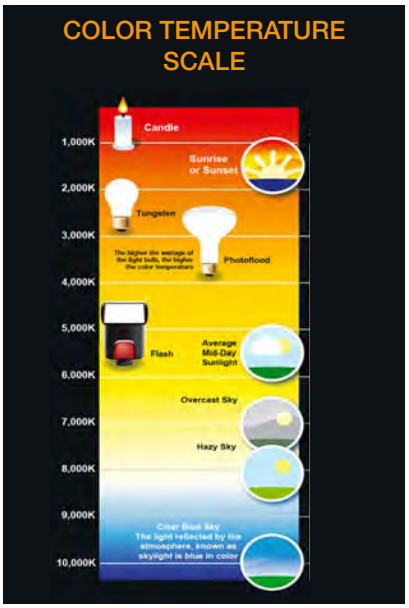
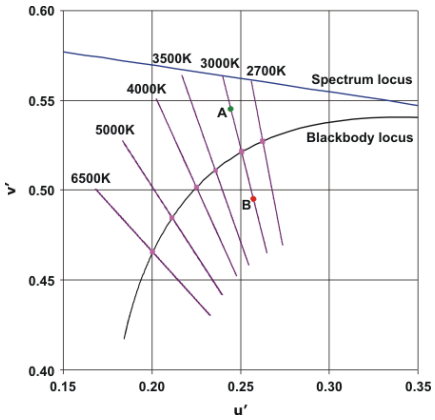
EDUCATIONAL
SECTION

WHAT IS COLOR TEMPERATURE?

Color temperature is a way of describing the Color (chromaticity) of a light source in a numeric value. It is usually expressed as either warm (yellowish) or cool (bluish) and measured in Kelvin (K). Color temperatures over 5,000K are called cool colors (bluish white). Clear blue skies, electronic flash and certain continuous light sources are examples of 'cool' blue light. Lower color temperatures (under 3,000 K) are called warm colors (orange or red), candles, sunsets and tungsten bulbs are examples of these types of light sources. The Kelvin Color Temperature scale is based on heating an object at various degrees of physical heat and recording the color changes. For example, if we heat up a lamp filament at some point, the filament will get hot enough to begin to glow. As it gets hotter, its glowing color will change, moving from deep reds, such as a low burning fire, to oranges and then yellows and finally up to white superhot. Light sources that glow in this manner are considered "incandescent radiators" (like blackbody) and the advantage to them is that they have a continuous spectrum of light. This means that they radiate light energy at all wavelengths of their spectrum, thus render all the colors of a scene being illuminated by them, equally. Only light from sources functioning in similar ways can meet the definition of color temperature.



WHAT IS CORRELATED COLOR TEMPERATURE (CCT)?



Incandescent radiators (such as a filament light bulb) glow in different colors as they get hotter and measured for their color temperature in Kelvin degrees (K). However, light sources, that don't have similar characteristics as incandescent radiators are measured by their color appearance or "Correlated Color Temperature" (CCT). Their reference to any part of the color temperature chart is strictly visually based. These types of light sources are defined by their proximity to the light source's chromaticity's coordinates on the blackbody locus (only one number is used, rather than the two necessary to identify a specific chromaticity). Lights with a correlated color temperature do not have an equal radiation at all wavelengths in their spectrum. These types of light sources create a disproportionate level (high & low) of color rendering. However, because CCT is easier to communicate value than chromaticity, lighting industries have accepted CCT as an abridged version of reporting the color appearance of "white" light emitted from various light sources. Most commercially available light sources offer a CCT range from 2700 K to 6500 K. their values are intended to give lighting designers and specifiers a general indication of the level of "warmth" or "coolness" created by the light source.

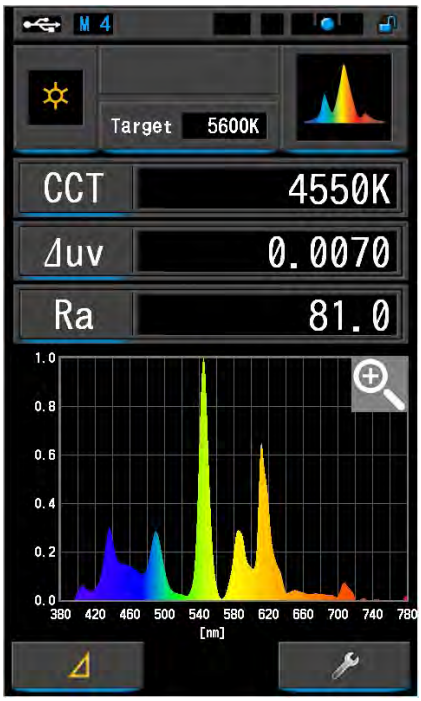
WHY IS COLOR TEMPERATURE IMPORTANT?

In order to accurately view or evaluate objects, environments, events or grow various plants, the consistence of color temperature and illumination of light is extremely important.

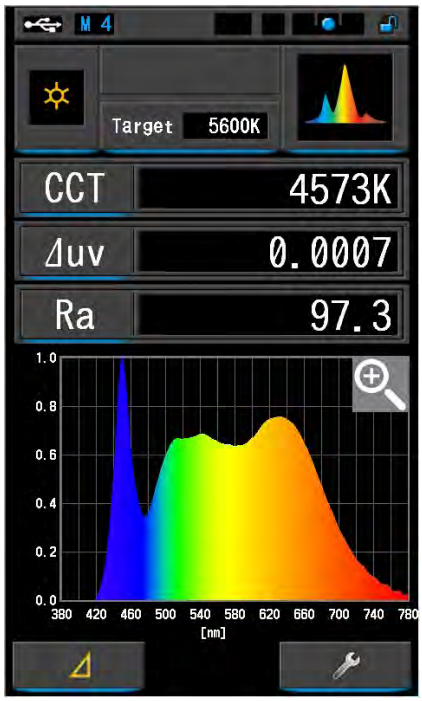
Like photography, videography and cinematography, light sources need to produce consistent, repeatable, and correct color temperature for optimum color representation. However, color temperature can be even more important for industrial lighting applications. Because different light sources can change the appearance of a product finish, the mood in theater lighting, a medical evaluation, quality control in manufacturing, proper plant growth and even the perceived value of jewelry, its critical to select and maintain the desired color temperature of a light source. Without color temperature control, the color of lighting can have a large impact on how people experience an environment or accurately achieve a desired result.

ARE ALL LIGHT SOURCES THE SAME COLOR TEMPERATURE?

As explained earlier, the color temperature of a light source is based on how it compares to a heated object such as a filament from a light bulb (black body radiator). As this object heats up at some point it will get hot enough to begin to glow. As it gets hotter, its glowing color will change, moving from deep reds up to superhot white. Light sources that glow in this manner are considered as "Incandescent radiators", and they have a continuous spectrum of light. This means that they radiate light energy at all wavelengths of their spectrum. Light sources that are not "incandescent radiators" don't react in the same way as they emit energy in different ways and from different power sources. All light sources have varying color temperatures and are often within a projected range that can be classified as closer to warmer (Tungsten balanced), or cooler, (daylight balanced) temperature. However, they may not render color accurately or at all throughout the spectrum even though they have same color temperature.



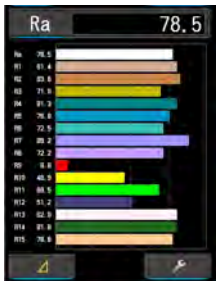
Fluorescent Lamp
4550K
Ra: 81.0



LED
4573K
Ra: 97.3

WHAT IS CRI AND WHY IS IT IMPORTANT?

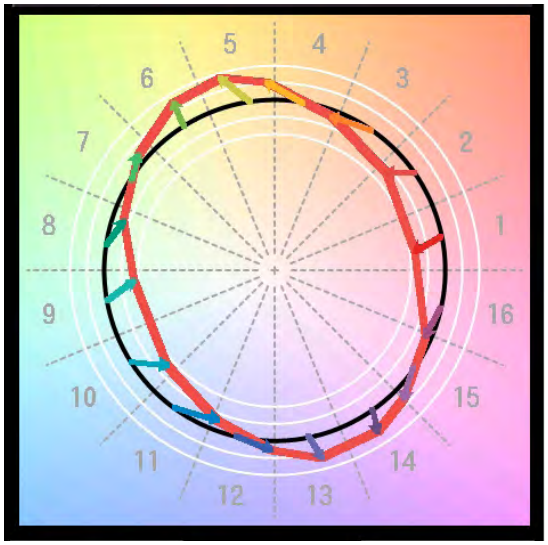
CRI (Color Rendering Index) is a quantitative measure revealing the ability of a light source to represent the colors of various objects faithfully in comparison with an ideal or natural light source. The Color Rendering Index (CRI) is a scale from 0 to 100, which describes how a light source makes the color of an object appear to the human eye and how well subtle variations in colors and shades are revealed. The higher the CRI, the better the color rendering ability. A Black Body Radiator (i.e.: a filament from a light bulb) is considered the "reference" light source and they produce a CRI value of 100. CRI values can be evaluated from R1 through R8 (color rendering index) and R9 through R15 (special color rendering index). Each R value represents a color for specific color rendering performance for the measured light source. Ra is commonly used because it represents an average color rendering performance of a light source from R1 through R8. It is important to measure various light sources for their CRI values before using them.



EDUCATIONAL
SECTION

WHAT IS TM-30 AND WHO USES IT?

TM-30 is an acronym for Technical Memorandum number 30 and is published by the Illumination Engineering Society (IES). It is standard used to evaluate light source color rendering capabilities including LED. The values are based on color appearance of objects with 99 color samples compared to their appearance under the defined reference illuminant. Within the TM-30 standard, there is a Fidelity Index (Rf), which expresses the accurate rendition of color and the Gamut Index (Rg) which expresses what the average level of saturation is. TM-30 is commonly used by lighting producers, designers, and R&D because of its accuracy and expanded range of information provided as compared to predecessor tools for assessing color rendition.

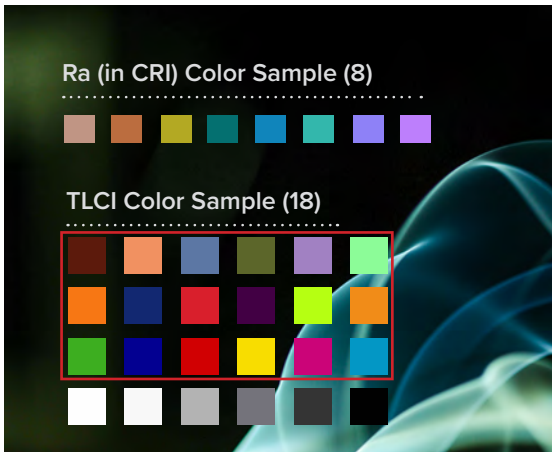


WHAT IS TLCI/TLMF AND WHO USES IT?

TLCI was developed by EBU (European Broadcasting Union) and it is the acronym for Television Lighting Consistency Index. This measuring standard is a method of evaluating the color rendition (the color appearance of objects) under a reference light source with 18 color samples and a mathematical model of a broadcast camera to see the colors. TLCI is an index used to evaluate television lighting equipment.

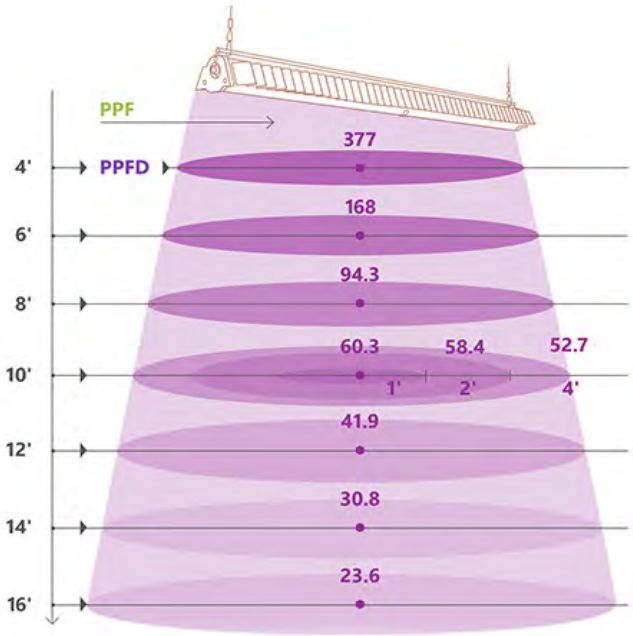
Similar to TLCI, Television Lighting Matching Factor (TLMF) provides the end-user the ability to set the data of their desired Light as the reference point or benchmark. TLMF is useful when several different light sources are being mixed and usually don't share the same light color characteristics.

According to EDU Tech3355, TLCI and TLMF are calculated in the same way (TLMF is an extension to TLCI). The higher the number, the closer you are to your reference. TLCI is comparing a light with a theoretical reference standard. TLMF is comparing a light with another light.



WHAT IS PPFD AND WHO USES IT?

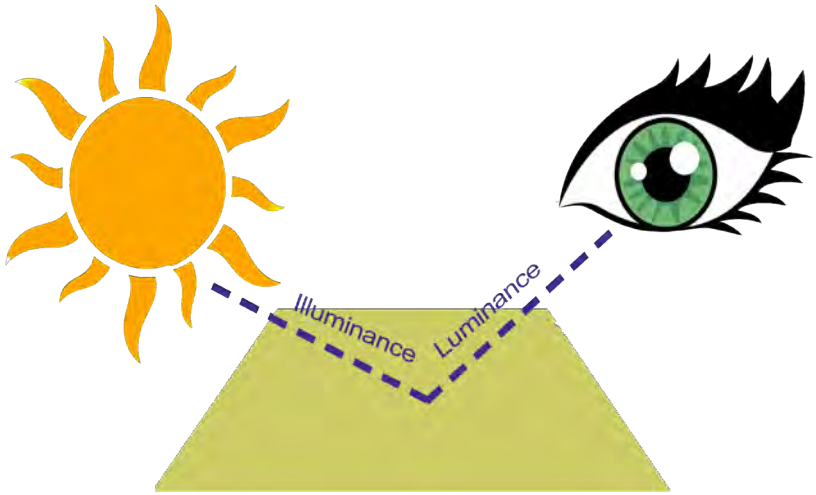
PPFD is the acronym for photosynthetic photon flux density. It is a unit of measurement that measures the number of PAR (photosynthetic active radiation) that arrives at the plant. This is expressed as the number of active photons that fall on a given surface per unit time and unit area needed for photosynthesis micromole-per-meter squared-per second (µmol/m2/s) (between a wavelength from 400 nm to 700nm). Widely used by horticulturist or growers who want to optimize their crop growth. PPFD measurements provide the information needed to understand the light source's ability to produce enough energy to attain the growth results desired.



WHAT IS ILLUMINANCE AND LUMINANCE?

Luminance

Luminance is the measurement of how much light is coming from, passing through or reflected from a surface at a particular angle. It also indicates how much light intensity can be perceived by the human eye. The International System of Units (SI) uses candela/square meter (cd/m^2) as the units to measure luminance. In the U.S. one of the most common units of measure is the foot-lambert (fl); 1 foot-lambert (fl) equals 3.426 cd/m^2. In the screens/ display industry the term nit (nt) is commonly used. Nit is a non-SI term used for luminance, and 1 nit is equivalent to 1 cd/m^2. In the display industry, luminance is used to quantify the brightness of displays.



Illuminance

Illuminance is the measurement of how much light is falling onto (illuminating) and covering a surface area. Illuminance also indicates how humans perceive the brightness of an illuminated area. The terms illuminance and brightness can be confusion as the same thing, but they're not, as brightness can also describe luminance. The difference between the two is that illuminance refers to intensity of light falling onto a surface, while brightness refers to the visual and physiological perceptions of light. Brightness should not be used as a quantitative measurement at all. The SI unit for illuminance is lux (lx). In the U.S. people sometimes use the non-SI term foot-candle when referencing illuminance. The term "foot-candle" means "the illuminance on a surface by a candela source one foot away". One foot-candle is equivalent to one lumen per square foot which is approximately 10.764 lux.

HOW DOES COLOR TEMPERATURE EFFECT THE WAY WE SEE?

The human eyes adjust automatically to subtle changes from light sources in brightness levels as well as differences in the color. However our eyes alone are not the sole determining factor in the interpretation of the color of light or its brightness. Our brains are continuously using stored information, our senses as well as our eyes to make the final determination of what we see and what we think we see. If you enter an indoor room, it is common to find warmer color temperature lighting, which promotes comfort and relaxation. Warmer color temperatures are frequent used deliberately in homes as they promote comfort and relaxation, whereas cooler color temperatures are commonly used in office, industry or manufacturing to promote focus and productivity.