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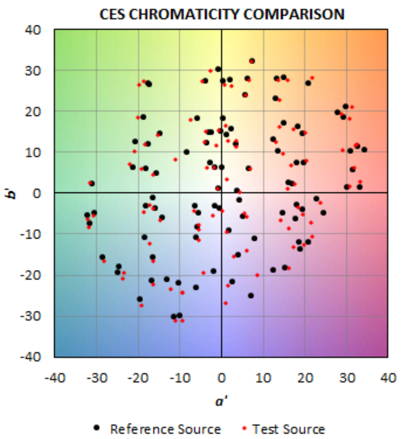
1. About this document

Tridonic has started to provide TM-30 information for selected products.
Product data sheets list the most important values, TM-30 Excel sheets are available on request and offer additional information in graphical form.

This document explains what TM-30 is and how the different information can be used.

2. What is TM-30?

TM-30 is a method for evaluating light source color rendition. Compared to CIE CRI, it is more detailed and contains more information. The basis is the comparison of 99 color evaluation samples (CES). The following graph shows an example of the test source (red) and reference source (blue) in the CAM02-UCS diagram (Color Appearance Model 2002 - Uniform Color Space).
a' correlates to redness - greenness of the color, b' correlates to blueness - yellowness of the color, J' (not depicted) correlates to lightness of the color.



The evaluation of color difference requires a method of measuring the distance between colors. The widely used CIE1931-xy chromaticity diagram does not provide the means of measuring color distances. Therefore MacAdam ellipses are used which have the same color distance from the center to the boundary. In the CIE Color Rendering index calculation the CIE 1964 (U, V, W*) color space is used, but this color space is meanwhile known to be inaccurate.

3. What are the main parameters of TM-30?

TM-30 has two main parameters:

- Fidelity Index R_f
- Relative Gamut Index R_g.

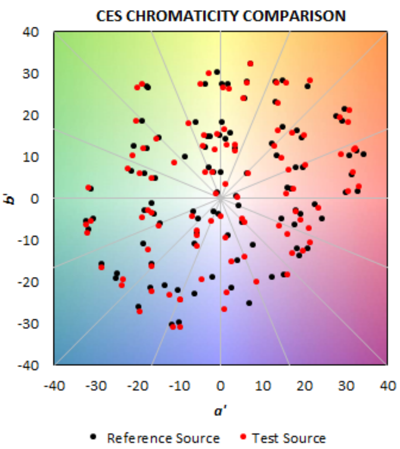
4. What is the Fidelity Index, R_f?

Color fidelity describes the similarity of colors. For this, the 99 CES are mathematically compared for the test source and a reference source.
The resulting R_f value can lie between 0 and 100 and describes the average difference for all 99 CES. A value of 100 indicates an exact match with the reference.

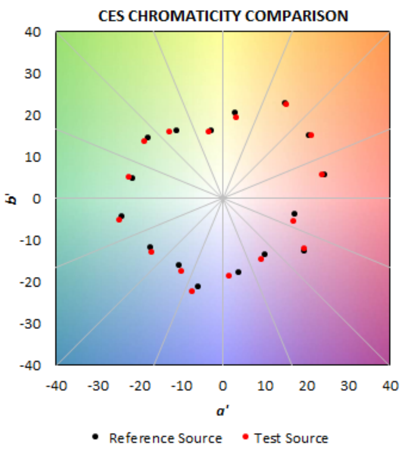
As an average value, R_f does not provide an indication of what types of colors are most distorted or if the distortions increase in saturation, decrease in saturation or hue shifts.
The addition of the gamut index R_g can help to overcome the limitations and possible misinterpretations of a fidelity-only evaluation.

5. What is the Gamut Index, R_g?

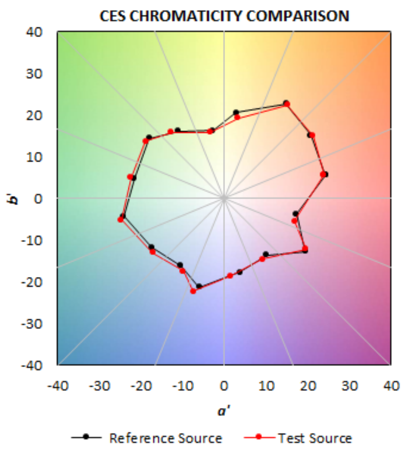
R_g is the TM-30 measure for average relative saturation. The following graphs explain how the R_g is calculated:



The color spectrum with all the 99 CES for test source (red) and reference source (blue) is divided into 16 hue bins.



The average chromaticity values for test source (red) and reference source (blue) are calculated for each of the 16 hue bins.



The average chromaticity values are connected, forming two polygons, a test source polygon (A_t) and a reference source polygon (A_r).

R_g is the ratio of the area of the two polygons. It can be calculated as $R_g = 100 \times A_t / A_r$.

A result of $R_g > 100$ indicates an average increase in saturation, a result of $R_g < 100$ an average decrease.

6. I have seen different graphical representations, what are they used for?

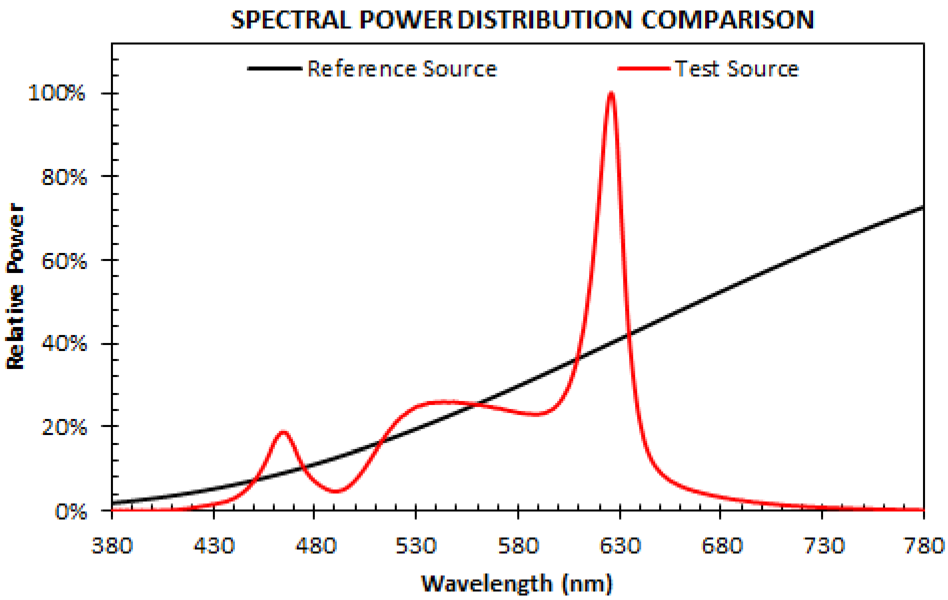
Both R_f and R_g are average measures. A limitation of any average measure is that there are multiple combinations that can lead to the same value.
For example, one source could render reds with high fidelity but not blues, while another could render blues well but not reds, with both having the same average performance. Even if R_f ad R_g are combined, there are multiple sources with the same combination of average values that can render colors very differently.

Using graphical representations and the associated numerical values for each hue bin helps to illustrate the performance of a light source.

The following graphical illustrations are used in the TM-30 Excel sheet and many other sources:

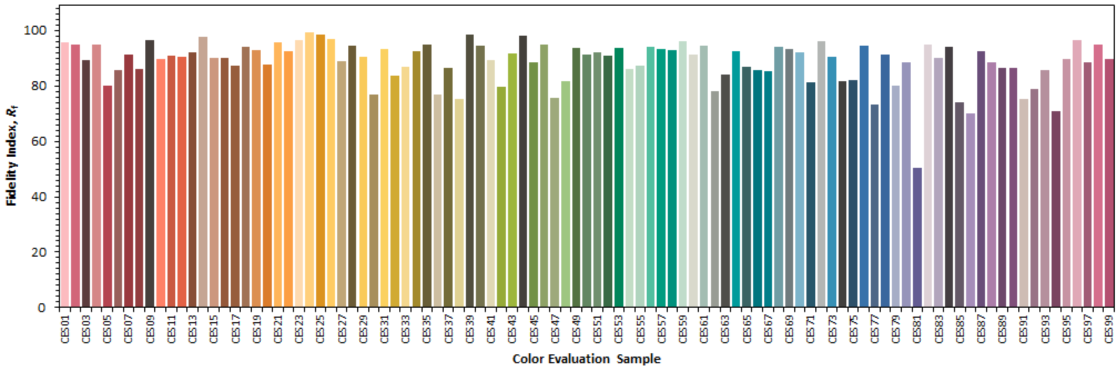
- Spectral power distribution comparison
- Fidelity Index and Fidelity Index by Hue bin
- Color Vector Graphic
- Chroma Change by Hue
- R_f-R_g Plot

6.1. Spectral power distribution comparison

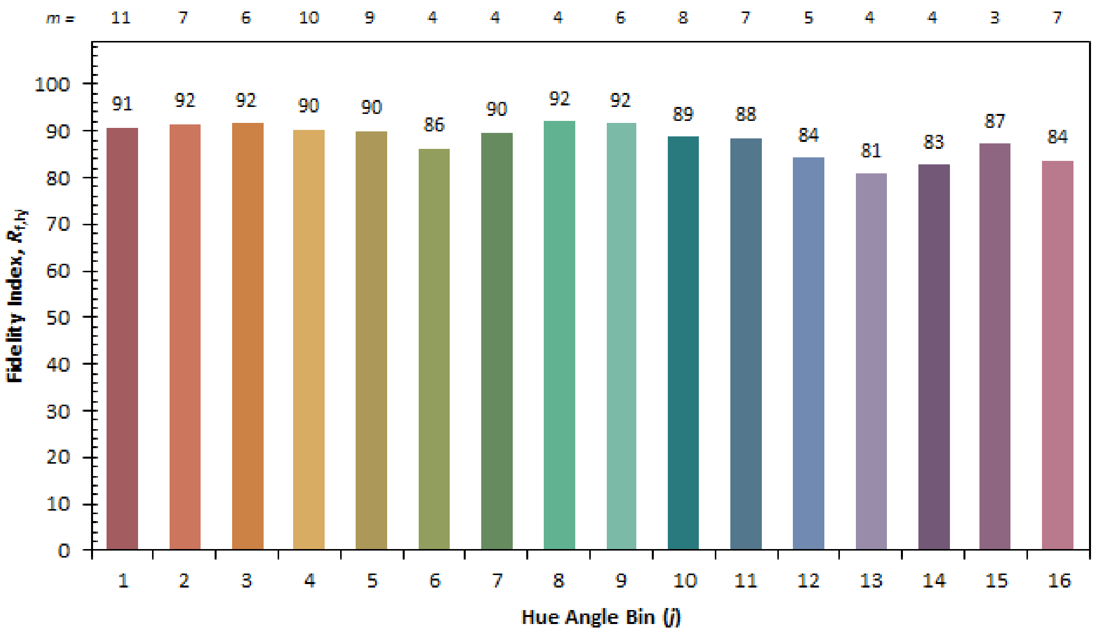


The spectral power distribution comparison shows the radiated power per wavelength of a light source. It has been normalized so that the maximum value is 100 %.

6.2. Fidelity Index and Fidelity Index by Hue bin

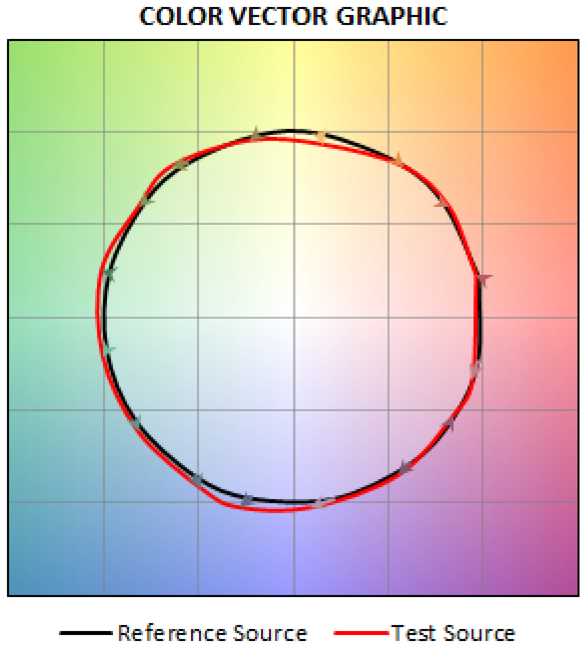


The Fidelity Index diagram provides a numerical characterization of color fidelity for each of the 99 CES. The length of the bars shows how similarly the test source renders the CES.



The Fidelity Index by Hue bin provides the same numerical characterization of color fidelity for the 16 Hue bins.
Both diagrams provide more detailed information than the average fidelity index, potentially providing information that is more relevant to a specific application where the object colors are known. For example, if fidelity of reds is very important, it is possible to examine $R_{f,h1}$.

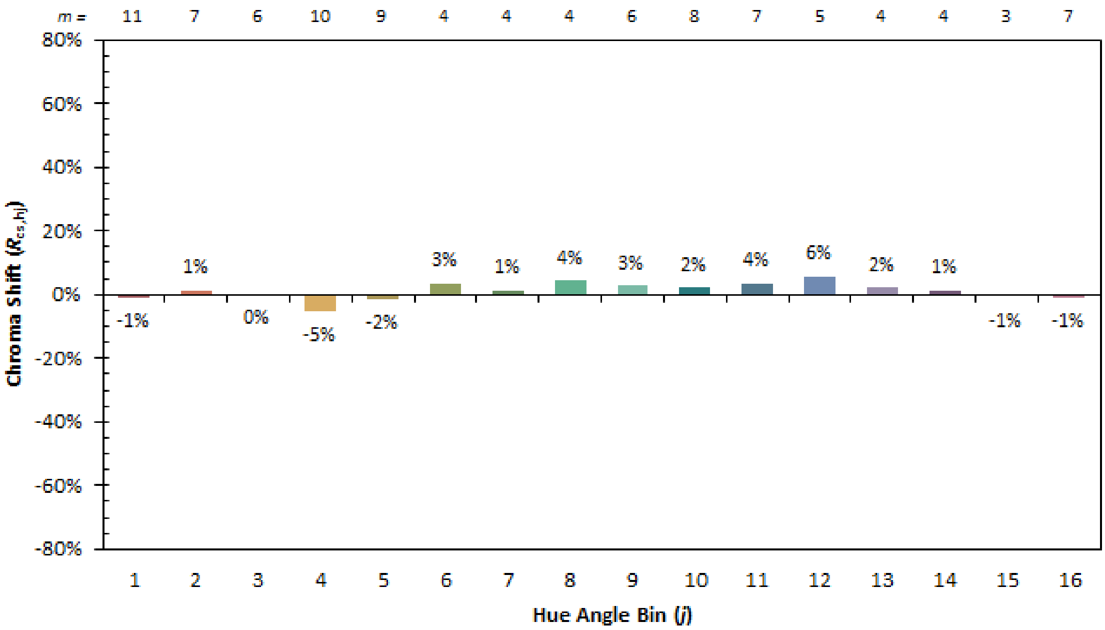
6.3. Color Vector Graphic



The Color Vector Graphic is a visual representation of hue and saturation changes for all colors. It is based on the average chromaticity coordinates calculated for the CES in each of the 16 hue bins. The difference to the Gamut Index R_g is that the averaged values of the 16 bins are normalized to a circle and not directly connected.

The Color Vector Graphic quickly conveys what types of colors are more saturated (lines outside the circle) or less saturated (lines inside the circle) and where hue shifts occur (arrows that are not perpendicular to the circle). Once the user is familiar with its elements and their meanings, the Color Vector Graphic can quickly and easily communicate how a source will render a wide variety of colors.

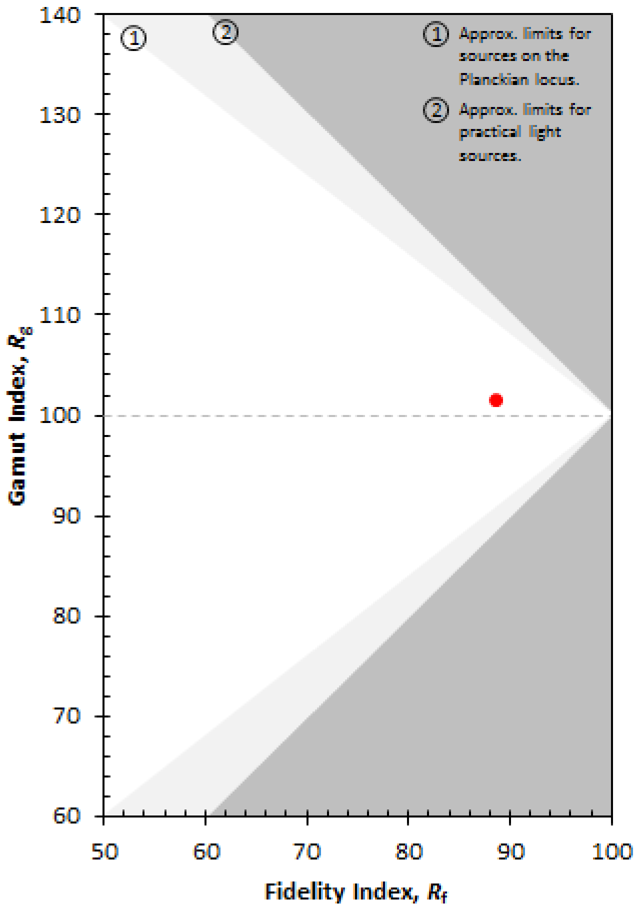
6.4. Chroma Change by Hue



The Chroma Change by Hue diagram shows the average saturation shift for the 16 hue bins. The diagram provides numerical values for relative saturation changes in each of the 16 hue bins. Positive values stand for increased saturation, negative values for decreased saturation.

From a scientific point of view there is a slight difference between the terms "chroma" and "saturation". But in this respect both terms can be used interchangeably and "chroma" can be translated as "saturation".

6.5. R_f-R_g Plot



The R_f-R_g plot shows a comparison of the R_f and R_g values relative to the range of possible values. It makes it possible to compare the combination of both values for different light sources.

The white area represents the range of all possible values.

7. Summary and interpretation

The average fidelity index, R_f, has a scale from 0 to 100. The average gamut index, R_g, has an undefined scale that varies with R_f, but is generally between 60 and 140 for sources appropriate for architectural lighting.

In general, there is no "best" value. The best combination of values always depends on the application as well as personal preferences. Simply maximizing both values is technically not possible.

An important aspect of R_f and R_g is the fact that they are both average values. Average values are helpful to summarize information but they may also hide important information about the source. Using R_f and R_g provides an easy measure for characterizing the base requirements of an lighting application in the same way as the color rendering index did. Only in special cases, the overwhelming information for 99 colors is useful and especially none of the color rendering index would give information about fluorescent colors (e.g. white cloth).

In some cases, maximizing fidelity is the most appropriate goal. In other cases, increasing saturation is more appropriate. Sometimes targeted deviations from the reference, such as an increase of the saturation of one color or hue bin, are not only acceptable but may be preferable. In color critical applications it is therefore important to not only rely on those two values but also consult other graphs and values like the Color Vector Graphic or numerical sub-indices of R_f and R_g.