**GE Lighting**

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August 24, 2012
Revised on October 2, 2012 with Appendix 1

Ms. Taylor Jantz-Sell
Environmental Protection Agency
ENERGY STAR Lighting Program Manager
1200 Penn. Ave NW 6202J
Washington, DC 20460

RE: GE Lighting Comments on ENERGY STAR® Program Lamp Specification v1.0, Draft 2

Dear Ms. Jantz-Sell,

GE Lighting appreciates the opportunity to comment on draft 2 of the Lamp specification v1.0. As a manufacturer of both CFL and LED products we understand the challenges of trying to combine both specifications. GE supports the NEMA comments, and would like to emphasize the following points:

1. The draft #2 specification sets the bar very high for SSL products and is so high for CFL that most existing qualified CFLs will not meet the proposed reliability and run-up requirements unless the lamps are redesigned.

2. We understand the rationale behind the expansion of the elevated temperature life testing. We would like to point out, however, that such a requirement will introduce, as an unintended consequence, double testing of the product. For CFLs, one test that follows the DOE protocol, and another test that uses the elevated temperature test protocol from Energy Star. This effectively doubles the testing costs for this part of the test and introduces capacity issues for the test lab.

3. Reintroducing the Non-Standard category for SSL from draft 1 will increase the likelihood of specification misuse and increased consumer dissatisfaction. We understand the need for a non-standard category, but ENERGY STAR should limit the changes to exceptions for lamp shape only and not introduce new non photometric performance exceptions. The performance requirements for all non-standard SSL lamps needs to be developed based on use of the product; otherwise this will confuse the end user and de-incentivize the manufacturer to design ANSI standard lamps which the fixture community has used for decades to ensure proper fit and function. For example, the term "Non-standard Semi-directional" is a limitless description for all types of non-standard lamp shapes that do not meet the omni-directional or directional intensity distribution requirements. This will cheapen and demote the products designed and certified to meet both the ANSI shape and current photometric requirements and, in the end, will increase the number of dissatisfied end users calling the EPA hotline. In addition, the use of a nonstandard lamp designation should be minimized because ANSI has a process in place to readily add new ANSI shapes. For example, ANSI is in process of developing MR16 extended and GU10 based lamp descriptions. If the specification contains non-standard lamp categories, limit only lamp shape. There must be photometric, i.e., intensity distributions, performance requirements, the same as the standard shaped lamp.

4. Throughout the specification, ENERGY STAR calls out special requirements for products marketed as "commercial grade", however; there is no definition of "commercial grade". Having this requirement complicates the specification and allows for misuse of the specification very similar to what was noted in the NEMA comments for Non Standard Lamp category. The intent of the "commercial grade" can still be met if we follow the life time and test temperatures requirements of the existing SSL Energy Star document V1.4. In addition to the adding complexity to the specification, the commercial grade requirement would result in product SKU proliferation, multiple product packaging changes and duplicate testing of products. Energy Star should let the market place drive the life requirements for products sold into the commercial environment. This is no value gained for the additional product cost; the term "commercial grade" should be removed from this specification.

5. For SSL products, there is no statistical justification for evaluating product at the test temperature of 55C to ensure a robust product for misapplication of the product. We agree in a misuse application, the ambient temperature of the lamp may be 55C or higher. However, when you consider the likelihood of this type of misuse, it is much less than 1%. To design a product for an operating environment where the population of lamps will only see less than 1% is not a good business practice. As mentioned in the NEMA notes, product cost would not only increase due to more robust component selection but also due to test equipment cost required to buy higher temperature test chambers. The in-house field data shows long term life testing at 45 C per SSL Energy Star V1.4 is working well for GE.

   See Topic 2 in appendix 1 for rationale on why Lamp 20Ws or greater should only be evaluated at 55C and continue to use 45C for lamp power 10Ws or greater up to 20W.

   See Topic 3 in appendix 1 for explanation why the Rapid Cycle test 5min on /5 min off will represent the accumulated stress of the Evaluated Life Test at 3 hrs. on / 20 minutes cycle rate.

   See Topic 4 in appendix 1 for defining the correct power tolerance requirements for measurement and test of products.

6. GE realizes the need for allowing innovation in the area of color for both CFL and SSL products. We note that lamp color quality can be improved if at times the R9 value can be negative. Thus, to ensure we continue to meet the intent of Energy Star's R9 value of greater than 0, and allow for innovation in color quality, we would like to amend the R9 > 0 requirement to read as follows:

   > R 9 > 0 is required if the strong red test color is less saturated under test lamp than under the Blackbody reference illumination, and R 9 may be any value if the strong red test color is more saturated under test lamp than under the Blackbody reference illumination.

   See Topic 1 in appendix 1 for detail discussion for the need and measurement method

Please contact either David Szombatfalvy or Anthony Serres with any questions.

Sincerely,

David Szombatfalvy
Anthony Serres

# Appendix 1

## Topic: Further Discussion on Energy Star Product Specification Lamps – Ver 1.0 , Draft 2
## Data Support for Letter issued to EPA on August 24, 2012

# Topics

1) To allow advanced development of White, there will be cases where R9 will be negative
2) High Temp Testing Proposal on Option B – Temperature selection based on Wattage
3) High Temp Testing Rack Cycle vs Rapid Cycle
4) Power Requirements vs Photometric measurement and long term tests

# Topic 1  Negative R9 proposal

Acceptable: R9 > 0

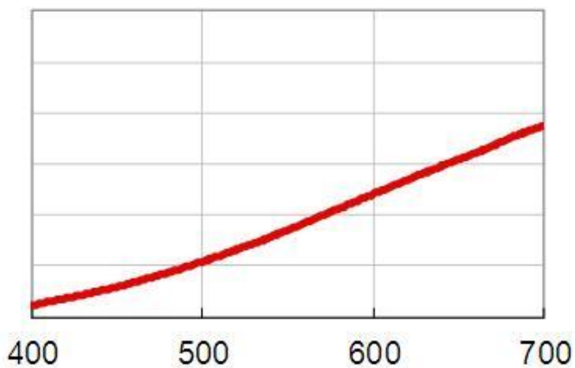
Acceptable: R9 < 0
AND
R9 Chroma for the Test Lamp > R9 Chroma for the Reference source

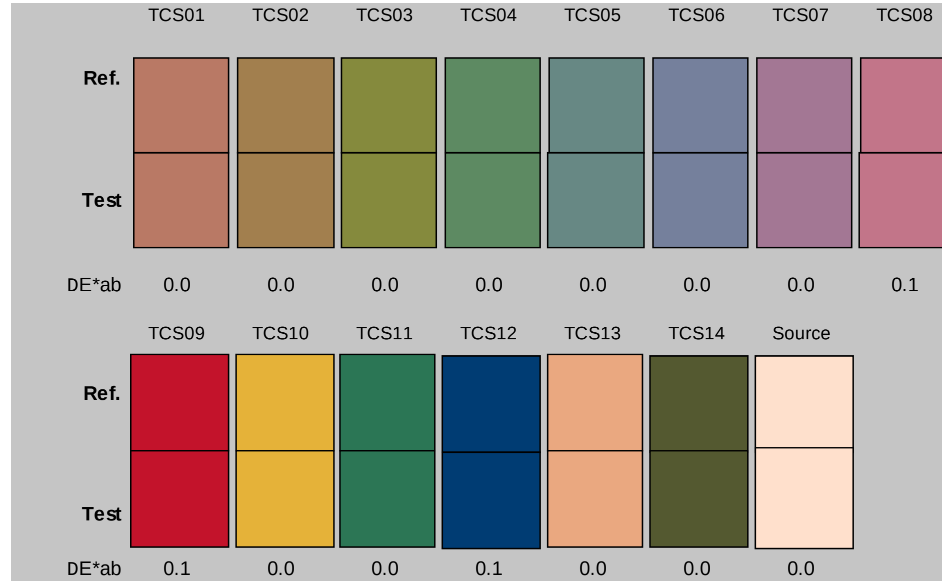
Unacceptable: R9 < 0
AND
R9 Chroma for the Test Lamp **<** R9 Chroma for the Reference source

# Negative R9 explained – Incandescent baseline

**Incandescent**

| | |
|---|---|
| **CCT:** | **2812** |
| Duv: | 0.000 |
| **CRI Ra:** | **100** |
| R9: | 99 |
| LER (lm/W): | 155 |
| **CQS Qa:** | **100** |




Incandescent is a nearly ideal black-body source with
CCT ~ 2800K
CRI ~100
R9 ~ 99

As seen above, the illuminated color of the 14 Munsell chips of the CIE CRI system, when illuminated by the Test Lamp (incandescent) are almost exactly the same as the color when illuminated by the Reference Source (BB at the same CCT). Especially notice that the R9 color chip looks the same under both illuminants.



Examples and plots excerpted from CQS Excel calculator with permission from Dr. Yoshi Ohno, NIST

# Negative R9 explained – Incandescent baseline

**Incandescent**

| | |
|---|---|
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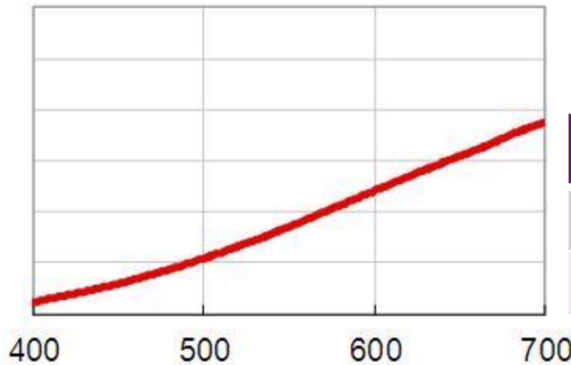
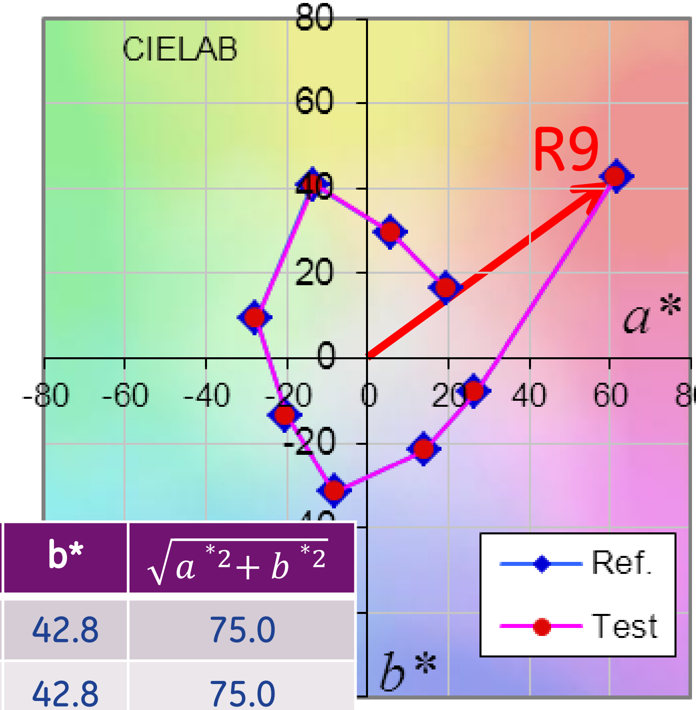



| R9 | a* | b* | $\sqrt{a^{*2} + b^{*2}}$ |
|---|---|---|---|
| Ref | 61.5 | 42.8 | 75.0 |
| Test | 61.6 | 42.8 | 75.0 |

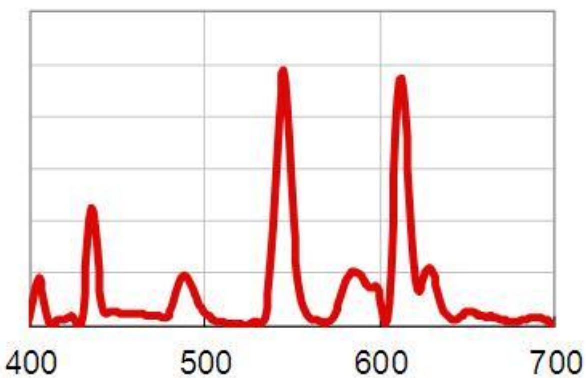
The visual response to the illumination by the Test Lamp and the Reference source of the 8 pastel chips and the R9 chip of the CRI system can be plotted quantitatively in the La*b* color space above-right, where each Test point is a nearly perfect overlap with the corresponding Reference point. The length of the red vector shown represents the “chroma” corresponding to the R9 chip. If the chroma when illuminated by the Test lamp is less (greater) than that of the Reference source, then the illuminant may be referred to as under(over)-saturated. The R9 chroma values are shown in the Table above for the Ref and Test sources.

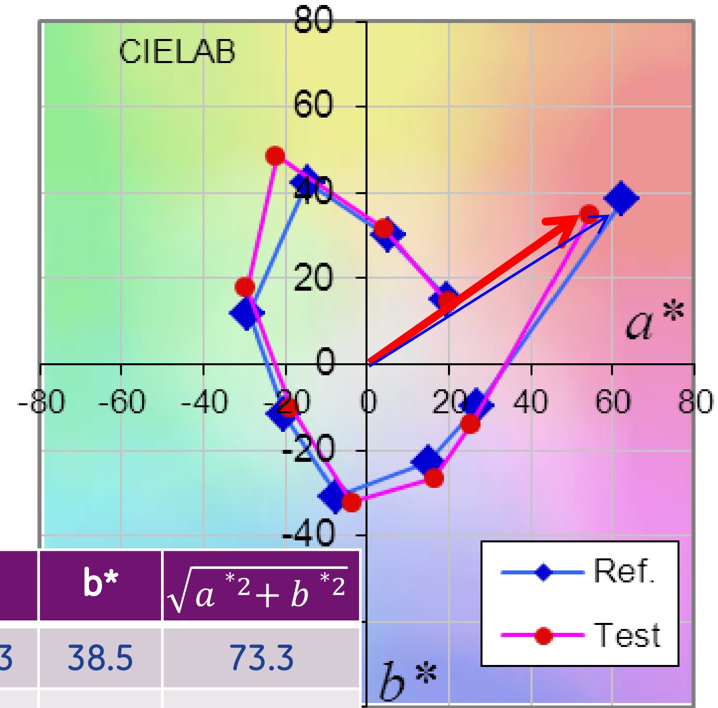
***In the La*b* color space, Chroma = 75.0 for both the Reference and the Test illuminants.***
***The incandescent lamp is neither over-saturated, nor under-saturated for the R9 chip.***

# Negative R9 explained – Tri-phosphor FL example

**Tri-phosphor FL**

| | |
|---|---|
| **CCT:** | **3380** |
| Duv: | 0.001 |
| **CRI Ra:** | **82** |
| R9: | 17 |
| LER (lm/W): | 347 |
| **CQS Qa:** | **81** |




| | a* | b* | $\sqrt{a^{*2}+b^{*2}}$ |
|---|---|---|---|
| Ref | 62.3 | 38.5 | 73.3 |
| Test | 54.4 | 34.8 | 64.6 |

The historical weakness of R9 for legacy Discharge Lamps as represented by a typical Tri-phosphor Fluorescent lamp is shown above. Especially, see that the Test Lamp is less saturated for the R9 chip than the Reference Source (BB at 3380 K), such that R9 is greatly reduced to 17.

***In the La*b* color space, Chroma = 73.3 and 64.6 for the Reference and the Test illuminants.***

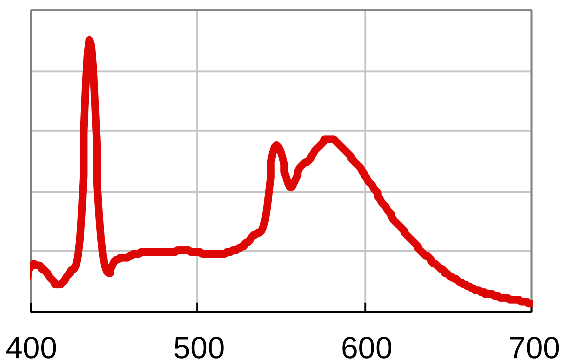
***The FL lamp is under-saturated for the R9 color chip.***

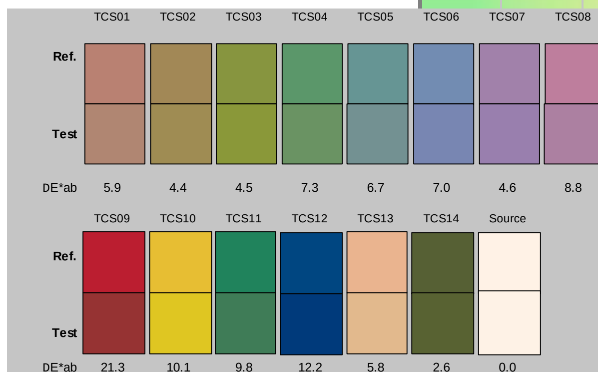
imagination at work

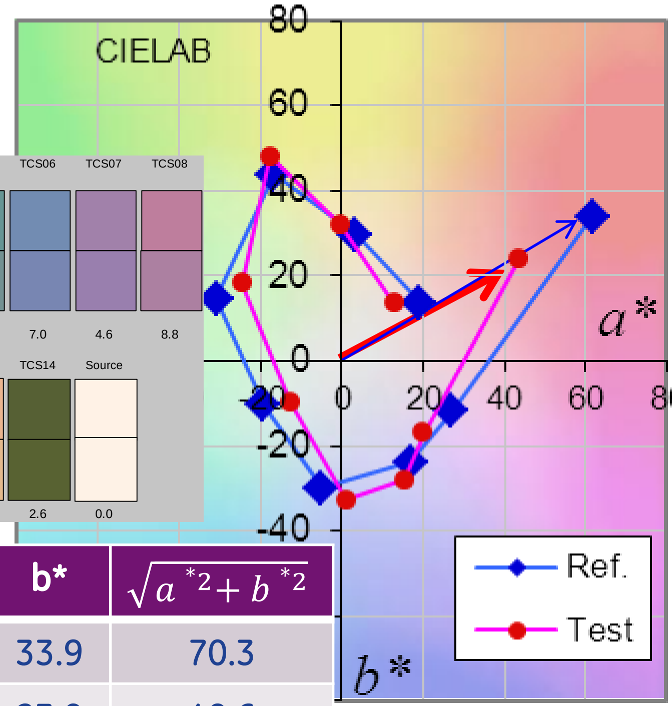
# Negative R9 explained – Cool White FL example

**Cool White FL**

| | |
|---|---|
| **CCT:** | **4290** |
| Duv: | 0.001 |
| **CRI Ra:** | **63** |
| R9: | -89 |
| LER (lm/W): | 341 |
| **CQS Qa:** | **63** |




| R9 | a* | b* | $\sqrt{a^{*2} + b^{*2}}$ |
|---|---|---|---|
| Ref | 61.6 | 33.9 | 70.3 |
| Test | 43.5 | 23.8 | 49.6 |

The extreme weakness of R9 for some Discharge Lamps as represented by a typical Cool White Fluorescent lamp is shown above. Test Lamp is far less saturated for the R9 chip than the Reference Source (BB at 4290 K), so much so that the R9 result is -89. The especially poor rendering of the R9 chip can be seen visually in the 14-chip Munsell set shown above.

***In the La*b* color space, Chroma = 70.3 and 49.6 for the Reference and the Test illuminants.***

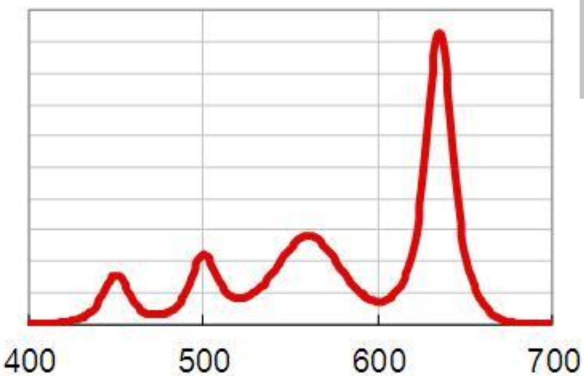
***The FL lamp is very under-saturated for the R9 color chip, so much that R9<0.***

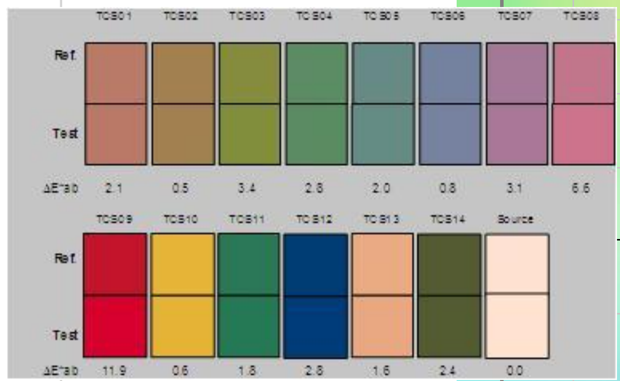
imagination at work

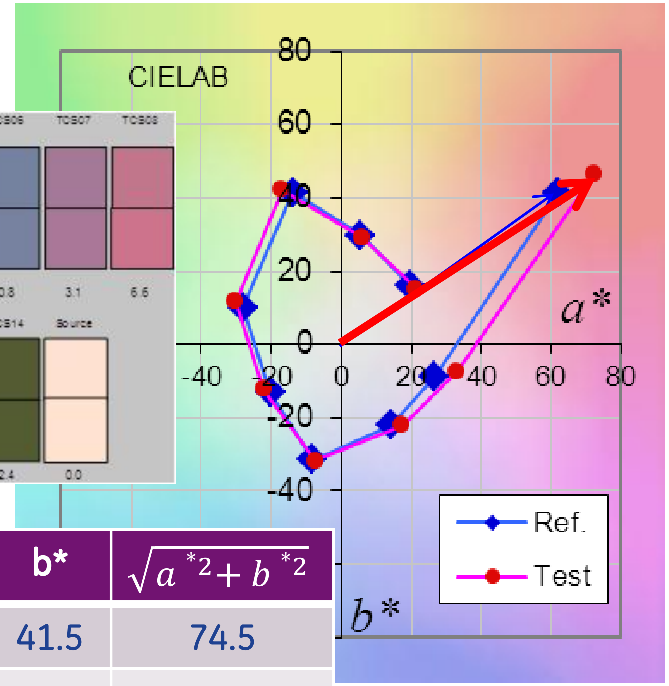
# Negative R9 explained – LED example

**4-LED model**

| | |
|---|---|
| **CCT:** | **2966** |
| Duv: | 0.000 |
| **CRI Ra:** | **80** |
| R9: | -19 |
| LER (lm/W): | 308 |
| **CQS Qa:** | **92** |




| R9 | a* | b* | $\sqrt{a^{*2} + b^{*2}}$ |
|---|---|---|---|
| Ref | 61.9 | 41.5 | 74.5 |
| Test | 72.2 | 46.5 | 85.8 |

However, R9 can also be negative when the Test Lamp provides ***more*** red than the Reference source. *This does not necessarily mean that the color quality is poor.* In fact enhanced-red light sources with negative R9 can be highly preferred by many customers in applications related to ambience, food, garments, furniture, skin tones, etc. The enhanced red chroma can be seen visually in the R9 Munsell chip above. LED sources incorporating strong red phosphors or Red LEDs can provide over-saturated Reds that are preferred by customers, while resulting in R9<0.

***In the La*b* color space, Chroma = 74.5 and 85.8 for the Reference and the Test illuminants.***
***The LED lamp is very over-saturated for the R9 color chip, so much that R9<0.***

# Negative R9 calculation

## How do we quantify Chroma relative to the CIE calculation method for CRI?

Chroma is defined in La*b* or Lu*v* or W*U*V* color spaces as the vector length of the chromaticity from the origin of the color space to the color point of the reference or test illuminant, as seen graphically in the previous pages with lamp SPD and chromaticity examples.

From IESNA Lighting Handbook, 9th ed. Color Chapter

"In 1976, the CIE10,11 recommended two new uniform color spaces, known as CIELUV and CIELAB. Although these give a more uniform representation of color differences and therefore supersede the U*, V*, W* space for most purposes, ***the earlier system (U*, V*, W* ) is still used for the calculation of CIE color rendering indices.***"

Therefore, to be consistent with CRI calculations, we recommend that Chroma for the R9 color be calculated using the U*, V*, W* color system. The Chroma formula in the U*, V*, W* color system is analogous to the Chroma formula in the La*b* color system, shown below in Eq4-17b.

From IESNA Lighting Handbook, 9th ed. Color Chapter

"Correlates of the subjective attributes lightness, perceived chroma , and hue can be derived from either CIELUV or CIELAB as follows (see Eq 4-17b to the right):

Although these quantities are approximate correlates of the respective subjective attributes, the actual perceived color depends significantly on the viewing conditions, for example, the nature of the surround."

$$\text{CIE 1976 lightness} = L^* \quad \text{(4-17a)}$$

$$\text{CIE 1976 } u,v \text{ chroma} = C^*_{uv} = (u^{*2} + v^{*2})^{1/2} \quad \text{(4-17b)}$$

or

$$\text{CIE 1976 } a,b \text{ chroma} = C^*_{ab} = (a^{*2} + b^{*2})^{1/2} \quad \text{(4-17c)}$$

and

$$\text{CIE 1976 } u,v \text{ hue angle} = h_{uv} = \arctan\left(\frac{v^*}{u^*}\right) \quad \text{(4-17d)}$$

or

$$\text{CIE 1976 } a,b \text{ hue angle} = h_{ab} = \arctan\left(\frac{b^*}{a^*}\right) \quad \text{(4-17e)}$$

# Negative R9 calculation

## How is the U*V*W* color system (used for CRI calculations) defined?

From IESNA Lighting Handbook, 9th ed. Color Chapter

"To convert the CIE 1960 UCS Diagram to a three-dimensional system that is useful in studying color differences, the CIE, in 1964, added a recommendation developed for the purpose by Wyszecki[15] that converts Y to a lightness index, W*, by the relationship

$$W^* = 25\,Y^{1/3} - 17 \qquad (1 \leq Y \leq 100) \qquad (4\text{-}5)$$

and converts the chromaticity coordinates u, v to chromaticness indices U, V by the relationships

$$U^* = 13W^*(u - u_n) \qquad (4\text{-}6)$$

$$V^* = 13W^*(v - v_n) \qquad (4\text{-}7)$$

The lightness index W* approximates the Munsell value function in the range of Y from 1 to 100%. The chromaticity coordinates $u_n$, $v_n$ refer to the nominally achromatic (neutral) color (usually that of the source) placed at the origin of the U*, V* system."

# Negative R9 calculation

## How is Chroma calculated in the U*V*W* color system (used for CRI calculations)?

Chroma formula in La*b* color space

CIE 1976 lightness = $L^*$ (4-17a)

CIE 1976 $u,v$ chroma = $C^*_{uv} = (u^{*2} + v^{*2})^{1/2}$ (4-17b)

Corresponding Chroma formula in U*V*W* color space

Lightness = W*

Chroma = $\left(U^{*^2} + V^{*^2}\right)^{1/2}$

The values for U*, V*, and W* for the R9 color chip can be found within the cells of any Excel file that calculates the 14 CRI components. The NIST CQS calculator could be proposed as such a calculator for general open use.

An example using the NIST CQS Excel calculator of the U* and V* values for the Chroma calculation U*V*W* color space for the example of the 4-LED light source having negative R9 is shown on the next page.

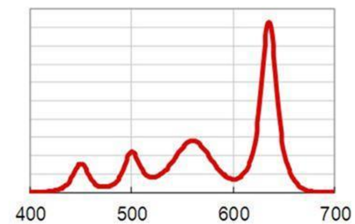
To revisit the proposed specification related to R9 < 0:

**Acceptable:** **R9 < 0**
**AND**
**R9 Chroma for the Test Lamp > R9 Chroma for the Reference source**

# Negative R9 calculation

**4-LED model**

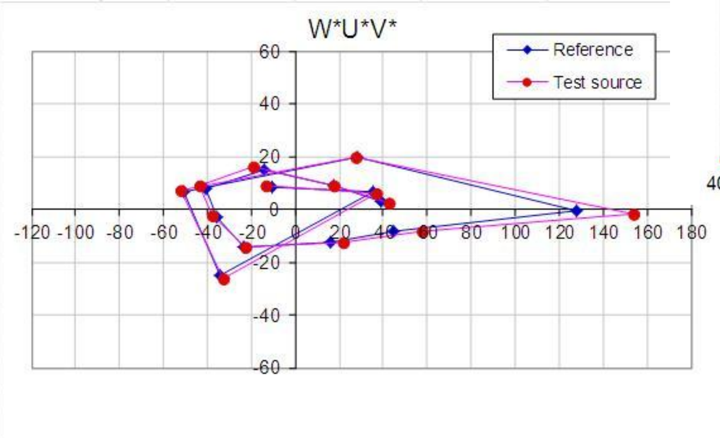
| | |
|---|---|
| **CCT:** | **2966** |
| Duv: | 0.000 |
| **CRI Ra:** | **80** |
| R9: | -19 |
| LER (lm/W): | 308 |
| **CQS Qa:** | **92** |




## calculation of CRI (CIE 13.3)

Chromaticity by Reference sour

| | u | v | Yr,i | W*r,i | U*r,i | V*r,i |
|---|---|---|---|---|---|---|
| TCS01 | 0.2998 | 0.3514 | 32.52 | 62.80 | 39.21 | 2.73 |
| TCS02 | 0.2733 | 0.3596 | 30.45 | 61.06 | 17.09 | 9.18 |
| TCS03 | 0.2343 | 0.3672 | 30.50 | 61.11 | -13.88 | 15.21 |
| TCS04 | 0.1978 | 0.3586 | 27.16 | 58.14 | -40.78 | 8.00 |
| TCS05 | 0.2057 | 0.3442 | 28.31 | 59.20 | -35.49 | -2.93 |
| TCS06 | 0.2209 | 0.3294 | 27.34 | 58.31 | -23.39 | -14.17 |
| TCS07 | 0.2725 | 0.3323 | 29.74 | 60.46 | 16.31 | -12.37 |
| TCS08 | 0.3054 | 0.3383 | 33.67 | 63.72 | 44.44 | -8.10 |
| TCS09 | 0.4645 | 0.3472 | 16.20 | 46.25 | 127.88 | -0.50 |
| TCS10 | 0.2781 | 0.3665 | 63.45 | 82.71 | 28.29 | 19.85 |
| TCS11 | 0.1711 | 0.3588 | 17.77 | 48.24 | -50.58 | 6.76 |
| TCS12 | 0.1451 | 0.2689 | 4.55 | 24.43 | -33.88 | -25.13 |
| TCS13 | 0.2851 | 0.3543 | 61.05 | 81.44 | 35.23 | 6.59 |
| TCS14 | 0.2318 | 0.3642 | 11.65 | 39.68 | -10.33 | 8.32 |
| white | 0.2518 | 0.3480 | 100.00 | 99.04 | 0.00 | 0.00 |
| Source | 0.2518 | 0.3480 | 100.00 | 99.04 | 0.00 | 0.00 |

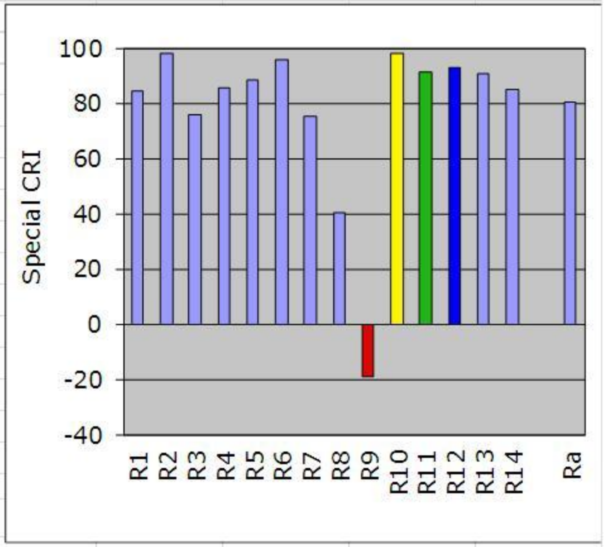



| | | | |
|---|---|---|---|
| TCS01 | 0 | 0 | 0.0000 |
| TCS02 | 0 | 0 | 0.0000 |
| TCS03 | 0 | 0 | 0.0000 |
| TCS04 | 0 | 0 | 0.0000 |
| TCS05 | 0 | 0 | 0.0000 |
| TCS06 | 0 | 0 | 0.0000 |
| TCS07 | 0 | 0 | 0.0000 |
| TCS08 | 0 | 0 | 0.0000 |
| TCS09 | 0 | 0 | 0.0000 |
| TCS10 | 0 | 0 | 0.0000 |
| TCS11 | 0 | 0 | 0.0000 |
| TCS12 | 0 | 0 | 0.0000 |
| TCS13 | 0 | 0 | 0.0000 |
| TCS14 | 0 | 0 | 0.0000 |
| white | 0 | 0 | 0.0000 |
| Source | 0 | 0 | 0.0000 |

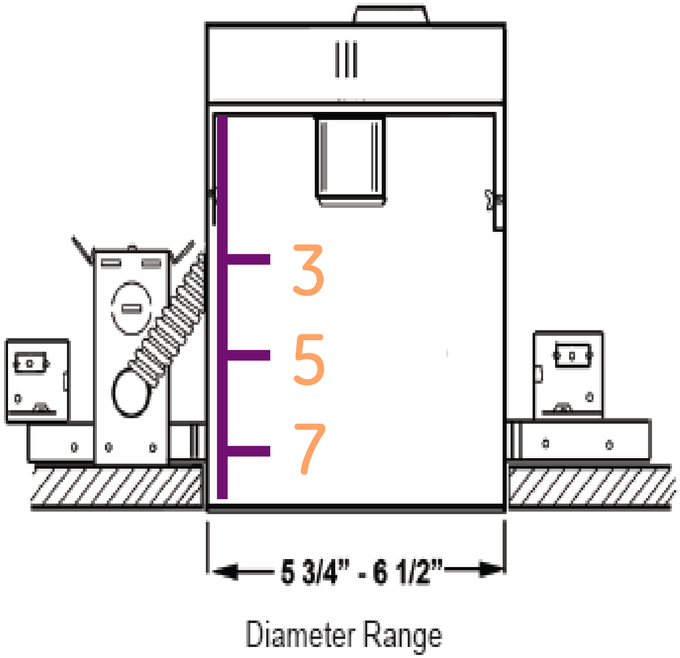
Chromaticity by Test source
after von Kries chromatic adaption

| | u'k,i | v'k,i | Yk,i | W*k,i | U*k,i | V*k,i | ΔEi | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| TCS01 | 0.3042 | 0.3507 | 31.92 | 62.30 | 42.48 | 2.11 | 3.36 | R1 | **84.5** | |
| TCS02 | 0.2738 | 0.3595 | 30.17 | 60.82 | 17.40 | 9.02 | 0.42 | R2 | **98.1** | |
| TCS03 | 0.2280 | 0.3680 | 31.05 | 61.58 | -19.04 | 15.96 | 5.24 | R3 | **75.9** | |
| TCS04 | 0.1941 | 0.3598 | 27.53 | 58.49 | -43.85 | 8.91 | 3.22 | R4 | **85.2** | |
| TCS05 | 0.2026 | 0.3450 | 28.54 | 59.40 | -37.99 | -2.33 | 2.58 | R5 | **88.1** | |
| TCS06 | 0.2222 | 0.3291 | 27.46 | 58.43 | -22.45 | -14.43 | 0.99 | R6 | **95.5** | |
| TCS07 | 0.2793 | 0.3318 | 30.20 | 60.85 | 21.73 | -12.83 | 5.46 | R7 | **74.9** | |
| TCS08 | 0.3198 | 0.3379 | 35.09 | 64.84 | 57.31 | -8.59 | 12.93 | R8 | **40.5** | |
| TCS09 | 0.4910 | 0.3454 | 18.74 | 49.40 | 153.61 | -1.72 | 25.95 | R9 | **-19.4** | Strong red |
| TCS10 | 0.2776 | 0.3666 | 63.46 | 82.72 | 27.81 | 19.99 | 0.49 | R10 | **97.7** | Strong yellow |
| TCS11 | 0.1686 | 0.3597 | 17.96 | 48.47 | -52.43 | 7.32 | 1.94 | R11 | **91.1** | Strong green |
| TCS12 | 0.1473 | 0.2642 | 4.49 | 24.25 | -32.95 | -26.44 | 1.61 | R12 | **92.6** | Strong blue |
| TCS13 | 0.2870 | 0.3538 | 60.07 | 80.91 | 37.09 | 6.04 | 2.01 | R13 | **90.8** | |
| TCS14 | 0.2258 | 0.3650 | 11.88 | 40.04 | -13.54 | 8.84 | 3.27 | R14 | **85.0** | |
| White | 0.2518 | 0.3480 | 100.00 | 99.04 | 0.00 | 0.00 | 0.00 | | | |
| **Source** | **0.2518** | **0.3480** | **100.00** | 99.04 | 0.00 | 0.00 | 0.00 | **Ra** | **80.3** | |

Chromaticity b
after von Kries



# Topic 2 – Elevated Temp – Option B




Testing at 55C ambient is actually a higher temperature than inside the UL8750 (UL Box – 6" enclosed can) measurement. Electronics design life is proven in this UL measurement as well as safety limits and material ratings.

Average ambient temperatures in the UL8750 for GE's 12W PAR30, 13W A19, and 18W PAR38 Energy Star lamps range from 39-43C.

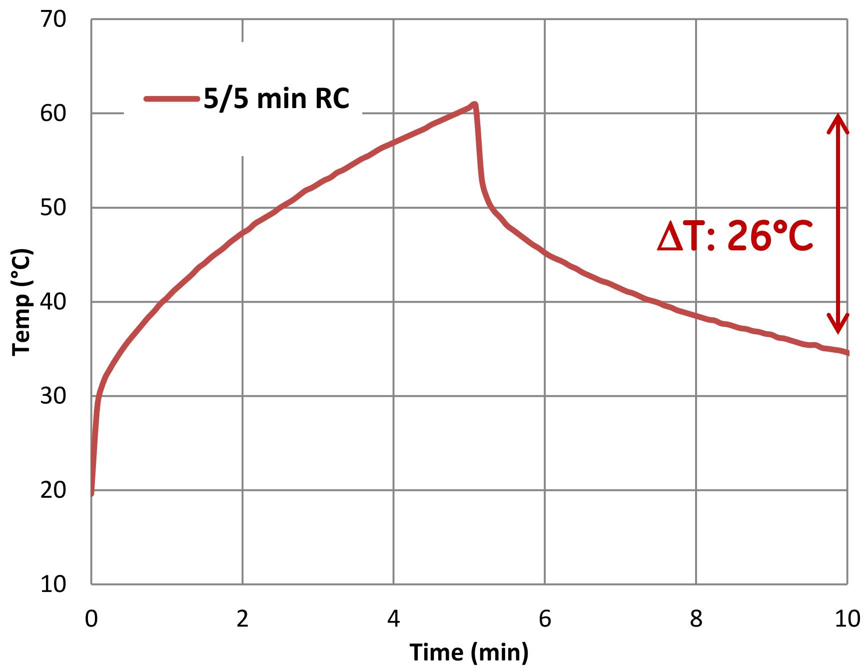
**GE proposes that lamps with operating power of 10W to less than 20W continue to test at 45C ambient and 20W and greater test at 55C , this is consistent with observed UL8750 Box inside temperature data.**

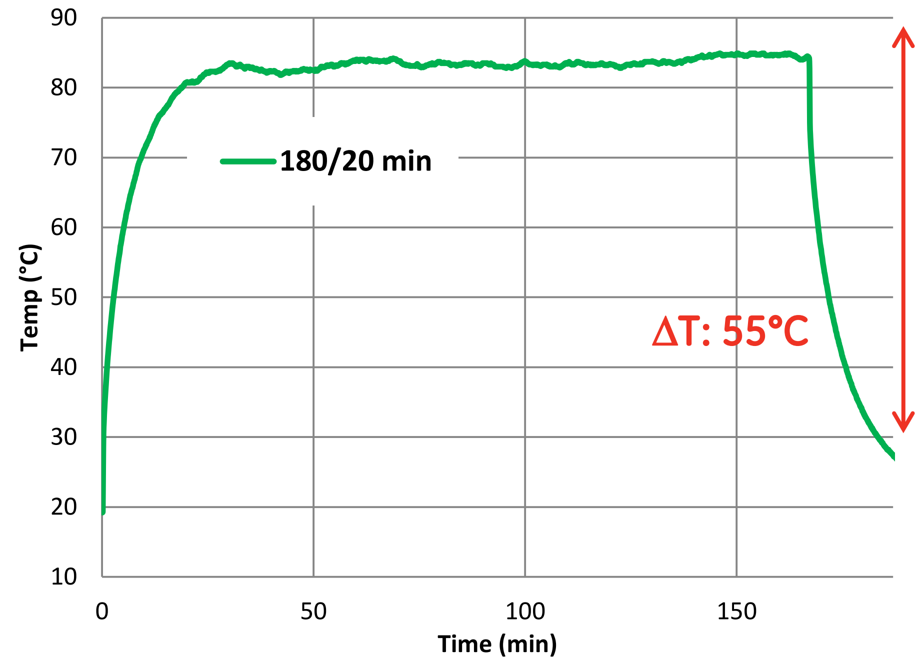
**Note: CFL – are higher wattage than SSL and driver for 55C requirement**

| | 12W PAR30 | 13W A19 | 18W PAR38 |
|---|---|---|---|
| Inside - 3" from top | 44.3 | 46.4 | 47.0 |
| Inside - 5" from top | 38.1 | 40.8 | 45.2 |
| Inside - 7" from top | 33.9 | 34.0 | 36.1 |
| **AVG temp** | **38.8** | **40.4** | **42.8** |
| Outside - Ambient | 25.1 | 25.2 | 25.4 |

# Topic 3 Cycling addition to Elevated Temp life test

## 60W A19 LED TMP




| | cycle | N | ΔT | AF | Stress (N*AF) |
|---|---|---|---|---|---|
| **life test** | 180/20 | 1800 | 55 | 1.00 | 1800* |
| **rapid cycle** | 5/5 | 15000 | 26 | 0.22 | 3352 |

*based on 6000h

$$AF \sim \left( \frac{\Delta T_{use}}{\Delta T_{test}} \right)^2$$

$T_{use} = 55°C$

If T use is 55C, complying to the rapid cycle test 5/5 exceeds the accumulated stress encountered by the ALT test 180/20. Adding product cycle time to the ALT test adds no additional value to understanding product performance.

Consequence : Complicates existing submission(s) rules and adds un-needed test time.

imagination at work

# Topic 4 Power Requirements and tolerances for Test and Measurement

Throughout the Energy Star Specification, the Power Requirements calls out the use of LM-66-11 or LM-79-08 .

For photometric *measurements* we support the use of LM-79-08 and LM-66-11 . This makes sense based on the power accuracy requirements needed for such sensitive measurements, 0.2% and 0.1%, respectively .

However there is Concern:

When performing *tests* such as Rapid Cycle ambient or Elevated Temp Life test, the power tolerance of 0.1/.2% are not critical. Instead LM -65-10 (Life Testing of CFL) with a tolerance of 2.0 % should be used.

For example: Annex A Energy Star ET Life Test calls out the power requirements as follows:

The power requirements shall be per IES LM66-11 or LM-79-08 as applicable. However it should read the power requirements for life *testing* shall be per IES LM65-10 and for photometric *measurements* shall be IES LM66-11 or LM-79-08 as applicable.

Recommend revising the power requirements to the applicable IES LM document for life testing products (LM65-10) and measuring products (LM79-08 or LM66-11) .