Really Understanding Daylight Simulation

Scope:

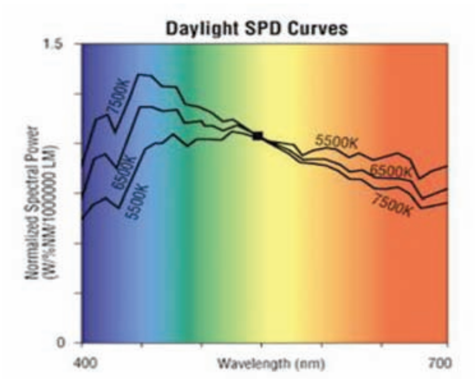
It is commonly known that natural daylight is the only light source that will not distort our color judgments. Any well managed color program specifies a form of daylight as the light source of choice for making accurate color evaluations.

The problem using natural daylight is that its appearance and spectral characteristics can change dramatically from day to day, season to season and even during a single day. Morning sunrise can have a very red hue. An overcast day can appear gray and drab and a crystal clear bright sky can appear very blue. Changes in daylight quality are effected by atmospheric conditions, the change of seasons, time of day, pollution, altitude and even whether you are in a city or in the country. Another major problem with natural daylight is that it does not exist at night. All of these factors affect how well we can accurately evaluate the color quality of a product. For these reasons, the use artificial or simulated daylight has become the standardized and accepted method for making accurate color quality evaluations. This paper reviews some of the technical terms and issues related to simulating daylight for color evaluation requirements. Through this paper we hope to educate end users on the technology employed in lighting and The Macbeth SpectraLight products. This paper will also address various negative selling techniques and some desperate allegations being made by manufacturers of fluorescent daylight products.

Quality of Daylight:

Natural daylight has been thoroughly defined by the CIE, International Commission on Illumination, as having a specific Correlated Color Temperature, Chromaticities and Spectral Power Distribution. The ability to simulate all of these color characteristics, not just some of them, is critical in providing an accurate daylight simulation. Below is a graphic representation of the relative energies, called Spectral Power Distributions found in different phases of Daylight. For color evaluation we should be most concerned with energy content of a light source from approximately 400 to 700nm. This range represents the human sensitivity to light energy. The energy content of a light source determines its ability to render colors accurately. Although this fact is probably very well understood, it is rapidly forgotten because its measurement requires highly specialized equipment known as a Spectroradiometer.

x-rite right on color

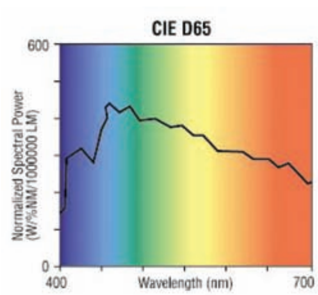


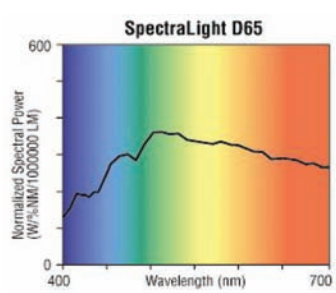
Spectral Power Distribution, SPD:

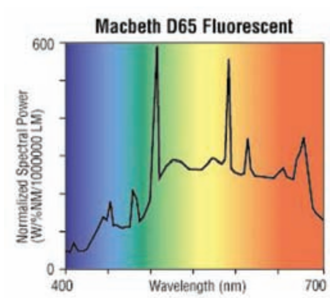
This graphic shows ideal curves for three daylight standard illuminants. D55 is representative of Noon Sky Daylight, D65 also known as Average Daylight and D75 or North Sky Daylight. Although the curves are uneven, all of the colors of the spectrum are present in relatively equal proportions. All three phases of daylight have very similar curves indicating very similar spectral content. Because of the very similar spectral content, sets of colors that match under one phase of daylight will also match under the other phases of daylight.

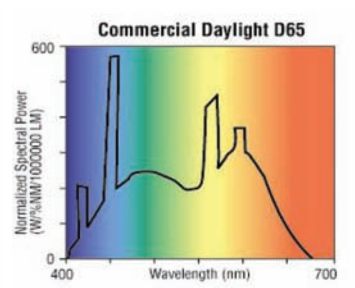
Daylight Simulation:

Simulated daylight can be achieved through many different lighting methods. They include, Wide Band Fluorescent (Commercial Daylight), 7-Phosphor Wide Band Fluorescent (Macbeth) and Filtered Tungsten Halogen as found in our SpectraLight products. All of these lighting technologies can produce light energy with a correlated color temperature and chromaticities equal to the phase of daylight it is supposed to simulate. However, with closer inspection of their energy content, it is obvious that they are not very similar. The following graphs show typical simulations for D65 daylight at 6500K. Directional daylight sources are used to accurately simulate daylight and also provide the effect of the Sun on directional products. Fluorescent lamps provide only diffuse illumination and are not recommended for evaluating objects with directional appearance characteristics like jewelry, metallics, pearlescents, or high gloss plastics and shinny fabrics.

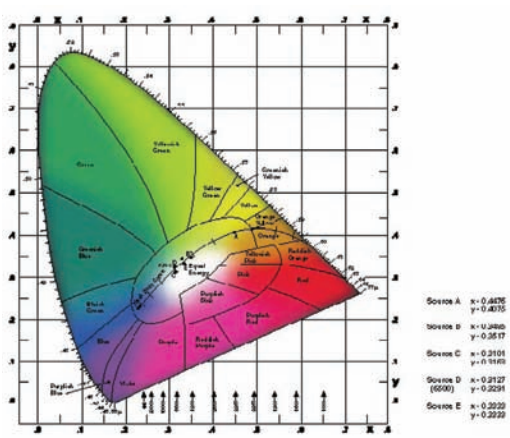








It should be obvious from these SPD curves that the closest simulation to the CIE D65 standard is the SpectraLight D65. The SpectraLight provides daylight using proprietary glass filters, an elaborate power system and specially selected Tungsten Halogen lamps to provide an extremely accurate daylight simulation.



Correlated Color Temperature (CCT)

All of these sources in the figure above have the same Apparent or Correlated Color Temperature of 6500K. This identifies a basic problem in the use of color temperature alone in the specification of a light source. A color temperature designation for a light source identifies the appearance of the light source as compared to the 1931 CIE Diagram. This is based on work done in 1900 by Max Plank, a German Physicist. The chromaticities or x and y coordinates for a light source are plotted and correlated to a tolerance acceptable for a specific color temperature.

There can be an infinite number of chromaticity coordinates all providing the same color temperature. This further explains why we can have different lamp technologies possessing substantially different Spectral Power Distributions all having the same Correlated Color Temperatures.

Color Rendering Index (CRI)

CRI, color rendering index alone is a poor indication of the performance of a fluorescent lamp. CRI for lamps below 5000K use an Incandescent lamp as its reference. An incandescent or tungsten lamp has a CRI of 100 but it is obvious that this source has very little blue energy and an over abundance of yellow orange and red energy. These sources are known to be not very good for judging accurate color but have a CRI of 100. For this reason a high CRI identifies that the lamps color performance is only as good as the reference source and may not be very good in rendering colors.

CIE Assessment Method (Publication 51)

This method tests Spectral Quality of Daylight Simulators for Visual Appraisals and Instrumental Measurements. It includes Test Methods for D50, D55, D65 and D75. It uses 5 Virtual Metamer Sets for Visible and 3 for Ultraviolet. Quality Grades are based on Delta E or total color difference of the metameric sets. This method is more accurate than CRI for evaluating the quality of a Daylight Simulation. (Note: A/C would mean an A in the visible region and a C in the UV)

Quality Grade	Metamerism Index	
	CIELAB	CIELUV
A	< 0.25	< 0.32
B	0.25 to 0.50	0.32 to 0.65
C	0.50 to 1.00	0.65 to 1.30
D	1.00 to 2.00	1.30 to 2.60
E	> 2.00	> 2.60

Standards:

The use of a good quality daylight simulation is not only a good idea but, in many industries in is an absolute requirement. This is further evidenced by the number of written, corporate, national and international visual color Standards requiring an accurate daylight simulation including ASTM D1729, SAE J 361, BS950, ISO 3664 and AATCC Procedure 9.

The following graphic shows the daylight requirements of several different standards.

ASTM D1729
"Visual Evaluation of Color Differences of Opaque Materials"
(BCrequired)
SAE J361 2000
"Visual Evaluation of Interior and Exterior Trim"
(rating of B and should be A)
ISO 3664 - 2000
"Viewing conditions for Graphic Technologies and Photography"
(C or better and should be B)
BS 950 Part 1
(BD required)
AATCC Evaluation Procedure 9
"Visual Assessment of Color Difference of Textiles"
(BC or Better)

Certification and Calibration:

It is true that annual certification and calibration are recommended for SpectraLight products. During this procedure the unit is measured with a traceable spectroradiometer for light levels, color temperature, spectral power distribution and chromaticity coordinates for all sources. The unit is thoroughly cleaned and all of the operating voltages are measured with a true RMS meter and set for proper operation. Just changing lamps in any system is inadequate. The final color rendering capability of a viewing booth, fixture or a room is the result of all the components. It is the effect of the diffuser, the reflective quality of the walls the cleanliness of the reflectors and filters and the performance of the ballast and power supply. This fact is critical in designing a lighting system because although the initial color temperature might be correct the effect of the fixture housing my shift the spectral characteristics.

Replacing just the lamps and assuming the unit is certified, just doesn't work. It would be like your Department of Motor Vehicles sending you an inspection sticker in the mail without you having the emissions, brakes, tires, lights and horn checked. Doesn't this sound foolish?

Lamp Stability and Voltage Regulation:

The stability of a lamp whether it is a fluorescent or tungsten lamp is the function of the current supplied to the lamp. In fluorescent fixtures, the use of a ballast or commonly known as a constant wattage auto transformer, is required to start the lamps at voltages in excess of 800 volts. Once the arc is struck the ballast maintain the proper operating voltage to the lamp. Every time the fluorescent is turned on and off the same event occurs. For this reason it is far better to leave fluorescents on rather then turn them on and off. Typical household tungsten or incandescent lamps are dependent on a constant current to maintain their color temperature and light output. A reduction in the voltage to a tungsten lamp will decrease light output, decrease color temperature and increase lamp life. The opposite is also true. An increase in voltage to a tungsten lamp will increase light output, increase color temperature and decrease lamp life. This is why we can use a simple rheostat or dimmer and change the light output and intensity of our home, store and restaurant lighting. In the SpectraLight products, we employ a very elaborate regulating power supply. Once calibrated at the factory, this system not only maintains constant power to the lamps but, will also correct for high or low voltage as a function or electrical load in a factory or office environment. Most SpectraLight users are very familiar with this feature because on start up this product checks for proper line voltage prior to start up. This system will also notify the user if the voltage being supplied to the unit changes below acceptable limits during operation.

This feature maintains constant color temperature, light output and Spectral Power over the life of the system.

Lamp Life and Usable Life:

In many instances lamp life and usable life are confused. Although the tungsten halogen lamp used in the SpectraLight III product has a relatively short average lamp life of 400 hours, the spectral characteristics remain very constant over its life. This is further proven by the number of SpectraLight products that remain in calibration and can be recertified with out any lamp change year after year.

Inherent to fluorescent lamps, they have a very high lamp life of 18,000 to 20,000 hours. This is not the usable life of this lamp. The color temperature and the light output of a fluorescent lamp change drastically over time. Studies of fluorescent lamps show as much as a 30% reduction in light output and as much as a 400K shift in color temperature over its life. The phosphors used in a fluorescent lamp, degrade over time. This degradation reduces the efficiency and also cause a change in the spectrum produced. The first color to change is in the red and orange region of the spectrum. The lamps red content is reduced, light output is reduced and the ultraviolet content is increased. This is the reason daylight fluorescent lamps must be changed every 3000 to 5000 hours at a minimum to maintain a reasonable light level, color temperature and spectral output.

Ultraviolet:

The SpectraLight products include two levels of ultraviolet energy. One setting provides approximately 5 times the amount of near UV found in actual daylight. This feature is designed to exaggerate the effects of optical brighteners or whitening agents, fluorescent dyes and pigments. When daylight is selected the amount of UV is equal to the level of near UV found in actual daylight. These are filtered lamps and only provide long wave, near UV, commonly known as Black Light Blue energy to the viewing booth. This energy is from 325nm and higher.

The glass works as a filter to eliminate harmful short wave radiation. Short wave radiation can cause retina damage, sunburn and skin cancer. Adding a UV component to a fluorescent lamp is not only impractical it is very dangerous. A fluorescent lamps changes very rapidly over time. As the phosphors degradate or get used up they allow more UV to pass through the envelope of the lamp. By not filtering this short wave energy, not only will the UV content change but harmful shortwave radiation will be flooding the viewing area and of course the observer.

Solarization:

Glass or Filter Solarization is defined by the Society of Optical Engineers as: " A phenomenon which occurs when certain types of colorless, transparent glass are exposed continuously to the sunlight. This exposed glass develops a pink or violet color. When bottles and fragments have this color they are usually referred to as "desert glass". However scientists and experts prefer the term solarized glass."

Solarization of glass can also occur when glass containing manganese oxide are exposed to ultraviolet light for long periods of time, causing the manganese to become photo-oxidized. This converts the substance back into an oxidized form which, even in rather low concentrations, imparts a pink or violet color to glass. The ultraviolet rays of the sun can promote this process over a matter of a few years or decades, thus accounting for the color of desert glass.

The fact is that Solarization can only occur if iron or manganese oxide impurities exist in the glass and the glass must be exposed for extended periods of time, like years and decades to very high intensity short wave UV and or X-ray radiation. Solarization is common in laser technology where clear glass filters are exposed to extremely high levels of short wave radiation for long periods of time.

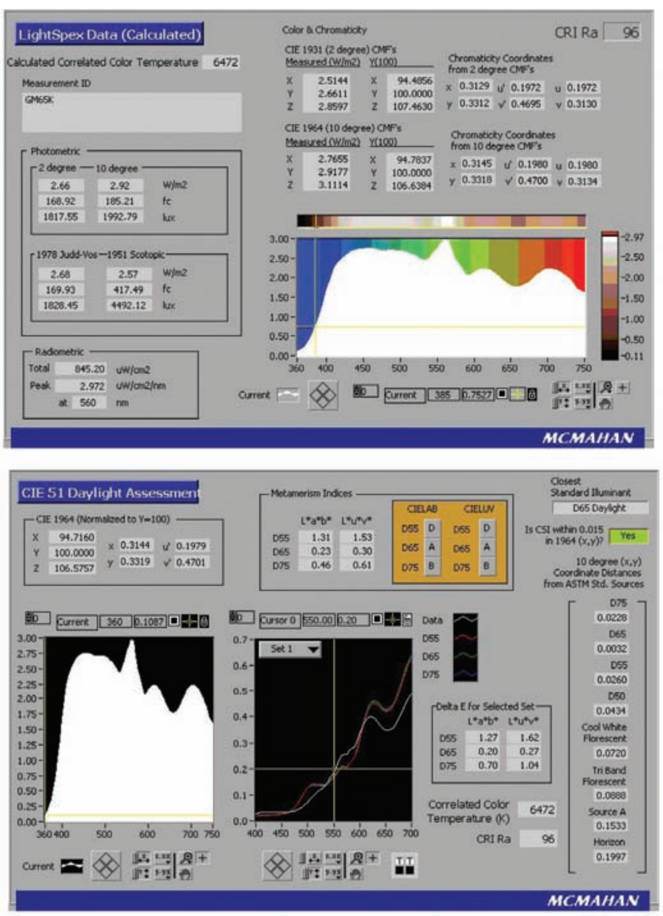
It is common knowledge and fact admitted by our competitors, that a Tungsten Halogen light source does not contain a large UV component so, Solarization does not happen with the SpectraLight filters. This fact is further evidenced by the thousands of SpectraLight products sold since 1976. Many of these units are still in service. They still maintain their original calibration and certification capabilities. The discoloration of filters is typically dirt deposited on the filters from a dusty environment which is baked on the filter from the heat of the lamp. We have found that a simple cleaning of the filters with a mild detergent removes this terrible "Solarization".

Conclusion:

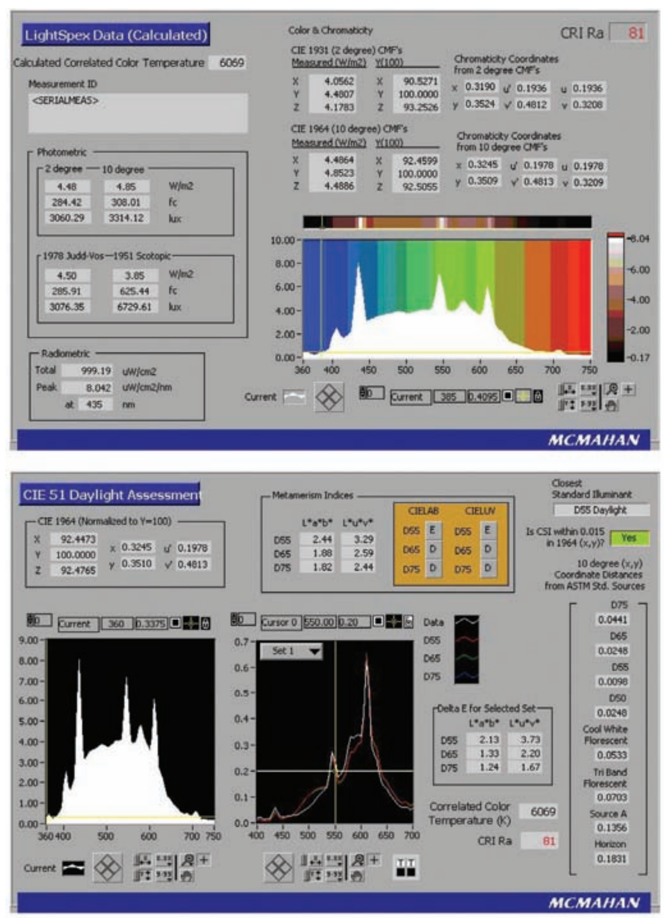
The real issues here are not the accuracy or performance of the Filtered Tungsten Daylight Simulation but the amount of market share that Macbeth Lighting has because of this technology. The SpectraLight product is written into hundreds of corporate, national and international standards. It provides uncompromised, accurate daylight simulation and product performance all of which is well documented and appreciated by the tens of thousands end users.

We leave it to the reader to make their own conclusion. The following graphics show a 10 year old SpectraLight and a competitive fluorescent aylight product with less then 2000 hours. Which one would you like to be making critical, profit related color decisions with.

Macbeth 10 year old SpectraLight with 96 CRI and CIE "A" Rating



Competitors Fluorescent at approximately 2000 hours with CRI of 81 and CIE Assessment of D



X-RITE WORLD HEADQUARTERS

Grand Rapids, Michigan USA • (800) 248-9748 • +1 616 803 2100

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