

Understanding Illuminants

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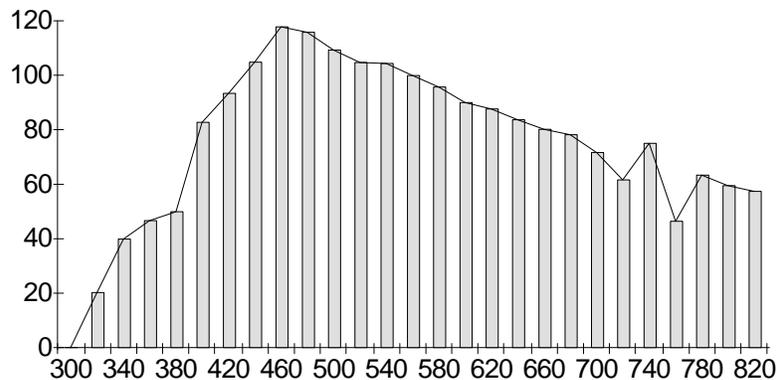
Many questions have been presented to the staff at X-Rite as to the meaning and application of the various standard illuminants referred to in an X-Rite Spectrophotometer. This document attempts to help our customers properly understand and apply illuminants when controlling color.

Illuminants Defined

Relative Spectral Power Distribution

To understand an illuminant it is necessary to first understand how we describe light. Light is described for our purposes by what is called a *spectral power distribution curve*. A specific type of light will emit different amounts of energy at each part of the visual spectrum. The graph of this power emittance over the visible spectrum is called the *relative power distribution curve* for that specific illuminant or source.

Daylight



Above we see the relative spectral power distribution curve for natural daylight. The horizontal axis represents the visible spectrum which is approximately between 380 and 750 nanometers¹. The highest peak in the graph occurs around 460 nm which represents the blue portion of the spectrum. This tells us that daylight, while appearing to be pure white, is largely composed of blue light. Every type of light has a unique, relative spectral power distribution curve that describes what it looks like, or more importantly, what other things look like when illuminated by it.

Illuminant vs. Source

Also important to understanding illuminants is the difference between an illuminant and a source. As described by Billmeyer and Saltzman, a source is an actual physical light, something that can actually be turned on to illuminate something. An illuminant however, is a light that has been defined by a spectral power distribution, but may not actually exist. For example, the light in your living room is a source. It can be turned on and off, and through experimentation, its spectral power distribution can be determined. However, if we take a blank spectral power distribution graph and draw a squiggly line across it, we have defined an illuminant. This light we have defined may not exist, but we can use its curve to test numerically how a certain color would look when viewed under it.

Color Rendering Index

A color rendering index (CRI) is a method by which sources are described. A CRI is a scale from 1 to 100 which rates a source by comparing color appearance viewed under the source to color appearance viewed under a standard illuminant; such as D65. A CRI value of 100 means the source is identical to the standard illuminant. Using the CRI as a guide, one can choose a light source based on that light source's ability to accurately display color as compared to a standard illuminant. For example, a common light source for office space may have a CRI in the 60's, but in areas where color appearance is very critical, a light source with a CRI in the 90's would be more appropriate.

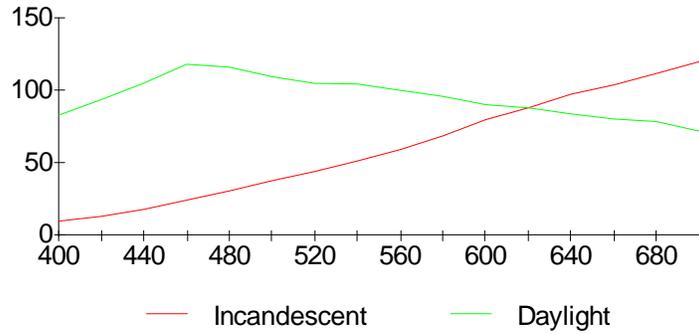
So an illuminant is basically a definition used to determine how the appearance of a color will be changed under a specific type of lighting. D65 illustrated above is an illuminant representing daylight. There is no actual light source that exactly matches the theoretical illuminant (though many sources come close). This illuminant is applied to color measurements that attempt to represent what a color would look like when viewed under daylight or some approximate light source.

How Illuminants Effect Color

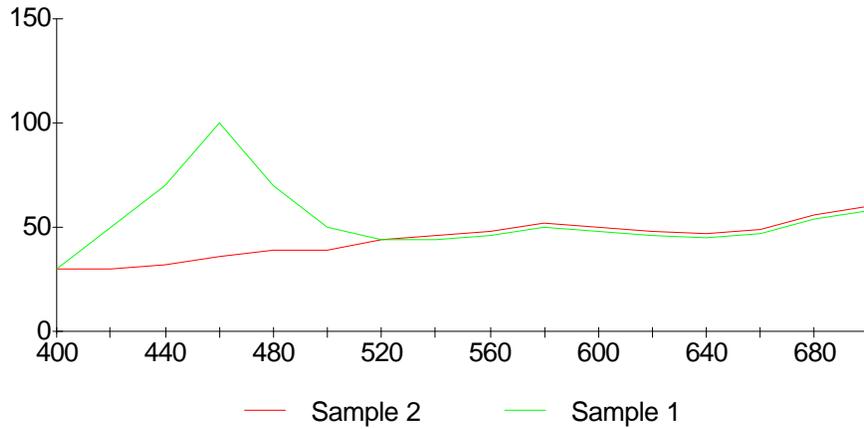
So how does this concern someone measuring color? Many colors undergo a common color phenomenon called metamerism when viewed under different light sources. Two colors may appear to match under one source but appear completely different under another source. This can be a potentially big problem if the color of your product changes when it hits the showroom floor. Let's take an extreme example. If your product was to be used in a red light dark room environment and the box was printed in blue, green and black, the box would appear solid black in the dark room. The pigments of the ink used to print blue, green, and black, all absorb the red portion of the spectrum. If your illuminant only emits light in the red portion of the spectrum, all the light will be absorbed and the whole box will appear black.

The following example combines the reflectance curves of two sample colors with the spectral power distribution curves of a daylight and an incandescent illuminant. These two color samples are metameric to one another.

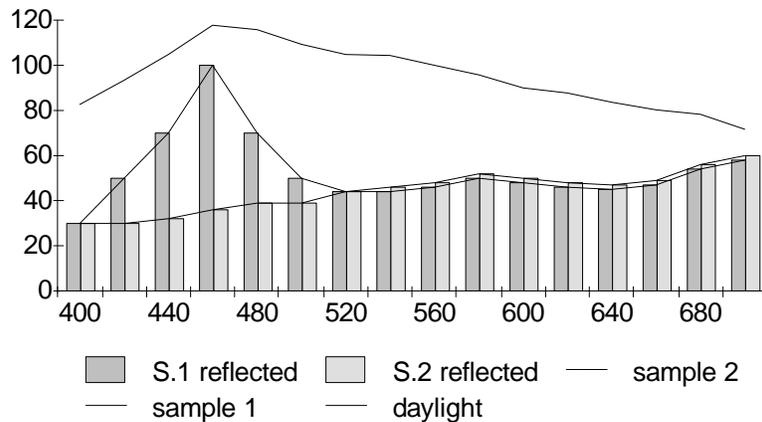
Daylight vs Incandescent



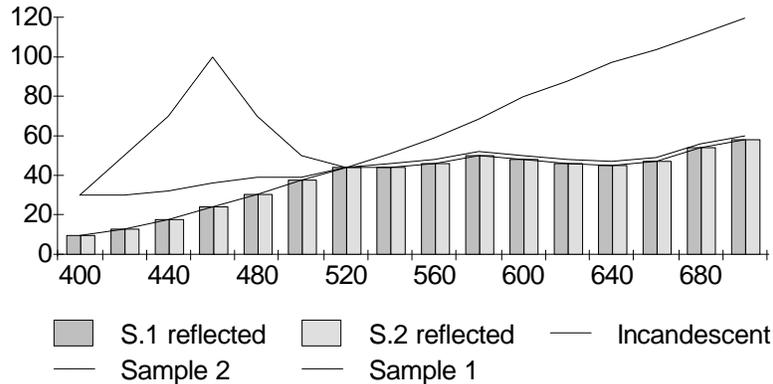
Sample 1 vs. Sample 2



Samples' Reflectance under Daylight



Samples' Reflectance under Incandescent

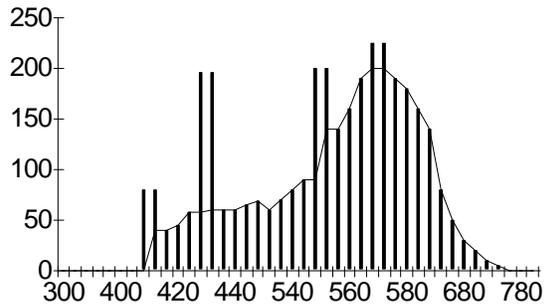


The two colors appear identical to the observer when viewed under the incandescent illuminant, but Sample 1 appears very blue compared to Sample 2 under the daylight illuminant. The two colors are spectrally identical from 520 to 700 nm, so they always reflect the same amount of light in the green and red portion of the spectrum. However, the two samples are very different in the 400 to 520 nm or blue range of the spectrum. While Sample 1 has the ability to reflect three times the amount of blue light as Sample 2, the incandescent light source has very little blue light available to reflect. Both samples only reflect a small amount of blue light and the colors appear the same. However, the daylight illumination has an abundance of light available in the blue spectral range. Under the daylight illuminant, Sample 1 reflects much more blue light than Sample 2 and therefore appears more blue than Sample 2. It is easy to see why choosing the proper illuminant can be critical to achieving quality color results in your product.

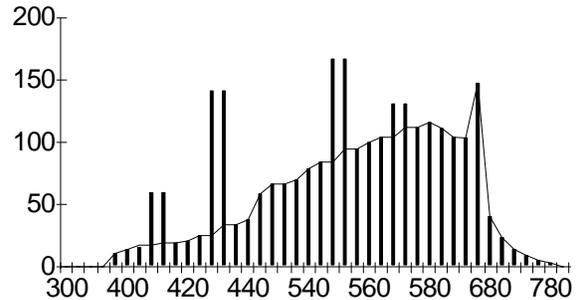
Choosing an Illuminant

So how does one use this information to choose a standard illuminant when measuring color with a spectrophotometer? The answer is actually very simple. Choose the illuminant closest to where you make your money. In other words, choose a standard illuminant that best represents the source that will light your product where it is sold. If your product is displayed outdoors, choose a few of the daylight illuminants to represent sunlight at different times of the day. If you sell your product at a department store, choose a representative fluorescent illuminant. The best way to determine what illuminant to use is to find out exactly what source your product will be exposed to at the point of sale. If you can find out the exact brand and type of bulb that will be used at the point of purchase, you can then obtain the spectral power distribution curves of that source from the bulb manufacturer. Now simply pick an illuminant whose spectral power curve most closely resembles the spectral power curve of the source. For example; if the lighting used in one particular store that sells my product is GE[®] Cool White fluorescent, the first step would be to obtain the spectral power distribution curves from General Electric. Next we would look at the spectral power distributions of the available standard illuminants.

GE Actual Cool White Source*



CIE F2 Standard Illuminant



* data was approximated (GE Lighting)

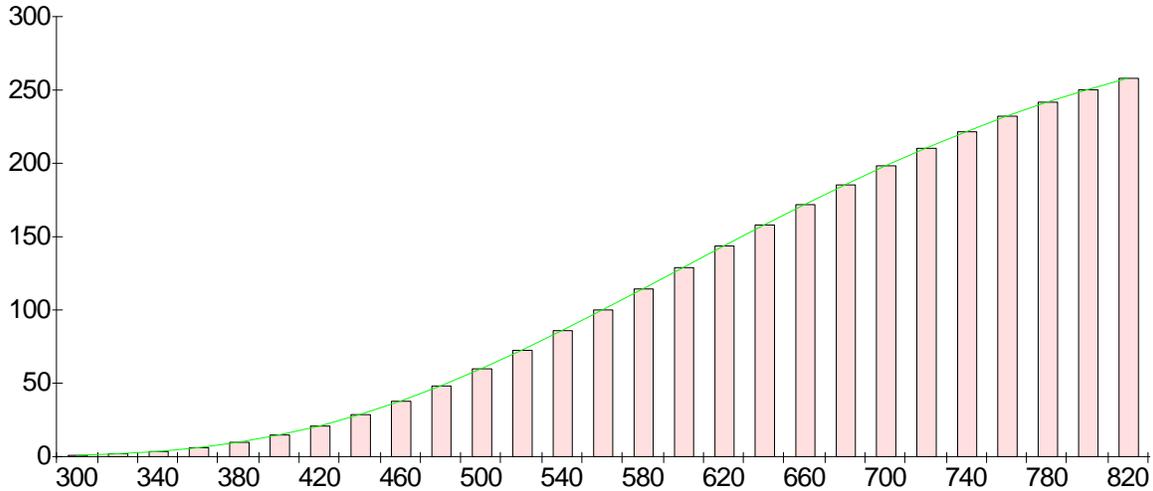
The F2 standard illuminant was based on the cool white variety of fluorescent bulbs available on the market. Comparing the two relative spectral power curves, we see that the GE[®] Cool White source is not an exact match to the F2 standard illuminant, but measuring under the F2 illuminant will give a good approximation of the results under the GE bulb. This illuminant would be an adequate choice for making your color measurements.

This solution however, is not always applicable to all situations. Not every bulb manufacturer makes spectral power data easily obtainable, and certain products are displayed under an infinite amount of light sources. In this situation we must look to the product first. The problem of metamerism is most common when a product is constructed of different materials, such as the plastic, cloth and metal in an office chair. If we insure that the different dyes and pigments are not metameric to each other, we have won most of the battle. Because we know the product will appear as one single color in all lighting conditions, we can now choose any standard to take our color measurements. As long as we use this same illuminant when measuring the color of our product, we will ensure color consistency.

Appendix

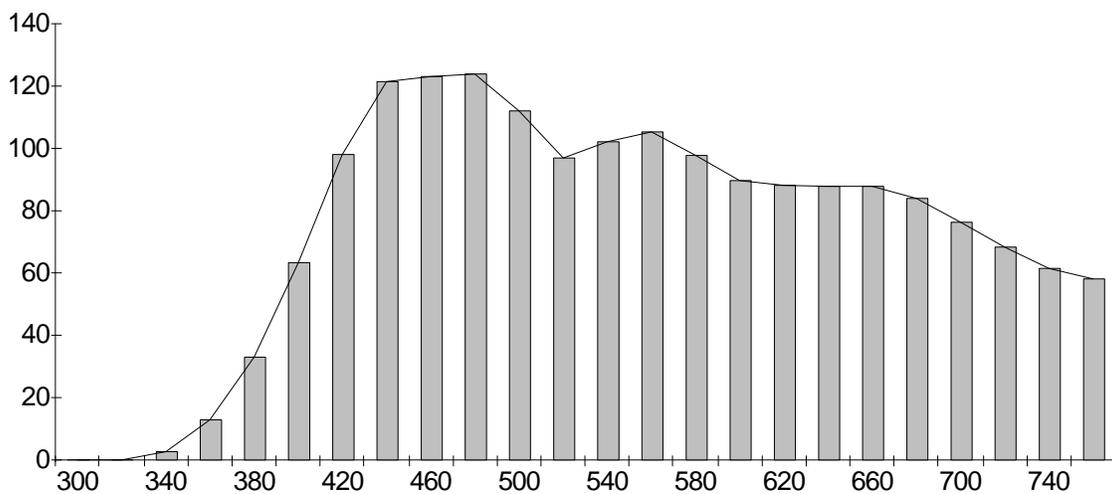
This appendix displays the relative spectral power distributions for standard illuminants A, C, D50, D65, F2, F7, and F11. All data was normalized to a relative power of 100 at 560 nanometers. Data was obtained and cross-referenced from multiple sources specifying CIE standard illuminant data. Some data points were approximated or interpolated.

Illuminant A - Incandescent



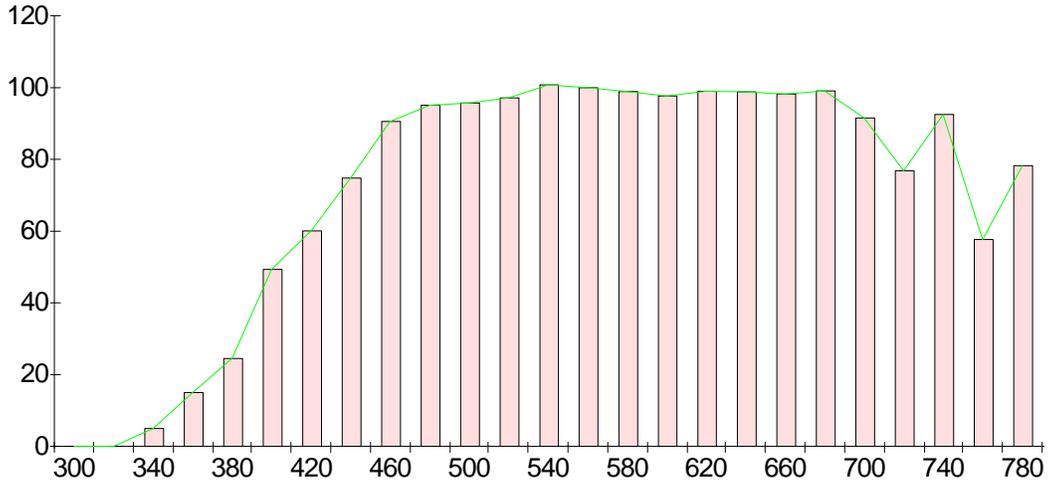
The CIE standard illuminant A was first recommended in 1931 to represent incandescent light sources with an approximate color temperature of 2856 degrees Kelvin.

Illuminant C - Daylight



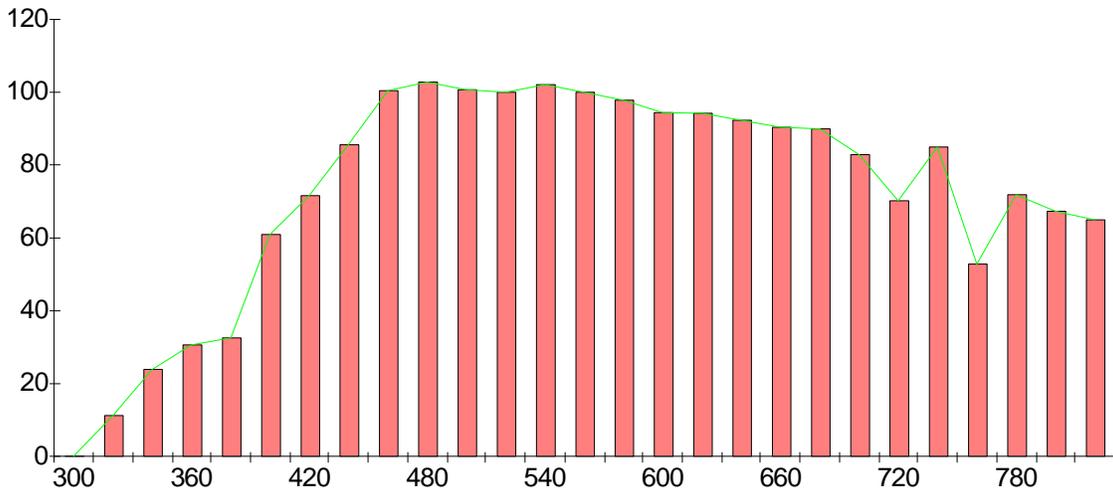
CIE standard illuminant C was recommended in 1931 to represent average daylight with a color temperature of 6774 degrees Kelvin.

Illuminant D50 - Daylight @ 5000K



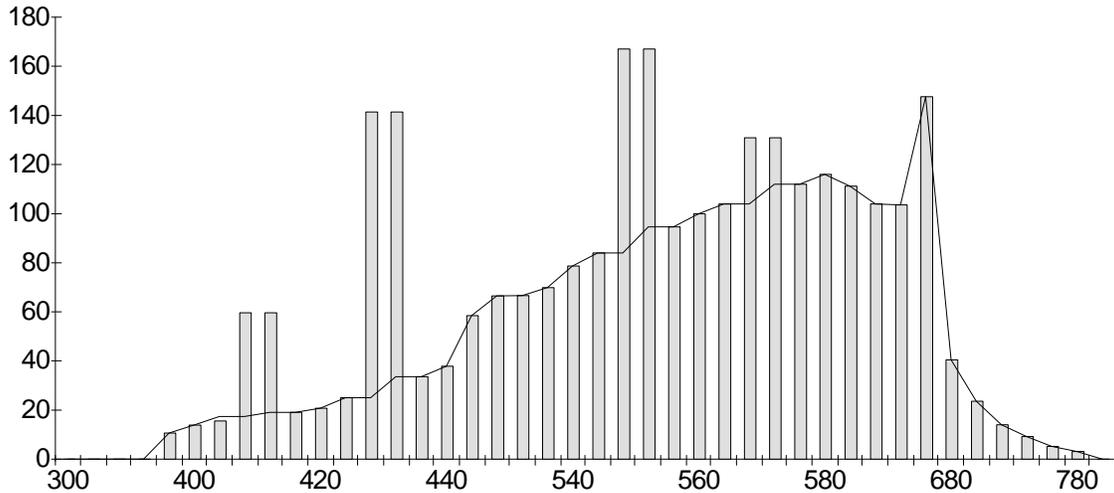
CIE standard illuminant D50 is correlated color temperature D illuminant which is calculated from the standard illuminant D65. This standard illuminant represents Daylight at 5000 degrees Kelvin and is the ANSI standard illuminant used in the graphic arts industry.

Illuminant D65



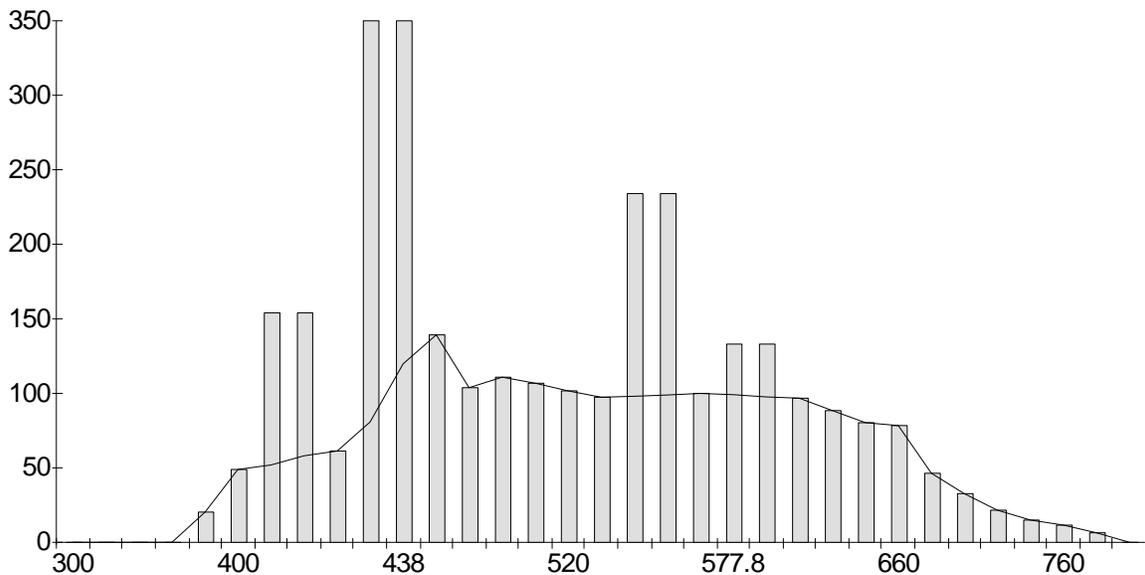
The CIE standard illuminant D65 represents daylight at approximately 6500 degrees Kelvin. This standard and the method for calculating different correlating color temperatures was introduced in 1964.

Illuminant F2 - Cool White



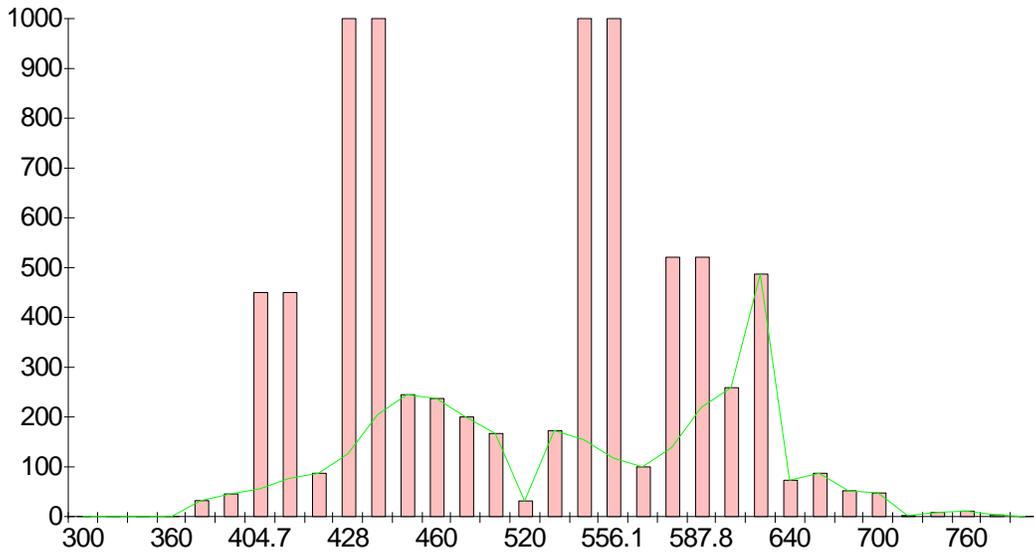
The CIE standard illuminant F2 represents the typical cool white fluorescent source. The spikes which protrude above the continuous graph in the fluorescent illuminants represent the power measurements at the principle mercury emission lines.

Illuminant F7 - Broad Band Daylight



The CIE standard Illuminant F7 represents a broad band daylight fluorescent source. Examples of this type of source are the GE[®] and Philips[®] Daylight fluorescent sources.

Illuminant F11 - Narrow Band White



The CIE standard illuminant F11 represents a narrow band white fluorescent source. Note the spikes at approximately 430 nm and 550 nm peak at approximate power values of 1200 and 2500 respectively. Sources similar to this illuminant are the Philips[®] F40AX41 and TL841, as well as the GE[®] SPX41.

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