Standards required for further penetration of solid-state lighting

The solid-state lighting industry urgently needs standards to assist its growth and to avoid hype and negative reactions. The good news, says **Kevin Dowling**, is that standards work is proceeding rapidly in a number of directions.

Without standards, nothing would fit, things wouldn't connect; it would be a miserable state of affairs. Lack of standards in any field or industry can slow adoption, growth and innovation. A lack of standards in a fast growing industry such as LED illumination has already resulted in confusion, hype and frustration. While lighting, as a whole, already has many standards for mechanical forms, electrical connections and measurement, LED lighting has many different characteristics from lighting predecessors, making it different and requiring new standards development.

The wonderful trends in LED lighting include increasing growth and adoption in the marketplace. One negative aspect, causing confusion to customers and manufacturers alike, relates to the specifications of LEDs, LED sub-assemblies and LED lighting systems. In many cases, these specifications are misleading.

A specific bewildering aspect is that of light output specifications. The light output, or luminous flux, of LED devices is typically evaluated using a pulse measurement at room temperature, whereas LED fixtures should use steady-state measurements. Thus, the announcements by LED manufacturers regarding efficacy values in excess of 100 lm/W (up to 150 lm/W) over the past months, while very encouraging, are unrealistic levels for LED lighting systems with these same devices.

Figure 1 shows the decrease in light output of an LED fixture in the 400–500 lumen range over time. Steady-state light output is not reached until approximately two hours of operation. This is approximately 85% of initial light output. This test was performance under the auspices of the Lamp Testing Engineers Conference (LTEC), an industry metrology group. This asymptotic decrease is due to thermal considerations; as LEDs heat up, light extraction diminishes. This is why realistic testing methods are required.

The recent US Department of Energy (DOE) product tests (see www.netl.doe.gov/ssl/comm_testing.htm) highlighted the sizeable gap between manufacturers' published measurements and measurements under more realistic conditions. Fixture manufacturers are using nominal LED values for lumen output and simply summing those values over the number of LEDs used in their system. This type of specification game is disingenuous. The whole does not equal the sum of its parts, especially when it comes to light output.

Some measurements can be made with existing equipment and standards. But we need numbers, we need methods and we need them soon. The bad news in the world of solid-state lighting is that there are few, if any, standards specifically applying to LEDs and LED systems. Conversely, there are examples of existing performance standards being applied to LED systems where the result is not quite what people expected.

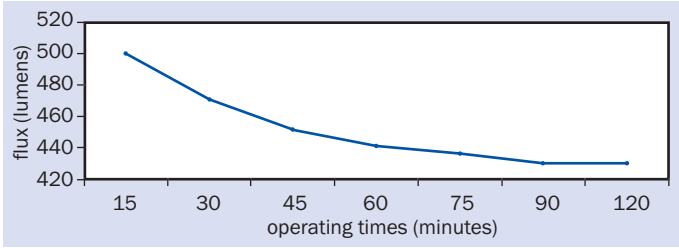

Fig. 1. Light output of an LED system showing a significant decrease, approximately 15%, in light output over time before the LEDs reach the steady-state temperature. LEDs are typically measured instantaneously at room temperature, giving results that do not relate to actual fixture performance.

The good news is that many LED applications continue to grow in spite of a lack of standards because the performance is considered perceptible – one doesn't necessarily need a measuring instrument to tell whether light output is useful or not. But standards are necessary to ensure consistency, to ensure we have metrics for fair comparison, and to keep the dimensions and condition of measurement equivalent so that we're not comparing apples and rocks.

The path to standards

Efforts to emplace standards began several years ago. The National Electrical Manufacturing Association's (NEMA) Solid State Lighting Section was founded with standards in mind and there are now many organizations working with each other to create a new family of standards. The network of standards organizations is an alphabet soup of acronyms: IESNA, ANSI, UL, CIE and more (see "Links" box). The DOE is also pressing for standards since energy efficiency criteria are needed for the Energy Star program to set thresholds for LED lighting systems (see "DOE accelerates Energy Star program for SSL" box).

More recently ANSI Working Group C78-09 was formed in December 2005, and the IESNA Testing Procedures Committee (TPC) solid-state lighting subcommittee was formed in April 2006. These two organizations have worked closely together to create LED standards.

General standards process

Each standards development organization (SDO) has a detailed process for creating and administering standards. The process is methodical, which for many is a euphemism for slow. However, the LED standards process is proceeding quite rapidly. Additionally, these developments are not happening in a vacuum and we are able to build upon existing lighting standards by adapting structure and format from existing standards.

The process for such standards development is generally an open one. People and companies can join these organizations and participate in the process. Each organization has its own policy but they are similar. When complete drafts are voted on by the respective committees, then the standards are released for public review. There are many conference calls and meetings resulting in a document submitted to the

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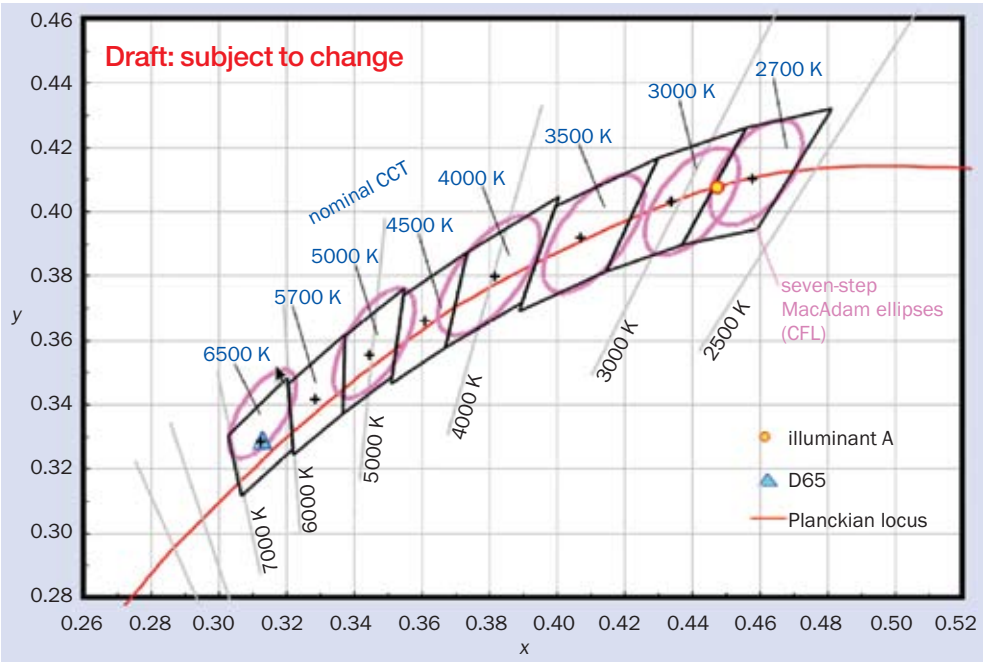

Fig. 2. Draft version of the ANSI chromaticity specification (C78.377A) showing eight nominal CCT quadrangles for LEDs. The specs are as consistent as possible with existing fluorescent lamp standards; the ovals show the seven-step MacAdam ellipses for CFLs. Six of the eight LED quadrangles have the same nominal CCT as Energy Star CFLs, and two CCTs (4500 and 5700 K) have been added. The LED specs are quadrangles and are contiguous to reflect the current binning capabilities of LED makers.

full committee and, at some point, voted upon by the members of the committee and later, submitted to the board of the respective organization.

Standards in development

There are several standards under development, as listed below, and many are in committee review right now:

- Chromaticity (color): ANSI WG-C78 (C78.377A) – see figure 2
- Luminous flux (light output): IESNA LM-79
- Lumen depreciation (lifetime): IESNA LM-80
- SSL definitions
- Photobiological safety: CIE S009
- Color quality
- Electrical safety: ANSI C82.XX

Luminous flux (LM-79)

Determining light output would seem straightforward. Simply put the device in an integrating sphere and measure it or use a goniometer and integrate the measurements. But placement, measurement techniques and stabilization

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DOE accelerates Energy Star program for SSL

By Tim Whitaker

The DOE has made further progress with its draft requirements for SSL luminaires to be incorporated into its Energy Star program, which identifies and promotes energy-efficient products (see *LEDs Magazine* February 2007, p9).

After releasing version 1 in December 2006, DOE received a great deal of constructive feedback from industry stakeholders and from its workshop in February, according to Richard Karney of the Energy Star program. Version 2 has now been released (see www.netl.doe.gov/ssl/energy_star.html). "Feedback is required by 4 May, before the final specifications are released," says Karney. "The criteria will come into force in nine months' time, which allows manufacturers to gear up for production."

There are two categories of SSL luminaires considered by Energy Star. Category A covers near-term niche applications, while Category B looks further ahead and sets high targets for SSL luminaires that are linked with the expected LED performance gains in the next two to three years.

Category A focuses on currently available products such as recessed cans, task lighting, under-cabinet task lighting and more. "The purpose is to guide consumers to buy products that are more energy-efficient," says Karney. "There are a lot of SSL products on the market that are really not very good, as the DOE testing program has highlighted."

In version 2, the luminaire efficacy requirements for products qualifying under Category B have been increased to 70 lm/W, regardless of correlated color temperature (CCT). In version 1, lower efficacy targets were set for lower CCT values. Also, color rendering index (CRI) requirements are 75 or above for indoor luminaires, with no CRI requirements for outdoor products.

Some lighting manufacturers have criticized the Energy Star program for setting the bar too low for SSL. However, says Karney, "we cannot set levels that only one company would meet". The purpose of the category B criteria is to acknowledge the rapid predicted increase in SSL performance during the coming years.

"LED technology is improving every moment, and we will need to be more flexible [with criteria for SSL luminaires] than we have been with CFL technology," says Karney. This will mean regular reviews of the SSL criteria, possibly as often as every year.

The fact that the criteria refer to luminaire efficacy is crucially important. Luminaire efficacy relates to the effective light output from the SSL fixture, i.e. the usable light delivered to the point of use. It is measured as the luminaire light output (from photometric measurements) divided by the driver input power. An IESNA procedure (LM-79) is being developed for photometric measurements. Lighting manufacturers have been known to quote efficacy values provided by the LED makers, but the luminaire efficacy will always be lower by a significant percentage due to fixture losses and other factors. In contrast, product qualification for CFLs relates to CFL system performance (i.e. the performance of the lamp and ballast), and does not take into account typical fixture losses that can often amount to around 50%.

of measurements are all very important and much care is required in measuring any lighting system. Many of the factors covered in existing IES LMs do not apply to LEDs. Thus a new standard, IES LM-79, is in process and under committee review at this time.

Lifetime – lumen depreciation (LM-80)

"Lasts forever!" was how an enthusiastic LED lamp sales person greeted me at one trade show. While LEDs do last a long time, any LED is unlikely to live up to the "forever" label. One complicating issue regarding lifetime is that the definition of lifetime is not the same for traditional lighting sources and LEDs. The primary reason for this is that traditional filament-based sources usually fail completely; filament breach results in no light. Since LEDs do not have filaments they do not fail in the same manner, but they do slowly fade over time. This fading is termed lumen depreciation. The end-of-life criterion is then determined by a percentage of initial light output. Today two numbers are used in this upcoming standard, L70 or 70% of initial light output and L50 or 50% of initial light output. Selection of L50 or L70 depends on the application. Methods of modeling and providing early measurements in the range of several thousand hours are required to determine lumen depreciation to L70 or L50 levels. IESNA LM-80 is under process and in committee review at this time.

SSL definitions

This standards activity may appear to be the simplest to put in place but this topic has resulted in many long discussions. This activity has focused on about two dozen definitions of terms related to solid-state lighting and LEDs. It includes such terms as module, assembly and so forth. In cooperation with the IEC, the IES, ANSI and NEMA, this smaller but important effort is aimed at clarifying the use of terms around solid-state lighting.

It's important to delineate such terms so that when safety standards and listing standards are applied to such systems, it is clear where those subsequent standards apply. These definitions will be adopted into IESNA RP-16, "Nomenclature and Definitions for Illuminating Engineers", which will now be updated on a regular basis. Harmonization between ANSI/IESNA and the IEC definition lists are also in process.

Photobiological safety

Are LEDs considered eye-safe? They are narrow band sources but LEDs used for general illumination are entirely within the visible spectrum and do not emit UV or IR, which would seem even safer than traditional sources. There have been active discussions over safety and LEDs. Until recently LEDs were treated similarly to lasers in IEC 60825 but this standard now refers to CIE S009, now under development to address the general issues of eye safety and LEDs. ANSI/IESNA RP 27.1-3 will be referenced; this addresses many of these issues as well.

Electrical safety

Although at an early stage compared to other standards work, ANSI C82.XX is focused on drivers and electrical safety issues regarding LEDs. A draft is in development.

Color quality

Color rendering index (CRI) has several known limitations. It uses an obsolete non-linear color space, color samples used in the calculation are of low saturation (unlike most LEDs), and CRI uses an outdated adaptation formula. It's very non-linear in the red region and also unfairly penalizes LED sources in the way it is calculated.

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While many efforts have been made to improve CRI, nothing has persevered but a new color quality metric is needed. This issue has come to the forefront and color quality was the focus of a 2006 Color & Light Symposium, led by the Lighting Research Office (LRO). One outcome of that gathering was the formation of a new technical committee, TC 1-69, within the CIE and headed by Wendy Davis of NIST to address a new color quality metric. While new color quality metrics have already been formulated and proposed to address CRI issues, this standards development will require additional substantial human factors testing.

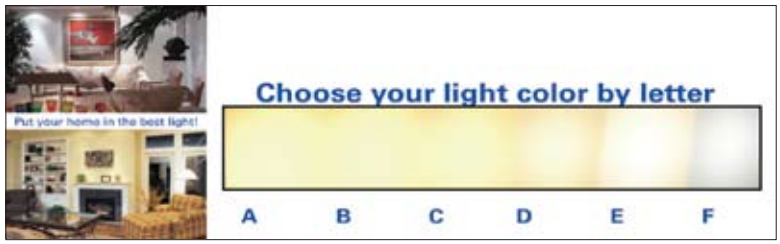

Fig. 3. Communication of color temperatures could use letters (as for other consumer goods), as shown in this prototype merchandising display.

Color communication

Color temperature of lighting sources is not well understood outside part of the lighting community and the notion of colors of white light is not well addressed by lighting companies either. An ad-hoc group within the lighting industry has also examined means to communicate the color of white light sources to end-users and consumers. This group, working with the environmental protection agency (EPA) and the Lighting Research Center at RPI has done market research and focus group studies that show communicating color can be a useful and productive measure. While this is not currently a proposed standard, it is likely to be a widely accepted means of communicating color to users (see figure 3).

On the horizon

There are other standards that are on the list but not active at this time until some of those under development are completed. These include Photometric Testing of Indoor SSL Luminaires, Photometric Testing of Outdoor SSL Luminaires and finally, an ANSI document, Specifications for Performance of SSL devices, which will be a consolidated text.

Accreditation

An oft-forgotten aspect of standards and measurement criteria is the means to accredit those who measure to such standards. Accredited laboratories are critical to the adoption and use of such standards. Equipment must be traceable to national laboratories such as NIST in the US, or NPL in the UK, and the laboratory personnel must be well versed in the actual measurement procedures. Laboratory accreditation procedures must be in place before standards can be used.

The National Voluntary Laboratory Accreditation Procedure (NVLAP) led by NIST does exactly this. It provides third-party accreditation to testing and calibration laboratories. NVLAP is in full conformance with the standards of the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC), including ISO/IEC 17025 and ISO/IEC 17011 (see ts.nist.gov/Standards/214.cfm for more details). This NVLAP accreditation process is underway as well.

Participation

If you have experience in standards development or in various areas such as photometry, you are welcome to join these organizations and participate in the standards development process. If you are interested in actively participating, please contact me at Kevin@ colorkinetics.com and I will put you in touch with the right folks (do not contact me to simply get copies of the latest drafts, most are available on the appropriate websites).

About the author

Kevin Dowling is Chairman of the NEMA Solid-State Lighting Committee and the IES sub-committee on Solid-State Lighting, and past Chairman of the NGLIA. In his spare time he works in the areas of new product development, IP, technology developments and leads government programs at Color Kinetics.

Links

ANSI – American National Standards Institute: www.ansi.org
CIE – International Council on Illumination: www.cie.co.at
DOE – Department of Energy: www.netl.doe.gov/ssl
IEC – International Electrotechnical Commission: std.iec.ch
IESNA – Illuminating Engineering Society of North America: www.iesna.org
NEMA – National Electrical Manufacturers Association: www.nema.org
NGLIA – Next Generation Lighting Industry Alliance: www.nglia.org
UL – Underwriters Laboratory: www.ul.com

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