<u>Comments on "Non-Standard" Provisions of Energy Star Requirements for LED Integral Lamps</u>

The EPA should not alter the Energy Star standard so that companies can self-certify the qualification to use a logo indicating suitability for down lighting. Doing so will lead to manufactures using the down lighting logo for products that are not suitable for down lighting. A prime example is the snow cone A-lamp which, as discussed in more detail below, is entirely unsuitable for ceiling mounted down lighting. Rather the EPA should formulate specific requirements that must be met for the down lighting logos to be used.

The principle focus of many interested parties is whether or not so called "Snow Cone" A-lamps will qualify for Energy Star certification. Snow cone A-lamps originated in the chaotic, any-thing-goes, Chinese LED industry no later than 2007. The snow cone lamp is a deception. While it closely approximates the <u>shape</u> of the common incandescent A-lamp the light distribution it provides is very poor. Additionally, snow cone A-lamps may not be able to dissipate sufficient heat to operate at a temperature conducive to long life when installed in a common ICAT recessed can down light fixture.

OPTICAL-LIGHT DISTRIBUTION

The EPA is proposing to allow snow cone lamps to carry the Energy Star logo, alongside a logo that indicates that snow cone lamps are suitable for down lighting. This would be an explicit, strong endorsement by the Energy Star program of using snow cone lamps in down lighting applications. <u>This should</u>

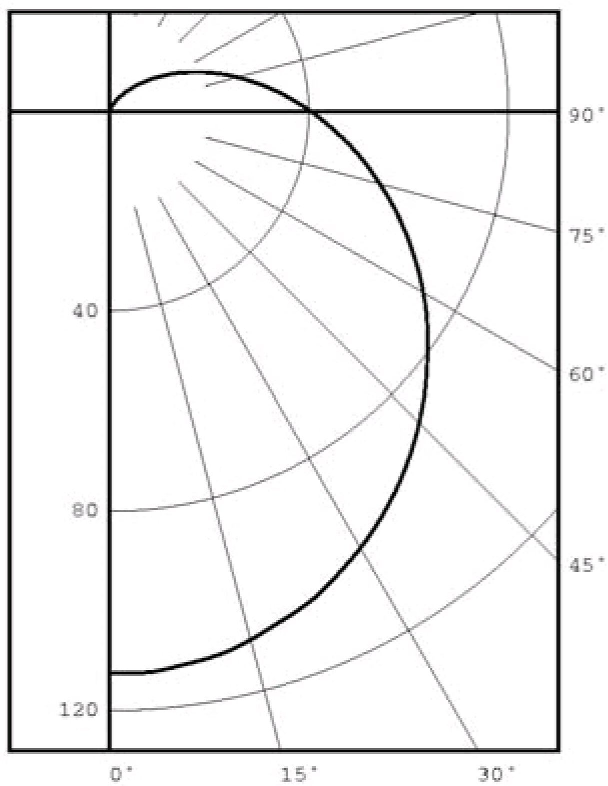
never be done because, it is abundantly obvious to any lighting professional that snow cone lamps are wholly unsuited to down lighting applications. Lighting is an area of technology where consumers can readily judge performance and by taking the proposed step the EPA would be harming consumer confidence in LED lighting and in the Energy Star imprimatur.

Light Distribution

A typical snow cone lamp (e.g., Caliper Ref. 10-03, Lednovation) produces a Center Beam Candle Power (CBCP) of 113 candela. , which at a typical 8' ceiling mounting height yields an illuminance of 19 lux. By comparison CALiPER 09-45 Downlight Benchmark Fluorescent provides a CBCP of 480 candela, no less than 4X greater!

The snow cone lamp produces a very wide distribution, too wide for directional lamp applications, with a FWHM of about 120° and also produces a highly non-uniform illuminance distribution. As a result, snow-cone lamps make very poor directional lamps.

The light distribution of Caliper Ref. 10-03 is shown in the figure below.



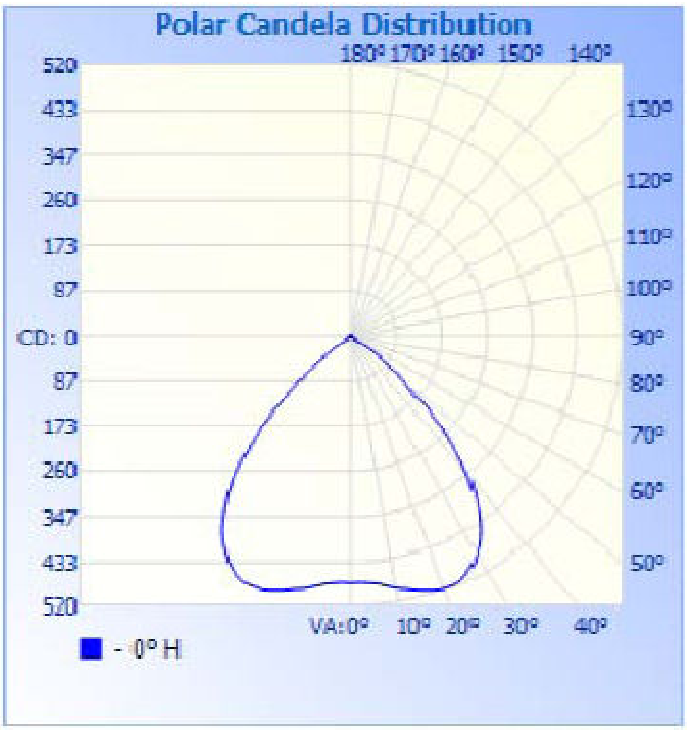
Quasi-Lambertian snow cone A-lamp Candela Distribution

Snow cone lamps provide an entirely different, very poor, light distribution. Most, if not all, snow-cone lamps are not based on thoughtful optical engineering. Remove the hemispherical diffuser and in the vast majority of cases it will be found that there are just bare packaged LEDs with no optics at all to control the light distribution. As a result the light distribution is basically the bare LED Lambertian (cosine) distribution (albeit lightly diffused so that there is some leakage of light beyond 90°).

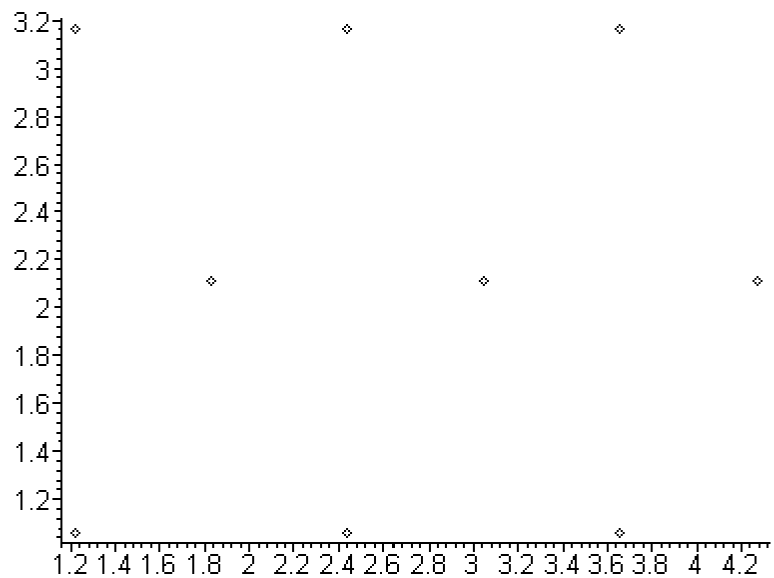
As a consequence of the Lambertian light distribution that snow cone lamps produce (e.g., with a 113 candela CBCP in the case of Caliper Ref. 10-03), it is virtually impossible to put light where you want, i.e., by positioning a down light fixture overhead. This is due to the fact that a large percentage of the light in a Lambertian light distribution is emitted at high angles (i.e., more sideways). For an 8’ ceiling the closest Caliper Ref. 10-03 lamp can only contribute at most 11 lux. Consequently the only way to increase the horizontal illuminance levels would be to physically increase the length and width of the room, which obviously is not an option. In the LEDnovation paper “Choosing the Proper LED lamp for Down Lighting Applications” that was submitted to the EPA this trick is used. The paper shows a 5 by 10 array of 50 lamps covering a 20’ by 30’ room. Such a large room lit with an array of 50 lamps does not correspond a residential application, and for commercial applications, complete fixture solution would be used in lieu of retrofit lamps.

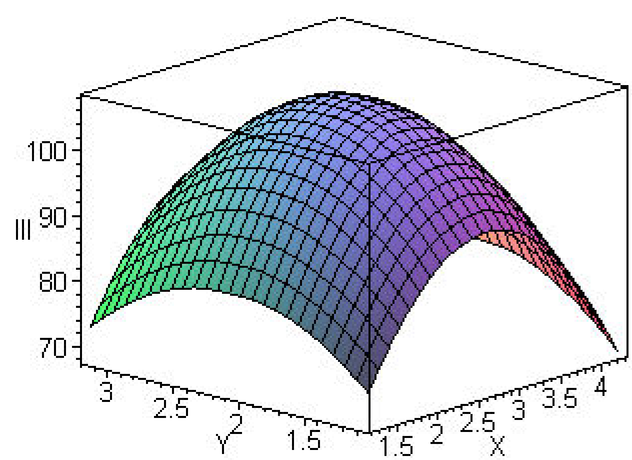
A second undesirable consequence of the Lambertian light distribution of snow cone lamps is that illuminance is maximum in the center of the room and drops off significantly towards the periphery of the room. This occurs despite the fact that the fixtures are evenly spaced throughout the room. This is also evident in the FIG. 7 of the above cited Lednovation paper which shows that the illuminance level is 34 lm/ft^2 in the center of the room, tapers down to 24 lm/ft^2 at the sides of the room and is 21 lm/ft^2 in the corners of the room. Thus one would need to over illuminate the center of the room, wasting energy, in order to get the light level at the sides of the room (or the average illuminance) up to the required specification. With the Lambertian light distribution of snow cone lamps, even fixture spacing does *not* lead to even illuminance light distribution.

By contrast in the case of a proper down light distribution such as in the CALiPER 09-45 Downlight Benchmark (figure below), a 2-D periodic arrangement of lamps (i.e., regularly spaced lamps) will provide a 2-D periodic illuminance distribution. A purpose built LED fixture will have a similar angular light distribution. With proper down lighting, each point in the room is generally predominantly lit by 3 or 4 luminaires, no more. If the spacing is correct a small MAX-to-MIN ratio will be achieved. It will then also be possible to control where in a room the illuminance is high and where it is low by positioning the fixtures as needed-what a lighting designer would expect when using recessed can down lighting.



Returning to the case of snow cone lamps, when the number is reduced from what is shown in the LEDnovation paper to a more reasonable number for typical residential applications the peaked aspect of the light distribution in the lighted space persists, but the horizontal surface illuminance drops. The first figure below shows a layout of 9 light fixtures in a space. The lamps are spaced 1.2 meters (4’) within each row and the rows are spaced by 1.05 meters (3’ 5”). The mounting height is set at 2.44 meters (8’). The second figure shows the strongly peaked light intensity distribution (lux) that results. Note that even at the maximum central peak in the space (room) the intensity is no more than 110 lux (=10 lm/ft^2), which is too low for the vast majority of applications for which one might provide an arrangement of 9 light fixtures (e.g., a kitchen for which the recommended IES light level is 500 lux).





<u>There should be no expectation on the part of companies that they can basically do no illumination engineering to control the light distribution of their products and yet be entitled to Energy Star certification.</u> <u>The light distribution of</u>

a lamp or luminaire is an important aspect of lighting systems that effects both the efficiency and the perception of the quality of light.

Many directional PAR 30 and PAR 38 LED lamps could be made to produce distributions equivalent to the quasi-Lambertian distribution produced by snow-cone lamps simply by removing the secondary optics. But of course makers of such directional PAR LED lamps do not offer versions of their lamps in such form. The reason that they do not do so is quite obvious and belies the argument from snow-cone proponents. The reason is simply that the Lambertian distribution is very far from a good directional distribution.

It should be accepted as a basic premise that Energy Star certification should not be extended to ill-conceived designs, the performance of which is demonstrably inferior to other existing products in the case of every significant application. The snow-cone designs are inferior to spot and flood LED products in applications that require directional lamps and are inferior to true omnidirectional lamps in applications that require such lamps (e.g., table lamps and floor lamps). One need only read a few blogs and reviews of snow cone lamps (e.g., at the Home Depot website) to see that consumers have been disappointed by the inadequacy of snow cone lamps for table lamp and floor lamp applications. These are the early warning signs that LED technology is likely to suffer the type of setbacks that delayed CFL adaption by decades and which the DOE has vowed to avoid in the case of LEDs. In the case of CFLs an early problem was the spectral power distribution and in snow cone lamps the problem is the angular candela distribution.

The proposed EPA action, coupled with desperate price reduction of snow cone lamps could lead to a spike in purchases of snow cone lamps which would be followed by spike in bad publicity for LED lamps. I should note, that consumer disappointment was anticipated in comments on earlier drafts of the Energy Star Integral Lamp standard[1]

Certain opportunistic proponents of snow cone A-lamps suggests that they are suitable for use in recessed can down light applications. This is a major application[2] however, in reality the light distribution produced by snow cone A-lamps is basically opposite of the established consensus on the preferred distribution for down lights. The established consensus is that down lights should produce a batwing distributions[3] so as to (1) limit glare (2) limit veiling reflections and (3) produce more uniform illuminance (which avoids energy waste in bright spots, and yields better visual comfort). Optics for distributing light from LEDs in a batwing distribution are readily accommodated in a 6" recessed. Snow cone lamps are not properly designed. In a down light applications, to limit glare, light should be substantially confined to within 45 degrees of nadir. In rooms with Video Display Terminals (monitors) it should be even more narrowly confined. Note the light distribution of CALiPER 09-45 Downlight Benchmark shown on page 4. In contrast, the snow Cone A-lamp, Caliper Ref. 10-03, emits more than 70% of its light above 45 degrees from nadir, less than 30% within 45 degrees of nadir (See distribution on page 2). Thus the expert consensus for down lighting is grossly violated.

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[1] http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/integral_leds/MathPath_Optics_2_IntegralLEDLampCommentsDraft2.pdf
http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/integral_leds/MathPathoptics_comments_Draft3.pdf

[2] PNNL estimates 350 million installed in U.S. Homes and 20 million added per year, See Dr. Jasmine Leger, "LEDs for Use in Downlights", LED Professional Review March 2007

[3] See cited books, patents in http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/lighting/MathPath_Optics_%283%29_OutdoorComments.pdf

In the recently issued Energy Requirements for Luminaires 1.0, pg 12 stipulates that residential directional down lights (including recessed, surface, pendant and SSL downlight retrofits shall deliver a minimum of 75% of the luminous flux in the zone 0 to 60 degrees. Bare snow cone lamps do not qualify under this standard as they emit only about 50% of their luminous flux in the zone 0 to 60. Taking Caliper Ref. 10-03 as an example, it emits approximately 51% of its luminous flux in the zone 0 to 60, and thus falls far short of the 75% within 0 to 60 standard.

Light Output Ratio in Legacy Recessed Cans

In a legacy technology **in**efficient recessed can fixture, glare is controlled by a light absorbing baffle leading to substantial losses in efficiency. It is likely that if Snow-Cone A-lamps proliferate, encouraged by the Energy Star *imprimatur*, they will likely be used by consumers in existing recessed cans and efficiency will be substantially compromised. The angular distribution of light and dimensions of a snow cone lamp are such that a substantial portion of the light would be absorbed by the absorptive baffle. Of course this scenario is entirely avoidable because the light distribution of LEDs is highly controllable and can be precisely tailored for down light applications in a well engineered product. In fact, many companies have designed light LED light fixtures specifically meant for recessed can applications. It is unclear that recessed can trim (internal optics) optimized especially for snow cones could be used without choking off convective and radiative heat dissipation and further degrading thermal performance of snow cones in recessed fixtures (see below). In any case it is unlikely that such optics will be utilized in significant numbers in the real world.

THERMAL CONSIDERATIONS

Premature failures of snow-cone lamps have also been reported in blogs and consumer product reviews and these are no doubt tied to the fact that the snow cone design encloses the driver circuitry within the heat sink thereby subjecting it to elevated temperatures. The Lighting Research Center identified this flaw stating:[4]

> "Similarly, the life of some components typically used in drivers (e.g., electrolytic capacitors) is likely to be affected by the operating temperatures inside the luminaire. This is particularly true in cases where the heat generated by the LEDs may contribute directly to the driver's temperature."

Additionally in the case of residential applications with Insulated Can Air Tight (ICAT) down light fixtures, the small, upward facing heat sink of a snow cone lamp will lead to deleterious higher temperature operation which reduces light output and shortens lamp life. The DOE indicates that a 13 watt CFL raises the temperature in an ICAT fixtures to 55 °C [5], a ΔT of 30 °C from a 25 °C ambient. Conservatively assuming a fixed thermal resistance, means that a 6.5 watt snow cone LED lamp would raise the temperature in the ICAT fixture to 15 °C + 25 °C= 40 °C [6]. Consequently the LED junction temperature and the power supply component temperatures would also be raised by 15 °C relative to what it would

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[4] http://www.lrc.rpi.edu/programs/solidstate/assist/pdf/AR-LEDLightEngine-revApril2009.pdf , Page 9

[5] See http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/integral_leds/IntegralLampsV1.0FINALCoverLetter.pdf

[6] In reality the thermal resistance associated with both convective and radiative heat dissipation decreases as a function of temperature, meaning that the temperature in the ICAT fixture would be more than 40 C.

be when the lamp operates in open space. The lifetime of electrolytic capacitors used in snow cone LED lamps is given by[7]:

$$Lifetime \propto 2^{(T_m - T)/10}$$

Where T_M is the temperature corresponding to the rated life; and
T is the actual operating temperature.

Consequently raising the temperature of snow-cone lamps by 15 °C when operating them in an ICAT down light fixture will shorten the lifetime by a factor of 1/3.

BUSINESS REASONS FOR URGING EPA TO ACCOMMODATE TECHNICALLY DEFFICIENT SNOW CONE LAMPS

It has been reported that slower than expected LED bulb sales is one factor leading to a short term increases in LED inventories[8]. This is an alarming signal for LED makers and for snow cone lamp makers many of whom have not been profitable for a number of years since their inception. The low sales is, no doubt, one motivation for the entreaties to the EPA to accommodate the snow cone lamps within the Energy Star standard. However, in so far as there are substantial technical deficiencies in snow-cone lamps, the EPA should not accede. The market will work itself out in due course-there will be good directional lamps

[7] http://www.edn.com/article/471688-Determining_end_of_life_ESR_and_lifetime_calculations_for_electrolytic_capacitors_at_higher_temperatures.php

[8] See http://webcache.googleusercontent.com/search?q=cache:w_CqInpS3FoJ:online.barrons.com/article/SB50001424052970204590704576092341919168966.html+http://online.barrons.com/article/SB50001424052970204590704576092341919168966.html&cd=1&hl=en&ct=clnk&gl=us&source=www.google.com

available with a wide range of beam angles and there will be good omnidirectional lamps for table lamps and floor lamps. The EPA cannot allow itself to be caught up in and influenced by the month-to-month fluctuations of the business cycle as though the EPA were a stock market day-trader. The EPA needs to reserve the Energy Star imprimatur for technically sound products.

One has to take account that many companies hawking snow cone lamps are backed by business men and financiers with no connection to the light field. These companies are only interested in moving product and grabbing market share, and are not in any way respectful of sound illumination engineering practice. The Energy Star program should not pander to business people who have made themselves beholden to impatient Wall Street analysts while marginalizing engineers and scientist who are able to provide the best solutions.

CHARLATAN ETHOS PREVAILING IN CURRENT LED MARKET

An example is useful to illustrate the charlatan ethos that is unfortunately too prevalent of late in the LED illumination sector. It has been reported that Philips expended considerable engineering effort to develop the LED A-Lamp shown in FIG. 1 below. The Philip's lamp includes a remote phosphor which is yellow when the lamp is in the off state. When the lamp is turned on the blue light emitted by LEDs which illuminate the remote phosphor combines with light emitted by the phosphor to produce white light. The Philip's lamp has been widely publicized.

Not to be outdone a certain LED light company decided to paint the heat sink of its snow-cone A-lamp a yellow color that closely matches the color of the remote phosphor of the Philips lamp, see FIG. 2. Of course functionally the yellow color of the heat sink serves no purpose. The only purpose would be to mislead the average consumer to think that the widely advertized high performance of the Philips lamp was also achieved by painted snow-cone LED lamp.

Fig. 1 *Fig. 2*

It is the same deceptive charlatan ethos that originally produced the snow-cone A-lamp design. Unfortunately, too many companies, convinced by the prevailing buzz a couple years ago that it was impossible to produce a truly omnidirectional LED light bulb, jumped on the snow cone bandwagon. Now that it has demonstrated that omnidirectional lamps are possible these companies feel they have missed the boat and are now clamoring for a free ride from the Energy Star program. They may have missed the boat as far as a true omnidirectional lamp, but don’t want to concede this and suffer the natural consequences of their failure to innovate. They want the endorsement of the Energy Star program irrespective of the their poor performing technology.

The proponents of snow cone lamps are akin to snake-oil salesmen[9], they have a "solution" which is nothing more than what is commonly available (i.e., the inherent Lambertian distribution of bare LEDs) and they have been out in search of a "problem" to address with their "solution" and have seized upon down lighting as a target "mark".

Ultimately snow cones cannot compete with true directional LED lamps for directional applications or true omnidirectional lamps in omnidirectional applications—inevitably the market will bear this out, but in a paroxysm of denial snow cone proponents submit strongly worded comments to the Energy Star program. The risk is that the Energy Star program is being caught up in the panic of the snow cone manufacturers, and lose sight of the obvious technical facts, leading to a situation in which both the LED lighting industry as a whole and the Energy Star program lose credibility with the public.

CONCLUSION

Ultimately, the snow-cone lamp is neither a good directional lamp or a good omnidirectional lamp. The light distribution is problematic for the reasons discussed above and these problems lead to inefficiencies and more generally to poor lighting performance in actual applications. The Energy Star program should not be open to integral lamps that do not produce light distributions that are conducive to efficient, high quality lighting. Energy efficiency is the mandate of the Energy Star program, and in the case of lighting it is well established that a proper light distribution is essential to system efficiency.

[9] "Snake Oil: A product that has been proven to not live up to the vendor's marketing hype. The term comes from the 1800s in which elixirs and potions of all kinds, even ones that supposedly included the oils from snakes, were sold as a cure for everything that ailed a person." http://encyclopedia2.thefreedictionary.com/Snake+oil+salesman

Energy Star should not allow manufacturers to use logos indicating suitability for down lighting applications based on self-certification of suitability. Rather Energy Star should stipulate basic requirements for down lighting applications. For recessed can lighting these should include a requirement that at least 90% of the luminous flux fall in the polar angle range 0° to 45°.

Sincerely,

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