Various Light Sources and Their Use In Color Matching

Proper lighting is important because the appearance of an object is significantly influenced by the light source and the environment in which it is viewed. All stakeholders in a supply chain need to evaluate a color under a consistent light source. To help achieve this goal industries have developed international standards for the viewing of color.

The primary two standards are ISO 3664:2009 and ASTM D1729-2016. ISO 3664:2009, which specifies a D50 daylight viewing condition, is used by the graphic arts and photographic industries. ASTM D1729-2016, which specifies D65 as the primary daylight viewing condition and others as secondary sources to check for metamerism, has been adopted by many industrial color applications including plastics, paints, textiles, and automotive. Other standards such as SAE J361 and BS-950 Part 2 are used in select applications.

Metamerism occurs when two colors match under one lighting condition but not under another. This can be a problem for manufacturers and shows the importance of evaluating colors under spectrally dissimilar light sources in addition to the daylight source specified by your industries specification.

Common Light Sources

The lower the color temperature of the light source, the warmer or redder the source will be. Inversely, the higher the color temperature of the source, the cooler or bluer it will be. Common color temperatures, names associated with them, and their associated colors are:

Color Temperature	Name	Color
7500K (D75)	North Sky Daylight	Moderate to Deep Blue
6500K (D65)	Average Daylight	Moderate Blue
5000K (D50)	Noon Sky Daylight	White
4100K	Various Fluorescent & LED Sources	Green
3500K	Various Fluorescent & LED Sources	Redder / Yellow
3000K	Various Fluorescent & LED Sources	Red / Yellow
2856K	Illuminant A / Incandescent / Tungsten Halogen	Yellow / Red
2300K	Horizon	Red

Daylight Sources

D75 (7500K) - A bluish colored light source that has been largely replaced by D65. It accentuates blue and subdues green and red. It is derived from the light coming in a north facing window in the northern hemisphere at noon at various times throughout the year. It is commonly called “North Sky Daylight.”

D65 (6500K) - A light bluish colored light source used in color matching applications of paints, plastics, textiles, inks, automotive, and other manufactured products. It accentuates blue and subdues green and red. D65 is commonly used as a primary light source in color measurement instrumentation. It is the specified daylight source for ASTM D1729-2016, and SAE J361 for automotive applications.

D50 (5000K) - A near white light source used for visual evaluation in printing, packaging, photographic, and other graphic art industries. It is the specified source in ISO 3664:2009. It has similar amounts of red, green, and blue energy. It neither accentuates nor subdues color, a prime requirement when viewing press sheets and original images (i.e., photographs) since they usually have many colors within the product to be evaluated.

Ultra Violet - Light energy not visible to the human eye, but is present in natural daylight. UV energy has the ability to excite optical brightener agents (OBAs) and fluorescent dyes and pigments within a sample causing them to emit light in the visible spectrum, usually in the blue region. These substances are used in various products to "brighten" colors, particularly whites. It is necessary to include correct amounts of non-harmful near UV energy in a color matching system to allow for optimum simulation of natural daylight.

Retail Light Sources

Cool White Fluorescent (CWF) – Simulates CIE standard illuminant F2. It is a wide band fluorescent source commonly used in commercial lighting applications in North America. It is characterized by emitting high amounts of green and very little red energy. It has a color temperature of approximately 4150K and a CRI of approximately 62. Due to energy regulations F2 CWF lamps are only available in lengths less than four feet long. However, lamp manufacturers still sell lamps labeled CWF, but they have a spectral power distribution similar to TL84.

Warm White Fluorescent (WWF) - Simulates CIE standard illuminant F4. It is a wide band fluorescent source used in commercial lighting applications in North America. It is characterized by emitting high amounts of yellow/red energy, with a color temperature of approximately 3000K. It has a CRI of approximately 53.

TL84 - Simulates CIE standard illuminant F11. A narrow band tri-phosphor fluorescent source originally designed for commercial lighting applications outside North America. It is characterized by emitting high amounts of green energy, with a color temperature of approximately 4100K. It has a CRI of approximately 86.

TL830 - Simulates CIE standard illuminant F12. A narrow band tri-phosphor fluorescent source originally designed for commercial lighting applications outside North America. It is characterized by emitting high amounts of yellowish red energy, with a color temperature of approximately 3000K. It has a CRI of approximately 86.

TL835 - A narrow band tri-phosphor fluorescent source originally designed for commercial lighting applications outside North America. It is characterized by emitting high amounts of reddish yellow energy, with a color temperature of approximately 3500K. It has a CRI of approximately 86. Very similar color rendition to SPX35.

SPX35 - A narrow band tri-phosphor fluorescent source designed for commercial lighting applications in North America. It is popular in retail applications and is characterized by emitting high amounts of reddish yellow energy, with a color temperature of approximately 3500K. It has a CRI of approximately 85. Very similar color rendition to TL835. SPX35 is often used in place of U35

Ultralume 30 & 35 (U30 or 30U, U35 or 35U) – (DISCONTINUED) A narrow band tri-phosphor fluorescent source originally designed for commercial lighting applications in North America where energy savings is required. It had high amounts of yellowish red energy with a color temperature of approximately 3000K or 3500K. It had a CRI of approximately 85.

LED - As more retail, office, and home environments switch to LED lighting it is becoming increasingly necessary to evaluate color in LED viewing conditions. The increased use of LED lamps is primarily being driven by the fact that they use less energy than other light sources. It should be noted that LED lamp technology is still rapidly advancing. As a result, it is difficult to ensure consistency of color temperature from lamp-to-lamp, batch-to-batch, and manufacturer-to-manufacturer. There is no official LED lighting standard for color matching. LED lamps are best utilized as an optional light source to gauge how the product may appear in an environment illuminated by a similar LED source.

Incandescent and Tungsten Illumination

Historically, the typical light bulb found in the home has been an incandescent tungsten lamp. It uses a tungsten filament that will glow when electricity is passed through it. However, today we are seeing a greater number of compact fluorescents and LED lamps used in the home environment.

A quartz halogen lamp is also a tungsten incandescent lamp, but has special characteristics to give the lamp a more even output over its life cycle. These lamps are very common and are used in color match applications where a yellowish to red source is required. The most common tungsten filament sources available, with their applications, are given below:

Color Temperature	Name	Color	Application
2856K	Illuminant A	Yellow / Red	Standardized source and illuminant for color matching
2300K	Horizon	Reddish	Source described in some specifications and used for color matching applications in select industries such as automotive

Tungsten - is used primarily in the photographic film and video industries where a “whitish” source and continuous light output are required. It is not commonly used for color matching applications.

Illuminant A – Simulates typical home or retail accent lighting. It is a standardized illuminant described in the international standard, CIE Publication 15.2004 and specified for use in color matching applications in ASTM D1729-2016. It is used where a yellowish-red source is required. It is the predominant source/illuminant used for both instrumental and visual color matching applications. Another source described as Horizon, an “Incandescent illumination of low correlated color temperature…” is used in instrumental color matching applications.

Horizon – A tungsten lamp operating at 2300K. It is a reddish light source which simulates early morning sunrise and late afternoon sunset. It is primarily used in the automotive industry.

Overall light output and color temperature of a tungsten lamp will vary greatly with the voltage. Even a change of three volts in a 110 volt lamp will produce a measurable change in both output and color temperature. Color matching systems using these lamps must employ voltage stabilization circuits to make certain the color temperature remains stable. Even with this circuitry, it is very difficult to maintain the overall stability of light output and color temperature for a reasonable amount of time with tungsten lamps. In addition, as a tungsten lamp heats up its color temperature and light output will change, sometimes quite drastically.

Conclusion

Industry standards require that viewing conditions meet strict specifications with regard to color quality, light intensity, evenness of illumination, viewing/illumination geometry, and surround conditions. Differences in any of these conditions can affect color appearance. The best way to ensure that you meet these requirements is to use a color viewing booth that meets industry specifications. GTI manufactures industry compliant viewing systems ranging from small desktop viewers to floor stand models to complete color harmony rooms.

Lamps are the key element of any viewing environment. GTI lamps are designed for use in critical color viewing stations and deliver the tightest match to the industry standard curves. The lamps are manufactured with a unique blend of fluorescent phosphors and produce a true full spectrum white light which renders colors with the highest degree of accuracy and efficiency. These lamps provide greater color fidelity and tighter compliance to the viewing standard than competitive lamps. All products with GTI lamps comply with industry standards and are shipped with a certificate of product conformance (NIST traceable).

ISO 3664:2009 Viewing Conditions

1. Color Quality: D50 light, which represents natural daylight, is used to maintain compliance with the standard. Use only ISO 3664:2009 compliant lamps.
2. Light Intensity: Color decisions should be under light that is between 1750 and 2250 lux, with 2000 lux being optimum.
3. Evenness: Evenness is ensured by measuring illuminance at several evenly distributed points on the viewing surface. Illumination should be at least 1200 lux (60% of 2000) intensity at all points on the viewing surface.
4. Surround: ISO 3664:2009 specifies that the surround and backing shall be neutral and matte. Munsell N8/ neutral gray paint is used by GTI Graphic Technology, Inc.
5. Geometry: The light source, image, and the observer's eyes need to be positioned to minimize glare. The standard does not specify lighting geometry, but states it should be minimized.

ASTM D1729-2016 Viewing Conditions

1. Color Quality: D65 is the specified daylight source for ASTM D1729-2016. Other sources (CWF, TL84, illuminant A, etc.) are specified for color matching and the detection of metamerism.
2. Light Intensity: The standard provides a target intensity range that allows for full tonal visibility of dark samples without over illuminating light samples. For very light materials the illumination can be as low as 540 lux, materials of medium lightness should be illuminated between 810 and 1880 lux, and dark materials can be illuminated as high as 2150 lux.
3. Evenness: Evenness is ensured by measuring illuminance at several evenly distributed points in the viewing area. Illumination should be at least 968 lux (20% of 1210) and not more than 1462 lux at all points on the viewing surface.
4. Surround: The surround and backing shall be neutral and matte. Munsell N7/ neutral gray paint is used by GTI Graphic Technology, Inc.
5. Geometry: Optimal light source and sample viewing geometry will depend on the characteristics (surface type, lightness/darkness) of the sample. 90 degree, 45 degree, and variable angled viewing geometry are recommended depending on the sample.