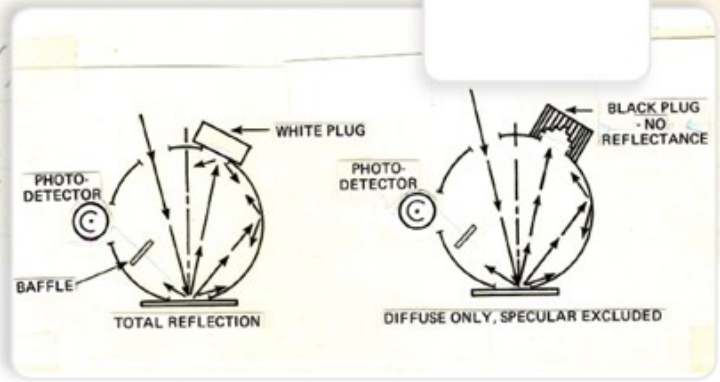
Applications Note

AN 1093



White Light Sources and CIE Illuminants

Without light, we cannot see color. With light, color is seen but may appear differently under one type of light than another.

Abstract

A light source can be defined as an object that emits light, such as the light in an office building. Forming its spectral power distribution curve, a light emits different amounts of energy at each wavelength of the visible color spectrum. Unlike a light source, an illuminant is not a physical object but rather a representation of a light's spectral power distribution curve in graph or numerical form.

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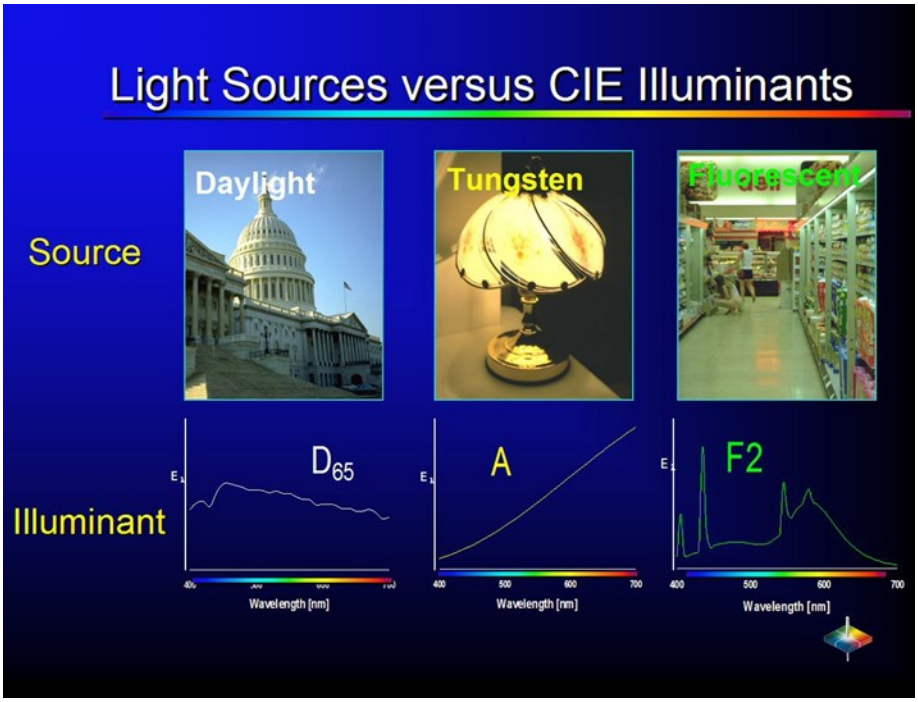
What is the Difference between a Light Source and an Illuminant?

A **light source** is a physical emitter of radiation (i.e., candle, lamp, or sunlight) that can be characterized numerically by a spectral power distribution curve of power versus wavelength. For each light source, the wavelength tells us where light energy is present. The relative energy values (power) indicate how much energy is present at a particular wavelength.

The CIE (Commission Internationale de L'Eclairage, http://www.cie.co.at) has codified the spectral power distributions of different types of white light sources and called them "illuminants."

An **illuminant** is a set of numbers (relative energy versus wavelength) that represents the spectral quality of a type of white light source and is used in the calculation of color measurements in colorimetric software. The choice of illuminant is independent of the instrument lamp.



Common CIE Illuminants

While there is a wide range of illuminants available, most industrial users will be using one of four CIE illuminants representing the general types of white illumination found in the home, office and exterior conditions. These illuminants are:

- **A**, which represents an incandescent or tungsten light source (2856° Kelvin) found in the home.
- **F2** (also called F, F02, Fcw, CWF, CWF2), which represents the spectral quality of the most common fluorescent lamp—cool white fluorescent—found in office environments.
- **D65**, which is the most commonly used daylight illuminant representing noon daylight (6504° Kelvin).
- **C**, which is an historical representation of average or north sky daylight (6774° Kelvin), still in active use.

If you have no prior conditions or requirements (test methods, SOPs) that tell you to use another, use the CIE D65 illuminant. It is the most commonly used illuminant and represents a full, even spectrum.

CIE Incandescent or Tungsten Illuminant

There is only one incandescent illuminant, and that is CIE Illuminant A (2856° Kelvin).

CIE Daylight Series of Illuminants

There are several CIE standard illuminants that represent various daylight lighting conditions throughout the day.

- **D50**, sometimes referred to as horizon light, represents warm daylight at sunrise or sunset (5000° Kelvin).
- **D55** represents mid-morning or mid-afternoon daylight (5500° Kelvin).
- **D65** is the most commonly used daylight illuminant, representing noon daylight (6504° Kelvin).
- **C** is an historical representation of average or north sky daylight (6774° Kelvin), which is still in active use.
- **D75** represents overcast daylight (7500° Kelvin).

CIE Fluorescent Illuminants

Historically, a series of some 20 different fluorescent illuminants were represented as codified tables of numbers by the CIE, of which only 12 are in active use today. Illuminants F2, F7 and F11 should take precedence over others when a few typical fluorescent illuminants need to be selected.

- **F2** (non-**standard** names include F, F02, Fcw, CWF, CWF2), the fluorescent illuminant in most common use, represents cool white fluorescent (4100° Kelvin, CRI 60).
- **F7 represents** a broadband fluorescent lamp, which approximates CIE illuminant D65 (6500° Kelvin, CRI 90).
- **F11** represents **a** narrow tri-band fluorescent of 4000° Kelvin color temperature, CRI 83.

Fluorescent Illuminant Specifications

White light sources and their corresponding illuminants usually have correlated color temperature (K) and color-rendering index (CRI) values associated with them.

White light sources vary from warm white to cool (blue) white. Expressed in color temperature values in degrees Kelvin (K), the higher the color temperature, the cooler or bluer the white light is. A lower color temperature indicates a warmer white.

Color Rendering Index (CRI) is a relative value (%) with respect to a reference source, which in the case of fluorescent illuminants and sources is D65. A high value indicates better visual match to D65.

Standard Fluorescent Illuminants

CIE Illuminant	Chromaticity *x* value	Chromaticity *y* value	K Correlated Color Temperature (Degrees K)	CRI – Color Rendering Index	Common Name(s)
F1	0.3131	0.3371	6430	76	Daylight
F2	0.3721	0.3751	4230	64	Cool White Fluorescent
F3	0.4091	0.3941	3450	57	White
F4	0.4402	0.4031	2940	51	Warm White
F5	0.3138	0.3452	6350	72	Daylight
F6	0.3779	0.3882	4150	59	Lite White

"Standard" fluorescent lamps consist of two semi-broadband emissions of antimony and manganese activations in calcium halo-phosphate phosphor. The F2 Cool White Fluorescent is most indicative of this class.

Broadband Fluorescent Illuminants

CIE Illuminant	Chromaticity *x* value	Chromaticity *y* value	K Correlated Color Temperature (Degrees Kelvin)	CRI – Color Rendering Index	Common Name(s)
F7	0.3129	0.3292	6500	90	D65 Daylight
F8	0.3458	0.3586	5000	95	D50, Sylvania F40 Design 50 (F40DSGN 50)
F9	0.3741	0.3727	4150	90	Cool White Deluxe

When compared with the "Standard" group, the "Broad-band" fluorescent lamps have enhanced color-rendering properties (higher CRI values) achieved by using multiple phosphors. The spectral power distributions of broad-band fluorescent lamps tend to be flatter (have less spikes) and a wider spectral range than the standard group.

Narrow Tri-band Fluorescent Illuminants

CIE Illuminant	Chromaticity *x* value	Chromaticity *y* value	K - Color Temperature (Degrees Kelvin)	CRI – Color Rendering Index	Common Name(s)
F10	0.3458	0.3588	5000	81	TL85, Ultralume 50
F11	0.3805	0.3769	4000	83	TL84, SP41, Ultralume 40
F12	0.4370	0.4042	3000	83	TL83, Ultralume 30

The narrow tri-band group of illuminants consists of three narrowband emissions (caused by ternary compositions of rare-earth phosphors) in the red, green and blue regions of the visible spectrum that when mixed together produce a highly efficient white light that can be tuned for color temperature by varying the amount of each phosphor in the manufacturing process. This group includes Phillips TL83, TL84 and TL85, and their US counterparts Ultralume 30, 40 and 50 which are sometimes called "prime color lamps." They tend to be warm white, with decent color rendering capabilities and highly efficient energy consumption.

Custom Illuminants

In addition to the CIE illuminants, there are several custom illuminants specified by large retail store chains. These retail companies have enough influence on suppliers and the marketplace to request that products being shipped to them match in color under the fluorescent lamps on which they have standardized within in their chain of stores. These custom illuminants are found in many color software packages.

- **Ultralume 3000** represents a Philips warm white, narrow tri-band fluorescent lamp (3000° Kelvin CRI 85, similar to CIE illuminant F12) found in many Sears stores in the United States.
- **TL84 represents** a Philips narrow tri-band fluorescent lamp (4000° Kelvin, similar to CIE illuminant F11) found in Marks & Spencer stores in Europe.
- **ALTO T8** represents a Philips fluorescent lamp (4100° Kelvin, CRI 86, most similar to CIE F11) found in most Wal-Mart stores after 1998, and also showing up in some Sears stores. This fluorescent lamp has decent color rendering abilities, high efficiency, and better environmental characteristics when disposed of.

References

CIE 13.3:1995 Technical Report - “Method of measuring and specifying colour rendering properties of light source.”

CIE Publication 15.2 (1986) - *Colorimetry* Second Edition, http://www.cie.co.at.

ASTM E308, “Standard Practice for Computing the Colors of Objects by Using the CIE System.”

ISO/CIE 10526, “CIE standard illuminants for colorimetry provides explanations and descriptions of the CIE standard illuminants.”

About HunterLab

HunterLab is the technology leader in color measurement solutions, providing instruments, software, knowledge and service to a wide variety of industries.
With over 5 decades of experience in more than 65 countries, HunterLab applies our leading edge technology to your products helping you measure and communicate color simply and effectively.

 11/2023

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