retina of the pilot looking at it by causing the appearance of an "after image" in the field of vision, a normal physiologic response to a bright or intense light. The "after image," a phenomenon experienced by all helicopter pilots, has been identified as a cause for the induction of spatial disorientation in helicopter pilots.[1]

In this document it is noted the FAA states expedient light sources can be used by "trained personnel." There is no reference to what "training" is involved, nor how such training can prevent the phenomenon of the occurrence of an "after image" in the helicopter pilot during night landing operations. The apparent disclaimer at the end of the paragraph, "To avoid the temporary destruction of the pilot's "night vision," special care must be taken in the placement and orientation of lighting." is incorrect in that it is not possible to use these light sources in any manner as to completely avoid the creation of an "after image" in the pilot's retina while using these lighting sources during night landing operations. By placement of this statement in the publication, it appears the FAA now openly embraces the concept of the ability of a "point source" of light to cause an after image, and possibly induce spatial disorientation in helicopter pilots.

Listed in Appendix B, "Outline of Elements for a Typical Helicopter and Tiltrotor Integration Plan" are multiple topics. Of interest to this review under section I (one) Establish Goals, subsection A "Guideline Goals," includes (1) save lives. In Section V (five) Landing Areas, subsection A "Selection criteria, no. 8 is "lighting." The FAA clearly recognizes the importance of including proper lighting at the temporary or emergency helicopter landing zone (HLZ).

While the FAA's position has shifted significantly since 1991, mention of the use of cold cathode lighting to completely avoid this problem was not included in this publication. This AC was issued by FAA's AND-710, and published concurrently with four additional research papers supported by AND-710. These four papers are reviewed below.

Heliport Lighting Research Conducted by the Science Applications International Corporation (SAIC) for FAA's AND-710

The following four papers were generated as a result of a research grant to the FAA's General Aviation and Vertical Flight Program under the sponsorship of AND-710, and whose office has since been reorganized. These research reports document the initial phase of an FAA/Industry effort to develop a cost-effective heliport lighting system for Global Positioning System (GPS) helicopter approaches. The reports include new technologies that could be employed in both the civilian as well as the military sectors. The research results add significant information and support for the use of cold cathode lighting technology for use at heliports, and airports as well.

[1] Schmidt, Reynold T., M.D., Reduce Risk of Inducing Spatial Disorientation Using Physiologically Compatible Ground Lighting, J. Aviation, Space, and Environmental Medicine, Vol. 70, No. 6, June, 1999, pp. 598-603.

3. Evaluation of a Heliport Lighting Design During Operation Heli-STAR, FAA / ND-97/20, June, 1998

The FAA was evaluating different lighting systems that could support precision instrument approaches to heliports using the Differential Global Position System (DGPS). Previous lighting systems developed by the FAA were determined not to be able to be installed at many heliports because of the lack of real estate available.

A prototype lighting system was developed and tested by the University of Tennessee Space institute, and after limited evaluation, was subjected to further evaluation as part of "Operation Heli-STAR," a demonstration helicopter transportation system established in Atlanta, GA during the 1996 Olympic Games. The prototype system used a 20-foot light pipe, green cold cathode lights, and electroluminescent panels.

As part of the heliport approach lighting requirements, "during the course of an instrument approach, the pilot had to perform a series of tasks. At or before the decision waypoint (DWP) the pilot will have to visually acquire the landing environment, transition to a visual scan, and proceed to a safe hover and landing." "The required visual cues are:

- visual acquisition of landing environment
- horizontal reference (horizon)
- lineup
- closure rate
- glideslope
  - relative altitude
  - obstacle clearance
- touchdown."

The results of the study revealed that cold cathode lights provide sufficient illumination of the heliport, making installation of incandescent flood lights unnecessary. The electroluminescent lights did not provide useful acquisition, closure rate, or lineup cues.

Conclusions of the study included:

- The lights appeared to be suitable for VFR and perhaps IFR as well. They appeared to be cost effective and could be arranged to fit typical heliport sites.

- The acquisition cues provided by the prototype lighting system are very strong and appeared to be suitable for most heliports. The color characteristics of the lights were unique to the well-lit city environment and they were easily identified in the midst of a variety of typical city lights. Their unique characteristics also improved the ease with which the pilot maintained visual contact with the heliport environment and significantly increased the amount of information provided to the pilot as compared to conventional incandescent heliport lights.

- In clear weather the cold cathode lights provide ample translational cues to support the transition to a hover, the hover itself, and land tasks, without the use of additional floodlights. (No data were available in anything other than clear weather.)

In the section "Some Recommendations for Further Work" key statements included the following comments:

- Light Pipe

  There were numerous concerns listed including what would be the proper height of the pipe, the proper distance from helipad to place the light pipe, the necessity to have two light pipes, the proper angle of approach and the correct placement of the light pipe to provide useful line-up cues, the concern that improperly installed the light pipe may pose a risk to flight operations. These concerns resulted in the conclusion that use of a light pipe would be very limited, if used at all.

- Electroluminescent Panels

  These units were judged not to be significant enough to warrant any additional research.

- Cold Cathode Lights

  The potential value of the cold cathode light was recognized immediately. The following points were posed as considerations for further study:

  - What is the optimum and minimum number of lights required for proper heliport lighting?
  - Can cold cathode lights be used to provide easily identifiable "lead-in" lights to lead the pilot to the heliport from a point that is farther away from the heliport than the existing visibility? If so, what is the best configuration for these lead-in lights?
  - Can a line of cold cathode lights spaced at specific intervals be used as close rate cue?
  - How well does the light from the cold cathode lights penetrate weather? Is it equal to, better than, or worse than conventional incandescent light?
  - How well do the cold cathode lights perform in the presence of snow, ice and frost? These lights are more efficient (than incandescent lights) because they do not "waste" energy in the generation of heat. This may be a serious disadvantage in cold climates. Will temperature-activated heaters be required? Should these lights only be used in mild climates?

At the end of this limited study, the prototype system was moved to Washington, D.C. for further evaluation. This was carried out at the United States Park Police Heliport in Washington, D.C.

Comments

During this demonstration, the cold cathode lights performed very well, and were unanimously recommended to be considered for further study by all pilots and other FAA personnel involved with this project. The questions posed in this demonstration project Operation Heli-STAR regarding the usefulness of employing cold cathode lights at heliports were answered in subsequent FAA demonstrations and further research conducted by the Litebeams Corporation.

4. Heliport Lighting - Technology Research, FAA / ND-98-1, November, 1998.

This report documents an initial part of a comprehensive program to develop a cost-effective lighting system to support GPS instrument approaches to heliports. This report specifically identifies lighting technologies suitable for use now and those for potential future systems.

The report states the problem to be stated in this manner: "In addition to the constraints of location, the approach lighting array must provide for the following items:

1. Acquisition of the heliport after breaking out of the weather. Although designed for a precision approach, the array should also permit acquisition of the heliport after breaking out from a non-precision approach as well as during visual conditions.
2. Safe Lineup and vertical guidance to the hover point over the helipad.
3. Spatial orientation during the visual segment to include:
    a. Depth perception of the pilot.
    b. Vertical orientation to prevent pilot vertigo.
4. Closure rate on the helipad.
5. Visual cues for final flare and touchdown.

In Section 3, Lighting Technologies, the researchers state in part: "By considering (and taking advantage of) the physiology of the human vision system, effective designs that provide an improvement over the present state-of-the-art can be produced. Perceptions of brightness, movement, color, contrast, and depth should all be involved to the greatest "scientific" extent possible in developing a suitable lighting system."

The following lighting systems technologies were evaluated, and their advantages and disadvantages summarized:

- Electroluminescent Lighting
- Visible Lasers
- Light Pipe or Light Bar
- Strobe Lights
- High Intensity Strobe Beacon for Acquisition
- Flush Surface Lights
- Flood Lights - Surface Mounting
- Perimeter Lights
- Pulse Light Approach Slope Indicator (PLASI)
- Cold Cathode Lights

While many of the above technologies offered valuable advantages, most had inherent disadvantages that outweighed their usefulness for wide deployment. The comments on cold cathode lights appeared quite promising:

"Advantages:

- Low initial cost
- Can operate using battery power
- Portable installation

- Does not degrade the pilot's night vision

Disadvantages:

- Low intensity"

In Section 5, Conclusions (Criteria for Test), an in-depth discussion of the key factors necessary to include if additional testing is carried out included the following factors:

- Acquisition
- Approach (line-up)
- Approach (glideslope)
- Closure (rate)
- Landing (flare, hover and touchdown)

Two specific final recommendations were made by the researchers:

1. "The possibility of enhancing the proposed lighting systems with the application of color should be explored.

2. In order to enhance the closure rate cues, the possibility for emphasizing pad texture by special marking (that is compatible with the installed lighting system) should be explored."

Comments

For the first time in its history the U.S. FAA officially addressed the physiology of the human visual factors which are of key importance for the helicopter pilot's operational requirements. The statement "By considering (and taking advantage of) the physiology of the human vision system," indicates that Litebeams' research contribution to the study and understanding of one cause of spatial disorientation (a "point source of light") was accepted as a valid percept / concept.

A second major point made by Litebeams research efforts focused on the "color" (nanometer range) of the light required to offer superior performance in night landing operations. The recommendation to explore the "color" of the landing light represents a significant step forward by the U.S. FAA in reaching the goal of developing the proper helicopter landing light. This recommendation supported the independent research conducted by Litebeams Corporation regarding this important physiologic factor of human visual requirements during night operations.

The second recommendation regarding targeting a light source which may emphasize helipad texture was another important feature that was successfully addressed by Litebeams cold cathode lights in a later project in this series.

5. Heliport Lighting - Configuration Research, FAA ND-98-2, November, 1998.

This report develops a methodology for researching and designing heliport lighting systems with particular emphasis on lighting system configurations. The report also catalogs lighting system components, subsystems, and systems identified to date. The main objective of this effort was to develop a basis from which to form a more efficient lighting system for instrument approaches to heliports using the Global Positioning System (GPS).

Review of existing heliports revealed that heliports of many different designs are found in a large variety of environments and simplification is very difficult. In addition, this study showed that the environment can have a significant effect on the relative importance of each lighting cue. Under clear daylight conditions, all the required visual cues were generally available. Under reduced visibility conditions, including darkness, the availability of the required cues varied with the environment. In the absence of a natural horizon, often encountered in approaches to very dark areas, the horizon cue may be the most critical for the designer to supplement. In an urban environment, the large number of lights provides a relatively high ambient light level and a strong natural horizon. In urban environments, obstacles may mean that glideslope cue is the critical lighting cue.

For purposes of this study, heliports were grouped into one of three groups:

- Rooftop
- Ground-Level / Off-Airport
- Ground-Level / On-Airport

Required lighting cues were identified as follows:

- Visual acquisition of the landing environment to include:
  - Identification as a heliport
  - Early acquisition in conditions of reduced visibility
- Lineup
- Closure rate
- Horizontal reference (horizon)
- Glideslope, that provides:
  - Relative altitude
  - Obstacle clearance
- Touchdown, which includes:
  - Transition to hover and hover position cues
  - Hover altitude and hover altitude rate cues

The report reviewed present conventional lighting and found that visual cues can be provided by a variety of methods. The research revealed lighting systems often provide multiple cues. Some of these cues are weak and may not be sufficient to fully satisfy a specific requirement. Also, some of these lighting systems may have undesirable attributes, such as poor maintainability, high life-cycle costs, a requirement for excessive real estate, interference with other lighting systems, interference with pilots' night vision, a tendency to cause pilot disorientation, or they may introduce a potential obstruction hazard. A detailed analysis is provided in Table 1, p.14 of the report.

- Qualitative characteristics of heliport lighting were examined carefully. The key qualitative aspects were summarized as follows:

  - Discrimination: the range at which the display can be discriminated from other displays
  - Intelligibility: can the display be understood?
  - Interpretability:
    - How difficult is the display to use?
    - Does the pilot have to interpret the displayed information or is it intuitive?
  - Responsiveness: is there time lag in the displayed information?
  - Simplicity
  - Visual Compatibility:
    - Is the display compatible with other aspects of the pilot's total visual task?
    - Is it much brighter or dimmer than ambient lighting conditions?
    - Is the display compatible with each segment of the approach?
  - Based upon the results of research to date, workload is a qualitative characteristic that should be included in the evaluation of a lighting system or display. Workload is dependent on some of the quantitative measures, such as resolution and sensitivity, as well as some of the qualitative measures, such as interpretability and intelligibility. There are measures to quantify workload, but a typical pilot response to high workload is fixation on one display or task, or the dropping of one display or task from the pilot's scan.

"Most lighting systems used to date have employed incandescent lights in one form or another. Two exceptions that come to mind are Xenon flash tubes and electroluminescent (EL) lighting, although there may be others. The lighting at aviation landing sites has been primarily incandescent. Recent research efforts have attempted to review alternative lighting technologies. Some have been around for years and have not previously been used in the aviation field, and some are relatively new technologies that have only recently become cost effective. A number of these alternative technologies show promise as potential components of heliport and vertiport lighting systems."

It was not possible for the researchers to thoroughly evaluate all of the lighting components and subsystems identified in the report. The lighting technologies were grouped into three major groups: (1) point source lights, (2) diffused lighting technologies, and (3) retroreflective markers.

- Point Source Lights

  "Point source lights are characterized by a very bright point of light typically generated by a glowing filament or arc. These lights are most often shielded from direct view by a pilot because of the negative impact on night vision adaptation and because of the "after-image" effect. If a bright light is viewed directly, it often leaves an after-image on the retina that continues to be seen for several seconds or longer. If incandescent lights are not shielded, they are typically filtered with color lenses, or directed away from the pilot. Exceptions to this are approach lighting systems where hundreds of 300-watt incandescent lights are aimed at the pilots of approaching aircraft."

Point Source Lights reviewed included:

- Light emitting diodes
- Lasers

- Diffused Lighting Technologies

  Diffused lighting technologies reviewed included:

  - Light Pipe
  - Cold Cathode Lights
  - Electroluminescent (EL) Lights
  - Fiber Optics

- Retroreflective Markers

Each type of light source was described briefly. The description of cold cathode lights was very complete, and is as follows:

"Cold cathode lights also provided a light that is very different from the incandescent "point source" lights found in urban environments and from those commonly used in aviation lighting. These lights use a gas filament that tends to disperse the light instead of a hot metal filament that burns an after-image onto the retina. Consequently, the lights leave very little, if any, after-image even after looking directly at the lights. The cold cathode lights are effectively monochromatic, and the lights tested in a prototype heliport lighting system had a greenish hue with a predominant wavelength of 512 nanometers. This wavelength (color) was selected to maximize the efficiency of the eyes' rods and cones at the low light levels encountered in nighttime aviation (reference 6). Since these lights can be viewed directly without adverse effects on pilot vision, they were used to outline the perimeter of the landing pad and to provide illumination of the landing surface. The cold cathode lights had an added advantage in that they did not require dimming as the pilot got closer to touchdown. Thus, the same light intensity setting was used to provide long-range acquisition cues and touchdown cues.

The cold cathode lights have advantages in power consumption and reliability. The cold cathode lights convert 65 percent of their power to light while 35 percent is lost to heat. Incandescent lights convert only 5 percent of their energy to light and 95 percent is lost to heat. This is an efficiency factor increase of 13. The cold cathode lights also have a considerable maintenance advantage over conventional incandescent lights. The cold cathode lights have an approximate lifetime of 20,000 to 40,000 hours compared to a lifetime of about 2,000 hours for the incandescent lights."

- Lighting Configurations

Lighting configurations were explored in great detail. An listing of the considerations reviewed is as follows:

- Acquisition
  - Acquisition Cues
  - Acquisition Design Considerations

- Line-up
  - Line-up Cues
  - Line-up Design Considerations
- Glideslope
  - Glideslope Cues
  - Glideslope Design Considerations
  - Horizon
  - Horizon Cues
  - Horizon Design Considerations
- Closure Rate
  - Optical Expansion Rate
  - Optical Flow Rate
  - Optical Edge Rate
  - Use of a Glideslope Indicator to Interpret Closure Rate Cues
  - Alternative Closure Rate Cues
  - Closure Rate Design Considerations
- Touchdown
  - Touchdown Cues
  - Touchdown Design Considerations

In the discussion of Touchdown Cues, Section 7.6.1 in the report, the following paragraph is of importance:

"Point source lights, used to outline the perimeter of a landing pad, do not adequately illuminate the texture of the landing surface. If point source lights are made bright enough to provide useful approach cues, they are too bright to be useful as a hover aid. The brightness of the point source prevents the pilot from seeing the surrounding texture and leaves an annoying and often disorienting "after image" in the pilot's view. Radio control of lighting intensity is often used to mitigate this problem although it adds to the pilot workload. (Cold cathode lights have also shown promise in solving this problem)."

In Section 8.0 Heliport Lighting Systems, Section 8.2 Operation Heli-STAR was discussed, and a summary of key elements which were learned and published previously in a report by these researchers in June, 1998, were restated. It is significant that the researchers felt compelled to repeat, to re-emphasize, and to add some information not published previously in the June, 1998 report. Important statements include the following excerpts:

- "Acquisition. The prototype system provides easy acquisition of the landing environment at ranges out to 20 miles in clear weather. Identification of the heliport is provided by the unique color (green) and the unique character of the cold cathode lights and light pipe. The same intensity setting that provides acquisition cues out to 20 miles does not adversely affect pilot vision in a hover over the pad. No dimming is required."

- "Closure Rate. In clear weather, the high ambient light levels and the well-defined landing zone provided adequate closure rate cues."

- "Touchdown. In clear weather, the cold cathode lights provided ample translational cues to support the transition to a hover, to hover itself, and landing tasks, without the use of additional flood lights."

The report concluded that the most promising candidate lighting components and lighting systems should be tested in a variety of operational environments and under a variety of different weather conditions at different times of the year. The report states also that "if possible, test locations should be chosen that allow a wide variety of industry helicopter pilots to participate in this flight testing."

Comments

This report provides an extensive analysis of the factors a design engineer is required to analyze when configuring a heliport. It is evident that multiple, complex issues have to be carefully considered and planned for. The report clearly emphasizes the reality that all heliports are not the same, and that each to has to be configured in its own setting for proper planning purposes.

What this report does do is to review the existing heliport lighting systems and to compare them to selected newer lighting technologies, weighing their advantages and disadvantages regarding the complexity of issues facing the design engineers.

Taking the information provided by this report in its totality, cold cathode lighting is very favorably reviewed, and key features of the cold cathode lighting technology are advanced for consideration. These features include:

- Not a "point source" of light - a critical safety factor for prevention of pilot disorientation. The cold cathode lights were determined to be able to be viewed "directly" by the pilot without adverse effects on pilot vision.

- No Dimming Requirement - the lights have a major advantage in that they do not have to be dimmed (decrease the brightness) for the pilot during landing operations. The same light setting (light intensity/brightness) can be used for both long-range acquisition cues as well as for touchdown cues, in contrast to incandescent lights.

- Cost effectiveness - when compared to the incandescent light the cold cathode lamp is truly superior in this aspect.

- Visibility - the pilot is able to "acquire" or view the cold cathode light from at least 20 miles in clear weather, a major accomplishment. This was stated to be due to the "unique green color" within the nanometer range of 512 nm. Litebeams researched and developed this light for this specific purpose.

- Closure Rate - in clear weather conditions the light provided excellent ambient light levels that defined the HLZ clearly and provided "adequate closure rate cues," a very significant necessity for safe approach and landing operations.

- Touchdown - in clear weather the cold cathode light provided "ample translational cues" which allowed the pilot to safely transition from flight to hover, from hover to landing "without the use of additional flood lights." Thus, the cold cathode lights illuminated the helipad to such an extent they allowed for safe operating procedures without the necessity for supplying auxiliary lighting, i.e., floodlights.

None of the other lighting sources reviewed possessed all of these characteristics in a single light source.

6. Heliport Lighting - U.S. Park Police Demonstration, FAA ND-98-4, November, 1998.

This report reviews a second demonstration project in the initial phase of an FAA/Industry effort to develop a cost-effective heliport lighting system for Global Positioning System (GPS) helicopter approaches. This demonstration utilizes new technologies that could be of use as part of a heliport lighting system as well as military lighting systems that could be useful if optimized for civil heliport applications. This report also documents previous research that has attempted to determine what helicopter pilots need in the way of visual cues for heliport approaches at night or in poor weather.

- <u>Background</u>

  "This demonstration/evaluation of prototype heliport lighting system components was part of a larger effort to research the requirements for lighting systems to support precision approaches to heliports. The heliport/vertiport precision instrument approach lighting system must provide or enhance the visual cues necessary to safely acquire the landing environment, decelerate, and land during the visual (final) segment of an IFR precision approach. This visual segment of a helicopter instrument approach is very different from a fixed-wing visual segment. The major difference is the requirement for the helicopter pilot to decelerate to a stop while maintaining a constant glide path.

  The lighting system, in addition to providing or enhancing cues for heliport acquisition, lineup, horizon, glideslope, and touchdown, must provide the pilot with strong closure rate cues. In comparison with airport lighting systems, all of this must be accomplished by lighting equipment located in a very limited physical space. Based on the success of a VFR prototype system demonstrated in conjunction with Operation Heli-STAR, it was decided to continue the demonstration/evaluation at the United States (U.S.) Park Police Heliport in Washington, D.C. "

  The report states in part: "Well-designed lighting systems (at heliports) can provide "credits" that reduce required visibility minimums for instrument flight rules (IFR) approaches. The approach lighting system should "reach out" from the landing area, assuring the pilot that a landing site is ahead, and visually guide a pilot to this landing site."

  "Flight tests conducted for the Federal Aviation Administration (FAA) by the University of Tennessee Space Institute (UTSI) and Science Applications International Corporation (SAIC) identified new technology lighting systems with great potential to meet the requirements for IFR approaches to heliports. Initially, these lights were briefly evaluated in a downtown environment.

The color characteristics of the cold cathode lights were so unique to the well-lit city environment that they were easily identified in the midst of a variety of traditional city lights. These unique characteristics also improved the ease with which the pilot maintained visual contact with the heliport environment (simulated during these tests) and significantly increased the amount of information provided to the pilot as compared to conventional incandescent heliport lights. These tests were sufficiently promising that the FAA decided to evaluate these lights in an operational city environment. The system was modified slightly and installed at the United States (U.S.) Park Police Eagles' Nest Heliport in Washington, D.C."

- U.S. Park Police Aviation Section - Eagles' Nest Heliport, Washington, D.C.

  "The U.S. Park Police Aviation Section is currently the only public service aviation provider within the District of Columbia. Its missions include aviation support for law enforcement, medical evacuation, search and rescue, high-risk prisoner transport, and Presidential and dignitary security. The U.S. Park Police have provided accident-free aviation services to our Nation's Capital for over 25 years."

- Components of Prototype System Installed at U.S. Park Police Heliport

  The prototype system that was installed at the U.S. Park Police Eagles' Nest Heliport (not all at the same time) are listed below:

  - laser guidance
  - high intensity strobe beacon
  - light pipe and cold cathode lighting system
  - glideslope indicator that used the "alignment of elements" concept

At the Eagles' Nest Heliport of the items surveyed prior to testing included the following items: acquisition, line-up, glideslope, horizon, closure rate, and touchdown. "By far the largest challenge in operations in the Washington DC area is the visual acquisition of the heliport. No rotating beacon is installed at the heliport. The amber perimeter lights are difficult to separate from the variety of amber and white lights in the city environment. Typically, the heliport is identified and then the perimeter lights are located in relation to the entire heliport."

- Lighting Technologies Evaluated

  The lighting technologies evaluated were similar to those evaluated at Operation Heli-STAR, described above, and included the following:

  - Point Light Sources
    - Lasers
    - High Intensity Strobe Beacon
  - Diffused Lights
    - Light Pipe
    - Cold Cathode Lights

Each of the above technologies was reviewed in respect to their (1) statistics; (2) advantages; (3) disadvantages; (4) current applications, and (5) potential aviation applications. While the information presented appeared to contain more factual information than in previous publications, the conclusions that could be reached from the data listed in this report were similar, if not identical to those which could be made from previous reports. While some of the descriptions contained additional factual material, the section on cold cathode lighting was expanded significantly in Section 5.2.2 Cold Cathode Lights. Due to the importance of this information, it is reproduced as stated in this report below:

- <u>Cold Cathode Lights</u>

"Manufactured by Litebeams, Incorporated, Burbank, CA, cold cathode lights are not new technology. they have been used as obstruction lights for 30 years. The lights work on the same principle as a neon sign. The lights generate an arc in an inert gas in a glass tube coated with metal compounds. Mercury is used to help initiate and sustain the arc. The combination of gas and metal coating determines the color. cold cathode lights produce a more uniform light output than the high intensity concentration that is typical of an incandescent light. consequently, cold cathode lights leave no after image on the retina, even after looking directly at the light. An after image is created by the slow recovery of the retinal neurons (rods and cones) following exposure to concentrated light. Since the light emitted from a cold cathode light is more evenly distributed across the retina, the retina recovers more quickly. This is important in aviation applications, especially for helicopter operations, because the cold cathode lights allow the pilot to see the ground around the light and not just the light itself.

Statistics:

Power: 25 watts (sized to match light output of standard 69-watt incandescent aviation lamp

Efficiency: approx. 65 percent of energy converted to light, 35 percent lost to heat (compared to 95 percent to heat and 5 percent to light for a typical incandescent lamp)

Color: color can be controlled without the use of filters

Life: 20,000 to 40,000 hours (compared to 2,000 hours for a typical incandescent lamp

Operating Temperatures: Lamp burns cool; electrodes reach 3000 degrees F.

Advantages:

Monochromatic in a wide variety of colors
Does not leave an after image on the retina
Low initial cost
Long life
Low power consumption
Operates on battery or 120 VAC power
Compatible with night vision devices
Can be operated as a strobe or steady burning light

Disadvantages:

Medium to Low intensity only
Requires special intensity level controls (cannot vary intensity by varying input voltage)
Requires a ballast to condition input power

Ability to melt ice and snow in winter has not yet been demonstrated

Current Applications:

Obstacle lighting

Potential Aviation Applications:

Runway lighting

Taxiway lighting

Heliport lighting (acquisition, line-up and approach applications)"

- Additional Comments - Cold Cathode Lights

  - "The cold cathode lights illuminate the surround ground providing the pilot with "texture" cues required to sense movement of the helicopter."

  - Section 6.3.4 Human Factors - "The distinctive blue-green color of the cold cathode lights is very easily identified. The color was selected by UTSI (University of Tennessee Space Institute) because it maximizes the ability of the eye to detect the light. This is because the blue-green wavelength (512 nanometers) is equidistant between the best frequency for the rods and the best frequency for the cones in the eye. Additionally, the cold cathode lights use a gas filament that tends to disperse the light leaving no after image on the retina. By comparison, the hot burning metal filament (point-source light) of an incandescent light will burn an after image onto the retina that causes a reduction in night vision. the pilot can see the cold cathode lights from miles away in good weather and then view the lights directly while at a hover without any loss of night vision and without an dimming required."

  - Section 7.3.2 Evaluation of Results - "the cold cathode lights could also be easily seen and identified at ranges of at least 3 miles yet did not need to be dimmed during an approach or in a hover over the lights. The pilots particularly liked the distinctive blue-green color of the cold cathode lights. this color was very distinctive when contrasted with the surrounding city lights. The cold cathode lights provided adequate illumination of the heliport surface. This illumination of the ground provided microtexture to the pilot, which allowed the pilot to control altitude and hover."

- Conclusions

  One conclusion stated in this report was: "As an indication of the positive impression of the prototype lights, the U.S. Park Police helicopter unit is interested in a permanent installation of cold cathode lights at their heliport."[2]

<u>Comments</u>

- This demonstration project was the most extensive and thorough of the demonstration projects conducted during this testing sequence by the U.S. Federal Aviation Administration in cooperation with the University of Tennessee's Space Institute and private industry.

[2] Subsequent to this demonstration and issuing of the report, the U.S. Park Police did purchase and install permanent cold cathode lights identical to those in used in the demonstration project.

- The information gained from this demonstration project fully and completely supported the usefulness of cold cathode lights for use at heliports.

- The information presented from the efforts of this project were similar, if not identical to the data collected from Operation Heli-STAR demonstration project conducted six months previous to this study.

- While other light systems had their positive attributes, i.e., lasers, high intensity strobe beacon, light pipe, LED's, and fiber optic light systems, the cold cathode light system emerged as the most cost effective, practical new technology to replace the incandescent lighting now in use.

- The cold cathode's unique blue-green light was proven superior in all tests for pilot acquisition, hover and landing operations. The light provided pilots with visual contact with the helipad surface allowing discrimination of the microtexture providing the pilot with the appropriate visual cues for translational movement and proper evaluation of the helipad for safe landing maneuvers.

- It is not necessary to alter the brightness (intensity) of the cold cathode light during approach and landing operations. No visual distortion or spatial disorientation is induced in the pilot by visual contact with the cold cathode light. The light aids the pilot during the final seconds of the landing process by providing an excellent soft illumination of the helipad or helicopter landing zone (HLZ) surface while allowing the pilot to detect simultaneously unwanted obstacles/hazards at or around the HLZ.

- While this research paper indicates the cold cathode light is only being used for obstacle lighting, this information is incomplete. Litebeams Corporation has its entire line of cold cathode portable aircraft landing lights being used for temporary runway, taxiway, and heliport lights by customers, world wide. The users include civilian and military units. The lights meet the specifications of the FAA's AC 150/5345-50 Specification for Portable Runway and Taxiway Edge Lights.[i]

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[i] **Since completion of this series of demonstrations, Litebeams Corporation has conducted additional research and development to improve the performance of its cold cathode aviation light product lines. Litebeams cold cathode lights recently have been tested to 98-100 candelas, and hence qualify as high intensity lights. In addition, recent testing has demonstrated excellent operation of the lights between -10^{o}F to -20^{o}F. Lower operating temperatures will be achieved shortly due to innovations in Litebeams technology. To date, collection of snow and ice on the lens during winter conditions has not been a problem.**

B-6

Bernard Diffin, Ph.D., *Technology Advances in Neon Result in Bright, Efficient Light*, IMAGEMAKERS (July/Aug. 2006)

FEATURE

TECHNOLOGY ADVANCES IN NEON RESULT IN BRIGHT, EFFICIENT LIGHT

When considering illuminated signage, probably the most important factor to be taken into account is sign brightness. From the point of view of attracting attention to your business or advertising your corporate identity, generally speaking, brighter is better. For many years, neon, in its multitude of colours, has been the medium of choice for performing this task – either in the exposed form or as a means of illuminating channel letters.

This type of gas-discharge lighting has always been considered very energy efficient, but this attribute has recently come into question, due mainly to the introduction of LED-based products into the market. Schemes such as the LEED system (Leadership in Energy and Environmental Design) and legislation (such as California's Title 24) have also served to focus attention on the efficiency of light sources. So, just how efficient is neon and how does it compare with other sources? In most instances, neon-based illumination systems still provide superior performance in terms of "light out for dollar in" – particularly when we take into account relatively recent advances in the areas of phosphor and transformer technologies.

Light-source Efficiency

Lumens/watt (lm/W) is often used as a measure of the efficiency (or, to be technically correct, efficacy) of a source in converting electrical energy to light. The lumen output of a source is a measure of the total amount of light emitted. This information is sometimes provided by a light-source manufacturer, but is very difficult to confirm without employing the services of a testing laboratory. Watts are a measure of power consumed, and there are two types of power: real power, which is measured with a wattmeter, and apparent power, which is obtained by multiplying input voltage by input current (also called VA). Real power is what you pay the electricity company for, and it's important to verify that real power is being referred to when discussing lm/W figures.

Lumens/watt is a fairly good comparative unit, as long as light sources of similar colour are being compared. This is because the detectors used to measure light are designed to respond like the human eye, which reacts best to green light; hence, green light sources generally have high lumen output compared with blue or red. To put things in perspective, for white light sources, an incandescent bulb has an efficacy of 17-20 lm/W, while at 100 lm/W, a modern T5 fluorescent lamp is one of the most efficient common sources. The best white LEDs used for signage have efficacies of 10-20 lm/W. How do neon sources compare?

High-efficiency Phosphors

There is an enormous range of colours available to the neon-sign manufacturer today, made possible by the blending of different luminescent phosphor types. But this was not always the case. Up until the late 1940s very few, relatively inefficient, phosphors were available. The subsequent introduction of the calcium halophosphate family of phosphors, together with improvements in the standard blue and green emitters, enabled the neon-sign industry to offer a full spectrum of colours and a large range of whites of different colour temperature. These phosphors and their blends are still in use today, albeit with some subsequent improvement in efficiency. A typical halophosphate white – 6500K Snow White, for example – running on a correctly loaded standard ferromagnetic 30mA transformer, has an output of 150 lumens per foot of tube for 15-mm-diameter glass. This results in an efficacy of 35-45 lm/W depending on the total number of sections of glass in the sign.

The real breakthrough in phosphor advancement began in the 1960s, with the development of phosphors for colour television. These were based on rare-earth compounds, which resulted in deeper, more saturated colours due to the fact that they emit light in far narrower wavelength bands than their predecessors. In the 1970s and 1980s, additional rare-earth phosphors were developed and adopted by the lighting industry for use in fluorescent lamps, resulting in light sources that today are still among the most efficient available. The trickle-down effect finally reached the neon industry, first impacting cold-cathode lighting in the late 1980s, and channel-letter illumination in the early to mid-1990s. Lumen per foot output increased by over 30 per cent for whites, leading to efficacies of 50-60 lm/W. Nowadays, all manufacturers of coated tubing offer a large range of colours and many different colour temperatures of white based on blends of these "tri-phosphors." Other advantages associated with rare-earth phosphors include greatly improved lumens maintenance with time and excellent colour-rendering properties.

Source	Efficacy (lm/W)
6500K standard white neon/magnetic transformer	43
6500K tri-phosphor white neon/magnetic transformer	60
6500K tri-phosphor white neon/electronic transformer	78
White LED	10-25
Standard green neon/magnetic transformer	48
Rare-earth green/magnetic transformer	69
Rare-earth green/electronic transformer	90
Typical green LED (channel-letter module)	12
High-power green LED	25
Standard blue neon/magnetic transformer	25
Rare-earth blue/magnetic transformer	23
Rare-earth blue/electronic transformer	30
Typical blue LED (channel-letter module)	2
High-power blue LED	15
Clear red neon/magnetic transformer	8
Clear red neon/electronic transformer	10
Typical red LED (channel letter module)	11

Rare-earth phosphors are particularly efficient when used to illuminate channel letters. Standard "broadband" phosphors have much of their light filtered out by coloured acrylic letter faces, but the narrow wavelength bands emitted by the rare earths mean that a greater proportion of the total available light is transmitted through the face, giving a brighter, more vibrant sign. For example, using rare-earth green neon behind green acrylic results in the face being 25 per cent brighter than when using standard green, and a massive 300 per cent brighter than with standard 6500K Snow White.

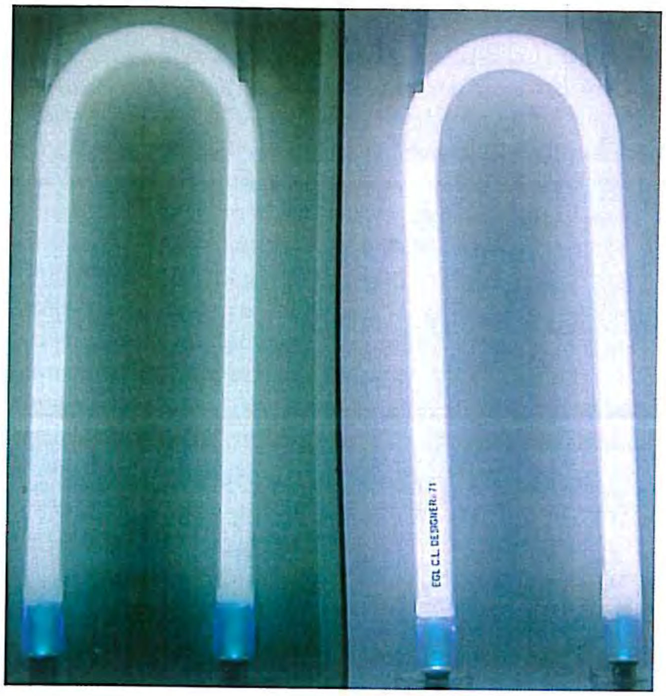
High-efficiency Transformers

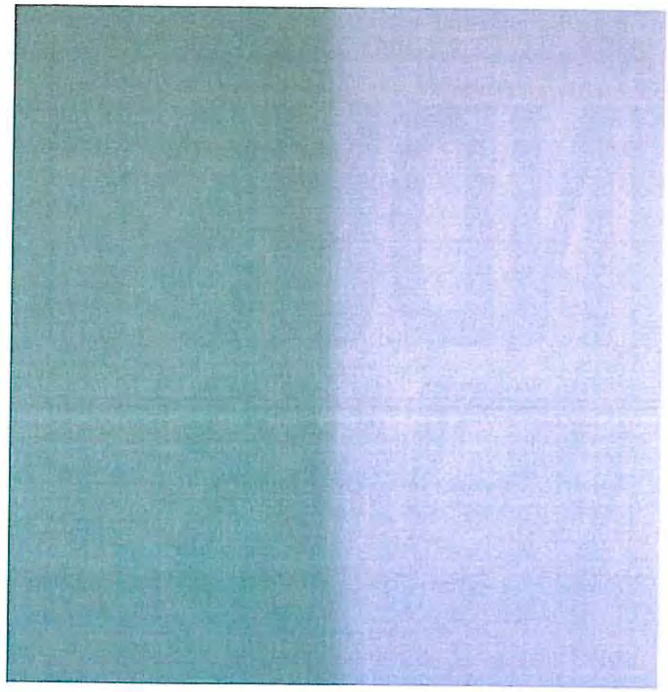
High-frequency electronic ballasts for fluorescent lamps were introduced in the early 1980s and now totally dominate that market. They are far more efficient than magnetic ballasts in converting input power to lamp power, resulting in an overall increase in efficacy of 15 per cent to 20 per cent. By the early 1990s, many companies were designing and marketing electronic transformers for driving neon. In those early days, reliability was an issue, but today there are several companies that make electronic transformers with excellent reliability records. Using these transformers serves to boost even further the efficacy of neon; for example, the 50-60 lm/W figure for tri-phosphor white neon is increased to around 78 lm/W at 30mA. With some transformers of higher current output (60mA), this value is increased still further.

Watts Per Foot

For linear light sources, such as neon and cold-cathode lighting, watts per foot is sometimes used as a measure of energy consumption. Note that this measurement does not have a lumen component and, therefore, by itself, tells us nothing about how bright a sign may be. For example, LED channel or border lighting may have a favourably low W/ft rating compared with the neon equivalent, but yields far less light because it is a less efficient source. Watts per foot figures for LED modules can also be misleading, since they depend on how the modules are laid out (how far apart they are). One manufacturer provides a guide on its channel-letter module spacing and the expected sign brightness; for its green LED modules, the recommended layout to achieve 45 per cent of the brightness of rare-earth green neon (green acrylic face) would result in an energy usage of 9.9 W/ft. Using its high-output white LEDs (white acrylic face) would result in a consumption of 11.9 W/ft and would be only 80 per cent as bright as 6500K rare-earth white neon. The neon in both cases, when powered with electronic transformers, would consume around 3.5 W/ft. A study of channel-letter lighting by the Lighting Research Institute found that, to produce the same amount of light, white LEDs consumed between two and eight times more energy than standard 6500K Snow White neon (30mA ferromagnetic transformer). If a tri-phosphor white and electronic transformer had been used in this comparison, the difference would be even greater.

For the currently available range of LED channel-letter modules, only red is able to approach neon in terms of brightness and energy efficiency when used with certain, sometimes specially developed, red acrylic faces. (However, it should be noted that red neon's light output will not degrade at all during its life, which can be a very important factor if sections of the sign ever have to be replaced.) Red (clear) neon has an efficacy of approximately 10 lm/W and a power consumption of 3.5 to 4 W/ft when run on an electronic transformer. The corresponding figures for the best red LED units used in sign applications are similar at 11 lm/W and 3 W/ft. This small difference is in stark contrast to the often-quoted statement from LED proponents that the use of LEDs can result in 90 per cent energy savings. For this to be the case, a red LED would need to have an efficacy of 100 lm/W or, in terms of energy use, the neon would need to consume 30W/ft!





If in Doubt, Prototype

Whether illuminating channel letters or lighting borders, high-efficiency, rare-earth-based phosphor neon tubing will almost always result in the brightest, most energy efficient signage, especially when used in combination with electronic (solid-state) transformers. Although these phosphor products have been available for a number of years, there has been a certain amount of resistance to their use from sign companies, due mainly to perceived cost issues. Rare-earth (tri-phosphor) coated tubing may cost double that of standard tubing, but in the context of a completed sign, the increase is very small – around 30¢/ft more in material cost – when compared with the benefits its use brings. In many cases, it may be required for a specifier to directly request that the sign company use these products. If any doubt exists as to the best illumination solution, the coated-tubing manufacturer should always be available for consultation and to provide appropriate samples for test. Prototype building is sometimes necessary; in fact, this is always to be encouraged, since it allows different products to be compared. For example, for channel letters, the lit sign can be scrutinized for pantone-colour match, comparative surface brightness can be determined with a relatively simple light meter, and power draw (real and apparent) can be measured with one of any number of commercially available power meters.

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B-7

Ventex Technology, Inc., *Ventex Powered Neon Outperforms Leading LED in Energy Efficiency and Light Output*

Ventex Technology, Inc.

www.ventextech.com info@ventextech.com 800.510.5400

Ventex Powered Neon Outperforms Leading LED in Energy Efficiency and Light Output

Comparison of Ventex 30 mA and Major Mfg LEDs

(with single white pane covering)

(without cover)

Results:

	Average Light Intensity	Power Usage
Ventex Powered Neon 30mA	5357 Lux	16 watts
Major Mfg Gen 1 LED	2011 Lux	34 watts
Major Mfg Gen 2 LED	1658 Lux	17 watts

Findings: The Ventex Neon 30 mA power supply when compared to the Major Mfg Gen 1 LED generated over **two and a half times the light output at half the energy cost**. The Ventex Neon 30 mA power supply when compared to the Major Mfg Gen 2 LED generated over **three times the light output at similar energy costs**.

Reference Data:

	Average Light Intensity	Power Usage
Traditional Electromagnetic 4030	5337 Lux	35 watts
Ventex Powered Neon 60mA	10814 Lux	33 watts

Test Protocol: This test compares the light output between the Ventex 4030-120 neon power supply, Major Mfg Gen 1 LED (CL4-HP) and Major Mfg Gen 2 LED (with EGL C71 glass). All tests were conducted under the same conditions utilizing the same equipment and darkened room. The test box consisted of two adjoining 10" x 18" x 5" boxes overlaid with a single white plastic face. The neon box contained 3 strokes of 15 mm glass at 3 1/2" on center spacing. The LED box contained 8 Major Mfg Gen 1 or Major Mfg Gen 2 for a total of 16 individual LEDs configured in an approximate 3 1/2" grid pattern. Individual light measurements were taken at the face surface in a repeatable grid pattern. Reference standards were gathered under the same test conditions.

Form: 125v0308

B-8

U.S. Department of Energy, *DOE Solid State Lighting Commercial Product Testing Program, Summary of Results: Round 2 of Product Testing* (August 2007)

DOE Solid-State Lighting
Commercial Product Testing Program

Summary of Results:
Round 2 of Product Testing

U.S. Department of Energy

August 2007

Building Technologies Program
Energy Efficiency and Renewable Energy
U.S. Department of Energy

DOE Solid-State Lighting Commercial Product Testing Program

Summary of Results: Round 2 of Product Testing

Round 2 of testing for the DOE Solid-State Lighting (SSL) Commercial Product Testing Program (CPTP) was conducted from March to May 2007. In Round 2 of the testing program, 13 products were selected for testing, representing a range of applications, designs, and manufacturers, continuing along the same lines of testing conducted in Round 1. [1] All luminaires and replacement lamps were tested with both spectroradiometry and goniophotometry. Testing also included measurements of surface temperatures (taken at the hottest accessible spots on the luminaire) and off-state power consumption. This testing does not include lumen depreciation testing or other forms of testing product reliability—these subjects will be addressed in future testing program studies.

The lighting testing laboratories were instructed to follow test procedures specified in LM-79 (IESNA Guide for Electrical and Photometric Measurement of Solid-State Lighting Products) which covers '…SSL fixtures as well as SSL sources used in conventional light source fixtures (e.g., replacement of screw base incandescent lamps).' [2] This method tests the luminaire or replacement lamp as a whole—as opposed to traditional testing methods that separate lamp ratings and system efficiency or as opposed to testing LED devices or arrays without control electronics and heat sinks. There are two main reasons for this: 1) there is no industry standard test procedure for rating the luminous flux of LED devices or arrays; and 2) because LED performance is temperature sensitive, luminaire design has a material impact on the performance of LEDs used in the luminaire. Similarly for replacement lamps, the integration of LED devices, heat sinks, drive electronics, and optics within an integral replacement lamp impacts the performance of the LED components within the lamp. For these reasons, luminaire efficacy (efficacy of the whole luminaire or integral replacement lamp) is the measure of interest for assessing energy efficiency of SSL products, as specified in LM-79.

Products which are sold as luminaires are tested using the entire luminaire. Products which are sold as replacement lamps are mounted for testing in standard lampholders corresponding to the format of the replacement lamp and the measurement instrument used for a given test. Performance results for replacement lamps are thus for the bare lamp, to which appropriate fixture losses should be applied to determine the luminaire output for the replacement lamp installed in a given fixture.

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[1] The DOE Solid-State Lighting Commercial Product Testing Program Summary of Results: Pilot Round of Product Testing, December, 2006 and DOE Solid-State Lighting Commercial Product Testing Program Summary of Results: Round 1 of Product Testing, March 2007. Available online at http://www.netl.doe.gov/ssl/comm_testing.htm.

[2] The draft testing standard entitled "IESNA Approved Method for the Electrical and Photometric Measurements of Solid-State Lighting Products," designated LM-79, is currently under review. This testing procedure is being developed by the Subcommittee on Solid-State Lighting of the IESNA Testing Procedures Committee (http://www.iesna.org/about/committees/) in collaboration with the ANSI Solid State Lighting Committee. This method describes the procedures to be followed and precautions to be observed in performing reproducible measurements of total luminous flux, electrical power, luminous efficacy (lumens per watt), and chromaticity, of solid-state lighting (SSL) products under standard conditions. It covers LED-based SSL products with control electronics and heat sinks incorporated, that is, those devices that require only AC mains power or a DC voltage power supply to operate. It does not cover SSL products that require special external operating circuits or external heat sinks.

Table 1 summarizes results for energy performance and color metrics – including light output, luminaire efficacy, correlated color temperature (CCT), and color rendering index (CRI) – for all products tested under CPTP in Round 2 of testing.[3]

The selection of products for Round 2 was designed to provide initial insight into variability across units, to provide benchmarking data with respect to other light source technologies, and to allow for initial round-robin testing. To enable observation of variability across units, two samples were purchased and tested for each replacement lamp and for one luminaire. To enable a direct comparison between different light sources, one product was purchased and tested in both an LED version and a halogen version of the same desk lamp. To investigate variability due to testing equipment and methods, round-robin testing was conducted by all four pre-qualified independent testing laboratories on one replacement lamp and on one complete luminaire.

In addition to performing product testing following LM-79, photometric data published by manufacturers for SSL products (in the form of standard IES photometric data files) were collected and analyzed for purposes of comparison.

[3] Detailed test reports for products tested under the DOE's SSL testing program can be requested online: http://www.netl.doe.gov/ssl/comm_testing_request.htm.

Table 1. DOE SSL CPTP ROUND 2 SUMMARY						
Photometrics based on IESNA LM-79 draft for --Luminaires and replacement lamps --25º C ambient temperature	**DOE TEST ID**	**Total Power (watts)**	**Output (lumens)**	**Efficacy (lm/W)**	**CCT**	**CRI**
Replacement Lamps						
R30 Replacement Lamps						
R30 Replacement Lamp Warm	CPTP 07-08*	8.8	239.1	27.1	2945	71.8
R30 Replacement Lamp Cool	CPTP 07-09*	9.1	310.3	34.1	5973	81.9
R30 Replacement Lamp, Warm, RGB	CPTP 07-13*	15.6	405.6	25.9	2689	14.5[1]
R30 Replacement Lamp, Cool, RGB	CPTP 07-14*	13.8	351.6	25.4	4006	13.3[1]
A-lamp Replacement Lamps						
A19 Replacement Lamp	CPTP 07-06*	0.7	10.3	15.7	3161	70.4
A-lamp (~A17) Replacement Lamp	CPTP 07-12*	1.5	19.7	13.4	25263[2]	79.1
Downlights (complete luminaires)						
Downlight	CPTP 07-04	31.0	356.7	11.6	5964	76.4
Downlight	CPTP 07-05	26.2	662.2	25.3	4402	76.0
Desk-Task Lamps[3]						
Desk-Task	CPTP 07-16	4.4	74.5	16.9 [6.3]	5800	77.8
Desk-Task	CPTP 07-22	13.1	156.6	12.0 [5.1]	3204	74.3
Desk-Task, Halogen[4]	CPTP 07-10	38.3	351.2	9.2 [8.9]	2856	99.5
Other Application Categories						
Outdoor Wall	CPTP 07-01	5.6	92.2	16.3	2693	68.3
Refrigerated Display	CPTP 07-07*	40.7	1237.0	30.5	5261	69.7

*For products shown with an asterisk, two units were tested, results show average between two units. The extent of variation between units is discussed under ‘Variability and Repeatability’ below.

[1]Note that CRI value does not reflect color quality of white light for RGB sources.

[2]This high CCT value is not a typo, see section, ‘Measurements of Color Quality,’ below.

[3]Adjusted efficacy values in brackets [ ] include the effect of measured off-state power consumption assuming 3 hours on-time per day. See below for discussion of the impact of off-state power consumption on average yearly efficacy.

[4]Test 07-10 was conducted on a product with a halogen source for benchmarking purposes. This luminaire has the same fixture head as 07-22, with a different light source.

Observations and Analysis of Test Results

Energy Use and Light Output

The range in application and performance of luminaires included in Round 2 is vast, from very weak, A-lamp style replacement 'bulbs' that put out less lumens than a typical 7W incandescent night light or sewing machine bulb, to some impressive downlights providing output levels and beam characteristics that directly rival incandescent replacement flood lamps for downlights. There is a similar range of results on the efficacy side, from desk-task lamps which are less efficacious than halogens due to their significant off-state energy draws, to downlights and the refrigerated display light that can rival fluorescent technologies in efficacy and luminaire light output delivered to the application area. This vast divergence in applications and in product performance is a key point to remember: any comparison between SSL products and luminaires using more traditional light sources should rely on specific performance data for the luminaires in question. Generalizations can provide an indication of the overall progress of SSL technology and markets, but should not be relied upon to make decisions regarding SSL luminaires.

A discussion of the performance of the products tested in Round 2 is provided for each different application below, as well as more general discussions on the continuing lack of credibility found in manufacturer literature, and issues of color quality, electrical design, and variability and repeatability.

Lack of Credibility of Manufacturer Literature

In Round 1 of testing, major discrepancies were seen between the output and efficacy values published in marketing material and the actual tested values. In general, Round 2 results show little to no improvement in the accuracy or credibility of published values for output or efficacy, save a few examples: exactly two products tested in Round 2 had accompanying manufacturer literature which presented values for luminaire output and efficacy which were close to measured values. All other tested products that offered claims of efficacy and lumen output overstated efficacy by 25 to 35% and light output by 30 to 95%.

Marketing literature for some products does not include values for efficacy or light output, but includes statements that may be entirely misleading. For example, one flyer referring to a desk lamp states "…the advanced optics allow the LED system to use 70 percent less energy than a comparable incandescent unit, even though the two light sources have similar energy efficiency." Another marketing article states that the same lamp "…produces more light than a 40-watt halogen bulb." This desk lamp was tested in comparison to the same luminaire in a halogen version. While the LED version uses 65% less energy than the halogen unit when it is on, it provides less than half the light output of the halogen version and consumes over 2.5 W of power in the off-state—making it far less energy efficient and far dimmer than the incandescent version.

Similarly, marketing literature for a replacement A-lamp that was tested states "Electricity consumption reduced 80-90%." Yet this lamp was found to have an efficacy of 13.4 lm/W—similar to an incandescent—so any reduction in electricity consumption from this lamp stems from the reduction in light output rather than efficiency gains. Furthermore, the lumen output of this lamp, less than 20 lumens, is less than 5% of a typical A17 or A19 lamp, making it unsuitable as a ‘replacement’ for most applications. The marketing literature about the product makes no mention of this.

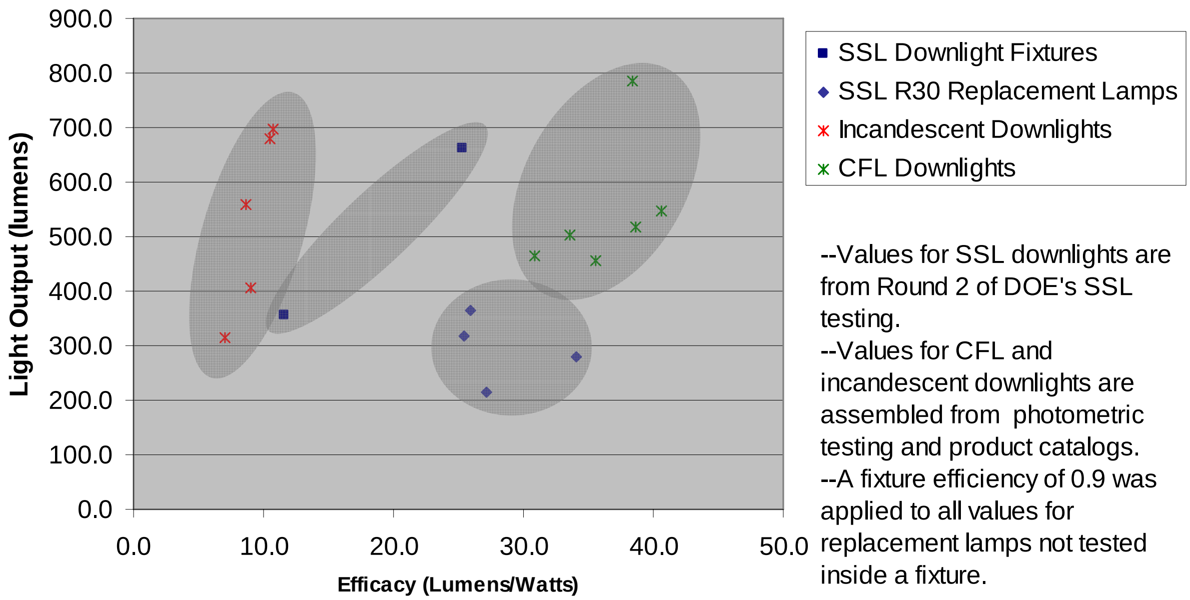
There may be a number of reasons for discrepancies between values published in marketing material and actual tested values:

- Lumen output and efficacy values in product literature may refer to the performance ratings of the LED device as published by the LED device manufacturer. Yet, there is currently no published standard testing method for measuring stand-alone LED device performance, and there is currently no consistent way to use the LED device performance values to accurately predict the performance the LED device when installed in a luminaire with power electronics and heat sinking.
- In some cases, marketing material clearly indicates that output and efficacy values are for the LED device and not for the luminaire. In some cases, marketing material does not indicate whether output and efficacy applies to the LED device or to the luminaire, leaving the data open to misinterpretation.
- Luminaire manufacturers may be publishing performance values from testing of luminaires conducted using methods or conditions that are very different from those specified in LM-79. In some cases, luminaire manufacturers specify the procedure they wish to have followed. In some cases, a testing laboratory may choose the procedure to follow but not yet be employing LM-79 (which is still a draft standard, not yet published and not yet familiar to some testing laboratories).
- Luminaire manufacturers may be publishing values which correspond to a product configuration that is not exactly the same as the production line version that was ordered and tested by the DOE testing program.
- Luminaire manufacturers may be inflating values to exaggerate performance.

Downlights and Replacement Lamps for Downlights

Figure 1 and the bullets below provide a general comparison between downlights based on Round 2 results. Note that these are very broad generalizations (not conclusions) to give a feel for where the industry is today. Such generalizations should never be used as a rule of thumb to compare one product to another. Comparisons must be done on a case-by-case basis due to the wide range in product performance, quality, and directionality, taking into consideration the specific requirements of a given lighting application.

Figure 1: Downlight Comparison: Light Output vs Efficacy



A general comparison (on average, without outliers) to similar **CFL reflector lamps** reveals the following:

- The SSL downlights and SSL R30 lamps have ½ to ¾ the efficacy of similar CFL lamps
- The SSL downlights and SSL R30 lamps are achieving ⅔ the output of similar CFL products on average
- The SSL downlights and SSL R30 lamps have tighter beam and field angles than the CFLs on average
- The SSL downlights and SSL R30 lamps have higher Center Beam Candle Power (CBCP) on average than the CFL lamps

Compared to similar **incandescent reflector lamps** (flood-style, not spot):

- SSL downlights and SSL R30 lamps achieve 2 to 3 times the efficacy of similar incandescent products
- SSL downlights and SSL R30 lamps are producing ⅔ to ¾ the output of similar incandescent products on average, though some SSL downlights surpass some incandescent downlights in output
- The SSL downlights and SSL R30 lamps tend to have a slightly wider beam angle than the incandescents (excluding one diffuse style of R30 replacement, the SSL average beam angle is 72 deg vs 60 deg in incandescents)
- The CBCP of SSL downlights and SSL R30 lamps is on average ¾ the CBCP of the similar incandescent products

For center beam candlepower, SSL lamps tested do not compete with 'PAR' lamps or 'reflector spot lamps', although the SSL lamp efficacies are higher and the overall lumen output of one downlight is as high as the output on some 40W and 50W PAR30s.

Close examination of results from LED downlights and R30 replacement lamps compared to similar incandescent and CFL products, reveals that the LED replacement lamps are generally still less 'focused' than the incandescents (i.e., competing incandescent reflector flood lamps tend to have tighter beam angles than LED replacement lamps), but the results are nuanced. We have tested two different R30 lines, with very different results for beam characteristics.[4] Basically, although some lamps use LEDs that emit light in a single hemisphere direction, they are still not at all focused in a tight beam—manufacturers have chosen wide angle LEDs in a product generally associated with directional lighting. This may reflect a choice on the part of manufacturers: that downlights, thought of as producing directional light, are very often used for large area lighting, and thus may be valued by users for having wide beam angles.

Figure 1 above highlights a wide divergence in performance across the products that were tested. Upcoming testing on more recent SSL downlights is expected to show more products that are close to or surpassing CFL products in output and efficacy.

Replacement A-Lamps

The two types of SSL replacement A-lamps tested very poorly. Both products had light output levels far below what would be expected in a replacement lamp for an A-lamp and one had a CCT value which placed it markedly outside the standard range for white light.

Task-Desk Lamps

As in Round 1 of testing, the results vary from product to product, but generally do not meet performance expectations, particularly if we consider off-state power use. One halogen desk lamp (07-10) was tested to provide a point of comparison, being a similar model to one of the SSL desk lamps (07-22), from the same manufacturer. Both of the two SSL desk lamps tested in Round 2 provide considerably less light output than a halogen or CFL desk lamp (¼ to ½ the output), and both have a cooler color temperature and lower CRI than the halogen desk lamp. In particular, both SSL desk lamps consume significant off-state power, making them less efficacious than the halogen desk lamp under average conditions of use (e.g., being used 5 hours or less per day).

Outdoor Lamps

One outdoor wall lamp tested in Round 2 demonstrated a lamp design which takes advantage of the low profile of LED technology—not restricted to the concept and dimensions of an Edison based socket and lamp. While we currently have no benchmarking available for outdoor wall lamps, based on the wattage of replacement lamps typically used in outdoor wall lamps, this lamp would be expected to exceed incandescent and halogen efficacy by 2 to 3 times, with probably ½ to ¾ the efficacy expected in a similar luminaire using a CFL source. Note that characteristics such as the cold temperature performance and longer life (particularly in cold

[4] Detailed test reports present CBCP values and intensity distribution curves. They can be requested online: http://www.netl.doe.gov/ssl/comm_testing_request.htm.

temperatures), and controllability (e.g., compatibility with dusk/dawn sensors) may be as important as efficacy factors for this application.

Refrigerated Display Case Lamps

We currently do not have data on fixture losses or delivered light for comparable fluorescent luminaires used in refrigerated display cases. Nevertheless, the luminaire efficacy (30.5 lm/W at 25° C) and intensity distributions of this luminaire place it within the range of competing with fluorescent for this application. Further testing was conducted to examine the luminaire at low temperatures, showing stable color quality and an improvement of 0.8% in efficacy at -5° C. Initial thermal imaging shows excellent heat management with almost no heat loss toward the front surface of the luminaire. SSL technology may be well suited to this application because of its comparative robustness: long life, improved performance in cold temperatures, dimmability, and insensitivity to frequent on/off cycling.

Measurements of Color Quality

ANSI chromaticity specifications define nominal CCT ranges for white light. Similar to the ANSI 7-step MacAdam ellipses which are used to define nominal white ranges for fluorescent light, draft ANSI C78.377A specifies eight nominal CCT quadrangles for solid-state lighting.[5,6] As shown in Figure 2, the quadrangles define ranges of CCT values and distances from the Planckian locus on the chromaticity diagram that are appropriate for solid-state lighting. These nominal CCT values range from 2700 K to 6500 K, (spanning 2600 K to 7000 K from the lower-most to the upper-most quadrangle limits). One of the products tested, sold as a white replacement lamp (similar in size to an A17 or A19 lamp), had CCT values far beyond the nominal CCT ranges—one unit was measured at 14588 K and the other at 35938 K. This does not meet the standard criteria for white light even though it is being marketed as a white light. All of the other luminaires tested in Round 2 had CCT values ranging from 2619 K to 6039 K, with an average of 4059 K.

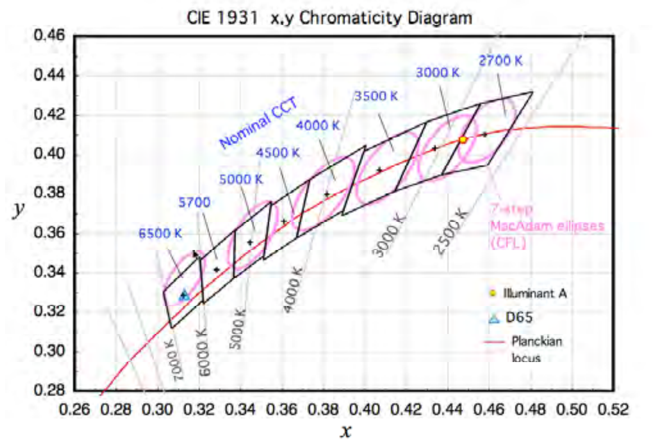


Figure 2. Draft Diagram Showing Eight Nominal CCT Quadrangles

The Color Rendering Index (CRI) of the luminaires using phosphor-conversion LEDs ranged from 68 to 84, with an average of 74. CRI values are reported with the reminder that, in certain cases, a light source may be acceptable (and even preferred) by users for given applications even though its CRI value is relatively low. Readers are urged to be aware of the complexities of assessing color quality and of the limitations of CRI with regard to SSL technologies.[7,8]

[5] American National Standards Institute: www.ansi.org.

[6] Dowling, Kevin. 2007. "Standards Required for Further Penetration of Solid-State Lighting." In *LEDs Magazine*, April 2007, pp. 28-31.

[7] Protzman, J. Brent and Kevin W. Houser. October 2006. LEDs for General Illumination: The State of the Science. Leukos. Vol. 3, No. 2, pp. 121-142.

Qualitative visual assessment by human observers may provide important insight regarding the suitability of color quality of a luminaire for a given application, particularly for RGB luminaires for which CRI should not be used.

Electrical Design

Off-state Power Consumption

Off-state power consumption, also called standby power consumption or 'vampire' loading, refers to power drawn by an electronic device while it is, in essence, switched off. Some electronic devices do need to power circuitry in permanence for control purposes or for other functional purposes, but many electronic devices consume power when turned off simply due to inefficient electrical design. In most cases, there is no functional reason for lamps and luminaires to draw power when they are turned off.

All products which incorporate an on/off switch are tested for off-state power consumption. Each of the task lights and one of the undercabinet lights tested to date consume energy in the off-state. In Round 2, one desk lamp was tested in both the halogen and LED models (07-10 and 07-22, respectively). While the LED version had slightly better efficacy than its equivalent halogen model, its off-state power use was very high (2.54 W), making it much less efficacious than the halogen model for any typical usage (such as 3 hours on per day). Even the other desk lamp which was tested would not out-perform the halogen desk lamp with a usage of 5 hours per day due to its off-state power consumption of 1 W. None of these desk lamps included features that would justify a need for off-state power.

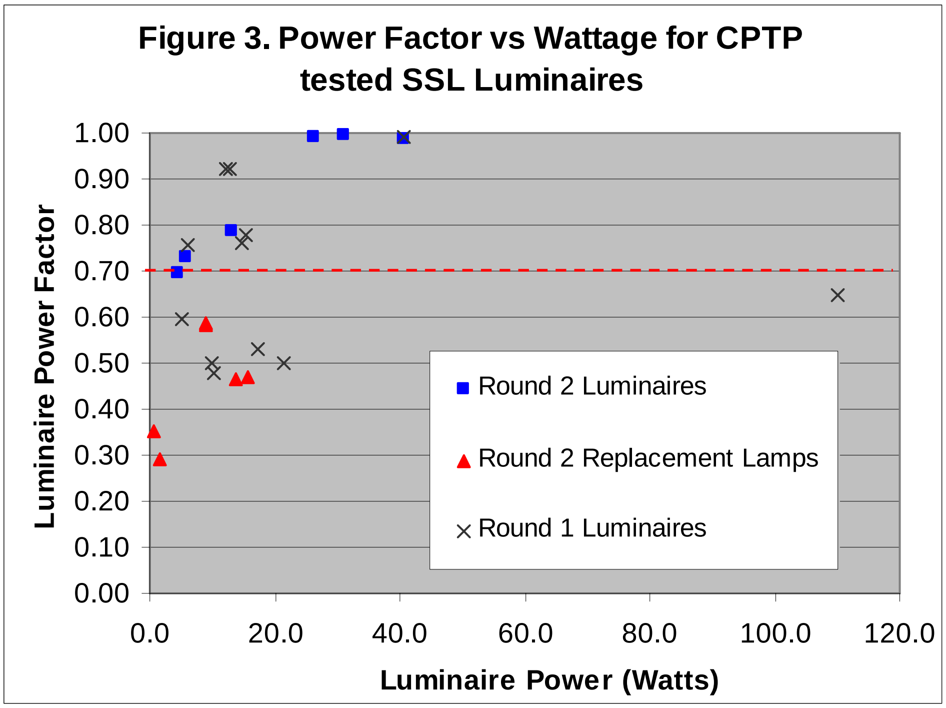
Table 2. Effective Average Efficacy Due to Off-State Power Use

		Measured Efficacy w/ Power On (lm/W)	Power Consumed in Off State (W)	Effective Average Efficacy (lm/W)		
				1 hour on per day	3 hours on per day	5 hours on per day
CPTP 07-10 Task/Desk	*Halogen*	9.2	0.16	8.4	8.9	9.0
CPTP 07-22 Task/Desk	LED	12.0	2.54	2.2	5.1	6.9
CPTP 07-16 Task/Desk	LED	16.9	1.06	2.6	6.3	8.9

Note that units operated for fewer hours per year may consume less energy, despite lower efficacies.
Lamps 07-10 and 07-22 are the same format from the same manufacturer, one with a halogen source and the other using an LED source.

[8] Narendran N, Deng L. 2002. Color rendering properties of LED light sources. Proc. of SPIE: Solid State Lighting II.

Power Factor
The average power factor of all SSL products tested to date is 0.7—equal to the minimum power factor currently required in the draft "ENERGY STAR® Program Requirements for Solid-State Lighting Luminaires."[9] The power factors are plotted in Figure 3 below, with a dashed red line representing this ENERGY STAR criteria limit at 0.7. All of the Round 2 products that are integral fixtures (as opposed to screw in replacement lamps) have power factors of 0.7 or higher; all of the Round 2 products that are replacement lamps have power factors below 0.7. In particular, the A-lamp style replacement lamps have very poor factors, below 0.4.



Variability and Repeatability
Two samples of each replacement lamp were tested to check for variability across units. In addition, three luminaires have been tested for variability to date (performing the same tests on two samples of a given luminaire). Excluding luminaires with very low levels of light output (i.e., excluding products that provide less than 30 lumens of light), the variability in output and efficacy between units of the same product has averaged less than 4%. For luminaires with very low levels of light output, (three products with outputs less than 30 lumens have been tested to date), the variability between units is much larger, averaging 10 to 15% variability of output and efficacy across units. With respect to color qualities, for non-RGB products with CCT values in the white range (up to 7000K), the variability of both CCT and CRI values across units was on average 1% or less.

[9] ENERGY STAR® Program Requirements for Solid State Lighting Luminaires Eligibility Criteria (draft 04/09/07) is available online: http://www.netl.doe.gov/ssl/energy_star.html.

Four independent lighting testing laboratories were pre-qualified to perform CPTP testing. Round-robin testing by each of these laboratories is being conducted on one integral downlight and one R30 replacement lamp to gain knowledge about variability stemming from testing equipment, geometries, and methods. Initial round-robin testing commenced in Round 2 has provided insight and feedback for standards groups such as the IESNA Solid-State Lighting Subcommittee of the Testing Procedures Committee. This feedback contributes to refining testing methods and to identifying areas where clarification or additional standards may be needed.

Conclusions from Round 2 of Product Testing

Key Points

Round 2 of the DOE's testing of commercially available solid-state lighting products has revealed examples of both excellent and dismal performances. Some downlights and directional replacement lamps produce light output comparable to similar incandescent and CFL downlights, while significantly surpassing the incandescents and approaching the CFLs in efficacy. On the other hand, a number of non-directional replacement lamps (A-lamps) perform very poorly and do not produce enough light output to be suitable replacements for any similar products in use today. Refrigerated display case and outdoor wall lamps that were tested performed quite well, while SSL desk lamps still tend to compare poorly due to their use of power in the off-state. This vast divergence in applications and in product performance provides a key point to remember: any comparison between SSL products and luminaires using more traditional light sources should rely on specific performance data for the luminaires in question. Generalizations can provide an indication of the overall progress of SSL technology and markets, but should not be relied upon to make decisions regarding SSL luminaires.

SSL product performance cannot be easily generalized. The large divergence in performance characteristics means that buyers will need to consider the performance of each product separately and require clear (and accurate) luminaire performance information from manufacturers.

Unfortunately there is still a wide disparity between performance claims in marketing literature and actual tested luminaire performance. While a few manufacturers are publishing credible values for luminaire output and efficacy, many are still making wild and misleading claims.

The poor results for omni-directional, A-style replacement lamps reinforce DOE's decision to emphasize whole luminaire measurements. Poorly performing products are seen when SSL technology is introduced without sufficient attention toward treating it as an integrated system. A well designed, integrated system for SSL technology can be designed into a complete luminaire or a replacement product—that is, designers need to consider thermal management, drivers, optics, the LED sources and their directionality as an integrated system and performance measurements need to assess the integrated system.

Next Steps for Testing

Upcoming SSL product testing will continue to encompass products in a range of categories. Further benchmarking tests will be conducted to improve our understanding of how SSL test results compare to similar results for products using other light sources. 'In situ' style testing and lumen depreciation testing will be conducted to better assess the effectiveness of thermal management and the long-term performance behavior of selected products. Round-robin testing across laboratories will continue to provide input to testing Standards Committees and convey lessons learned about SSL testing to other stakeholders.

Next Steps for the Industry

A problem with many designs is the off-state power use when there is no functional need for it. The small profile of SSL technology makes it particularly well adapted to applications like desk lamps that may not be connected to a wall power switch. This would imply that SSL will see significant market opportunities in applications that require an on/off switch, but the net end result on energy efficiency as compared to existing technologies will not improve—and may possibly worsen—if cost-effective designs are not found to eliminate off-state power consumption.

DOE and industry leadership will be applying "lessons learned from CFLs" to address the concerns raised by the subset of products that are underperforming or providing misleading performance information.[10] This focused effort may contribute to understanding why some products are under-performing, with luminaire efficacies that are 20 to 50% of the LED rated efficacy, which may lead to effective improvements in designs and their associated product literature.

[10] See the June 2006 report, "Compact Fluorescent Lighting in America: Lessons Learned on the Way to Market," http://www.netl.doe.gov/ssl/publications/publications-lightingtechreports.htm.

B-9

Kenny Greenberg, *A Channel-Letter Comparison*, SIGNS OF THE TIMES (May 2002)

From Signs of the Times. May 2002

A Channel-Letter Comparison

We have two sets of channel letters -- one with neon and one with LEDs -- We then compare their brightness and ease of use.

By Kenny Greenberg

With 22 years in the field, not surprisingly, I love neon. Quite simply, I enjoy all forms of light, and that would include LEDs. Their recent entry into the illuminated-sign field has caused many sign professionals, including myself, to step back and ask some basic questions about the future of illuminated signs and lighting.

So when ST asked me to scientifically compare covered LED and neon channel-sign components, I decided to conduct a test designed to measure the light output for each lighting technology.

Test parameters

What should we examine when investigating different lighting technologies? What might concern the average shop? How easy is it to assemble? How much does it cost? How difficult will it be to maintain? Will it produce enough light?

An architect or designer might wonder: How energy-efficient is it? What color ranges and effects are possible at what cost?

The architect or designer may have different concerns than the fabricator, but it's the end-user who must ultimately be satisfied. An owner's bottom line is: Will it attract clientele, will it be a good value?

My test examines these basic questions about light output and energy input. After the installation cost is complete -- and before the cost of repairing or replacing system parts occurs -- there is, hopefully, a long period during which a useful and attention-getting, illuminated sign provides efficient and affordable service. I will answer some questions about the amount of visible light and the cost of producing it.

Channeling energy

My very simple test base was conducted with minimal equipment. Note that these investigative tests intentionally provide anecdotal information. A laboratory test involves significantly more thought concerning test structure and variables, many more sample types and test runs. A controlled experiment also requires equipment to be spectroscopically corrected because a color may have a different concentration of energy at a certain wavelength that my lower-cost sensor might not detect.

My tests don't prove or disprove anything. Instead, I offer a short journey into making a few channel letters, illuminating them, reading a few meters and analyzing my findings.

The test comprises two, channel-letter cans with #2283 acrylic, transluscent red faces. One is lit with two rows of neon, and the other with the manufacturer's recommended number of LED modules. The high-output LED -- Permlight's LED'R system -- is relatively new to the sign trade. Currently, its best output is in the red range. While virtually all other neon colors are many times brighter and more efficient, I focused on red because LED and neon can be most closely compared in this color range. Also, red is commonly used in advertising campaigns to grab attention.

I chose the Permlight LED'R system because it was among the first on the market -- I remember seeing its channel-letter display a few years ago at a tradeshow. Also, Permlight, which provides detailed technical data and product information, specifically recommends equivalency guidelines -- namely two modules for every foot of neon. And the company sells a sample kit that includes everything needed to light a channel letter.

I used two, identical, covered, white, interior, 12-in., Helvetica channel letters. Specifically, I chose the letter "N" because I wanted to compare output levels and how well both light sources dealt with sharp turns. I fabricated an outline-style, 12mm neon letter and first tested it with a 3000V, 30mA standard magnetic neon transformer (operating current 24mA) and later, with a solid-state, 3000V, 50mA model.

Neon footage measured just over 5 ft. I used 10 LED modules, which didn't fit quite evenly, and, thus, a portion of the letter received a greater density of light. Fortunately, this corresponded with the neon doublebacks and electrodes -- also an area with a greater concentration of light -- to foster a good comparison.

For my measurements, I used a foot-candle meter attached to a digital, true-RMS multimeter. Then I created as dark a space as possible and isolated the meter's illuminated screen. Afterwards, I took a set of readings against the covers at seven points along the letter. I repeated these measurements three times for each different source for greater reliability. Because it's a more common unit for light output as perceived by the human eye, I converted the readings to lux (lumens per square meter).

The channel-letter comparison comprises two, channel-letter cans with #2283 acrylic, translucent faces. The left one, in each photo, is lit with Permlight's LED'R high-output system, while the right uses two rows of neon. The sets show (from left) covered, partially covered and exposed letters.

Two sets of channel letters -- one with neon and one with LEDs -- then compare their brightness and ease of use.

By Kenny Greenberg

Lusting for lux

When both units were powered, my eye told me the neon was much brighter. Therefore, I played with the LEDs at different heights and directions to see if I could maximize their output. The manufacturer's recommended placement was indeed the best option.

From my subsequent meter readings, I obtained the following results: The average light output on the face of the LED-illuminated letter measured 464 lux, while the average reading for 12mm neon on a nominal 30mA transformer measured 1,439 lux. In this test, neon proved to be more than three times brighter (310%), so my eyes weren't deceiving me.

I then measured the LEDs' power consumption. My calibrated Fluke 87III meter read 730mA at 13.79V. At first, I was surprised to find nearly 50% higher consumption than the LEDs' printed ratings. Then, I realized on-board resistors are required to regulate the modules. I also realized that different efficiencies depend on the power-supply design and whether or not it was fully loaded or partially used -- thereby wasting some energy.

I measured approximately 10W power consumption on the transformer's secondary side; a theoretical value, assuming 3% losses from an ideal transformer, would yield 10.4W. The actual AC current to the DC power supply used 17.85W. This shows the importance of fully loading a low-loss transformer with LEDs. Otherwise, power is wasted.

For comparison purposes, note that the wattage figures apply at the LEDs' level of light -- approximately one-third that of the neon letter. Thus, to properly compare neon with LED, we must multiply LED output by 3.1. We must also do the same with the wattage, as we can assume a linear relation. The measured neon voltage of 2065V at 24mA agrees with expected values. Given the transformer, the letter uses approximately 49.5W.

If we used the AC power consumed by the test kit, the result of 17.85W * 3.1 gives us 55W for LED. In this test, the neon letter (at 49.5W) is actually more efficient than LED.

If we assume better design conditions for a real-world system, and apply the same factor of 3.1 to the 10.4W, the system has a lower power consumption of 32.2W.

There are some trade-offs. To achieve a 33% reduction of watts at a comparable light output, we must use three times as many modules. The good news: This efficiency is possible. The bad news: The system will cost more.

I then tried a 50mA electronic neon power supply. The neon letter's high output gave a reading of 2,250 lumens, while consuming 76.8W. The LED system would use only 50W to achieve that output, but nearly five times as many modules would be required.

Will LED replace neon?

My usual reply to this question is: Did the light bulb make the candle obsolete? Fortunately, a constant influx of new light sources must always be investigated to determine their best applications. As a theater professional who always works with various light sources, I know that each technology handles certain tasks better than others. Sometimes you can substitute one source for another, sometimes you can't. Often, it's the interplay between different types of light that makes a sign or an environment interesting.

Still in its infancy, the LED sign industry (electronic-message centers should be considered a different category) has a long way to go to match neon's century of performance. Neon technology has benefited from its long existence -- time and extensive usage have allowed its traits to be understood and its problems to be solved.

Plus, neon technology continues to evolve. Being the new kid on the block, the LED industry has little negative history. Novelty alone gives it appeal. But this industry may also run into unanticipated challenges -- that's true for any new technology. Undoubtedly, both technologies will continue to evolve, grow and prosper.

B-10

Marcus Thielen, *Neon Visibility – Understanding the Basics of Light and Color Creates Satisfied Clients*, SIGNS OF THE TIMES (Feb. 8, 2006)

Neon Visibility

Understanding the basics of light and color creates satisfied clients

By **Marcus Thielen** (02-08-2006)

August is frequently a time for vacations and relaxing. Nobody wants to think about work because business will soon become stressful enough. Because this is the time when new neon installations are planned, it's a good time to discuss design properties that affect appearance. To ensure that neon signs deliver maximum impact, sign builders need to put themselves in their customers' shoes. This month, I focus on the physiological or human factors that influence neon-sign design.

Because physiology is not an exact science, I present statistics that represent averages of subjective responses. As a physicist accustomed to exact measurements, this makes me uncomfortable. Substantial human diversity, however, dictates that this type of perceptual study be based on averaging responses.

Visual perception

The sensory point of entry for a neon sign's message is the human eye. Thus, the sign's visibility depends on three principal factors:

1. The viewer's peculiar eyesight characteristics;
2. The atmosphere's ambient transparency and its effect on color; and
3. The viewed object's luminous properties.

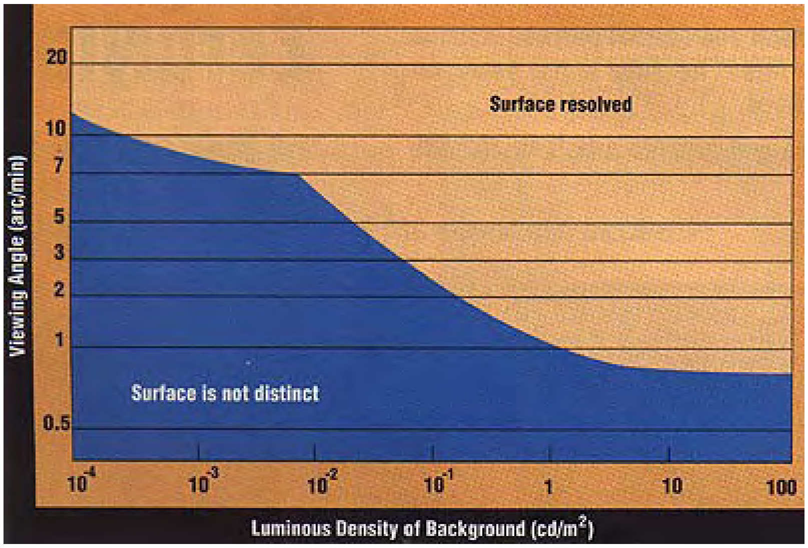


Fig 1: Critical viewing angle at different background intensities (Gut, *Handbuch der Lichtwerbung*, page 188)

Human-eye resolution and sensitivity are closely related. We know, for example, that the "average" eye can resolve two objects separated by a viewing angle of 1 arc/minute when the background has an average luminous density of 1 candela per square meter (**Fig. 1**). From this curve, we determine that nighttime viewing requires greater separation between various portions of a neon sign than would be necessary in daylight. The sign's size requirement can be calculated using the normal, estimated viewing distance (**Fig. 2**).

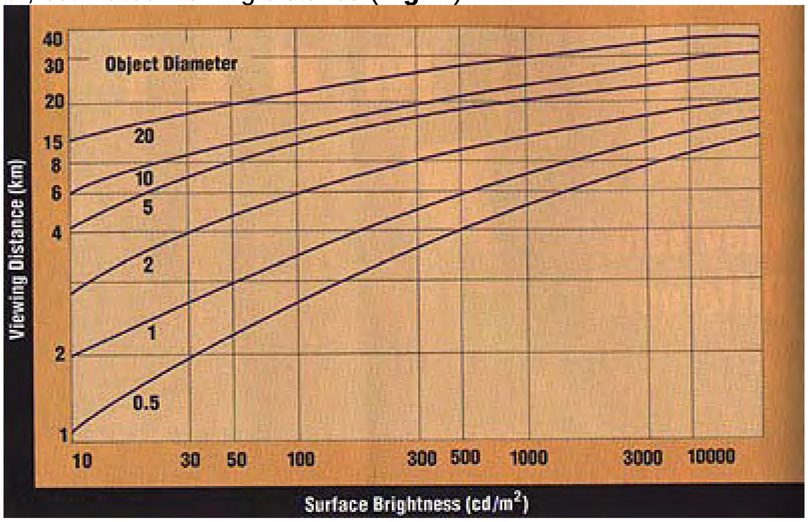


Fig.2: Maximum viewing distance over sign brightness for resolving different point sizes (Gut, *Handbuch der Lichtwerbung*, page 189)

The values given in **Fig. 2**, however, are valid only in good weather conditions. Since the 1920s, we have known that the atmosphere's transparence is reduced in bad weather, but not equally for all wavelengths or colors (**Fig. 3**). The superior penetrating power of a red-neon discharge still stands as one of the neon industry's principal marketing arguments.

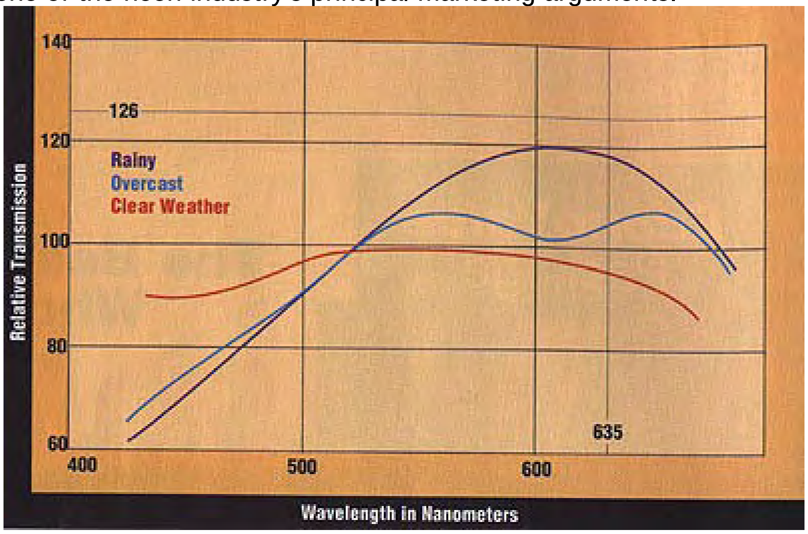


Fig.3: Relative transmission of different colors under various weather conditions (Samuel Miller, *Neon Signs*, page 38)

Luminous properties of neon signs

When discussing the minimum brightness necessary to distinguish two separate points, we must also discuss the opposite effect: image blurring or irradiation. At high intensities, light activates surrounding optical nerves, as well as those at the spot where light is focused. This increases the visible light spot's diameter. For sign installations where incandescent lightbulbs are used, this is a desirable effect (**Fig. 4**). But the effect is undesirable for neon signs because letter contours become blurred. In this case, halos form around the entire sign, decreasing visibility.

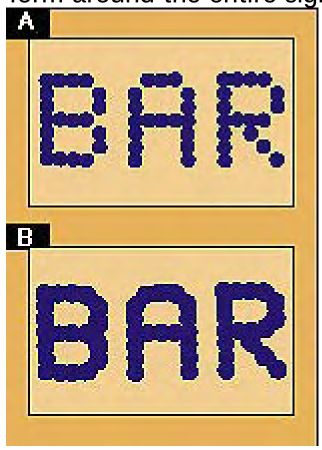


Fig.4: Example of the irradiation (blurring) effect, a desirable effect in incandescent-bulb signs (A), but not in neon signs (B)

Without reducing a sign's light output, a sign builder can counter irradiation by:

- Increasing the letter height. This provides more dark space between critical letters (B,E,G,H,R,S). Thus, the eye is given a wider viewing angle to better distinguish the letter.
- Aligning the tube layout properly. For longer viewing distances, neon lettering usually is created in multiple rows of tubing. Concentrating tubes in the center of the letter, however, does not give the font a very bright appearance because of irradiation. Therefore, when bright colors are used, single- or double-stroke neon letters may provide better readability than multiple rows of tubing.
- Properly designing channel-letter shapes. The ability to restrict neon's light-emission angle is one key reason for channel letters' popularity. The typical reflection of light radiated sideways from exposed neon is reduced, which, in turn, reduces the halo effect for better readability.
- Calibrating the sign's brightness according to background brightness.

Because human-eye sensitivity comprises a wide range of visual impressions, "brightness" always depends on the ambient environment. For example, to avoid the irradiation effect, a neon sign cannot be more than 10-100 times brighter than the background surface. Because many signs must be readable by day and night, a designer encounters problems. Either the sign appears too dark in daylight or too bright after dark. One solution is to make the neon bright enough to be seen well by day, but to illuminate the sign's surroundings with additional lights to avoid blurring at night.

Because the surface brightness of acrylic-face letters is approximately 10 times less than for exposed neon, irradiation is reduced greatly in enclosed channel letters. To provide visibility equivalent to exposed neon, enclosed neon signs must either be made considerably larger or equipped with more powerful illumination.

Color, brightness and power

We know the human eye is most sensitive to yellow/green colors. Thus, the blurring effect is much more likely when using greenish colors than, for example, a deep red. Both radiate the same power, but at different wavelengths. Furthermore, lighting efficiency (electrical input power vs. light output power) varies widely depending on the type of gases, fluorescent powders and glass colors used. **Fig. 5** gives typical surface brightnesses for 15mm, exposed neon operated by a typical, 60mA transformer. This table also suggests that it might be unwise to place a ruby-red tube of equal size and operating current beside a standard green tube. The green tube will definitely overpower the red.

Figure 5

Color	**Brightness (cd/m^2)**
white 6,500 K	6503
clear red	2160
clear blue	900
standard green	10026
standard blue	2560
ruby red	800
cobalt blue	1600
noviol gold	6500

Fig. 5: Average values calculated from different manufacturers' measurements for a 15mm tube operated at 50mA (or 60mA standard transformer).

Choice of colors is often dictated by the client company's philosophy or existing logo. Some customers accept deviations, while others will not. Thus, a signmaker must calculate a sign's size, as well as the brightness and operating current of each component color, to create a successful design.

Acrylic-face signs

When company logos or sign messages are too complex for exposed neon, they must be created as backlit acrylic signs or channel letters. Backlighting acrylic plastics with neon offers several advantages over fluorescent lamps, but achieving good results can be challenging. The principal advantages of neon backlighting include unlimited shapes and longevity of the lighting system. The ability to fabricate neon tubes in any shape allows signmakers to optimize brightness uniformity throughout the illuminated surface. Because brightness, shape and spacing are critical, sign builders should experiment before they quote jobs.

Specific face colors must be combined with the proper neon backlighting colors for optimum appearance. For example, if you're backlighting a large-format, full-color digital print, you need a "Daylight" neutral white with a color rendering index (CRI) of at least 95. Otherwise, some colors may appear as dirty shades. When backlighting red acrylic, you can use clear red or, even better, a bright purplish red for maximum brightness. Conversely, using standard white (6,500K) neon in this application creates a dirty-brown shade, not red. In short, to avoid a mismatched appearance, you must choose a neon hue that provides the same colors of the light spectrum that exist in the acrylic face.

Because the acrylic face reduces surface brightness to less than 10% of it's original value, the blurring effect I've discussed is negligible for enclosed neon signs. Daylight visibility of acrylic-face signs is rarely an issue because faces typically reflect daylight quite well. But to achieve good visibility at dusk (when most people view signs), the neon must be bright enough to overcome the 90% loss incurred when the light passes through the plastic. In this respect, more is usually better to create dynamic signs that meet your clients' expectations.

B-11

Marcus Thielen, *LED or Neon? A Scientific Comparison*, SIGNS OF THE TIMES (Feb. 10, 2006)

LED or Neon?
A scientific comparison

By Marcus Thielen (02-10-2006)

All but a few LED manufacturers and sign companies have confused their clients when comparing their products to neon. In their advertisements, they've published incomplete and misleading information, using such slogans as, "Our lighting system consumes less than one-fourth of the energy of comparable neon." But in these comparisons, they failed to mention that their "comparable neon" will give 10 times more light output than their LEDs.

To clarify the situation, as a physicist, I'll compare LEDs to neon for illuminating channel letters. But please note that the development in the semiconductor industry is so fast that the picture given here may change in a few months or years.

Comparing apples and peas

In the lighting industry, it's been difficult to compare values because a reliable international standard for brightness and luminous flux didn't exist before 1931.

Luminous flux, measured in lumen, is the total light output of a light source into spherical space around the source, independent of the source's directivity. Simply put, lumen represent the total amount of light generated.

Contrary to this is the parameter brightness. A luminous surface can be very bright but small. But a tiny, bright surface usually doesn't emit a huge amount of light because it's concentrated in a small spot.

Many different types of lighting units are historically based and still used in marketing, and these units can't be easily compared. Therefore, it's difficult to obtain comparable numbers for products not directly related to lighting -- especially from LED manufacturers.

Overall efficiency of a lightsource is what's really important because it states how many lumen will result from one watt of electrical input.

Now, the first experimental results on LED light output, measured according to lighting standards, are available. Thus, we can accurately compare the luminous efficiency of LEDs to other types of lighting for sign applications.

For this comparison, remember that, by definition, the unit "lumen" is weighted by the human-eye response curve. Comparisons of colored light provide reasonable data only when comparing light sources of similar spectral distribution.

Lifetime considerations

Some store chains that adopted LED illumination for channel letters have reverted to neon. Having operated approximately 1 1/2 years outdoors, their signs' LED light output has reportedly degraded to a degree that's inadequate. It has been proven (see ST, *August 2001, p.85*) that environmental operating temperatures over 150° F, even for a short duration, can permanently damage the LED, leading to a light-output drop of as much as 70% in a few weeks.

The intensity of this diffusion-based effect depends on many factors, of which all are not exactly known today. However, it can be stated assuredly that the frequently advertised lifetime of LEDs in outdoor applications -- 100,000 hours -- can't be reached. A realistic value may be 5,000 to 10,000 hours, depending on environmental conditions.

Ninety years of experience (yes, this is the 90th anniversary of the invention of the neon tube by George Claude) have shown that an average neon tube will provide approximately 20,000 to 30,000 hours of useful life, but tubes with more than 80,000 hours are also common.

Sample calculation

As an example, let's consider a motel sign with 2-ft.-tall channel letters **(Fig. 1)**. We'll do one sample calculation in red (LED's best color) and a second calculation for green (a color of neon that is quite intense). This way, the results obtained for all other colors will range between these two example values.

Note that custom-made, hot-cathode slimline lamps can reach the same high efficiency as linear fluorescents and can be up to 45% more efficient than neon. They can be made in any shape to fit into channel letters.

Fig.1: Motel sign layout used for sample calculation. Tube lengths for single-stroke neon: 25.3 ft. for six tubes.

Table 1: LED Efficiency			
	Available for the Sign Market [lumen/W]	**Maximum Exceptional Single-Value Experiments [lumen/W]**	**Neon (Based on Example) [lumen/W]**
Color			
Red	38	42	11.50
Orange	40	53	43.50
Yellow	32	35	52.90
Green	20	42	65.00
Blue/Green	18	25	48.60
Blue	9	12	23.11
White	20	20	50.25
Data shown is lamp efficiency: electrical input vs. light output. Power supply or resistor loss isn't included. All values are dated as of Aug. 28, 2001, and are subject to change quickly. Thus, they may not reflect the complete or latest information at the time of publication.			
For comparison in white (OSRAM catalog data):			
Standard Incandescent Lightbulb	13.8 lumen/W		
Low-Voltage Halogen Incandescent	23.0 lumen		
Compact Fluorescent	60.0 lumen/W		
Linear T8 Fluorescent	93.0 lumen/W		
HID without Phosphor Conversion	107.0 lumen/W		
The best in the yellow range is still sodium:			
Sodium High Pressure	150.0 lumen/W		
Sodium Low Pressure	183.0 lumen/W		

"Red" calculation

First, our sign shall be illuminated by single-stroke, 15-mm, clear, red neon, running on a 30mA, US-style magnetic transformer. Total tube length is 7.6 meters (25.3 ft.) for six tubes; the calculated operating voltage (gradient formula of Wickmann used) is 5213V, and the operating current is 25mA. This gives an electrical consumption of 5213V * 0.025 Ampere = 130.3W.

Now, how much light will be produced?

Fifteen-mm-diameter, clear red neon at 25mA will give a luminous output of 193 lumen per meter (equal to 64.3 lumen/ft., measurements by the independent Instituto G. Ferrara, Milan, Italy), so the total light output of the 7.6m will be 1480 lumen.

The efficiency then is equal to 1480 lumen/130W = 11.3 lumen/W. But this is for the tube only. An American style core-and-coil transformer will work at about 90% efficiency, which leads to an overall efficiency of 10.2 lumen/W.

Now onto the LED. The LED chip of the new model generates 2.5 lumen (according to the data sheet of Teledyne, Los Angeles) at an operating voltage of 2.2V at 30mA, (which equals 0.066W), thus producing 37.8 lumen/W.

Three LED chips are usually put on a small board in series with a resistor for current stabilization and run on 12V. Thus, one board is consuming 30mA at 12V, making 0.36W and giving off 7.5 lumen in total -- having an efficiency of 20.8 lumen/W.

Let's assume the 12V power supply is one of the modern switching power supplies with a high efficiency of 97%. The overall efficiency of the LED sign is 20.2 lumen/W (compare this to 10.2 lumen/W for neon).

To produce an equivalent to neon's light output (1480 lumen), you need 592 LEDs or 198 LED board modules. The total consumption is 71.3W (compared to 130W for neon to achieve the same amount of light). The cost of an LED module is approximately $10; you could invest $1,980 U.S., plus approximately $60 for the 12V supply.

At a cost of $5/ft., the 25 ft of "clear red" neon will cost $125. Adding $50 for the transformer, it costs $175 to fit the channel letters with neon. In comparison, the cost of LED is 11 times that of neon.

"Green" calculation

Now let's do the calculation for the same sign in green letters. On 7.6m (25.3 ft.) of 15-mm standard green, filled argon/mercury tubes, the operating voltage is 3425V at 25mA. Thus, the power consumption equals 85.6W for the tubes, with transformer losses (assuming again 90% efficiency) of 95.1W. Light output of 15-mm, standard green neon at 25mA is 790 lumen/m (263 lumen/ft.), so total light output from the sign is 6059 lumen, which makes an overall efficiency of 63.7 lumen/W.

Again, our calculation for a Teledyne LED is as follows: Flux is 2 lumen/LED operating on 3.5V at 30mA, making 19.04 lumen/W for the LED. One module of three LEDs will consume 0.36W and give 6 lumen, making 16.7 lumen/W for the module. With a 97% efficiency of the 12V supply, overall efficiency will be 16.2 lumen/W (this is only 25% of the efficiency of neon).

To achieve the same light output from our sign illuminated with LEDs, rather than neon, we'd have to stuff 3,030 LEDs or 1,010 modules into the channel letters, consuming 30.3 Amperes at 12V, thus consuming 363W of energy (ignoring the power supply losses for now). Consequently, LEDs require 4.3 times more power than neon to produce the same amount of light.

Additionally, the green LED modules cost $13 each, so you'll pay $13,130 just to acquire the LEDs without a power supply. In fact, LEDs are typically less effective (except red), more expensive and shorter-lived, compared to classical lighting methods. And the reader may share my personal opinion that the uniformity of LED lightspots can never replace the handcrafted, warm touch of a nice neon sign made with pride from molten glass.

Neon is -- and will remain for a while -- the winner for sign lighting in the long run.

B-12

J.P. Freyssinier et al., *Evaluation of Light Emitting Diodes for Signage Applications*, Lighting Research Center, Rensselaer Polytechnic Institute (2004)

Evaluation of light-emitting diodes for signage applications

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Evaluation of Light-Emitting Diodes for Signage Applications

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ABSTRACT

This paper outlines two parts of a study designed to evaluate the use of light-emitting diodes (LEDs) in channel-letter signs. The first part of the study evaluated the system performance of red LED signs and white LED signs against reference neon and cold-cathode signs. The results show a large difference between the actual performance and potential savings from red and white LEDs. Depending on the configuration, a red LED sign could use 20% to 60% less power than a neon sign at the same light output. The light output of the brightest white LED sign tested was 15% lower than the cold-cathode reference, but its power was 53% higher. It appears from this study that the most efficient white LED system is still 40% less efficient than the cold-cathode system tested. One area that offers a great potential for further energy savings is the acrylic diffuser of the signs. The acrylic diffusers measured absorb between 60% and 66% of the light output produced by the sign.

Qualitative factors are also known to play an important role in signage systems. One of the largest issues with any new lighting technology is its acceptance by the end user. Consistency of light output and color among LEDs, even from the same manufacturing batch, and over time, are two of the major issues that also could affect the advantages of LEDs for signage applications. To evaluate different signage products and to identify the suitability of LEDs for this application, it is important to establish a criterion for brightness uniformity. Building upon this information, the second part of the study used human factors evaluations to determine a brightness-uniformity criterion for channel-letter signs. The results show that the contrast modulation between bright and dark areas within a sign seems to elicit the strongest effect on how people perceive uniformity. A strong monotonic relationship between modulation and acceptability was found in this evaluation. The effect of contrast seems to be stronger than that of spatial frequency or background luminance, particularly for contrast modulation values of less than 0.20 or greater than 0.60. A sign with luminance variations of less than 20% would be accepted by at least 80% of the population in any given context.

Keywords: LED, channel letter, sign, fluorescent, neon, cold cathode, backlit, illuminated

1. INTRODUCTION

The size of the electric signage industry was estimated at approximately $2 billion per year in 1997,[1] making it an attractive market for LED manufacturers and energy savings advocates. With the advent of new materials and manufacturing processes in recent years, LEDs have increased in brightness and now have increased efficacy compared with incandescent lamps.[2, 3, 4] Additionally, a greater variety of colors now available, including white, opened a new realm of applications for LEDs such as commercial channel-letter signs. In trying to expedite the penetration of LEDs into the signage market, the lighting industry has extrapolated from some of the very successful applications of colored LEDs – e.g., traffic and exit signs, and high-mounted stop lights in vehicles – to claim similar results for red and white channel-letter systems. Neon and fluorescent lamps are the two most commonly used light sources in this application, but it has been shown that there is a large potential and interest for their replacement by LEDs to attain energy and maintenance savings. However, the literature lacks research comparing the performance of LED systems to that of neon and fluorescent systems.

Although LEDs pose potential benefits for signage applications, their initial benefits need to be maintained over time before a fair comparison to neon or fluorescent lamps can be made. For example, one of the most publicized characteristics of LEDs has been their long life, often claimed to be up to 100,000 hours. However, it has been shown that the light output can diminish rapidly over time, particularly for phosphor-based, indicator-type white LEDs, and that light output is dependent on a series of factors including drive current, temperature, and humidity.[5, 6, 7, 8] As a result, there is a need for a series of metrics to consistently evaluate the life and efficiency of LED systems. Such metrics could develop into a quality- and performance-labeling program for channel-letter signs, e.g., Energy Star®. In addition to these metrics, qualitative factors play a role in signage systems. One of the largest issues with any new lighting technology is its acceptance by the end user. Consistency of light output and color among LEDs, even from the same manufacturing batch, and over time, are two of the major issues that also could affect the advantages of LEDs for signage applications. Presently, there are no brightness uniformity standards for signage. To evaluate different signage products and identify the suitability of LEDs for this application, it is important to establish a criterion for brightness uniformity. The discrete nature of LEDs could potentially create non-uniformities if their number or positioning is not carefully considered. LED arrays operating at different temperatures or having different rates of depreciation could also cause non-uniformities. Depending on the context, a sign with increasing degrees of non-uniformity could be, at some point in time, deemed no longer acceptable. In this sense, the brightness uniformity of a sign could be used, in addition to light output, to define the useful life of a sign.

Based on these needs, the goals of this study was to further the understanding of LEDs as they pertain to channel-letter signage systems and to develop a set of tools to help optimize these signs for efficiency and acceptability. The tasks included a system performance evaluation and a study of brightness uniformity subjective perception.

2. SYSTEM PERFORMANCE EVALUATION

The objective of the system performance evaluation was to compare the electrical, photometric, and thermal characteristics of the LED signs against neon and cold-cathode fluorescent references in order to document potential energy savings. The scope of this task was limited to the measurement and analysis of parameters such as power (P), current (I), voltage (V), power factor (PF), relative light output (LO), temperature (T) inside the signs, and spectral transmittance of the acrylic diffusers.

2.1 Methods

A total of 13 signs were tested in two colors: 7 red (neon plus 6 different manufacturers of LEDs) and 6 white (cold-cathode plus 5 different manufacturers of LEDs) signs. The signs were prepared by an independent neon shop following typical manufacturing practices for the neon signs and manufacturer recommendations for the LED signs. All had the same 24-inch nominal height and represented the same character (uppercase G).

Figure 1 shows a schematic diagram of the measurement equipment setup for the evaluation. The evaluation was conducted inside a 12 ft. by 9 ft., temperature-controlled room. The ambient temperature was set at 25±1 °C. All major surfaces in the room were covered with a black matte cloth to minimize the effects of stray light and inter-reflection. A data acquisition system formed with two computers collected the data in a systematic and consistent manner. One computer, connected to a spectroradiometer, monitored the spectral power distribution of the signs. The second computer received the data from a power analyzer (P, I, V, PF), a photometrically corrected [$V(\lambda)$] sensor (LO), and nine thermocouples (T). Eight thermocouples were uniformly distributed inside the sign under measurement while the other one monitored the room's ambient temperature. A rack built for this experiment kept the relative geometry among the spectroradiometer, the photosensor, and the sign being measured constant.

All electrical and thermal measurements had a sampling rate of 15 seconds; therefore, 4 measurements were taken per minute. Measurements were taken from the moment the signs were switched on, but only the last five sampled measurements of a 90-minute period were used for the analysis. The rest of the measurements were used to monitor the behavior of the different signs under test and to confirm that they had reached photometric and thermal stabilization.

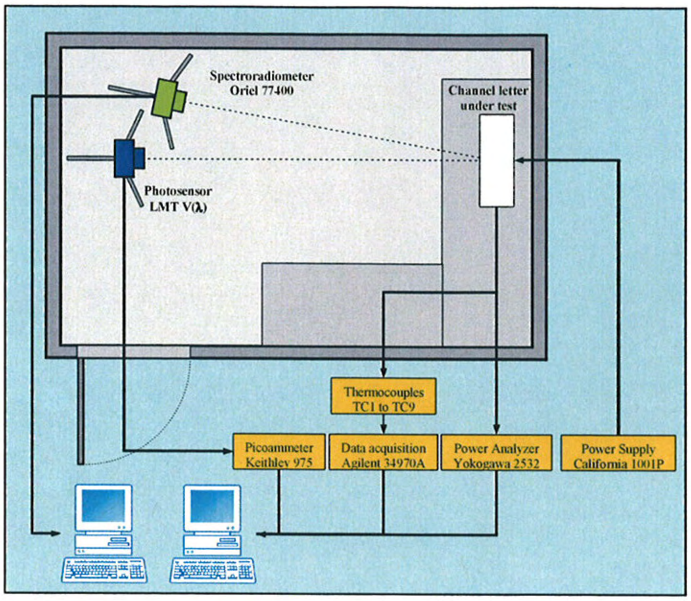

Figure 1. Schematic of the equipment used for the evaluation. Two computers collected the data systematically. The first controlled the spectroradiometer; the second controlled the LMT photosensor, the thermocouples, and the power analyzer.

2.2 Results

2.2.1 Light output and power

The graphs in Figures 2 and 3 show the average light output and power, respectively, for all red and white signs tested. These figures show the large differences in the light output and the power of the signs measured. Therefore, to make the comparison between signs of the same color meaningful, calculations were used to equate the light output of the LED signs to that of their respective reference. It should be noted that light output was defined as the average luminance (cd/m^2) of the sign for reference only. It is not intended to characterize fully, nor to provide further information on the brightness uniformity of the signs, nor their absolute light output (in lumens), nor their absolute brightness (as perceived by people). These calculations assume that the efficacy and power factor remain constant, and that the power of each sign could be increased or decreased linearly to reach the reference light output. The scaled power for equal light output is plotted in Figure 4.

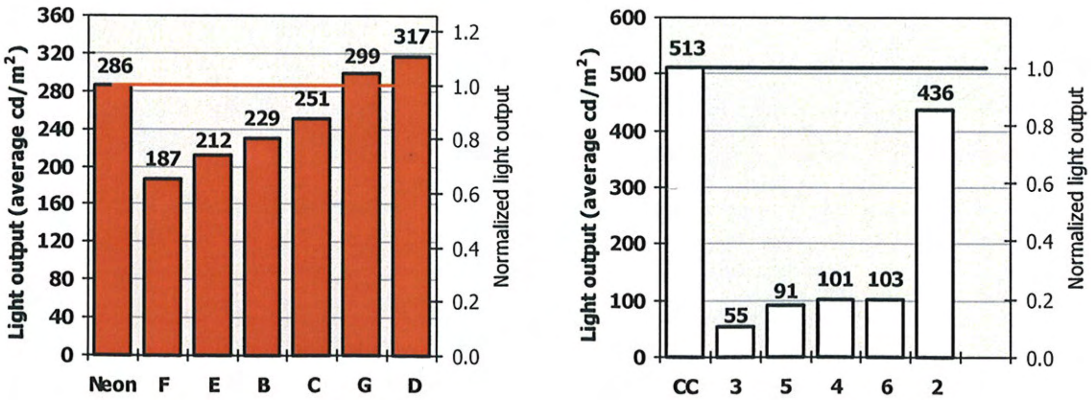

Figure 2. Measured light output of all **RED** (left) and **WHITE** (right) signs tested. Each value is the average of five measurements at the end of the 90-minute stabilization period. The references for normalization (secondary axis) are the neon sign (for **RED**) and the cold-cathode sign (for **WHITE**).

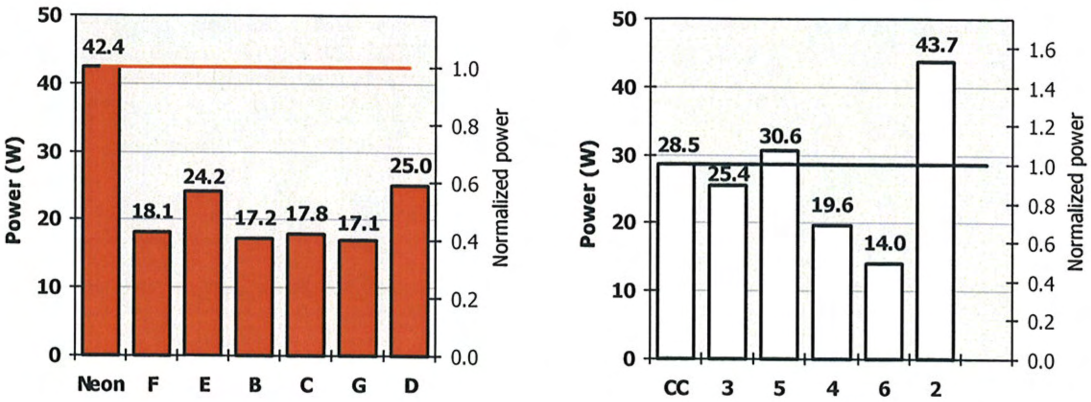

Figure 3. Measured power of all **RED** (left) and **WHITE** (right) signs tested. Each value is the average of five measurements at the end of the 90-minute stabilization period. The references for normalization (secondary axis) are the neon sign (for **RED**) and the cold-cathode sign (for **WHITE**).

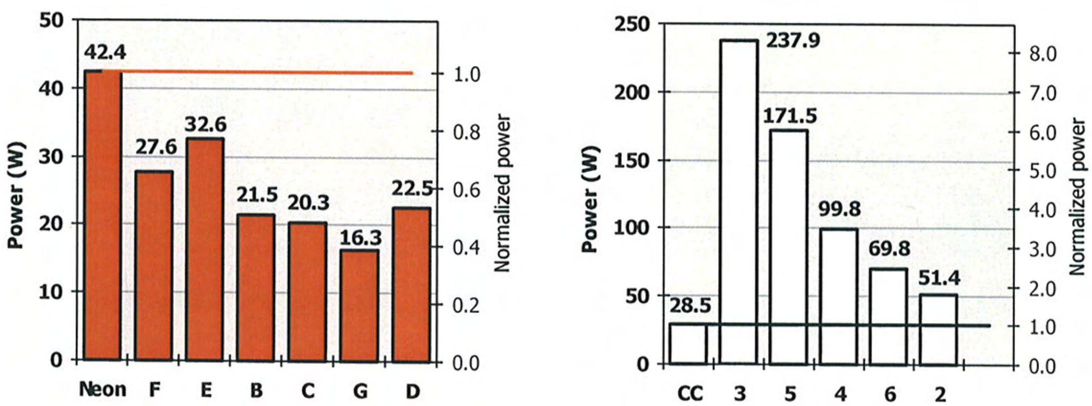

Figure 4. Scaled power of all LED signs for equal light output as the neon (for **RED,** left) and cold-cathode (for **WHITE,** right). The references for normalization (secondary axis) are the neon sign (for **RED**) and the cold-cathode sign (for **WHITE**).

2.2.2 Temperature

At the end of the testing period, the average temperature of the red neon sign had increased by 9.63°C. The increase of the average temperature of the six red LED signs ranged from 0.63°C to 4.61°C. For the white signs, the average temperature of the neon sign increased by 4.27°C, while the increase of the average temperature of the five LED signs ranged from 1.57°C to 6.58°C.

2.2.3 Transmittance of the acrylic diffusers

The measured relative spectral transmittance of the diffusers, the spectral power distribution of the neon and cold-cathode lamps, and the photopic [V(λ)] luminous efficiency function are shown in Figure 5.

As can be seen in Figure 5, the average transmittance of the acrylic diffusers is extremely low. The average reduction in light output due to the diffusers was calculated at 66% for the neon sign and at 59% for the red LED signs. In the case of the white signs, the average reduction in light output was calculated at 60% for both the cold-cathode and the LED signs.

2.2.4 Color variations
An additional issue is the color difference among LED manufacturers. The CIE color chromaticity coordinates of the different red and white LED signs exhibit differences among signs larger than 4-step MacAdam ellipses when compared to their references.

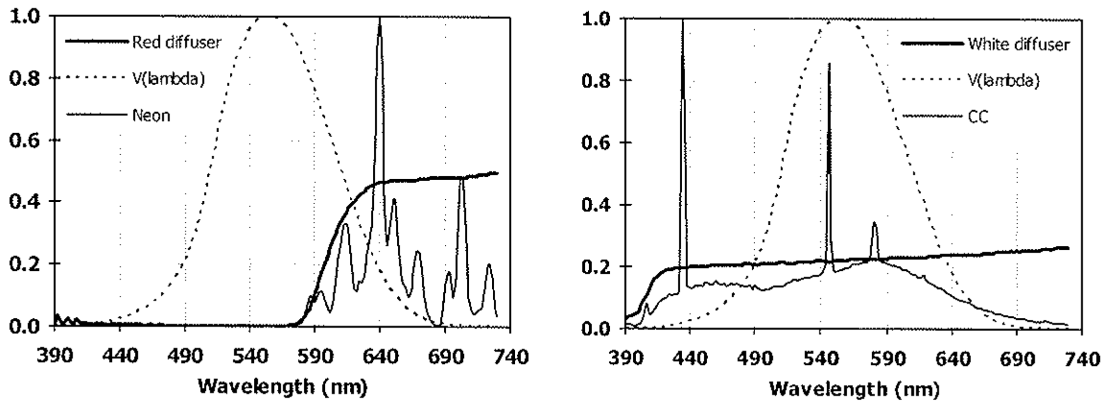

Figure 5. Relative spectral transmittance of the red (left) and white (right) acrylic diffusers, and spectral power distribution of the neon (left) and cold-cathode (right) lamps.

2.3 Discussion
As expected, a large difference exists between the performance and potential savings from red and white LEDs. While only two of the red LED signs had a slightly higher light output than the reference (+5%, +11%), the power consumed by all of them was at least 42% lower. The potential in connected load savings ranges from approximately 42% to 60% (Figure 2). Because there are no current standards for how high the luminance of a sign should be, sign manufacturers may want to equal the light output of the LED signs to that of neon. Therefore, depending on the configuration, a red LED sign could still use 20% to 60% less connected load than a neon sign (Figure 3). The light output of the brightest white LED sign was 15% lower than the cold-cathode reference but its connected load was 53% higher. The other signs produced between 10% and 20% of the cold-cathode light output, while their connected load was only 11% to 51% less, and in one case, 7% higher than neon. The efficacy of the white LED signs was 44% to 88% lower than the reference.

Temperature increase inside the sign was not an issue for any of the red LED configurations, since it was less than 5°C. Because the signs were manufactured according to standard practice or recommendations, some had the power supplies or drivers inside the sign, while others were installed remotely. This fact, along with the difference in the number of LED modules, could explain the variation among systems, although it did not appear to negatively impact the performance of the signs in either case. While the absolute increase in temperature inside the white LED signs may not be objectionable, it was, with the exception of one sign, higher than that of the red signs. In two cases, the average increase inside the sign was higher than the reference. Different configurations or heat sinking may be needed for white LED signs to diminish any potential problem with temperature build-up, especially when trying to equal the light output of cold-cathode signs.

One area that offers significant potential for further energy savings is the acrylic diffuser of the signs. Use of materials with lower transmission losses will result in attractive energy savings. For white LED signs, other issues such as non-uniformities in luminance and color between individual LED modules should be considered[9] before a decision can be made regarding the number and location of the LED modules.

A potential limitation of this study is the small number of samples tested, which might not be representative of the respective technology that each sample uses. Based on information from the manufacturers and with further testing, the variability of a neon system's efficiency could be shown to be greater than 100%. Different types of transformers, the inherent variability of neon tubes that are processed by hand, and other factors yield large differences from sign to sign and from manufacturer to manufacturer. A similar variability can be expected from LED drivers and power supplies, depending on the configuration and number of LEDs operated. Additionally, it is worth mentioning that all these measurements are initial values and that all systems are expected to depreciate at different rates.

The collected data support the conclusion that red LED channel-letters based on current technologies are much more efficacious than conventional neon channel-letters. As seen in this preliminary evaluation, the best product has the potential to save approximately 60% of connected load compared with the neon sign tested. Red LED channel-letter systems could probably be easily optimized to provide more than 80% energy savings in the near future. However, issues that need to be addressed in order to achieve such energy savings include improved drivers for LEDs, a better match between LED emission wavelength and the transmission characteristics of the red acrylic front face, better optics to direct light, dedicated photocells or dimmer controls, and standardized luminous requirements. Conversely, the data collected shows that white LED channel letters are not as efficient as cold-cathode at the present time. It appears from this study that the best white LED system is still 40% less efficient than the cold-cathode system tested. This is not surprising since white LED technology is still under development. However, it is expected that white LED signs can eventually be made more efficient than neon signs. Achieving 50% energy savings with white LED systems is a reasonable goal. To reach this goal some issues need to be addressed. First of all, the white LED systems evaluated use phosphor-based LEDs. The use of RGB white LEDs would likely have shown the LED channel letters to be comparable to white neon in terms of energy use. This is because RGB white LEDs offer twice the efficacy of phosphor-based LEDs. The remaining issues are similar to those relating to the red LED systems.

3. BRIGHTNESS-UNIFORMITY PERCEPTION

Two human factors experiments were conducted for the evaluation of the perception of brightness uniformity. The first one was designed to determine the threshold for just-noticeable differences and is described in detail in Ramamurthy *et al.* (2003).[10] The second experiment was designed to determine a criterion of uniformity that could be used to predict the acceptable brightness uniformity of signs for retail applications.

3.1 Experimental design, setup, and procedure

It was determined that the three most important variables affecting the perception of brightness uniformity were contrast, spatial frequency, and luminance of the background. A channel-letter sign representing the uppercase character G was modified to provide experimental conditions for which the aforementioned variables could be controlled independently. The sign was divided internally into six sections of nominally the same area. The brightness of each section was controlled independently to provide different groupings (spatial frequency) and different degrees of uniformity (contrast). The sign was presented to subjects at background luminance values of 1 cd/m^2 and 100 cd/m^2. The range of spatial frequencies (0.09 to 9.0 cycles per degree) tested was achieved by combining the viewing distance (10', 30', 60' and 340') and the number of independent sections of the apparatus used to create non-uniformities. The six sections of the apparatus were combined into three patterns: SPF1 (six small sections), SPF2 (three large sections), and SPF3 (two larger sections) (Figure 6). See Ramamurthy *et al.* (2003)[10] for a complete description of the apparatus and experimental conditions.

Figure 6. Reference conditions for each pattern: SPF1 (left), SPF2 (middle) and SPF3 (right). The contrast modulation value of these conditions was calculated at 0.70, 0.90 and 1.0, respectively.

Each pattern had ten equally spaced values of contrast modulation measured by the ratio of the difference of average luminance of two adjacent sections to the sum of these two values. For a completely uniform sign, the modulation was equal to zero, while for a sign with alternated sections turned on and off the modulation approached unity. Given the limitations of the apparatus, the maximum achievable non-uniformity for each pattern was different – 0.70, 0.90 and approximately 1.00, for SPF1, SPF2 and SPF3, respectively . However, comparable conditions between patterns were nominally the same. The combination of three patterns and ten modulation values yielded thirty possible conditions. Each one of these conditions was presented three times in random order to each subject to avoid spurious responses. The conditions were presented at four distances and at two different background luminance values (1 cd/m^2 and 100 cd/m^2) for a total of 720 experimental presentations per subject.

The experiments took place inside a dark photometry laboratory (for viewing distances of 10', 30', and 60'), and in a parking lot for the viewing distance of 340'. The main lighting system for the parking lot was turned off during the experimentation to replicate laboratory conditions. Although some of the street lighting could not be controlled, the ambient conditions were similar to those inside the laboratory. Sixteen subjects participated in the experiment and were asked to imagine that while approaching a store, they glanced at the store sign for about 1.5 seconds. After this period of time, the sign was turned off and the subjects were expected to answer whether the overall brightness uniformity of the sign was acceptable or not within that context.

3.2 Results

The subjective responses were used to calculate the percentage of times that each condition was considered acceptable, on a base of 48 independent presentations. Figure 7 shows the results for all patterns and modulation values at all distances.

3.3 Discussion

Contrast modulation seems to elicit the strongest effect on how people perceive uniformity. There is a strong monotonic relationship between modulation and uniformity acceptability. From the two pairs of conditions with the same spatial frequency (SPF1-10' and SPF3-30'; SPF1-30' and SPF2-60'), it could be inferred that as the number of non-uniform segments increases, the acceptability rating decreases. This could also mean that the number of the non-uniformities could be more important than their visual size. This conclusion is consistent with the results described by Ramamurthy *et al.* (2003)[10] for detectability of contrast.

The effect of contrast seems to be stronger than that of spatial frequency or background luminance, particularly for contrast modulation values of less than 0.20 or greater than 0.60. As expected, for the same background luminance, subjective acceptability increased with distance. In other words, the longer the viewing distance, the more uniform the sign appears to be. Also as expected, for the same viewing distance the sensitivity to uniformity increased with background luminance. In other words, the non-uniformities of a sign become more apparent when the background luminance increases. Acceptability ratings are higher for longer viewing distances at the same background luminance, and are lower for the bright background for the same viewing distance.

The results of the acceptability ratings are important because, for all practical purposes, the design of a given sign should be based on this criterion. From these results we can determine the required contrast modulation needed for a sign to be acceptable to a given percentage of the population. For example, a proposed value of 80% would require a sign to be within 0.20 and 0.60, which concurs with the estimated uniformity rating of a neon sign. Additionally, this range could be further refined depending on the estimated viewing distance, background luminance, and type of potential non-uniformities.

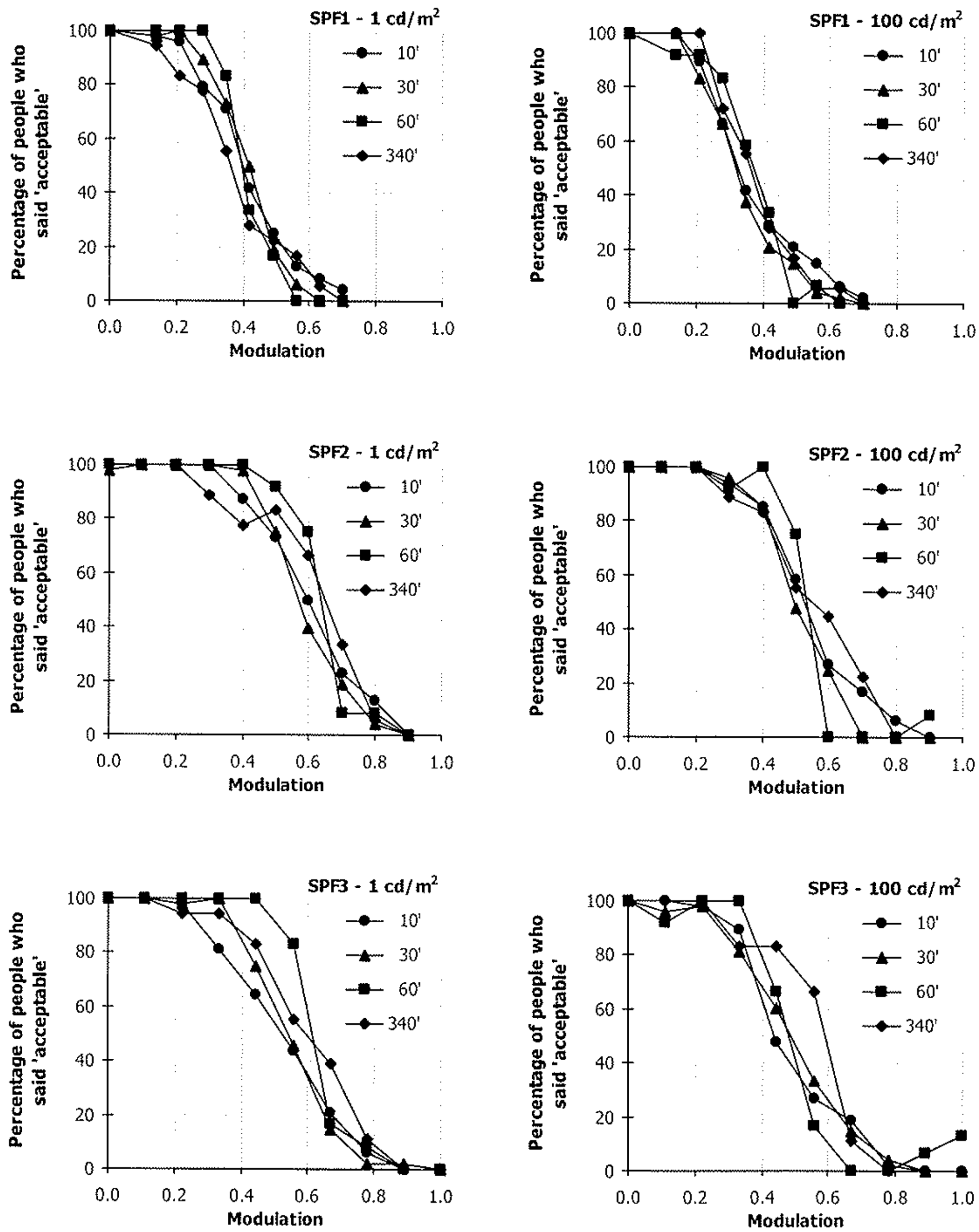

Figure 7. Acceptability rating (percent) for each condition, based on 48 answers from 16 subjects for patterns SPF1 (top), SPF2 (middle) and SPF3 (bottom) at four viewing distances (10', 30', 60', 340') for background luminances of 1 cd/m^2 (left) and 100 cd/m^2 (right).

4. CONCLUSIONS AND RECOMMENDATIONS

Given the lack of standards for measuring the brightness of signs, the overall average luminance could be used to estimate light output and efficacy of channel-letter systems representing alphanumeric characters. Based on the results of these experiments, it can be concluded that all red LED systems evaluated are more efficacious than red neon. All of the white LED signs evaluated had lower light output and efficacy values than that of the white cold-cathode sign. Only LED systems providing efficacies above 10 $cd/m^2/W$ should be considered for signs if the evaluation criterion is energy efficiency. A sign with luminance variations of less than 20% within the sign would be accepted by at least 80% of the population in any given context.

ACKNOWLEDGEMENTS

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B-13

Pacific Gas and Electric Company, *Codes and Standards Enhancement (CASE) Initiative, Draft Report: Requirements for Signs* (2007)

CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

2008 CEC Title 24 Building Energy Efficiency Standards Rulemaking Proceeding
February, 2007

Draft Report
Requirements for Signs

This report was prepared by Pacific Gas and Electric Company and funded by the California utility customers under the auspices of the California Public Utilities Commission.

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Document information

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Overview

This CASE proposal addresses the energy savings opportunities available in outdoor signs. The key elements of the proposal are as follows:

- Turn off lights in signs when no one is present or when the light is imperceptible because there is vastly more daylight than the light produced by the sign. Require automatic time and daylight responsive lighting controls for all outdoor signs. Require switched receptacles for indoor plug-in signs.

- The amount of light needed to see an unfiltered sign during the day is substantially greater than that needed at night. Require automatic dimming controls for outdoor signs that are illuminated during daytime hours.

- Set minimum efficiency requirements for transformers or power supplies serving neon and cold cathode sources.

- Require demand responsive controls for large signs illuminated during the day. Dimming loads or turning off a fraction of the load for a few hours per year can help prevent loss of utility service and yield significant cost savings for the owner.

Description

In Section 132 add a new subsection (c) to require automatic time schedule lighting controls for all outdoor signs. The control strategy required will vary based on sign usage patterns. Photoelectric controls combined with time switches will be required for all signs not used in the daytime. Dimming controls will be required for signs that are illuminated during daytime hours, to enable a minimum of 65 percent reduction in lighting power at night.

In Section 132 add a new subsection (d) to require switched receptacles for plug-in indoor signs. The control strategy required will be a manual time schedule based on owner/operator preference.

Requirements for minimum efficiency transformers or power supplies in neon and cold cathode signs. When complying with the alternative to Section 148 (a) or (b), minimum efficiency transformers or power supplies are required to drive neon and cold cathode lamps for all signs. Minimum efficiency power supplies can reduce overall energy use by as much as approximately 25% for indoor applications and by as much as approximately 22% for outdoor applications.

Energy Benefits

The following table illustrates the energy savings per square or lineal foot of each major sign category for which we are proposing efficiency upgrades. The assumed load is 12 Watt per square foot for fluorescent signs, 68 to 75 Watt per square foot for LED signs and 8.5 Watt per lineal foot for neon and cold cathode signs.

Table 1: Unit energy savings per measure

Efficiency Upgrade	Energy Savings
Automatic Controls for Outdoor Signs	4 to 57 kWh/SF
Switched Receptacles for Plug-in Indoor Signs	8.8 kWh/SF
Dimming Controls for Outdoor Signs Operated during Daytime Hours	176 to 196 kWh/SF
Minimum efficiency Transformers or Power Supplies for Neon and Cold Cathode Sources	2.4 to 5.3 KWh/LF

Non-energy Benefits

The implementation of lighting controls will reduce operating time and/or lighting power, leading to longer lamp life and reduced maintenance. The implementation of high efficiency power supplies in neon and cold cathode signs can reduce the quantity of materials used in sign equipment. The use of dimming controls in LED message centers operated both in the day and at night will enable optimum control of sign conspicuity.

Statewide Energy Impacts

The statewide energy impacts will be estimated in the final CASE report when the estimates of energy savings are refined and applied to the statewide estimates of new signs added in the state. The statewide estimate of new sign construction is based on the PIER Outdoor Lighting survey.

Environmental Impact

No direct environmental impact is anticipated from implementation of these measures.

Primary environmental impacts are based upon air emissions reductions from power plants due to electricity savings... We will base these estimates of reduced emissions by multiplying the statewide energy savings by the emissions factor values generated by the California Energy Commission for evaluating the environmental impacts of the 2005 standards as shown in Table 2 below.[1]

Table 2: Emissions Factors used to calculate the air emissions reductions resulting from end-use reductions in electricity and natural gas consumption

Emissions factors	NOx	CO	CO2	PM10
Natural Gas, California (lbs/MMBtu)	0.094	0.03	115	0.01
Electricity, Western States (lbs/MWh)	0.383	0.23	1200	0.06

Statewide estimates of savings will be developed for the final report.

[1] Table 1, Appendix B page 2, Initial Study/Proposed Negative Declaration for the 2005 Building Energy Efficiency Standards for Residential and Nonresidential Buildings September 2003 P400-03-018. Values provided by the CEC System Assessment and Facilities Siting Division http://www.energy.ca.gov/reports/2003-09-12_400-03-018.PDF

Type of Change

All of the measures described here mandatory, they cannot be by-passed by saving more energy somewhere else in the permit application.

Proposed Measure	**Type of change**	**Impact on standards**	**Documents to be modified**
Require combination of time scheduling and daylight responsive lighting controls for all outdoor signs.	Mandatory measure	Expands the scope of the existing standards. There currently is no requirement for time scheduling lighting controls.	Standards, Manuals and Compliance Forms
Require switched receptacles for plug-in indoor signs.	Mandatory measure	Expands the scope of the existing standards. There currently is no requirement for switched receptacles for plug-in indoor signs.	Standards, Manuals and Compliance Forms
Require dimming controls for outdoor signs that are illuminated during daytime hours.	Mandatory measure	Expands the scope of the existing standards. There currently is no provision for lighting controls	Standards, Manuals and Compliance Forms
Require high efficiency transformers or power supplies for neon and cold cathode sources serving unfiltered signs or filtered signs exceeding 12 watts per square foot..	Mandatory measure	Expands the scope of the existing standards. Transformer type currently is not regulated.	Standards, Manuals and Compliance Forms
Require demand responsive lighting controls for large signs on during the day.	Mandatory measure	Expands the scope of the existing standards.	Standards, Manuals and Compliance Forms

Currently the performance approach calculations contained in the Alternative Compliance Method (ACM) Manual do not include outdoor lighting or sign lighting energy consumption. This proposal would not change this approach and thus this measure will not impact the ACM manual.

Technology Measures

The energy savings from this proposal are based on the added energy efficiency of the following technologies.

1. The use of time switches or photoelectric controls for the control of outdoor signs.

2. The use of dimming controls for the reduction of power in outdoor signs that are illuminated during daytime hours.

3. The use of switched receptacles for plug-in indoor signs.

4. The use of high efficiency power supplies for neon and cold cathode sources.

5. The use of demand responsive controls for larger signs illuminated during the day.

Information about the availability, cost, and performance of the technology is readily available and were compiled from the following sources:

- Sign product manufacturers' and sign industry association websites.
- Communication with sign manufacturers' associations.
- Communication with sign manufacturers and fabricators.
- Sign Industry Workshops facilitated by Southern California Edison (SCE) in December 2005 and February 2006.
- Attendance at the Western Sign Show in San Diego on February 10 and 11, 2006.
- Research institutions including the California Lighting Technology Center (CLTC) which is performing internally lit sign research for SCE

For the proposed use of automatic time schedule lighting controls with all signs the measure compares those cases where signs are controlled dusk on , dusk off to a dusk-on and time-off, time on, dawn-off control strategy. Astronomic time switches are readily available and currently are regulated by the standards for interior and exterior lighting. Dimming controls and time scheduling software are readily available for signs that are illuminated during the daylight hours (message centers) and can provide the capability to reduce the power input by as much as 90 % during nighttime use.

For the proposed use of switched receptacles for control of indoor signs, the measure compares those cases where signs are left on because there is no switch control to a time scheduled-on, time scheduled-off, control strategy. Sign mounted switches often are not readily accessible and operators leave signs on in unoccupied areas not visible to viewers outside the building. Switched receptacles are a readily available wiring method to provide a readily accessible manual controls.

For the proposed use of minimum efficiency transformers or power supplies with neon and cold cathode sources, the measure compares the commonly used ferromagnetic transformers from three manufacturers to establish minimum efficiency standards. The sign industry uses ferromagnetic transformers predominately because they are suitable for use in all applications, including high ambient temperature and for dimming and flashing. Although higher efficiency, high frequency electronic power supplies are readily available, these are not suited for high temperature applications above 100^{o} F ambient, dimming and flashing applications and applications requiring long lead lengths (due to issues with capacitive coupling that severely limit capacity).

Measure Availability and Cost

To develop the costs for this proposal we contacted these major manufacturers for electric sign components.

1. Automatic time schedule lighting controls: Intermatic, Tork and others.

2. Switched receptacles: Leviton.

3. Automatic dimming controls: Daktronics, Barco, Vantage and others.

4. High efficiency neon and cold cathode power supplies: Ventex, Transfotec, Philips, France, Allanson and Transco.

The costs of automatic time scheduling controls combined with daylight sensing (astronomic or photoelectric) add to the costs of sign installations as compared to the installation of photoelectric controls only. The analysis assumes a $500 cost. Since the cost of controls is fairly fixed regardless of size and number of loads, the cost per sign is inversely proportional to the number of signs on a single meter. The analysis assumes the smallest sign load which will be cost effective for implementation of this measure. This sign load is 180 Watt.

The requirement for switch receptacles adds to the cost of the plug-in signs. The analysis assumes a $200.00 cost. The analysis assumes the smallest sign load that will be cost effective for implementation of this measure. This sign load is 180 Watt. This load is so small that the requirement is for all signs.

The provision of automatic dimming controls adds to the cost of LED signs without dimming controls. For a basic outdoor LED message center with a monochromatic four-module display, these controls add approximately $1000 to the cost of the sign installation. This represents approximately 27% of the cost of the sign installation used in the analysis. For larger signs, the proportional cost of the dimming controls relative to the total cost of the sign will be less. The analysis assumes the smallest signs for a range of viewing distances from 110 to 500 feet. This sign load varies from 240 to 960 Watt.

The costs of minimum efficiency transformers and power supplies for neon and cold cathode compare favorably to the costs of low efficiency ferromagnetic transformers. For minimum efficiency transformers the evaluation shows a slight cost increase over their lower efficiency counterparts. The analysis found a cost of $1.53 per lineal foot.

Although the measure does not require the use of higher efficiency, high frequency power supplies, a previous evaluation showed that high power factor high efficiency power supplies are equivalent in price to normal power factor ferromagnetic transformers and are less costly than high power factor ferromagnetic transformers. The analysis found a savings of $0.64 per lineal foot. If a high efficiency power supply is misapplied in a high temperature application, then premature failure could occur, resulting in the cost of replacement of the failed power supply. For this reason it is anticipated that increased maintenance costs will result from the use of high efficiency neon power supplies. For the nighttime operation scenario, the analysis assumes replacing 25% of the high efficiency power supplies in years 5 and 10. For the 24 hour operation scenario, the analysis assumes replacing 25% of the high efficiency power supplies in years 5 and 10 and full replacement of standard transformers and high efficiency power supplies in year 15.The additional maintenance cost is $1.41 per lineal foot for the 24 hour scenario and $2.26 for the nighttime scenario. The results show that in spite of anticipated increased maintenance costs the measure is cost effective because of lower first costs and energy savings.

For demand response controls, the costs assume the addition of a control relay for switched loads and a control program for LED message centers per electric meter. For switched loads the analysis assumes a cost increase of $400. For programmed loads the analysis assumes a cost increase of $1,000.

Table 3: Summary of Unit Measure Costs

Measure Description	Cost ($)	Unit
Time scheduling controls	$500	Site
Automatic dimming controls	$1,000	Sign
Portable sign manual switch control	$200	Sign
Minimum efficiency transformers or power supplies - neon and cold cathode	$ 1.53	Lineal foot
Demand response controls	$400 – $1,000	Meter

Useful Life, Persistence and Maintenance

Sign Lighting Controls

A photoelectric switch control (dusk on / dusk off) is assumed to be the base case. It is assumed that 25% of the installation cost for the proposed automatic time schedule lighting controls will be incurred midway through the 15 year life of the system to maintain the lighting controls. For the base case photoelectric switch control, a maintenance cost of 100% of the installation cost is assumed midway through the 15 year life of the system. The energy savings will persist for the entire life of the measure provided it receives proper maintenance (replacement units must include all features of the measure) and the control schedule follows the model schedule.

Performance verification will be required during initial compliance and may be useful after installation to determine actual scheduling practice. Commissioning including programming of the time scheduling controls and required inspection by the authority having jurisdiction are necessary with this measure. Since the performance of the measure is dependent on properly installed and programmed applications, performance verification may affect persistence of savings. It is essential that the installations are inspected to meet the requirements of the Energy Standards and the California Electrical Code. Compliance verification at the time of building permit issuance and inspection are essential to the persistence of this measure.

Automatic dimming controls are part of time scheduling software available for LED message centers and displays. It is likely that dimming LED displays will increase the maintained life of the LED modules. For the purpose of analysis, the assumed life for the LEDs is 100,000 hours as stated in manufacturers' product literature. In service, this assumed life depends on electrical operating characteristics and temperature. By definition, at the end of rated life, the LEDs are operating at 50% of rated output. Therefore, for the purpose of analysis, it is assumed that 50% of the modules will be replaced at 70% of rated life (70,000 hours) for the base case and the remaining 50% of the modules will be replaced at 100% rated life (100,000 hours). Since the proposed case significantly reduces the average energy and operational temperatures during the measures' lifetime, it is assumed that 50% of the modules will be replaced at the end of rated life (100,000 hours) and the remaining 50% of the modules will be replaced at 120% rated life (120,000 hours)..

The energy savings will persist for the entire life of the measure provided it receives proper maintenance (replacement units must include all features of the measure) and the control schedule follows the model schedule. Performance verification will be required during initial compliance and may be useful after installation to determine actual dimming practice. Commissioning including programming of the dimming controls and required inspection by the authority having jurisdiction are necessary with this measure. Since the performance of the measure is dependent on properly installed and programmed applications, performance verification may affect persistence of savings. It is essential that the installations are inspected to meet the requirements of the Energy Standards and the California Electrical Code. Compliance verification at the time of building permit issuance and inspection are essential to the persistence of this measure.

For switched receptacles, sign-mounted controls for 50% of the signs is assumed to be the base case. It is assumed that 20% of the installation cost for the proposed manual switch controls will be incurred at the end of the 15-year life of the system to maintain the lighting controls and control wiring for a percentage of the installations. Also, for the base case local sign switch control, a maintenance cost of 20% of the local sign switch installation cost is assumed at the end of the 15 year life of the system. The difference in the cost of relamping is included in the analysis. The energy savings will persist for the entire life of the measure provided it receives proper maintenance (replacement units must include all features of the measure) and the control schedule follows the model schedule. Performance verification will be required during initial compliance and may be useful after installation to determine actual scheduling practice. Commissioning including required inspection by the authority having jurisdiction are necessary with this measure. Since the performance of the measure is dependent on properly installed applications, performance verification may affect persistence of savings. It is essential that the installations are inspected to meet the requirements of the Energy Standards and the California Electrical Code. Compliance verification at the time of building permit issuance and inspection are essential to the persistence of this measure

Minimum Efficiency Neon / Cold Cathode Transformers Power Supplies

From our experience with the relative failure rates between earlier versions of electronic ballasts and their magnetic counterparts, we expect that neon high efficiency power supplies will require more frequent replacement than their ferromagnetic counterparts. For the purpose of comparison, the analysis assumes 25% of the high efficiency neon power supplies would be replaced at a five year life and another 25% would be replaced at a 10 year life. At the end of the useful life (15 years), the analysis assumes 100% of both the ferromagnetic transformers and high efficiency neon power supplies would be replaced. The energy savings will persist for the entire life of the measure provided it receives proper maintenance (replacement units must be high efficiency). Verification that the correct equipment is installed is needed initially and this can be solved with a label that indicates compliance with either the W/sf requirements or the efficiency of the installed components. Commissioning other than required inspection by the authority having jurisdiction is unnecessary with this measure. Since the performance of the measure is inherent in properly installed applications, performance verification will not affect persistence of savings. It is essential however that the installations are inspected to meet the requirements of the Energy Standards and the California Electrical Code. Compliance verification at the time of building permit issuance and inspection is essential to the persistence of this measure.

Performance Verification

The performance of automatic time scheduling lighting controls, dimming controls (for signs on during the day) and manually switched receptacles are based on effective commissioning and in some cases, programming of the controls. Performance verification may include monitoring a representative sample of installations for actual operating schedules. The existing acceptance tests for time switches could be applied to this type of control.

The performance verification for minimum efficiency transformers and power supplies for neon and cold cathode lamps are based primarily on making sure they are installed. This activity is a function of the building permit compliance verification and installation inspection.

Cost Effectiveness

The cost-effectiveness of each measure is described in detail in the “Results” section of this report.

- The automatic time schedule lighting controls measure is demonstrated cost effective. The benefit/cost is 1.0 for a sign of 180 Watt. The measure is cost effective when the sign load controlled is greater than 180 Watt.

- The automatic dimming controls measure for LED signs operated during daytime hours is demonstrated cost effective. For the smallest physical size signs for a range of viewing distances from 110 feet to 500 feet, the range of benefit/cost ratios is between 1.1 and 4.1. The measure is cost effective when the sign load is greater than 240 watts.

- The switched receptacles manual control measure for indoor signs is demonstrated cost effective. The benefit/cost is 1.1 for a sign load of 180 Watt. The measure is cost effective when the sign load controlled is greater than 180 Watt.

- The minimum efficiency neon transformer or power supply mandatory measure is demonstrated cost effective for both nighttime operation. For nighttime operation, the benefit/cost ratio is 1.6. For 24-hour operation; the benefit/cost ratio is 5.0. The measure is cost effective for an aggregation of signs above 170 Watt.

- The demand response measures are assumed to be cost effective at a benefit/cost ratio of 1.5 for large signs. This measure would apply only to very large installations of signs on a single electric meter.

Analysis Tools

The analysis to quantify energy savings and peak electricity demand reductions uses a spreadsheet developed to compare alternative lighting technologies for use in sign illumination based on input power and time of day (TDV) cost values for each hour of the year. This spreadsheet kept track of the sunset times by day. We based this on a site in Fresno which is near the middle latitude of the population in California.

Relationship to Other Measures

No other measures are anticipated to be impacted by this change.

Methodology

The evaluation of proposed technologies and operating strategies included assumptions of number of operating hours for signs supported by studies conducted by Southern California Edison in 2005 and 2006. Sign manufacturers and sign component manufacturers provided information regarding the power characteristics, operational limitations and costs of proposed technologies. The results of SCE's sign control survey are tabulated in Table 4. It should be noted that this survey did not differentiate between standard time only time switches and those that are astronomical based (i.e. turn lights on and off relative to sunrise and sunset times calculated based on date and latitude and longitude).

Table 4: Sign controls: Frequency of use and resulting hours of operation

Type of Control	Controlled			Uncontrolled	Total
	% of controls	Hours of operation	Weighted average hours of operation	Hours of operation	Weighted average hours of operation
Time Switch	78%	9.59	7.5		
Photocell	4%	13.81	0.6		
Manual	15%	11.62	1.77		
Other	2%	6.33	0.14		
Total	100%		10.01	24	
Percent Controlled / Uncontrolled			79%	21%	
Weighted Hours Controlled / Uncontrolled			7.91	5.04	12.9

Controls

Automatic time schedule lighting controls

The use of automatic time schedule lighting controls was investigated as a proposed mandatory measure. The proposed measure will require automatic time schedule controls with astronomic feature or used in conjunction with photoelectric controls to preclude daytime operation of signs intended to operate at night only. The proposed measure was compared to a base case with photoelectric controls. The information in the Table 3from the sign survey completed by Southern California Edison in November 2005 (Phase 1) and June 2006 (Phase 2) was used to establish the baseline for existing sign operation.

As a comparison to the base cases, an automatic time switch lighting control schedule was modeled. As compared to the base cases operating signs from approximately 6 to 14 hours per day on average, the proposed case simulated sign operation from dusk to midnight and from 4 am to dawn.

Automatic dimming controls

The use of automatic dimming controls for outdoor LED signs operated during the day was investigated. If an LED sign is operated during the day then the required sign luminance should be reduced at night to provide readability. The sign industry generally supplies dimming for these types of signs, however data obtained from surveys conducted by the city of Anchorage, Alaska in 2004 and the Heschong Mahone Group in 2006 indicate that not all LED signs operated during the day are dimmed at night. Sign manufacturers provide software with time scheduling and dimming capabilities. To model automatic dimming controls on LED signs, two 4-module signs rated 240 watts, designed for viewing distances from 110 to 235 feet and 245 to 350 feet respectively, and one 8-module sign rated 960 watts, designed for viewing distances up to 500 feet were selected. To simulate the effect of dimming on LED signs operated during the day the load was decreased to 35% of maximum rated load for the dusk to dawn period. These signs were selected as representative of small signs for outdoor applications.

Manually switched receptacle plug-in sign lighting controls

The use of manually switched receptacles to control plug-in signs was investigated as a proposed mandatory measure. The proposed measure will require switched receptacles for indoor plug-in signs. The proposed measure was compared to a base case with local sign switch or no controls. The information in the Table 3 from the sign survey completed by Southern California Edison in November 2005 (Phase 1) and June 2006 (Phase 2) was used to establish the baseline for existing sign operation.

As a comparison to the base cases, a manually switch receptacle schedule was modeled. As compared to the base cases operating signs from approximately 12 hours per day on average, the proposed case simulated sign operation for approximately 10 hours per day.

Demand response controls

The use of demand response controls for indoor cabinet signs and outdoor message centers was investigated. Under a demand response condition, sign owners could opt to receive an incentive from the electric utility. Two options would be available. The first option would allow the electric utility to control the sign for the hours from 1 pm to 5 pm, inclusive, 10 days per year. The present value of turning off 1 kW for 10 days for these four hours over the course of 15 years is $250/kW. The second option would allow the electric utility to control the sign for 2.4 hours during the most severe demand conditions annually. The present value of turning off 1 kW for 2.4 hours per year over the course of 15 years is $366/kW. The total societal value of demand response per kW of load is $616 present worth over 15 years. The analysis considers two measures. The first measure is the application of demand response controls to indoor cabinet signs. The measure assumes that the cabinet sign would be turned off in response to receipt of the utility's load shed signal. The second measure is the application of demand response controls to outdoor LED message centers.

Neon

The use of minimum efficiency transformers or neon power supplies as an alternative to lower efficiency ferromagnetic transformers was investigated. Based on the analysis the minimum efficiency was established at a value that could be satisfied by at least 50% of the standard manufactured analyzed for all of the voltages at both 30mA and 60 mA output currents.

This analysis is summarized in the following table

Table 5:Neon Transformer Efficiency Summary

			High Power factor				Normal Power Factor				Overall min
Input	Output	Tube	Manuf 1	Manuf 2	Manuf 3	2nd highest	Manuf 1	Manuf 2	Manuf 3	2nd lowest	2nd lowest by mA
Volts	Volts	mA	Eff %	Eff %	Eff %	Eff %	Eff %	Eff %	Eff %	Eff %	Eff %
120	15000	30	94.7	90.9	88.9	90.9	90.9	96.0	88.9	90.9	
120	12000	30	95.0	90.3	88.4	90.3	90.3	95.3	88.4	90.3	
120	10500	30	92.9	92.9		92.9	93.8	95.2		93.8	
120	9000	30	88.7	85.8	83.7	85.8	81.5	90.5	83.7	83.7	
120	7500	30	84.2	80.8	78.7	80.8	76.8	85.3	78.7	78.7	
120	6000	30		85.9	84.1	84.1	81.6	90.7	84.1	84.1	
120	5000	30		78.6	83.0	78.6	79.1	84.0	84.0	84.0	
120	4000	30		75.8	83.1	79.4	77.1	77.1	83.1	77.1	
120	3000	30		78.1	83.3	78.1	81.6	81.6	83.3	81.6	77.1
120	15000	60	81.3	80.5		80.5	85.0	85.0	78.7	85.0	
120	12000	60	82.9	82.9		82.9	87.5	87.5	81.0	87.5	
120	9000	60	71.2	71.2	69.5	71.2	68.2	75.1	69.5	69.5	
120	7500	60	71.1	68.2	66.7	68.2	68.2	72.0	66.7	68.2	
120	6000	60	79.8	75.8	74.2	75.8	75.8	80.0	74.2	75.8	
120	5000	60	73.6	73.6	73.3	73.6	74.3	74.3	73.3	74.3	
120	4000	60	78.4	87.4	83.1	83.1	81.5	74.5	83.1	81.5	
120	3000	60		85.1	83.3	83.3	89.8	67.3	83.3	83.3	68.2

To simplify the analysis, it was assumed that the tubing use is 12 mm in diameter. To perform the analysis, the power capacity in watts was determined for both ferromagnetic transformers and high efficiency neon power supplies from information provide by the sign component manufacturers. The capability in linear feet of tubing driven was determined using industry standard performance tables for both ferromagnetic transformers and high efficiency neon power supplies. Costs of typical signs and components were obtained from sign manufacturers. Several measures are analyzed – indoor applications, outdoor applications and varying schedules depending on the application (i.e. filtered or unfiltered). To develop a representative measure four signs containing normal and high power factor transformers at 30mA and 60 mA respectively were aggregated into one measure. The total power input, cost and cost of maintenance of the measure were compared to the base case. Transformer efficiency at 60 mA was typically lower than transformer efficiency at 30 mA. This analysis assures that two out of three transformers considered can meet the requirements for the worst case output voltage, power factor or tube current.

Results

First and foremost, the study indicates that there is a significant opportunity to achieve energy savings through the use of controls on signs. Secondly, the study indicates the effectiveness of improving the efficiency of neon transformers and power supplies. The study found time scheduling and daylight responsive control measures to be cost effective, providing sign owners with greater operational control flexibility. The measures are intended to preserve the signs' messages while affording the benefits of energy savings resulting from operational control and equipment efficiency. In the case of nighttime dimming controls for signs normally operated in the daytime, the controls can provide the operators with the capability to achieve optimum sign conspicuity both during the day and at night.

The research demonstrated that available product operating and performance data is inconsistent. One overriding issue with respect to lighting products used in signs is the interdependency between electrical operating characteristics, performance and temperature. The products available to the sign industry vary widely in efficiency and performance. One significant barrier to the wide use of electronic ballasts is operating temperature.

Although not included in any of the measures presented, there appears to be a significant opportunity to improve the efficiency of fluorescent systems used in cabinet signs. The sign industry currently uses T12 high output fluorescent technology powered by ferro-magnetic ballasts as a fundamental technology. The current standards address measures which encourage the use of more efficient technology such as electronic ballasts and rare earth phosphor lamps. To improve further the efficiency of these systems will require the cooperation of the sign product manufacturers, sign manufacturers, electric utilities, end users and industry associations. Information, such as watts input, ballast factor, power factor and relative light output, needs to be reported by all parties in a consistent manner to enable performance evaluation. Typical cabinet signs utilize fluorescent lamps as a light source to illuminate a translucent image on the face(s) of the sign. In addition to the improvement of technology efficiencies, there appears to be an opportunity to develop new designs for cabinet signs that utilize alternative optical system design to the typical fluorescent array. For larger signs, there are alternative high intensity discharge systems available. For smaller signs, there are signs, edge-lit with T5 fluorescent lamps that are significantly more efficient than the typical back-lit signs.

The neon sign industry has an opportunity to solve the issue of incompatibility of high efficiency power supplies with standard applications due to temperature limitations and capacitive coupling issues. Potentially, medium frequency high-grade steel laminated core transformers with copper windings could provide enhanced efficiency without the limitations experienced with the current high frequency models. This study found the need for a consistent method for rating and labeling the efficiency of neon transformers and power supplies.

The LED industry is emerging as a dynamic element of the sign market. Message centers provide a significant opportunity to display multiple messages, graphics and video content on a 24 hour per day, 7 day per week basis. Currently these displays have average input power densities ranging from nearly 15-20 watts per square foot to over 85 watts per square foot. Maximum power densities can exceed 300 watts per square foot. The industry is progressively developing more efficient LEDs. As the technology improves, it is anticipated that LEDs will approach the efficacy of fluorescent systems. There is a particular need for standardization of LED products, as the current variability of products from manufacturer to manufacturer makes it difficult for the industry to adopt LED technology. As the technology improves, it will be increasingly important to have testing standards to evaluate system performance relative to other technologies.

This study investigated using electronic high efficiency power supplies (drivers) for LED signs. The study found that high efficiency power supplies can be15 to 35% more efficient than their low efficiency counterparts are. For the proposed use of high efficiency power supplies with LED sources the evaluated measure compared low efficiency ac input / dc output power supplies to high efficiency switching mode power supplies. High efficiency switching mode power supplies are readily available and provide increased efficiency. Typical efficiency for a high efficiency switching mode power supply is 80% or greater. Although it is apparent that many manufacturers are producing high efficiency power supplies, they do not publish technical data consistently. Basic quantities such as input/output watts, efficiency and power factor are not readily available to specifiers and consumers. There also is a lack of available testing standards. For these reasons, no efficiency standards are proposed as a result of this study. It is recommended that efficiency standards for LED power supplies be developed as part of the Title 20 Standards revision process. The development of LED driver operating, performance and testing standards must occur first to enable the inclusion of efficiency requirements in the California Energy Standards and harvest persistent energy savings.

Energy, Cost Savings and Cost-effectiveness

The energy cost savings was calculated via a spreadsheet that had statewide average costs per hour for all hours of the year. These were then aggregated into weekday daytime values for each hour of the day, weekend daytime values, weeknight values and weekend night values. By entering the schedule that signs are on during days and nights one can compare the kWh and time-of-day value (TDV) costs over the course of a year. The TDV energy cost savings are then compared to the incremental costs of each measure. Cost-effectiveness is calculated by the following relation:

Cost-effectiveness = Life cycle O&M cost savings / Incremental cost

Often life cycle savings is merely the energy savings multiplied by the present value of the energy cost over 15 years at a 3% discount rate. In other cases where the maintenance or replacement costs or periods change then these costs are also considered as part of the life cycle savings. When the maintenance occurs, impacts its present valued cost as the maintenance cost is derated by a future worth factor.

Following is a series of tables showing an example savings calculation for the measure of using an astronomic time switch (or combination of photoelectric switch in conjunction with a time switch so that both scheduling and presence of sunlight is the function of the control) to replace a photoelectric switch (presence of sunlight only function of control). Table 6 shows the assumed schedule of operation for the photoelectric cell control, the “base case,” as derived from SCE study data, the installed cost and the load in kilowatts and then that of the “proposed case” control, the astronomic time switch. Note that or the “daytime base” column the kWh and TDV kBtus are calculated the day time hours during this schedule. Similarly, for the “nighttime base” column only night time hours during this schedule are kWh or TDV calculated. The proposed case table shows the assumed schedule of operation for the proposed case (i.e. lights can be turned off later at night) and the installed cost. The schedule indicates that the load will be on from dusk to midnight, off at midnight and then back on from 4 am to dawn.

Base case Description: PE Cell Controlled Sign
Installed cost: $200.00
Enter kW schedule for base case

Hour	Daytime base			Night time base		
	M-F	Sat	Sun	M-F	Sat	Sun
1				0.18	0.18	0.18
2				0.18	0.18	0.18
3				0.18	0.18	0.18
4				0.18	0.18	0.18
5				0.18	0.18	0.18
6				0.18	0.18	0.18
7				0.18	0.18	0.18
8				0.18	0.18	0.18
9				0.18	0.18	0.18
10				0.18	0.18	0.18
11				0.18	0.18	0.18
12				0.18	0.18	0.18
13				0.18	0.18	0.18
14				0.18	0.18	0.18
15				0.18	0.18	0.18
16				0.18	0.18	0.18
17				0.18	0.18	0.18
18				0.18	0.18	0.18
19				0.18	0.18	0.18
20				0.18	0.18	0.18
21				0.18	0.18	0.18
22				0.18	0.18	0.18
23				0.18	0.18	0.18
24				0.18	0.18	0.18
	Only day time hours during this schedule are kWh or TDV calculated			Only night time hours during this schedule are kWh or TDV calculated		

Proposed case description: Astronomic Time Switch Control / PE
Installed cost: $500.00
Enter kW schedule for proposed case

Hour	Daytime proposed			Night time proposed		
	M-F	Sat	Sun	M-F	Sat	Sun
1						
2						
3						
4						
5				0.18	0.18	0.18
6				0.18	0.18	0.18
7				0.18	0.18	0.18
8				0.18	0.18	0.18
9				0.18	0.18	0.18
10				0.18	0.18	0.18
11				0.18	0.18	0.18
12				0.18	0.18	0.18
13				0.18	0.18	0.18
14				0.18	0.18	0.18
15				0.18	0.18	0.18
16				0.18	0.18	0.18
17				0.18	0.18	0.18
18				0.18	0.18	0.18
19				0.18	0.18	0.18
20				0.18	0.18	0.18
21				0.18	0.18	0.18
22				0.18	0.18	0.18
23				0.18	0.18	0.18
24				0.18	0.18	0.18
	Only day time hours during this schedule are kWh or TDV calculated			Only night time hours during this schedule are kWh or TDV calculated		

Table 6: Day and night schedules for Astronomical Time Switch measure

Table 7: Maintenance cost calculation including 3% real discount rate

	Maintenance Costs		Maint Savings	Future Value
Year	Base case	Proposed case	PV $	Multiplier
1			$0.00	97%
2			$0.00	94%
3			$0.00	92%
4			$0.00	89%
5			$0.00	86%
6			$0.00	84%
7			$0.00	81%
8	$ 200.00	$ 250.00	-$39.47	79%
9			$0.00	77%
10			$0.00	74%
11			$0.00	72%
12			$0.00	70%
13			$0.00	68%
14			$0.00	66%
15			$0.00	64%
Total			-$39.47	

Table 7 shows the assumed maintenance costs for the base and proposed cases. In the base case, the photocell is replaced and it is assumed that the entire of the cost of the initial installation will be spent. In the proposed case, it is assumed that either a photoelectric cell is replaced or that the astronomic time switch has to be reprogrammed and that this will cost slightly more. For the purpose of the analysis, it is assumed in both cases that the maintenance will occur at the halfway point of the system's life. Since the maintenance cost is higher for the proposed system, it is represented as a negative maintenance cost savings for this measure