

# There's something about **RED**: Applying TM-30 in Your Practice



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Philadelphia PA

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# We care about color (DUH!)

It provides us information about and appreciation of

- People
- Nature
- Surroundings

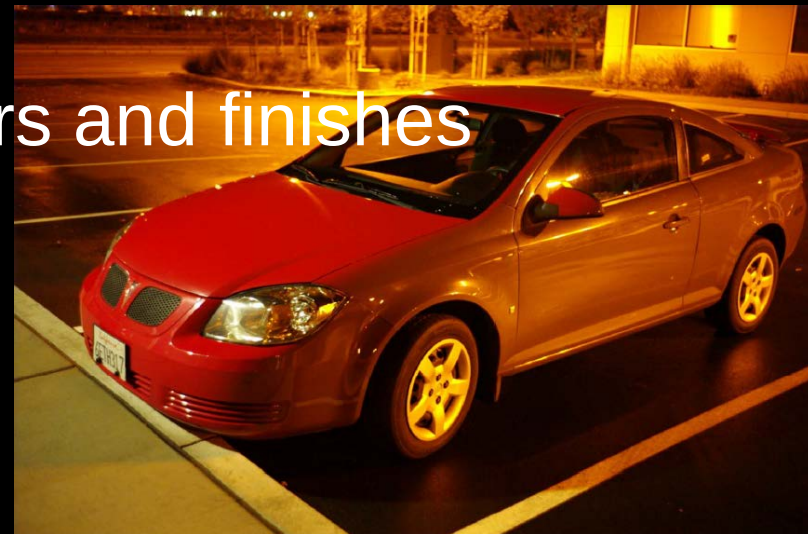


Photos courtesy Osram Sylvania, Microsoft, Bruce Kinzey

It improves visibility through color contrast

- Identifying colors of objects
- Matching or blending of colors and finishes
- Evaluating quality or health

Photo courtesy Ron Gibbons



# We care about color

Applications where **Color Fidelity** matters:



Healthcare (jaundice, erythema, cyanosis)



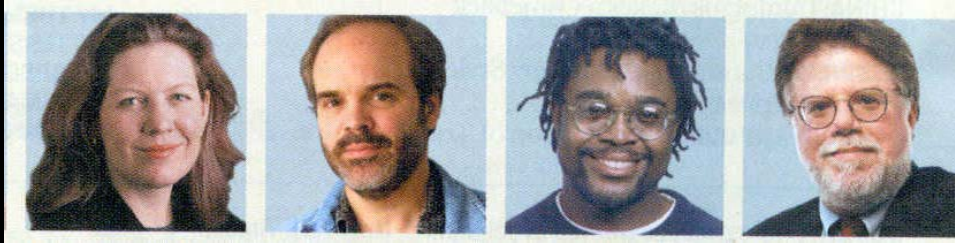
Food inspection



Industrial color matching, interior design selections

# We care about color

Applications where both **Color Fidelity** and Preference matter:



Anywhere faces are  
important



Anywhere food is  
served

# We care about color

Applications where both **Color Fidelity** and Preference matter:



Homes



Retail  
(produce)



Retail clothing/  
Furnishings

# We care about color

Applications where both **Color Fidelity** and Preference matter:



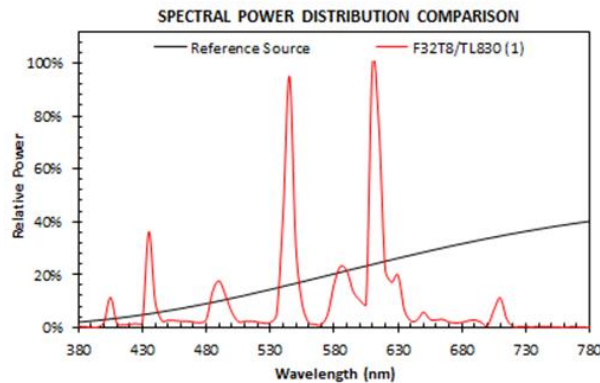
Hospitality  
(hotel/spa/restaurant, fine finishes)



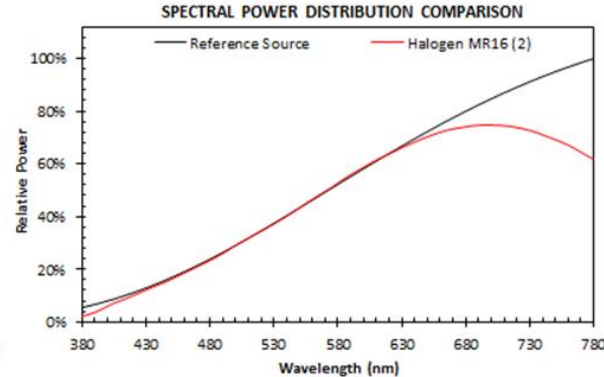
Face-to-face  
communication,  
schools

# We have tools for evaluating color

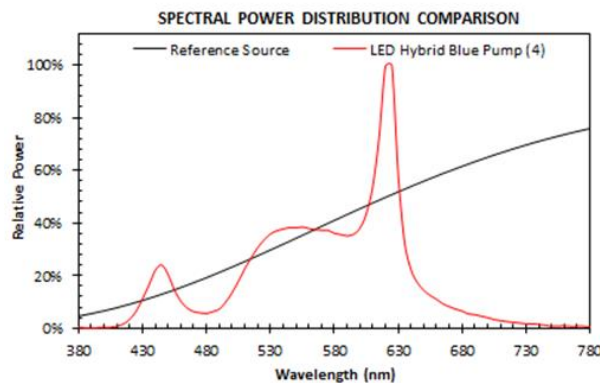
We could just use Spectral Power Distributions (SPDs)



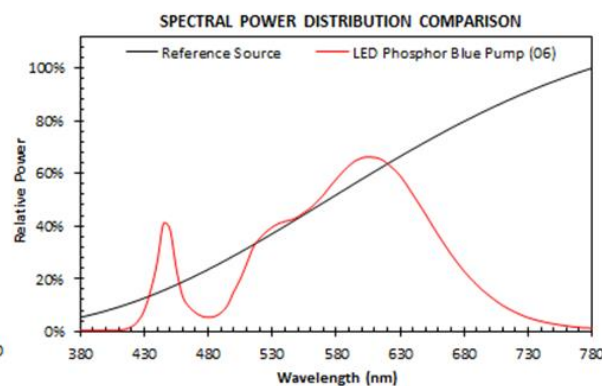
3000 K Fluorescent Narrowband (830)



Halogen MR16 3000 K



3000 K LED, Phosphor Blue Pump  
+ Red LED



3000 K LED, Phosphor Blue Pump

**But...** few people can look at an SPD and visualize how it will render colors.

# Couldn't we just use Correlated Color Temperature?

Are you kidding me?? All the different SPDs on the previous slide produce the same CCT!

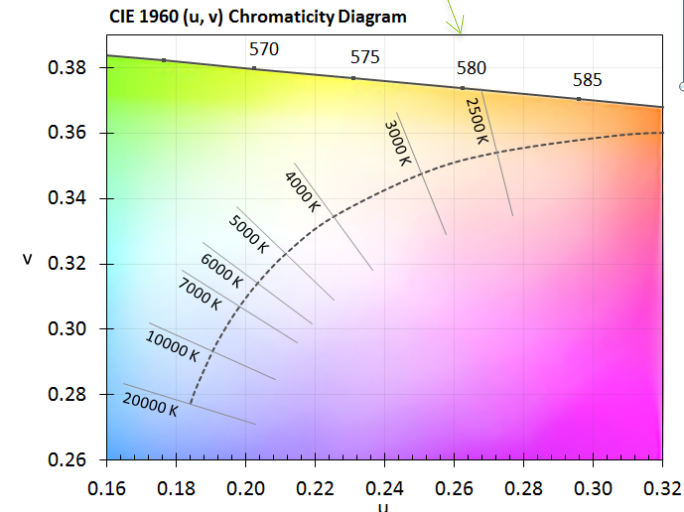
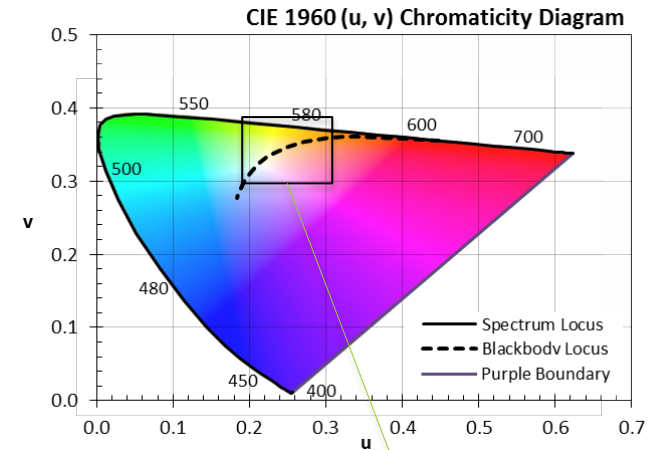


2700K

3000K

4000K

5000K



# What does a Duv *near zero* look like?



# What does a small *negative* Duv look like?



# What does a large *negative* Duv look like?



# What does a Duv *near zero* look like?



# What does a small *positive* Duv look like?



# What does a large *positive* Duv look like?



# What's wrong with CRI ( $R_a$ )?

## Color Rendering Index (CRI) was developed as a fidelity metric

- Developed in the '60s to describe color rendering of fluorescent lamps
- Metric based on 8 pastel colors
- Does not include saturated colors, does not evenly represent all areas of color space
- It's the *average* of the relative ability of a light source to render those 8 colors, compared to a reference source at same CCT
- Ranges from 100 to below 0 in scale (LPS has CRI of -44)
- CRI can over or under-estimate color rendering ability compared to human perception
- Some lamp manufacturers have learned to game the system
- “R9” value used in addition to CRI to give better estimate of color rendering ability in red hues, but values are skewed because of distorted color space.

Color Samples for CRI



Color Samples for  $R_9$ – $R_{14}$



# Is color fidelity always the goal?

No. Sometimes a little boost in color saturation draws your eye, makes that apple look more appetizing, makes your skin look healthier....

This is described through color gamut. A boost in color saturation *necessarily* reduces CRI values.



Photo: GE Lighting

# Solution: New IES TM-30\* color metrics

Developed by IES Task Force of color scientists, manufacturers, and designers.

$R$  = Rendering

$f$  = fidelity

$g$  = gamut

Based on 99 object colors more evenly distributed in color space

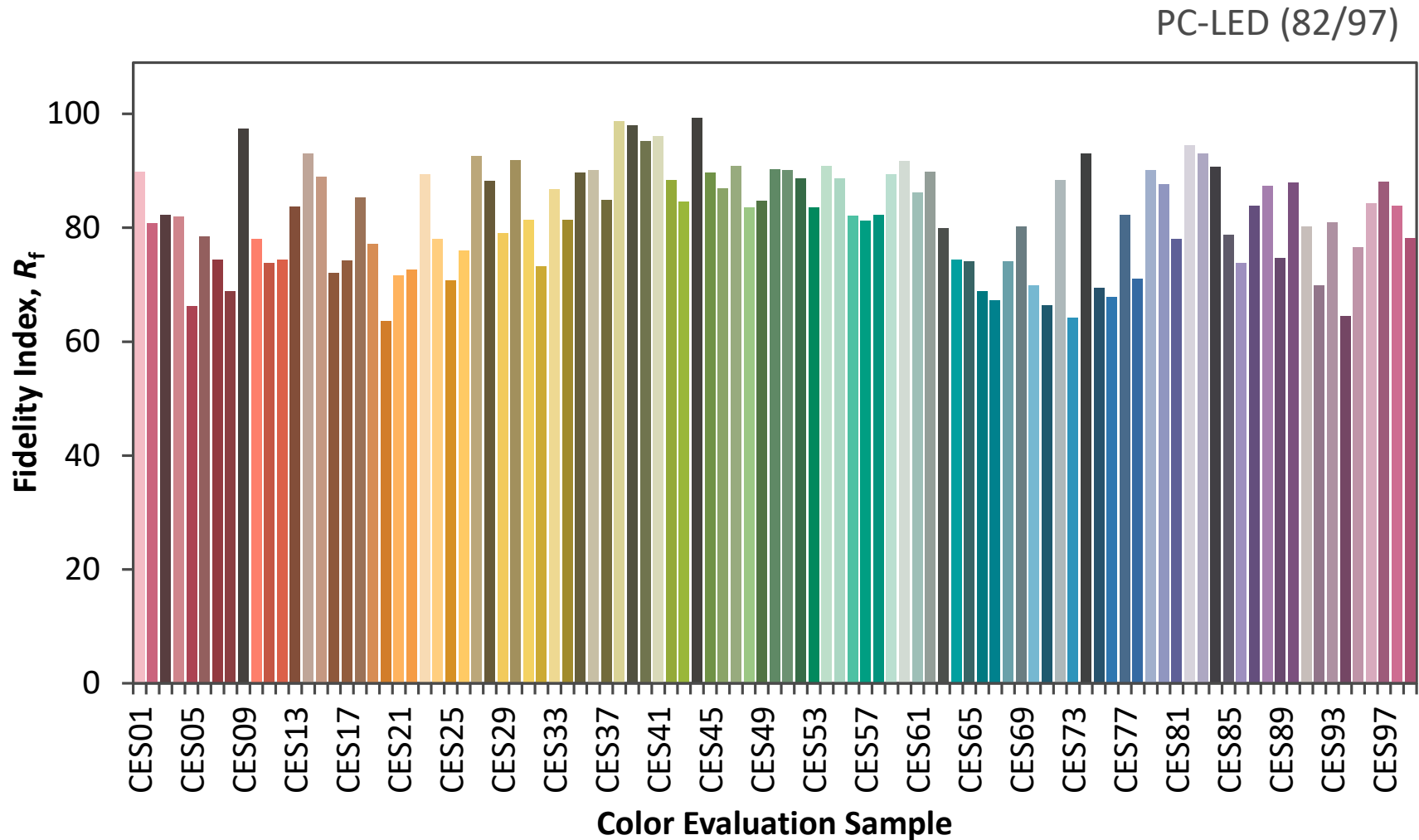
Fidelity and gamut are still compared to a reference source (BB or daylight or a mix of the two)

Color fidelity of a single color sample ranges between 0 and 100.

\* IES TM-30 and CIE color rendering standards will be harmonized

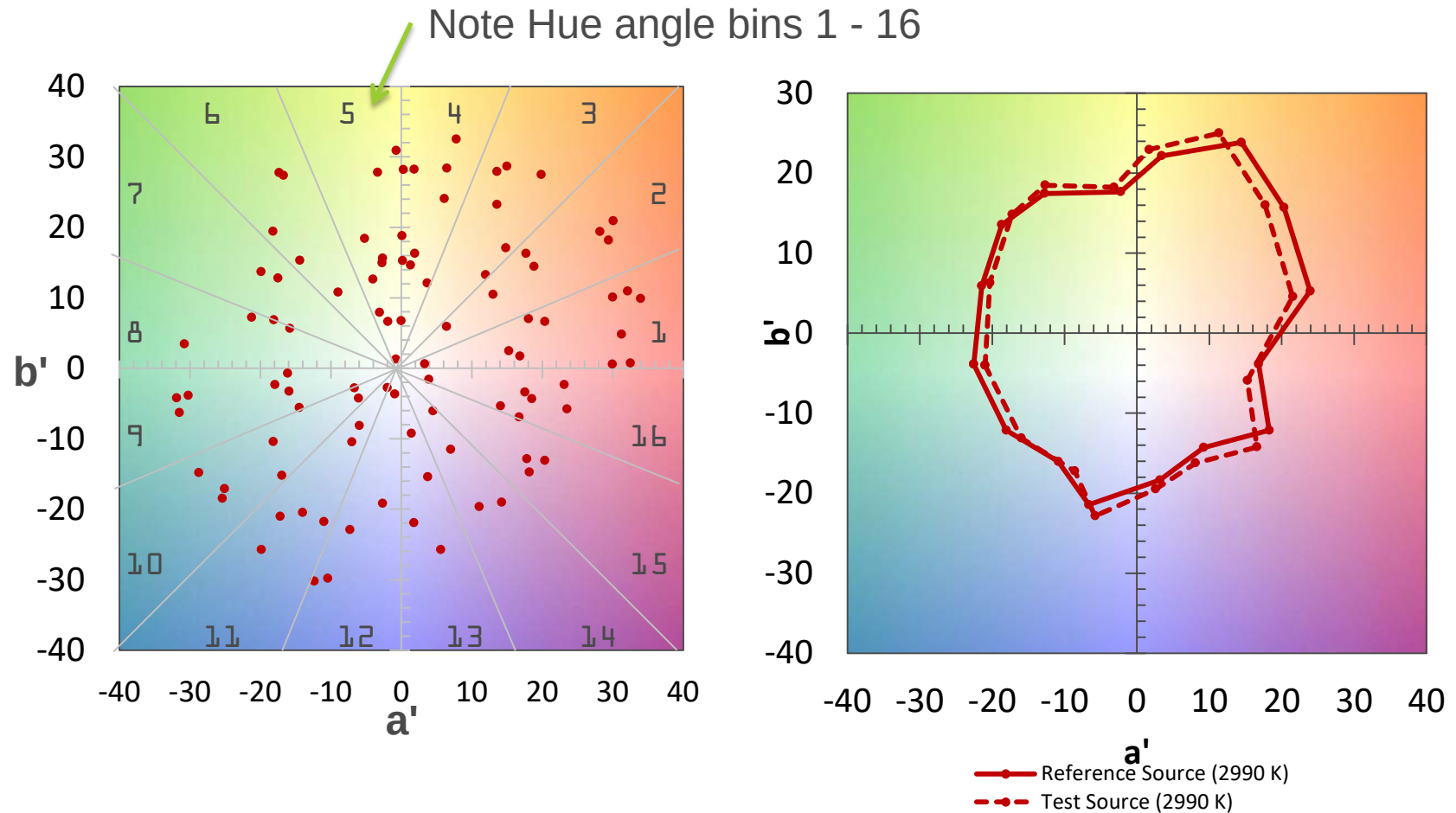


# $R_f$ by Sample



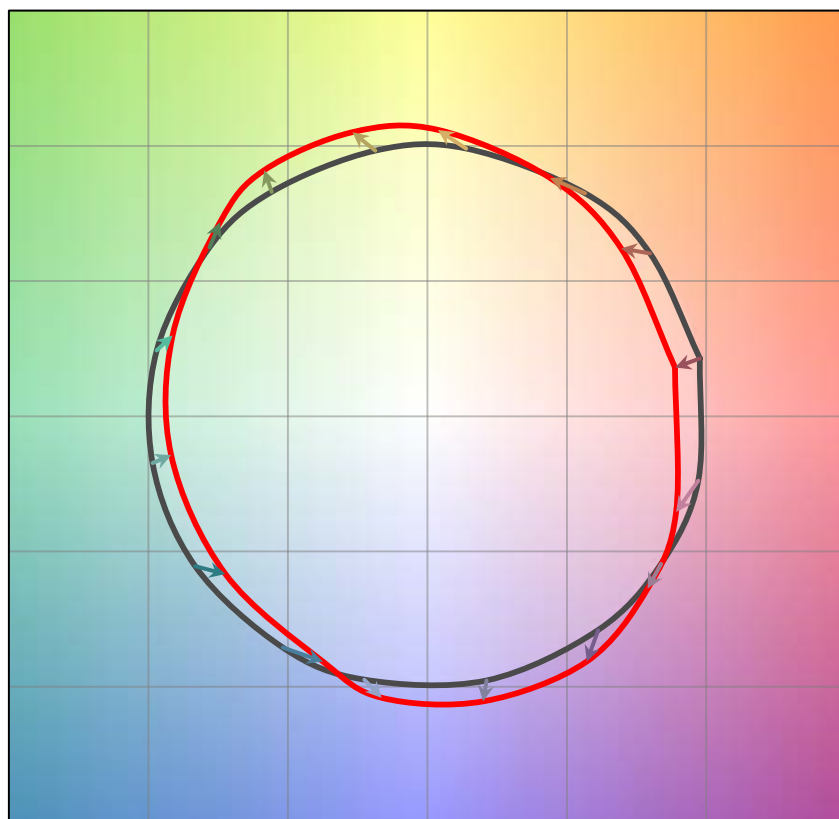
Fidelity Index  $R_f$  is an average of all 99 color sample values

# Gamut ( $R_g$ is the average gamut of the 99 samples)



Gamut is generally considered a measure of overall saturation or chroma. An  $R_g$  value greater than 100 indicates an average increase in saturation, whereas an  $R_g$  value less than 100 indicates an average decrease in saturation. Excessive gamut *increases* look cartoon-like; excessive gamut *decreases* look greyed-out. A boost in color saturation *necessarily* reduces CRI and  $R_f$  values.

# Color Vector Graphic



—Reference Source    —Test Source

- Reference source is normalized to circle
- Arrows show hue shift and saturation (“chroma”) shift
- In this example, greens and purples are generally more saturated, while reds and blues are desaturated, relative to the reference.
- Chroma shift (cs) expressed in % variation from normal circle. “+” means greater chroma, “-” means reduced chroma

# Examples of chroma shift in red



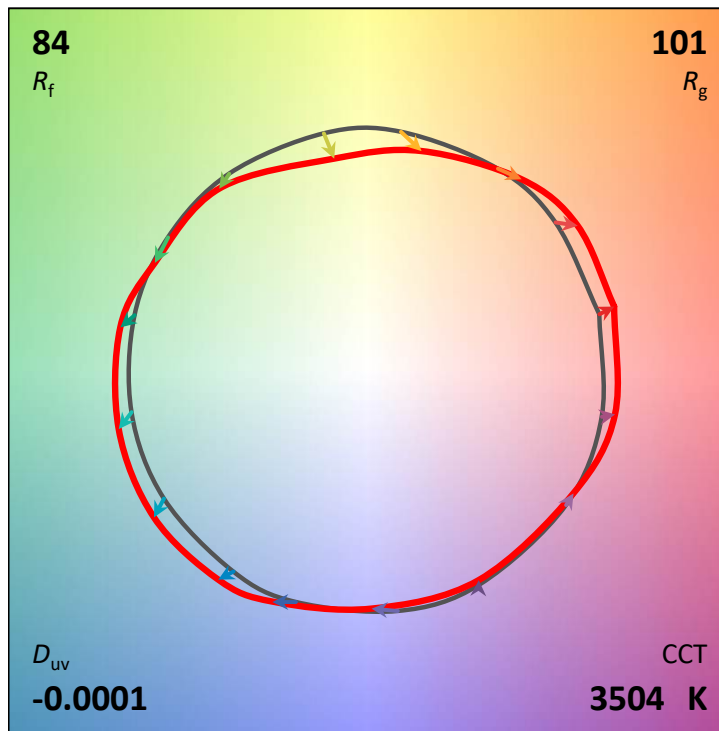
Desaturated  
(e.g.  $R_{cs,h1} \leq -10\%$ )

Normal saturation  
(e.g.  $R_{cs,h1} = 0\%$ )

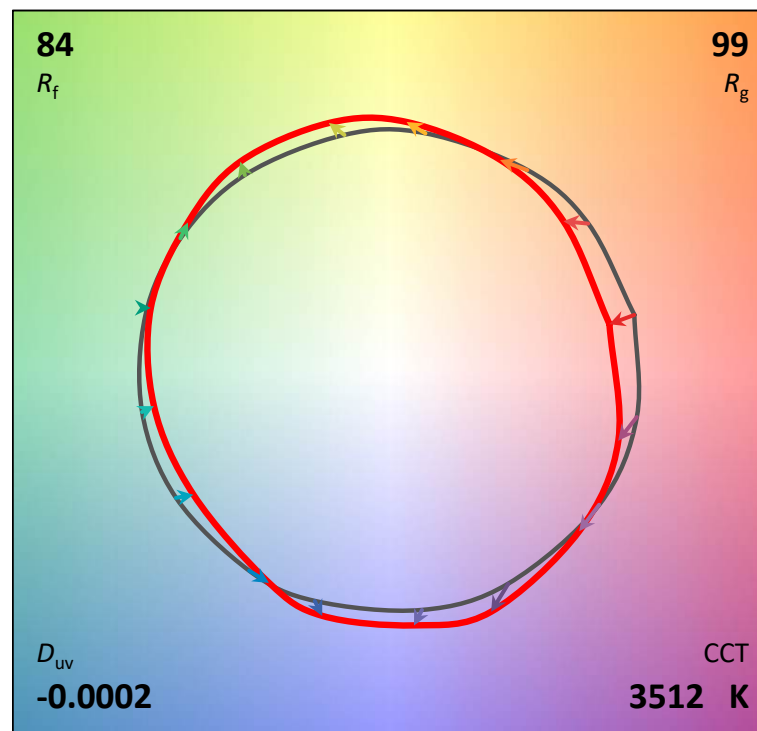
Highly saturated  
(e.g.  $R_{cs,h1} \geq +10\%$ )

Read, “chroma shift of hue  
angle bin 1 = 0%”

# Which light source would you choose for red apples?



$$\begin{aligned} R_f &= 84 \\ R_g &= 101 \\ R_{cs, h1} &= +7\% \end{aligned}$$



$$\begin{aligned} R_f &= 84 \\ R_g &= 99 \\ R_{cs, h1} &= -13\% \end{aligned}$$

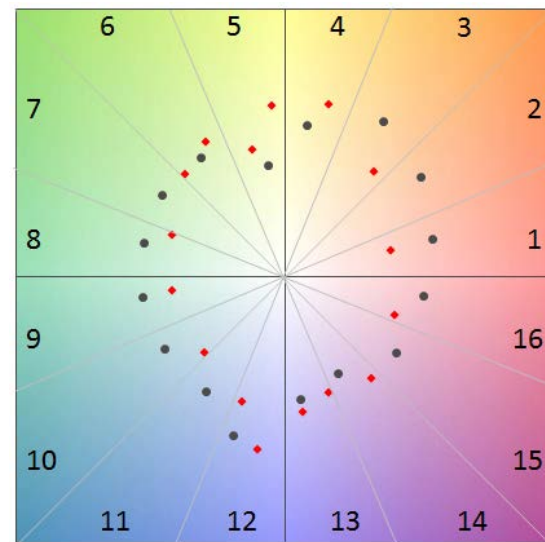
# What about R9?? Do we need it anymore?

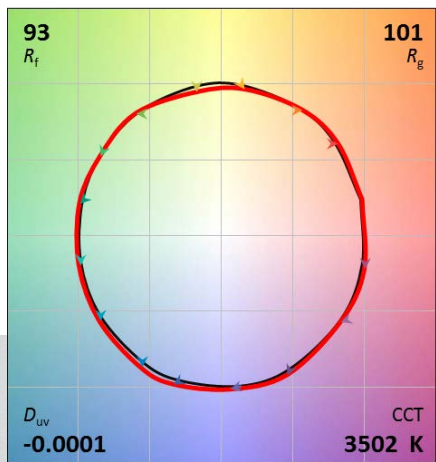
There's something about red. It has symbolic meaning. Our blood is red and skin is colored by blood. Color preference studies show light source preference is strongly affected by the rendering of colors in the red hue bins.

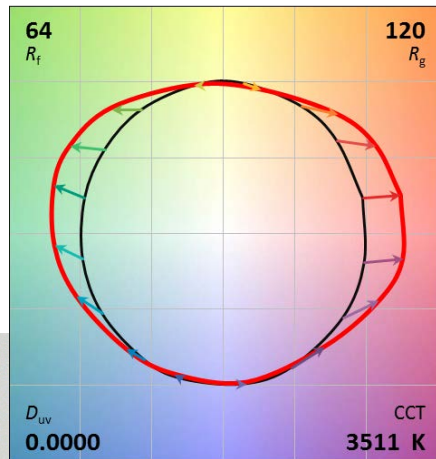
Even though the red end of the spectrum doesn't count heavily toward lumens, our eye/brain/experience weigh red more heavily than other colors.

Look at the Color Vector Graphic to check for +/- chroma shift percentages in the hue angle bins 1 and 16.

Or, look for % saturation increases/decreases in hue angle bins 1 and 16. [ $R_{cs,h1}$ ,  $R_{cs,h16}$ ]. It works like R9 to identify red saturation oddities or acceptability.

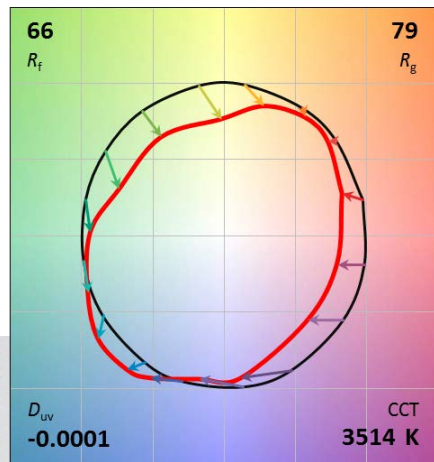






Most Saturated

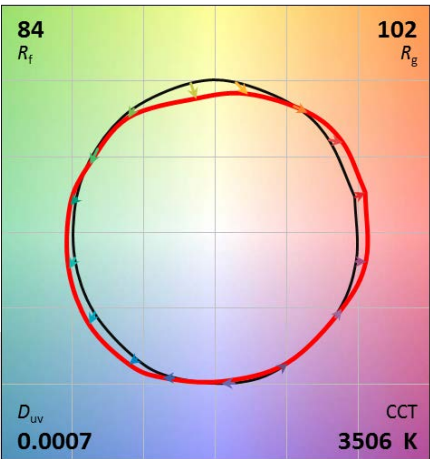




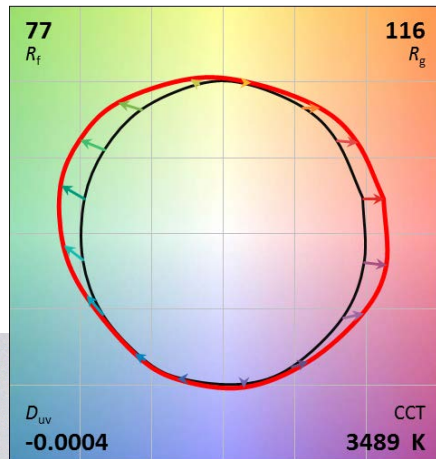
Least Saturated

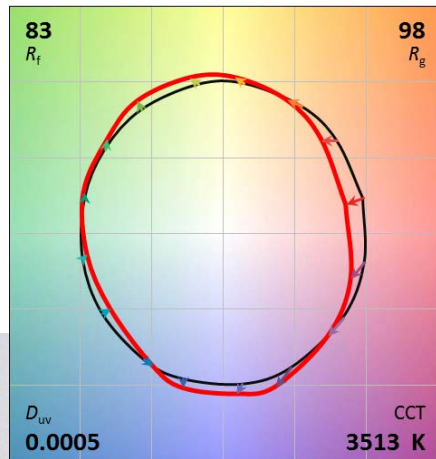


Preferred



Preferred





Not Preferred



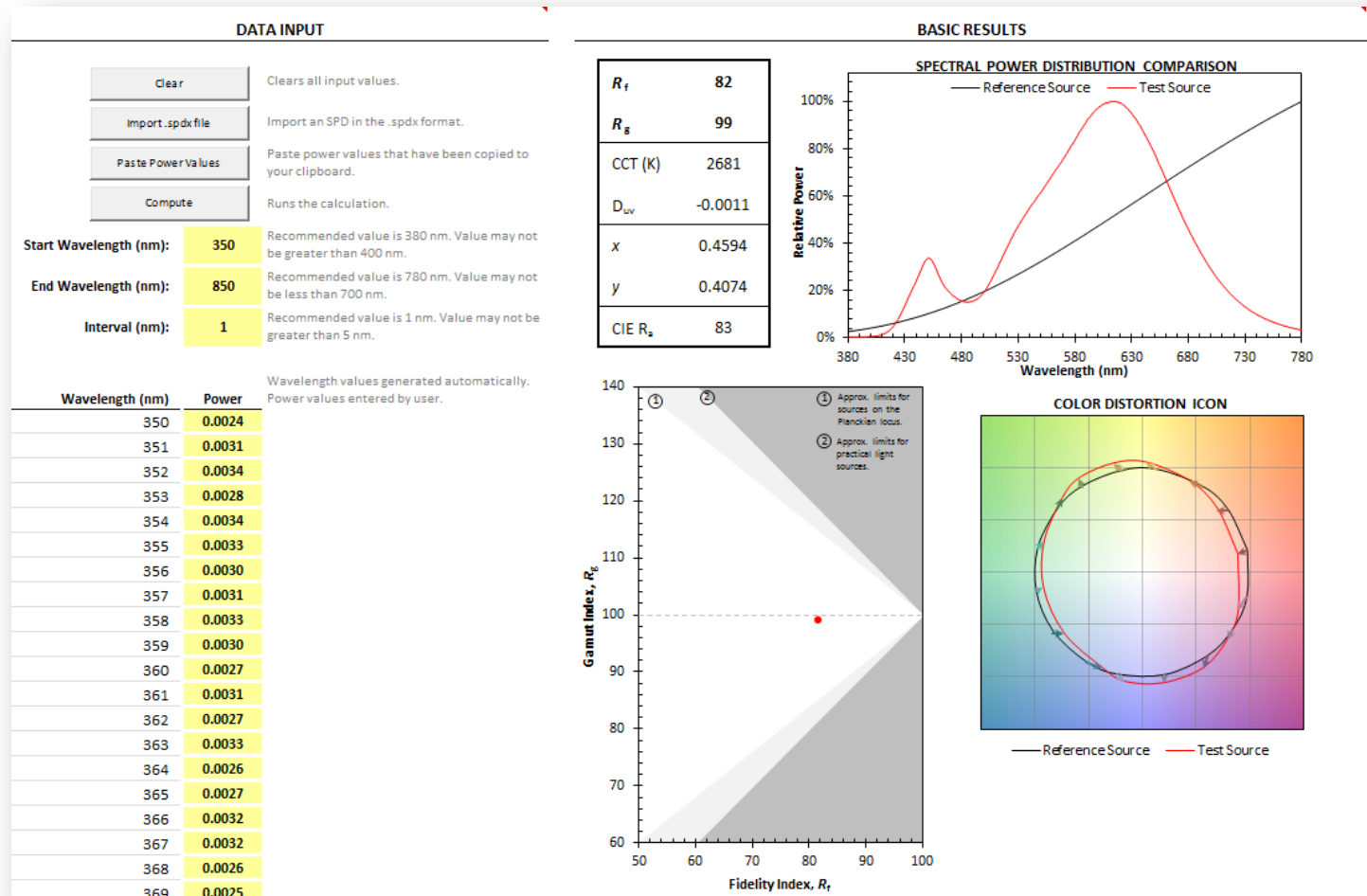
# How to use TM-30-15 metrics in your practice

- Look at tables of CRI,  $R_f$ ,  $R_g$  values for familiar light sources to develop your own scales of acceptability for different applications
- Use  $R_f$  just as you used to use  $R_a$  where 80 = good; 90 = excellent (except  $R_f$  is more reliable)
- Use  $R_g$  to look for wonky color sources
- Use  $R_{cs, h1}$  chroma shift values to look for red rendering (-1% to 15% preferred)

| Source Type                | Description                        | CCT  | CRI( $R_a$ ) | $R_f$ | $R_g$ | $R_{cs, h1}$ |
|----------------------------|------------------------------------|------|--------------|-------|-------|--------------|
| Tungsten Filament          | MR16 Halogen 12V                   | 2776 | 100          | 99    | 100   | 0%           |
| Tungsten Filament          | A-lamp 75W Halogen                 | 2836 | 100          | 99    | 100   | 0%           |
| Tungsten Filament          | A-lamp Neodymium Incand.           | 2757 | 77           | 86    | 109   | 11%          |
| LED Phosphor Blue Pump     | LED module 3000 K                  | 2940 | 97           | 95    | 101   | 1%           |
| LED Phosphor Blue Pump     | MR16 2700 K 12V                    | 2789 | 82           | 81    | 99    | -10%         |
| LED Phosphor Blue Pump     | MR16 3000 K 12V                    | 3081 | 84           | 80    | 101   | -9%          |
| LED Phosphor Violet Pump   | MR16 2700 K 12V                    | 2723 | 96           | 91    | 101   | 0%           |
| LED Phosphor Violet Pump   | MR16 3000 K 12V                    | 2969 | 96           | 92    | 101   | 0            |
| LED Hybrid                 | Phosphor blue pump + Red LED       | 3416 | 95           | 90    | 99    | -5%          |
| Fluorescent Broadband      | F32T8/930                          | 2908 | 95           | 89    | 103   | -3%          |
| Fluorescent Broadband      | F40T12/C75 7500K                   | 7412 | 93           | 93    | 101   | -2%          |
| Fluorescent Broadband      | F34T12/ES Lite White               | 4165 | 50           | 53    | 78    | -33%         |
| Fluorescent Broadband      | F34T12/ES Cool White               | 4196 | 59           | 63    | 83    | -27%         |
| Fluorescent Broadband      | F40T12 Cool White Deluxe           | 4030 | 87           | 83    | 100   | -12%         |
| Fluorescent Broadband      | F34T12/ES Warm White               | 3011 | 50           | 51    | 82    | -28%         |
| Fluorescent Narrowband     | F32T8/850                          | 5072 | 86           | 84    | 101   | -8%          |
| Fluorescent Narrowband     | F32T8/830                          | 2940 | 85           | 77    | 103   | -8%          |
| Fluorescent Narrowband     | F32T8/835                          | 3480 | 86           | 80    | 102   | -8%          |
| Fluorescent Narrowband     | F32T8/841                          | 4194 | 83           | 80    | 100   | -9%          |
| HID (Mercury Vapor)        | 100W Deluxe phosphor               | 3725 | 53           | 44    | 89    | -23%         |
| HID (Quartz Metal halide)  | Standard MH 100W 4K Clear          | 3923 | 55           | 56    | 83    | -31%         |
| HID (Ceramic Metal Halide) | 100W MH 4K Protected               | 4256 | 92           | 90    | 102   | -3%          |
| HID (High Pressure Sodium) | Standard HPS                       | 1967 | 16           | 32    | 61    | -48%         |
| HID (High Pressure Sodium) | White HPS                          | 2496 | 85           | 80    | 106   | 3%           |
| Daylight model             | CIE D5000                          | 4999 | 99           | 98    | 99    | 0%           |
| Daylight model             | CIE D7000                          | 7001 | 100          | 100   | 100   | 0%           |
| Equal energy model         | Flat SPD - no spectral differences | 5455 | 95           | 94    | 104   | 2%           |

# Calculation Tools for $R_f$ and $R_g$ and red rendering...

- Ask for SPD files from light source and luminaire manufacturers
- Or, ask for  $R_f$ ,  $R_g$ ,  $R_{cs, h1}$  values, and color icons
- Basic and advanced tools are publicly available.



# Be the first one on your block to be fluent in TM-30 color metrics!

For more information on LEDs and color  
metrics:

<https://energy.gov/eere/ssl/downloads/led-color-characteristics-0>

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