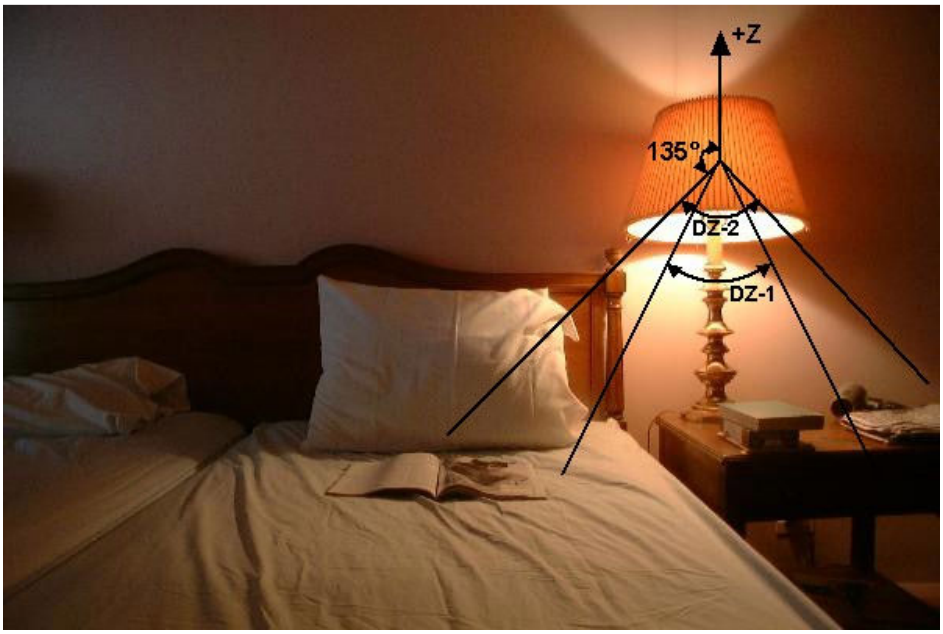
Comments on Energy Star Lamps Product Specification Framework Comments

The photo in FIG. 1 below shows a table lamp in typical use on a nightstand. The original Energy Star uniformity standard for omnidirectional LED lamps specified uniformity of within +/- 10% from average in the polar angle range from 0° to 150°[1]. Ultimately, in Version 1.0[2] and subsequent versions of the standard, the uniformity requirement was relaxed so that light intensity in the polar range from 135° to 180° only needed to be 30% of the intensity in the polar angle range in the polar angle range 0° to 135°. The polar angle range 135° to 180°, labeled DZ-2 in FIG. 1 (with the aid of some light scattered by the lamp shade) provides the light for reading and other tasks for the light from table lamps are used, so it is inappropriate that this light zone be singled out and allowed have intensity that is down to 30% of the intensity in the range 0° to 135°. The Department of Energy itself conducted two studies in the late 1990's that specifically determined that it was crucial to provide high intensity in the nadir region 120° to 180°. The Energy Star standard contradicts the DoE's own research. The origins of the present standard can be traced back through the sequence of drafts. In doing so it is found that there is no rational for contradicting the DoE's own research. The EPA should promulgate a standard that requires uniformity within +/- 10% from average in the full polar angle range from 0° to 180°, so that "omnidirectional" bulbs are actually omnidirectional with no zone arbitrarily excluded. The current standard is a step backward from the light distribution of the common household incandescent lamp. At the very least the EPA should restore the original +/- 10% within 0° to 150° standard.

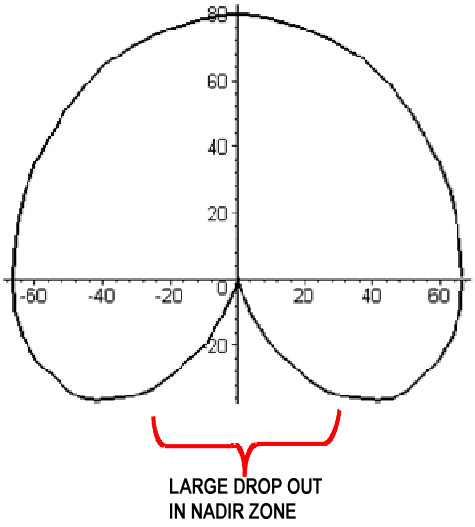
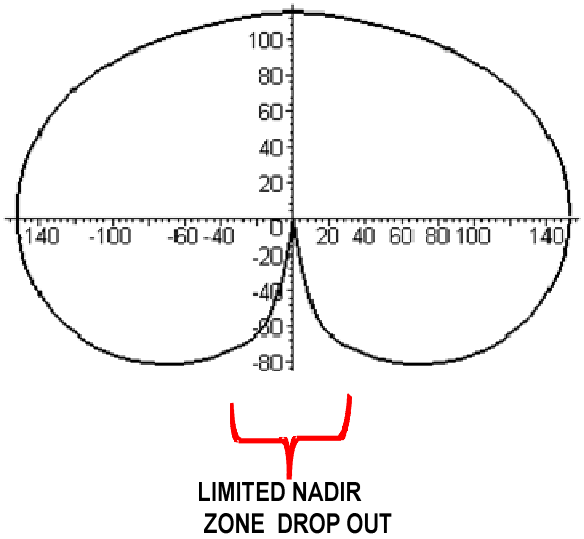
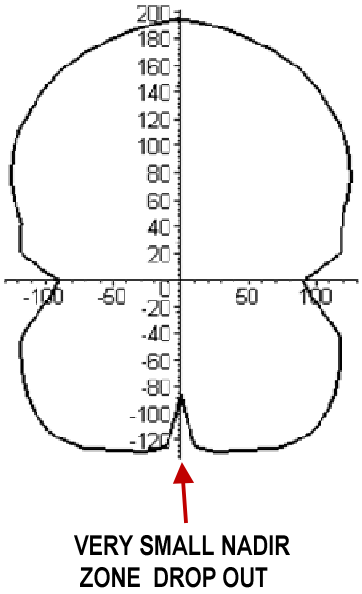
FIG. 1



[1] See http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/integral_leds/ESIntegralLampsCriteria_Draft1.pdf , page 4 "Luminous intensity distribution" section

[2] See http://www.energystar.gov/index.cfm?c=new_specs.integral_leds

Energy Star should be an improvement over existing technology. It should improve performance in accordance with the Department of Energy's own research[3]. Instead at the urging of General Electric's lobbyists, the Department of Energy actually lowered the performance of Energy Star products below the soon to be obsolete Incandescent light bulb!

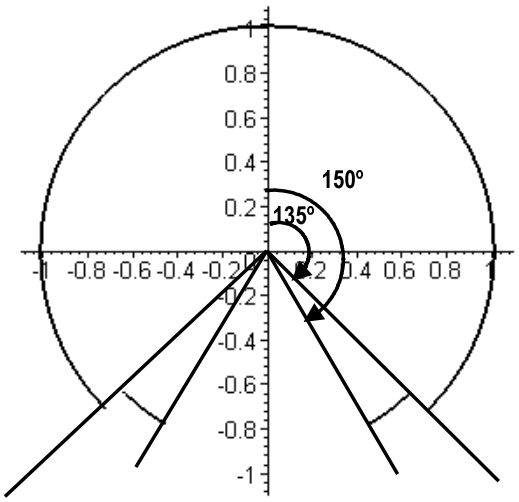
Weak nadir region light intensity. Contradicts Department of Energy's Own Research Meets Energy Star but satisfies standard adapted at urging of GE lobbyists.	**OK** light Intensity in Nadir region. Standard 100 watt incandescent lamp to be phased out per 2007 EISA.	**Stronger** light intensity in nadir zone. Recommended by Department of Energy's research.
		
Strongly Diffused bubble remote phosphor "Snow Cone" LED replacement lamp. Weak light intensity in nadir zone which was deemed crucial by Department of Energy's own	100 Watt Incandescent lamp. 9.6% of light is in zone 135° to 180°. Average light intensity in 135° to 180° zone is 50% of average intensity in 0° to 135° one.	Circline Fluorescent. Regarded as best by Dept. of Energy's Research. LED lamps can also be made to have this very small nadir drop out zone. 15% of light is in zone 135° to 180°.

[3] See E. Page et al. "A Comparative Candle Power Distribution Analysis for Compact Fluourescent Table Lamp Systems", 1995.
E. Page et al., "Integral CFLs Performance in Table Lamps",1997
The research was conducted by the Lighting Systems Research Group of the Buildings and Technology Program of the Energy and Environment Division of the Lawrence Berkley National Lab.

research studies. 6.5% percent of light is in zone 135° to 180°. This low amount meets the ***weakened*** Energy Star Standard. Average light intensity in 135° to 180° zone is only 25% of average intensity in 0° to 135° one.		

Comparing Nadir Zone Illumination Required Per Original and Final Energy Star Omnidirectional Pattern Specifications

It is useful to compare the amount of light that is required to be in the nadir zone of 135° to 180° per the original (+/- 10% within 0° to 150°) draft-1 standard to what is required in the weakened (+/- 20% in 0° to 135° & 5% in 135° to 180°) current standards. The worst case scenario for the original standard as far as the nadir zone illumination would be zero normalized intensity in the range in 150° to 180°, 0.9 normalized intensity in the range 135° to 150°, and 1.0111 average mean normalized intensity in the zone in 0° to 135°. Even in this worst case scenario there would still be 1.5 times as much energy in the nadir zone compared to what is required per the weakened standard.



WORST CASE FOR NADIR ZONE UNDER ORIGINAL +/- 10% IN 0° TO 150°
INTENSITY IN 0° TO 135° IS 1.011
INTENSITY IN 135° TO 150° IS 0.9 (THE LOWER LIMIT)
INTENSITY IN 150° TO 180° IS ZERO !
PERCENT OF LIGHT FLUX IN 135° TO 180° IS 7.5% WHICH IS 1.5 TIMES THE 5% FLUX REQUIRED BY THE WEAKENED FINAL ENERGY STAR STANDARD

Each case: (1) consumers cherished incandescent A-lamp, (2) the Dept. of Energy's researcher's favored circline, and (3) the worst case scenario under the original, draft-1 Energy Star standard, has significantly more light flux in the crucial nadir zone than is required by the weakened current standard.

GE's Disingenuously Proposed a Weakened Standard that was Adapted by the Energy Star Program

The Energy Star program adapted a weakened uniformity standard proposed by GE[4]. The original uniformity standard specified uniformity of within +/- 10% from average in the polar angle range from 0° to 150°[5]. The looser uniformity standard which was suggested by GE and then adapted by the Energy Star program calls for +/- 20% in the polar angle range 0° to 135° plus at least 5% of the energy in the polar angle range 135° to 180°. According to this standard the average intensity in the polar range 135° to 180° can be down to 1/3 of what it is in the range 0° to 135°. As I have previously pointed out this contradicts the Department of Energy's own research.

Now information has come to light, in a published GE patent application, which proves that in the same time frame that GE was proposing a standard that allowed for weak intensity in the nadir zone, its own scientist considered it appropriate to extend the light pattern uniformly as close as possible to nadir. As is made clear from reading GE's patent, GE's own design was limited in regards to how far the uniformity could be extended into the nadir zone. The GE patent in question is U.S. Pat. App. 20110080096 (attached). Paragraph 0068 of the patent is as follows:

> *"[0068] Referring now to FIG. 12, the benefits of using a specular surface finish on thermal heat sink regions that interact with light emitted from a typical LED lamp are demonstrated for the uniformity of the light intensity distribution in latitude angles. The intensity level at angles adjacent to the south pole (in this example, 135.degree., identified with arrows) is shown to be 23% higher for a specular surface compared to a diffuse surface when compared to the average intensity from 0-135.degree.. Also shown is the intensity distribution for a 50% specular and 50% diffuse surface that captures approximately half the benefit of a fully specular surface in average intensity. The effect of the specularity of the surface cannot be understated as it has a dual effect benefiting the uniformity of the light intensity distribution. Point G on the graph defines a point that will be referred to as the `pivot` point of the intensity distribution, which is nominally located in the equator of this design. As the specularity of the heat sink*

[4] http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/integral_leds/GE_Comments_Draft3.pdf , pgs 30-35
[5] See http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/integral_leds/ESIntegralLampsCriteria_Draft1.pdf , page 4 "Luminous intensity distribution" section

surfaces increases, the intensity to the north of the pivot decrease, and to the right of the pivot, increase. This reduces the average intensity as well as increasing the southward angle at which uniformity is achieved. This is critical to generating a uniform intensity distribution down to the highest angle possible adjacent to the south pole." {emphasis added}

In view of this revelation of GE's true opinion on the matter of uniformity and intensity in the nadir zone, it is clear that the Energy Star program should never have agreed with GE's comments and lowered the uniformity standard. The mistake should be rectified by amending the uniformity standard to require variation of less than +/- 10% from 0° to 180°, or at the very least restoring the original uniformity standard of +/- 10% from average in the polar angle range from 0° to 150°.

GE Lacked the Expertise to Specify the Uniformity Standard that was Adapted by Energy Star

Large companies like GE will hire staff when needed to pursue emerging business opportunities. At the time that GE suggested the weakened standard that was ultimately adapted by the Dept. of Energy GE lacked the expertise to know what was and wasn't possible in terms of light distribution uniformity. This is evidenced by the very rudimentary nature of the design of GE's 40 watt equivalent lamp. That lamp relies entirely on strong diffusion to achieve some measure of uniformity. Diffusion is a very basic practice in illumination optics and is within the grasp of generalists who have elementary knowledge of illumination. GE's lack of expertise is also evidenced by the fact that for the past several months GE has been trying to hire the expertise it lacks in the area of illumination optics, specifically GE has been seeking to hire an engineer to develop illumination optics for LED integral lamps. The expertise GE is seeking, is precisely the expertise GE would have needed speak authoritatively on how the Dept. of Energy should set the omnidirectionality standard. It appears that GE had some engineers with more generalist knowledge in illumination who didn't see how the original standard could be met, and requested that GE's lobbyists should seek a weakened standard. Review of the record shows no compelling reason was provided by GE that would overcome the specific conclusions of the Dept. of Energy's own research that it was important to have strong intensity in the nadir zone. The Dept. of Energy should not have weakened the standard to accommodate companies who lacked the expertise or didn't want to "go back to the drawing board" to meet the standard.

Faulty Maximized Diffusion Snow Cone Approach

Certain companies exemplified by GE have took the approach of trying to stretch the optical design of a "snow cone" A-lamp which has all the LEDs mounted facing upward into an omnidirectional lamp. To do so they try to maximize diffusion with one or two concentric bubble shaped diffusers. It is counter intuitive that this would be possible and in fact it has not been able to meet the original (+/- 10% within 0° to 150°) standard. In its recently published patent application US2011/0080740, GE advanced a theory of how such lamps are supposed to work to provide high level uniformity. While the theory is elegant in its simplicity, it is based on a naïve understanding of how diffusers function. The actual prototypes described in the patent application do not meet the original (+/- 10% within 0° to 150°) draft-1 standard. As shown in the above mentioned patent GE's best uniformity was (+/- 20% within 0° to 150°). Rather than "going back to the drawing board" GE successfully lobbied Washington for a lower standard. Now the public at large, soon to be deprived of the common household incandescent lamp, will be compelled to make do with lamps that have a light distribution that is judged inferior by the Dept. of Energy's own research.

Helical tube CFL's also have inadequate luminous intensity in the nadir zone, and this may be one reason that they are judged inadequate by many consumers not withstanding lumen output being equal to incandescent lamp equivalents.

ADAPTED STANDARD CONTRADICTS DEPARTMENT OF ENERGY'S OWN RESEARCH

The DOE Office of Energy Efficiency and Renewable Energy itself funded research in the 1990's on the effect of differences in omnidirectional bulb light distributions on overall performance. The research was conducted by the Lighting Systems Research Group of the Buildings and Technology Program of the Energy and Environment Division of the Lawrence Berkley National Lab. This research was reported in Erik Page et al. "A Comparative Candle Power Distribution Analysis for Compact Fluorescent Table Lamp Systems", 1995 and in Erik Page et al., "*Integral CFLs Performance in Table Lamps*",1997 . While this research was conducted in the context of CFL lamps the focus of the research is on what distribution of light is best for omnidirectional light bulbs. Therefore the conclusions of this research are equally applicable to LED based omnidirectional light bulbs. [6]

[6] (By far the most significant omnidirectional light bulb, in terms of energy use is the common household light bulb)

Both of these papers draw the unequivocal conclusion that omnidirectional light bulbs should provide strong light intensity in the vicinity of zenith (0°, for up lighting through the top of the lamp shade) and nadir (180°, for task illumination around the lamp). The current standard has greatly weakened the intensity requirement in vicinity of nadir such that the light intensity in the entire nadir zone 135° to 180° which is applicable to reading and other tasks which are the primary purpose of table lamps can be down to 30% of the intensity in the polar angle range in the polar angle range 0° to 135°.

Some quotes from these DOE research papers are relevant to what standards should be established for omnidirectional LED integral lamps. In discussing the impact of table lamps and floor lamps on energy consumption the researches state in the 1995 paper:

> *"A significant portion of these high use sockets are table or floor lamps"*

In discussing consumer expectations regarding such lamps the paper states:

> *"Consumers are used to a bright halo of light emanating from the top aperture of the shade and* bright illumination directly below the shade for high-definition tasks such as reading.*"*

Most relevant to the compromised uniformity requirements for LED omnidirectional lamps , the researcher's state:

> *"A comparison of the A-lamp and the circline demonstrates the advantage of focusing output vertically."* {emphasis added, vertically means near nadir and zenith}
>
> *"While the A-lamp yields the largest total lumen package of 1815 lumens, the circline has a much more intense output at the crucial nadir and zenith angles. In effect, fewer total lumens are required to produce sufficient illumination where it is actually needed: at nadir for task lighting and zenith for indirect lighting" {emphasis added}*

In the abstract of the 1997 written after more extensive research the researchers state:

> *"It is our assertion that the lumen distribution of the light source within the luminaires plays a critical role in total light output, fixture efficiency and efficacy, and, perhaps most importantly, perceived brightness."*

On page 4 the 1997 DOE paper states:

> *"The most critical angles are those below the shade (Figure 1, 0° to 60°)[7] because the light output from this area illuminates the task plane."*
>
> *"The results displayed in Figure 1 agree with our hypothesis. We can see that the globe and horizontal sources generate more light than verticals at near zenith angles, the horizontal sources yield the most light at nadir angles, and all three sources yield similar output in the shade region."*

and

> "The horizontal sources yield significantly more light out the bottom aperture of the shade. They concentrate their illumination vertically and most extend radially out around the center of the fixture circumventing light blockage due to the fixture base."

In conflict with the Dept. of Energy's own research which drew the definite conclusions that it is important to provide adequate light in the vicinity of nadir and zenith, the Energy Star program has greatly reduced the requirement of light in the nadir zone.

Abridged History of Revisions Concerning "Omnidirectional" Lamp Uniformity

DRAFT 1

Draft 1 required uniformity of within +/- 10% from average in the polar angle range from 0° to 150°. This corresponds to the L-Prize uniformity requirement. The zone 150° to 180° which is weak in legacy incandescent bulbs was excluded but need not have been because LED technology is not subject to the same limitations as incandescent bulb technology. The intensity distribution of the circline bulb which the above mentioned Department of Energy study concluded was best does not drop out in the zone 150° to 180°.

[7] Note that 0 degrees in the coordinate system used in this paper corresponds to 180 degrees in the proposed draft 3 standard, so the 0 to 60 degree deemed "most critical" in the DOE/LBNL paper corresponds to 120 to 180 degree range of the draft 2 proposed standard.

In response to Draft 1 NGLIA/NEMA proposed that the uniformity standard require variance of no more than +/-20% over the polar angle range 0° to 135°. Unlike in the case of other suggestions NGLIA/NEMA offered they did not provide any rational for this proposal. My assumption is that at the time some the corporate constituents of NGLIA/NEMA were trying to stretch the "snow-cone" LED lamp design beyond it natural limits by using heavy light diffusion in order to try to attain a semblance of omnidirectionality, and had discovered that the original +/-10% over 0° to 150° standard could not be met and prompted NGLIA/NEMA to offer these comments. If this is the case, I would say that it is no surprise that they ran up against this limitation, that there are other designs now coming to the fore, and that the standard should not have been compromised, in a way that directly contradicts DoE research, based on such unsophisticated early approaches.

As I noted in earlier comments one NGLIA constituent company also had a patented design that met the weaker proposed standard but did not meet the original standard, and contrary to NEMA's own policies concerning disclosure of patents in the context of its own standard setting activities this patent was not disclosed in the NGLIA/NEMA comments.

DRAFT 2

Draft 2 adapted the looser +/-20% over 0° to 135° standard proposed by NGLIA/NEMA. In response to draft 2, GE implied, perhaps inadvertently, that a certain specialty incandescent bulb, the vertical filament clear bulb, was "The incumbent technology" and did not meet the loosened standard and that the loosened standard should only apply to lamps intended to replace diffuse (frosted) bulbs. If the requirements were to be tied to what was intended to be replaced a very large loop hole in the standard could have been introduced.

Also in response to draft 2, a certain Neo-Neon company (P.R.C.) having misconstrued the purpose of a legal definition of light bulbs subject to phase out per a European Union Commission regulation, and having confused two different ways to specify angular ranges, suggested that this legal definition of what the European Commission intended to phase out should be adapted as the U.S. standard for uniformity of LED omnidirectional lamps[8].

DRAFT 3

[8] See pg. 2 of http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/integral_leds/MathPathoptics_comments_Draft3.pdf

The draft 3 uniformity standard can only be described as a major screw-up. Draft 3 adapted the European Commission legal definition that was not meant to be a standard as the U.S. Energy Star uniformity standard but added a requirement that rendered the adapted legal definition superfluous. The resulting uniformity standard for omnidirectional lamps did not require any semblance of uniformity at all.

Both General Electric and I responded to draft 3 by pointing out that it failed to require any uniformity at all and permitted wildly varying intensity and substantial dark zones. GE suggested as one possible alternative the weak uniformity standard that the Dept of Energy Ultimately adapted.

VERSION 1.0 ET SEQ.

The Department of Energy adapted the weaker standard.

PROPOSED UNIFORMITY STANDARD

The Energy Star Program Requirements for omnidirectional Integral Lamps should be issued with a stipulation of +/- 10% over the entire 0-180°. This would restore the original +/- 10% tolerance which can certainly be achieved and extend the angular range so that the emission pattern will be truly "omnidirectional". It requires that light be provided to the nadir region as recommended by the DOE's own research.

The advent of LED based light bulbs is an opportunity to improve upon the light distribution of the incandescent light bulbs. With a better light distribution the same effective illumination, e.g., in the crucial nadir region, can be obtained with less total lumens and less wattage (e.g., dimmed down, or lower power bulbs) thereby saving energy.

At the very least the EPA should restore the original (+/- 10% within 0° to 150°) standard.

It is inappropriate for the Energy Star program to have lowered the standard, relative to legacy incandescent products that will no longer be available to the public, and in contradiction of the governments own research, for the sole reason of accommodating a lobbying corporation that was unable to meet the original standard.

Cordially,
Philip Premysler
Founder
MathPath Optics
(561) 271-2178
SSL@MathPathOptics.com

Effect of Candela Distributions on Task Plane Illuminance for different " Omnidirectional" lamps.

The EPA Energy Star program indicated that the intensity distribution requirements will be under consideration[1]. The effect of intensity distribution of omnidirectional light bulbs on performance when used in table lamps (a high energy use application) was extensively studied by the DoE in the late 1990's. The research was reported in the paper "Integral CFLs Performance in Table Lamps" by Erik Page et al., of the Lighting Systems Research Group, Building Technologies Program, Environmental Energy Technologies Program, Lawrence Berkeley National Laboratory. One aspect of this research was to study the task plane illuminance provided by different types of light bulbs that could be used in table lamps. In the conclusion of the paper the researchers noted that they had not covered the spiral type compact fluorescent lamps (CFLs) that were then starting to reach the market. At present spiral CFLs have become the predominant type of CFL used by consumers, so it is worthwhile to look at their candela distribution and the illuminance they produce and compare it to the traditional incandescent light bulb.

The most common type of CFL (FIG. 1) has a bulky lower electronics housings which blocks some light from reaching the nadir zone.

Fig. 1

Fig. 2

[1] See ENERGY STAR® Lamps ("Light Bulbs") Product Specification Framework March 2011 letter, section III b (i)

The intensity distribution of the common CFL is very weak in the nadir as shown in the polar plot below.

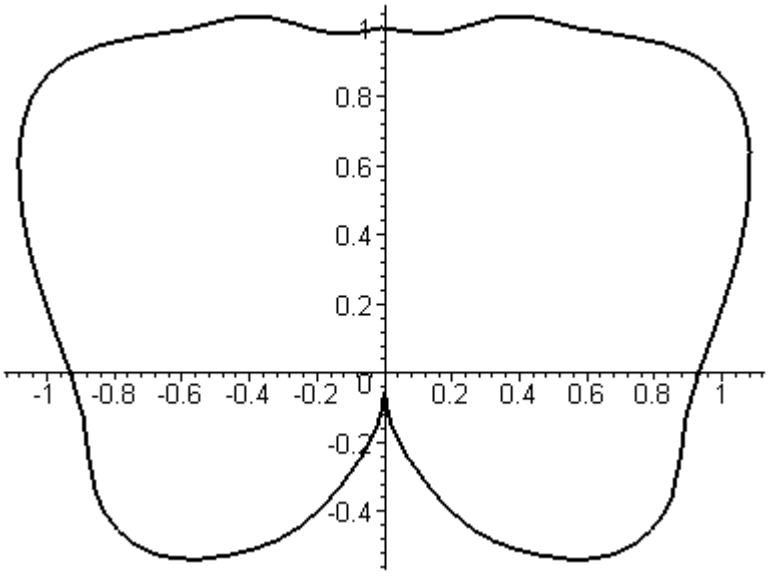


FIG. 3, CFL INTENSITY DISTRIBUTION

The effect of the weak nadir distribution of the common CFL is seen when comparing the actual task plane illuminances of the common CFL and the traditional incandescent lamp. Figure 4 below illustrates the geometry of the table lamp used in the measurements. Note that the radial coordinate is measured from the centerline of the lamp.

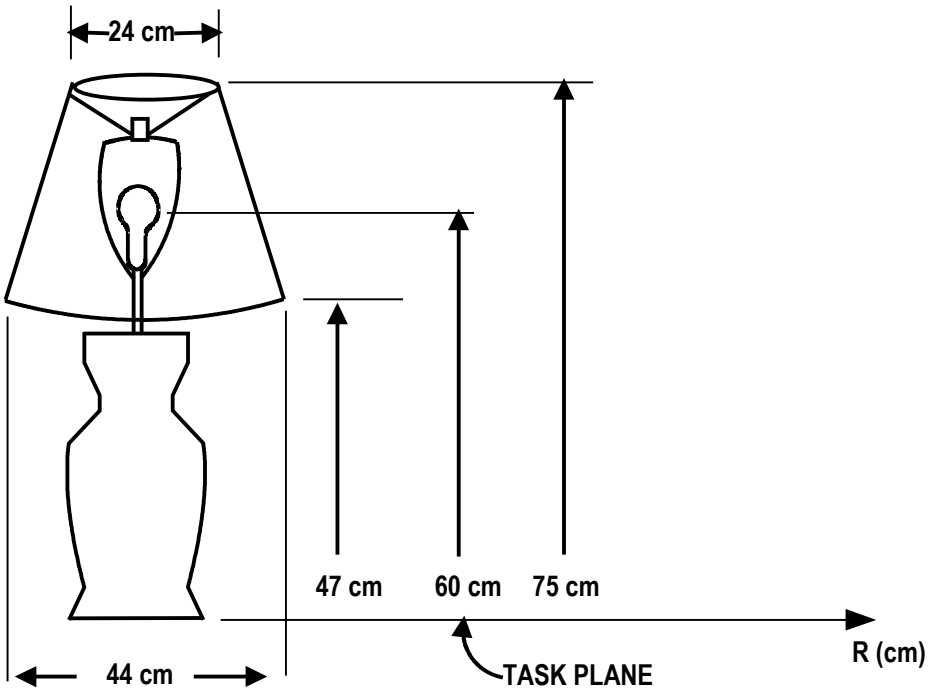


FIG. 5 shows the plotted illuminances of the common CFL and traditional incandescent lamp when used in a table lamp with a somewhat absorbing (lossy) yellowed old lamp shade. Package information indicated that the CFL consumed 13 watts and produced 825 lumens, and that the incandescent consumed 60 watts and produced 840 lumens (2% more).

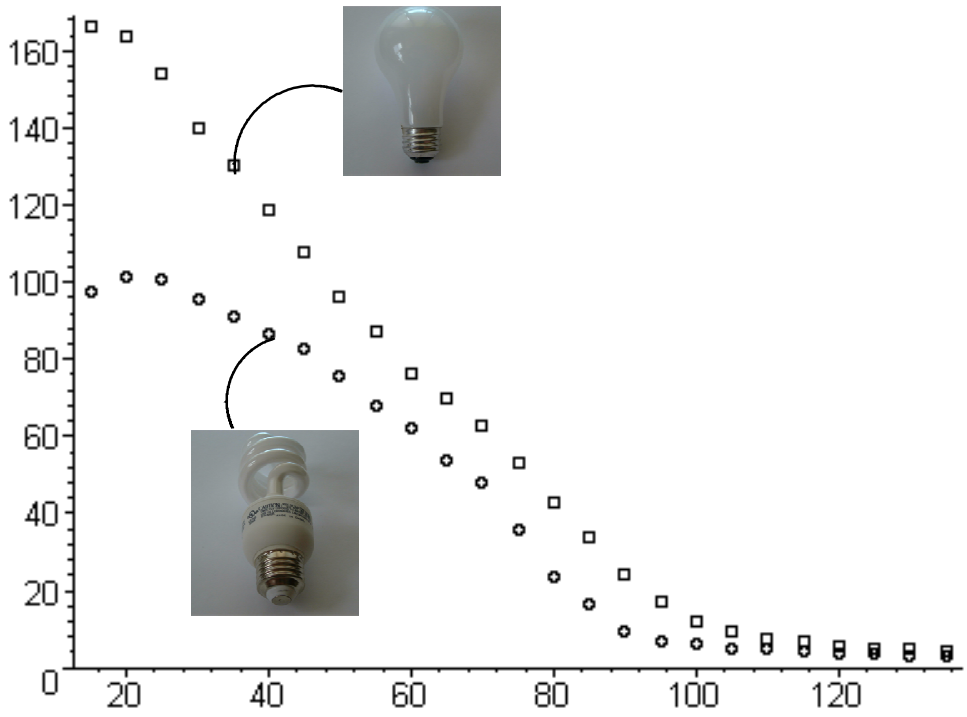


FIG. 5 Task Plane Illuminance (LUX) vs. radial coordinate in task plane (cm) for CFL and Incandescent lamps in lamp with lossy lamp shade

As shown in FIG. 5 the CFL produced substantially less task illuminance despite the fact that it produced about the same total lumens. The ratio of the illuminances is shown in FIG. 6. It varies between 1.2x and 2.5x. Note that the large peak in the ratio is located at a distance where a person in the vicinity of the lamp is likely to be situated, for example a person seated in an easy chair next to a table lamp on which the lamp is located.

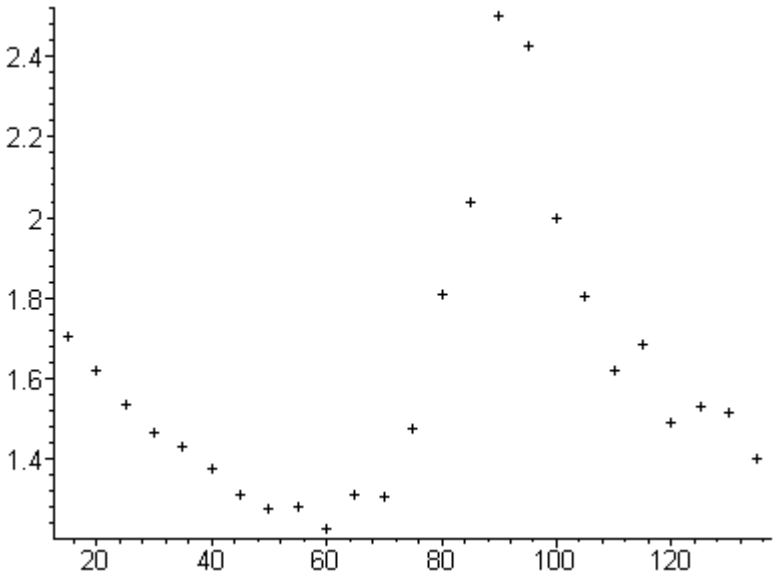


FIG. 6 ratio of illuminances (unitless) vs. radial coordinate (cm) produced by incandescent and CFL in table lamp with lossy (absorbing) yellowish lamp shade.

FIGs. 7 and 8 show the task plane illuminances and their ratio when using a lamp shade with a highly reflective white liner.

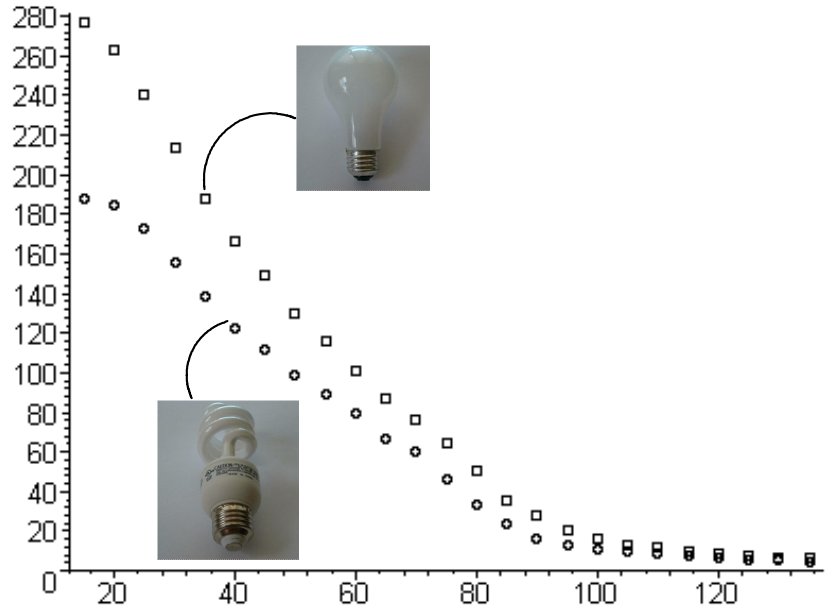


FIG. 7 Task Plane Illuminance (LUX) vs. radial coordinate in task plane (cm) for CFL and Incandescent lamps in lamp with reflective lamp shade.

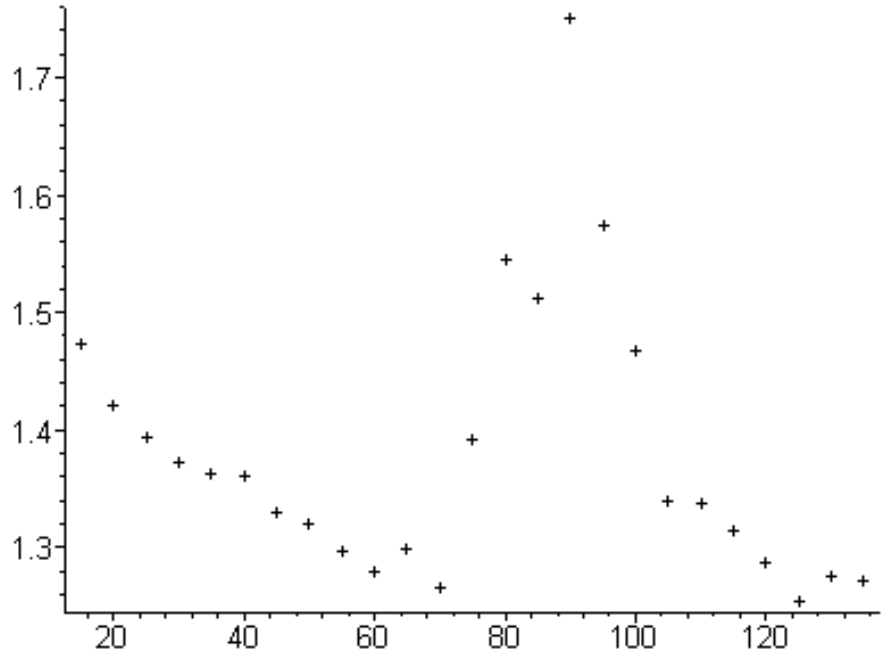


FIG. 8 ratio of illuminances (unitless) vs. radial coordinate (cm) produced by incandescent and CFL in table lamp with highly reflective white lamp shade liner.

Also, in the case of a lamp shade with a highly reflective white liner, the common incandescent lamp produced significantly greater (1.25x to 1.75x) task plane illuminance compared to the CFL even though both light bulbs produced nearly the same total lumens.

Conclusion

The weak nadir zone light intensity produced by the common CFL leads to poor task plane illumination. As a practical matter because task illumination is important, the effective efficiency for common CFLs in terms of average task plane LUX per watt is less than commensurate with the advertised efficiency benefit of CFLs stated in terms of lumens per watt. Because the intensity distribution of LEDs can, in principle, be more tightly controlled, LEDs can afford more favorable performance. The Energy Star program should insure that that any standard that is adapted encourages better distributions, not worse as is presently the case with the weakened Version 1.0 uniformity standard. The standard as it is written encourages strongly diffused “snow cone” LED lamps which provide weak task illumination.