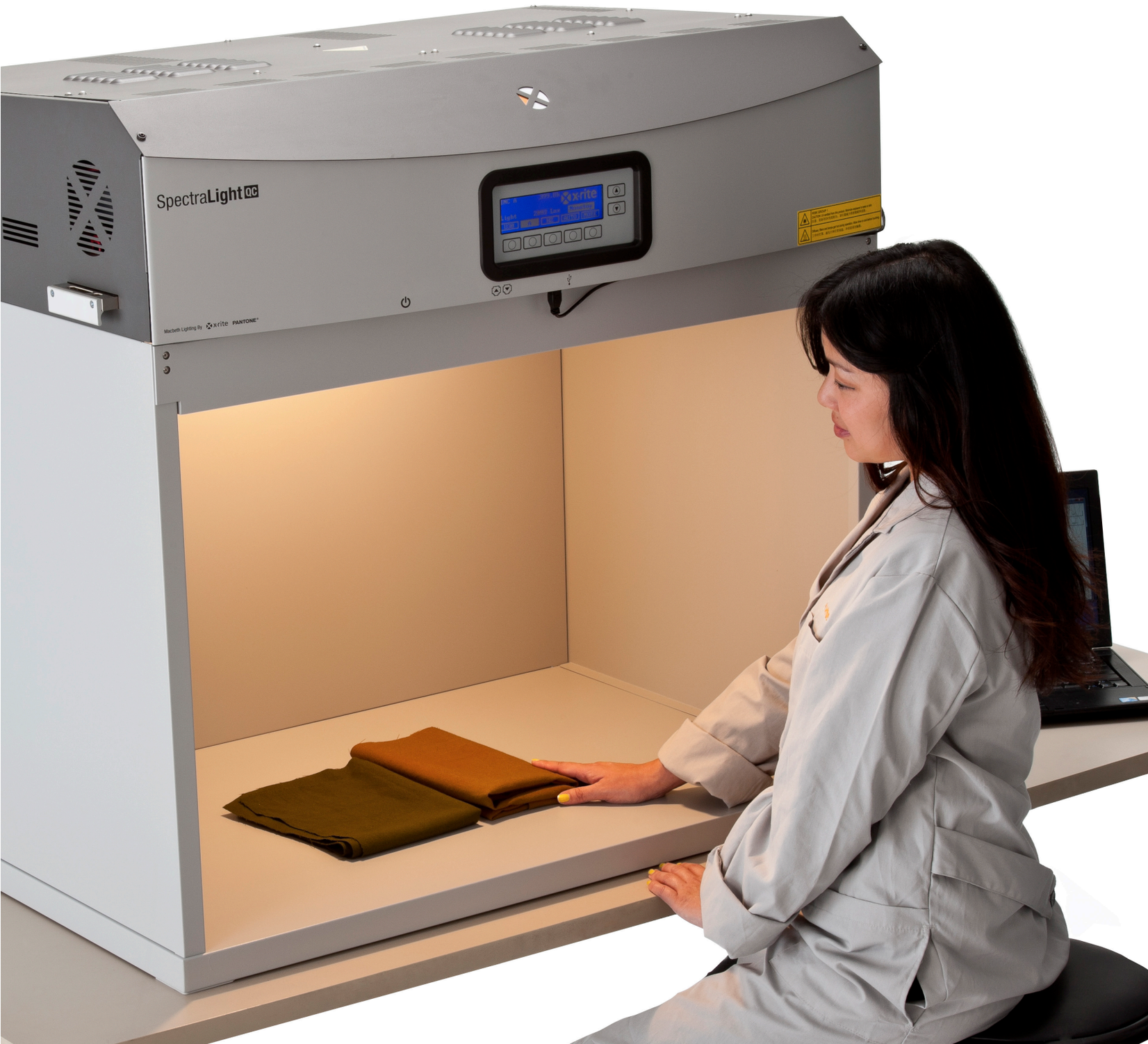
x-rite
PANTONE®

Illumination Guide

Choosing the right lighting to evaluate products



Illumination Guide

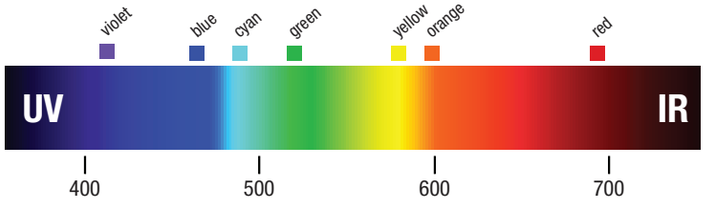
Companies that are concerned with the color quality of their products may use sophisticated instruments to make sure their processes adhere to tight numerical specifications, but they can easily overlook the need to do proper visual evaluation of colors and color differences as part of their quality control process.

While readings from a spectrophotometer may show that a process is running within specification, a company could still be turning out unsatisfactory parts if the product color isn't what the customer expected when goods are arranged on store shelves. At some point in the supply chain, people need to visually evaluate how the colors of products look when they are placed together under approximately the same illumination as where they are sold or used.

By taking the initiative, companies can achieve an advantage over their competitors by implementing best practices of proper illumination and procedures in their visual evaluations.

All whites are not the same

Since we can't see the components of white light without the help of a prism or raindrops that create a rainbow, we tend to assume that all white light is roughly the same. Nothing could be further from the truth.



To a great extent, the process used to produce white light gives an indication of the intensity of colors of the visible spectrum — sometimes defined as red, orange, yellow, green, blue, indigo, and violet — that make up the white light. If that process happens to be a thermonuclear reaction that takes place in our sun, then the white light has all of the wavelengths of the visible spectrum, in varying proportions. Another process used to produce white light — a glowing tungsten filament in an incandescent bulb — does not generate as much light energy in the blue range of the spectrum as does sunshine, making it difficult for us to judge small color differences of products that are dark blue.

We perceive the color of an object differently depending on the relative amount of each color of light that combines to makes the white light we observe. An apple appears red to us because its skin absorbs most of the colors of the visible spectrum except red, and reflects red light to our eyes. That apple could appear a vibrant red under a white light source that is rich in red light or a dull red under a white light source that is somewhat deficient of red light. We often do not notice this difference in our perception of colors based on illumination due to color constancy. (Our visual system is adapted to adjust the perceived color of an object for the color of the incident light. Therefore, a white piece of paper seems to be the same color if we walk from our desk to a window. Poor color memory contributes to our experience of color constancy, too.)

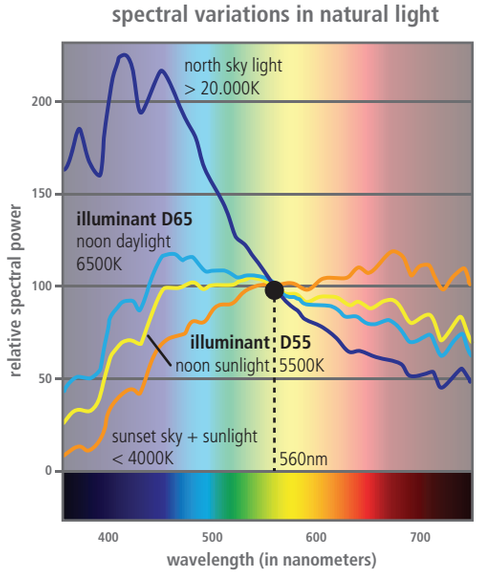
Our world is geared to accept daylight as the most commonly accepted standard because human eyes are adapted to view colors under light from the sun. Daylight renders a great variety of colors, makes it easy to distinguish between subtle shades of colors, and has the right proportions of wavelengths for natural appearance. And, people have been viewing objects in daylight longer than under any other light source.

But even daylight isn't constant

Best practices demand that we use the best standards that are measurable and constant, so it would seem that natural sunlight would be the logical choice for making accurate color evaluations.

But aside from the fact that it isn't always convenient and available, natural daylight has a constantly changing proportion of visible colors. For instance, natural daylight's intensity of red light compared with blue light will change dramatically depending on the time of day, the weather, season of the year, altitude and geographic location, and air quality.

The light from a morning sunrise on clear day is weighted with yellow and red wavelengths, but the curve shifts more strongly to the blue side of the spectrum by noon. Daylight in Sao Paulo is markedly different than it is in Shanghai at the same day and time, even if the weather conditions are identical in both cities.

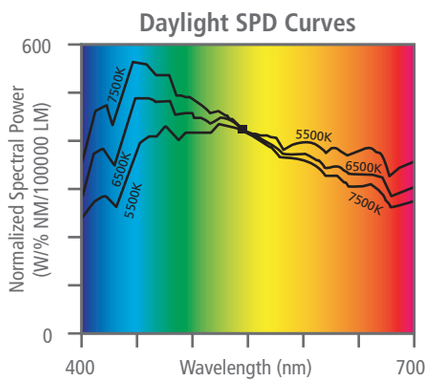


Since daylight is neither constant nor accessible 24 hours a day, manufacturers need the next best thing: environments that accurately simulate a standardized daylight (based on specific conditions such as times of the day and latitudes) to act as a common standard along the supply chain. But companies need more than just daylight simulations, since consumers often make their purchasing decisions or use products under artificial lighting, such as fluorescent , halogen and incandescent lamps.

Also, light booths often contain a near ultraviolet (UV) source of light that is invisible to humans, but that causes objects under this form of illumination to glow as the UV rays are converted by the samples to visible light. Visual assessment with UV helps manufacturers determine how the colors of certain products containing optical brighteners will be perceived, since these object are often used or sold in environments with UV energy as part of the overall illumination.

To arrive at illumination standards that everyone can use the international organization Commission Internationale de l'Eclariage (CIE) created systematic definitions of white light from particular sources, including the numerical amount of energy of each color described as wavelength. These values are known as spectral power distributions (SPDs) and may be graphed or listed as tabular data. When they are graphed, the curves show the wavelengths of visible light — roughly from 380 to 830 nanometer (nm) — on the horizontal axis and the amount of energy of those wavelengths on the vertical axis.

There are two types of SPD curves: one that is developed by taking measurements from an actual light source and another called an illuminant that is a mathematical model of an ideal light source. The CIE created the system of illuminants to define constant standards by which mathematical comparisons of actual measurements could be made. For instance, CIE Standard Illuminant D65 defines an SPD curve that theoretically corresponds to mid-day light in northern and western Europe.



CIE standard illuminants are tables of numbers that are used by instrumental color measurement systems to determine colorimetric values to describe the color of an object under specified illuminants. Physical light sources are sometimes measured in order to provide data for the same task, but these measurements aren't international standards. The benefit of international standards is that different users in different companies around the world can share common practices when they follow a standard. However, measurements of specific light sources or lighting environments can also be useful to assess the color of an object in under non-standard lighting conditions.

There are a number of daylight illuminants based on measurement of the sun's SPD when it reaches certain positions in the sky. For example, the graphic arts industry usually uses the D50 illuminant that describes noon sky daylight. Textiles and other industries often use D65. The "horizon" (HOR) illuminant simulates early morning sunrise or late afternoon sunset.

The CIE also has created standard illuminants for tungsten, halogen, and multiple fluorescent light sources. For instance, illuminant F2 is the mathematical representation of lighting from cool white fluorescent bulbs.

The gold standard

Manufacturers of standardized lighting cabinets provide sources which simulate the desired CIE illuminants or sources as closely as possible. These sources often include: daylight D50, D65, D75, daylight horizon at 2300K, incandescent, cool white fluorescent, filtered near ultraviolet, U30 (3000K), U35 (3500K) and TL84.

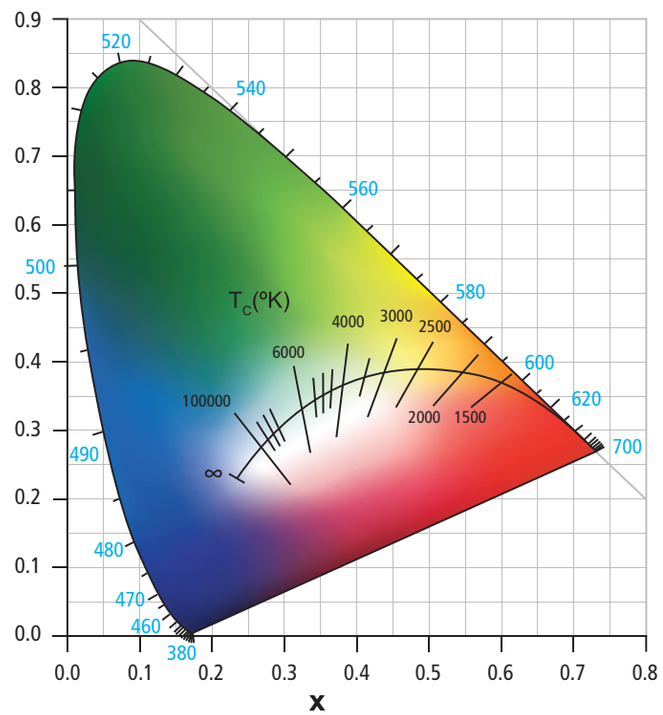
For instance, X-Rite's filtered tungsten/halogen SpectraLight is an extremely close match to natural daylight. When one compares the SPD curve of its D65 SpectraLight to that of the D65 Illuminant, there aren't significant energy differences between the two. CIE Publication S 012 describes the method for quantitatively measuring the ability of a source to simulate D65. Lightboxes with the best D65 simulation are rated "A", followed by "B", then "C", "D", "E". This method is called the Quality Grade Metamerism Index, which may be included in the specifications that come with a lamp. The index uses precise physical samples to assess the closeness of an illumination system to D65.

Metamerism is an optical phenomenon in which a pair of samples matches in color under one light source, but do not match under another light source. The index uses quality grades that are based on Delta E* or total color difference of the metameric sets, with A being the smallest difference and E being a large difference for industrial applications. A notation of A/C would

mean an A grade in the visible region and a C grade in the UV region. The best practice is to use a standardized lighting environment that provides A simulation in visible range and B in UV range. Fluorescent daylight lamps usually have grades of "B" or "C", but filtered incandescent sources achieve "A" or "B".

Correlated color temperature gives limited guidance

When a manufacturer asks a customer to specify the illumination source for color evaluation, the customer may provide the correlated color temperature of the light source. As its name suggests, the color temperature defines the color of a black body — imagine an iron rod — as it is being heated to thousands of degrees Kelvin (K). If you apply the flame of an acetylene torch to the iron rod, it first glows dull red, then bright red, then yellow, and finally approaches bluish white.



The red color of the iron rod at approximately 2300K is about the same color as the setting sun. The glow of the iron rod at about 2800 - 2900K approximates the color of a typical incandescent bulb. If you were able to heat the iron rod to 5000K or above without it melting, the rod would glow with a light that approximates direct sunlight. Daylight lamps generally have color temperatures between, 5000K and 7500K.

Light sources with low color temperatures generally have a higher proportion of red and yellow wavelengths, while light sources with higher color temperatures generally have higher proportions of blue light.

But the color of an object illuminated by noon daylight measured at 5000K still may appear quite differently when it is illuminated by an artificial light source rated at 5000K. Taken by itself, the color temperature can be deceiving when it comes to color perception because it is only a partial description of the lamp. The SPD is a much more complete description of a light source. Two lamps with the same color temperature may have very different SPDs, and therefore may result in very different visual experiences for the same object.

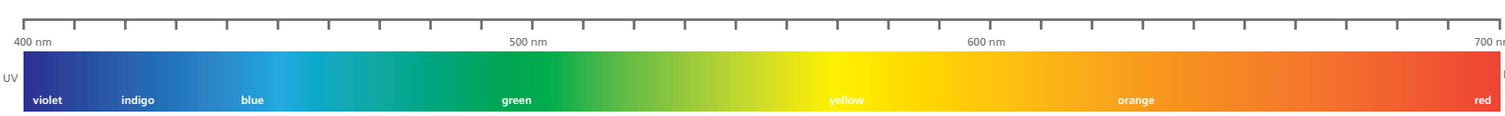
The color temperature listing gives only a very rough estimate of the proportions of visible colors that are contained in the white light — certainly not anywhere near the precision to predict how colors will be perceived.

Color Rendering Index helps with predicting color perception

When asked what light source to use for color evaluation, a customer may also respond by giving the Color Rendering Index, a quantitative measurement of the ability of a light source to reproduce the color of an object faithfully in comparison with a standard source. CRI is expressed in a value of zero to 100, where zero is no color rendering and 100 is perfect color rendering, compared with a standard light source. The reference light source for lamps below 5000K is Illuminant A, which is incandescent. Incandescent light has very little blue energy and an overabundance of yellow, orange and red energy – not the best choice for accurate color evaluation. Yet this light source has a CRI of 100.

The reference illuminant for sources with color temperatures above 5000K is D65, which is a much bluer and more full-spectrum illuminant. Therefore, any sources with color temperature above 5000 are compared to D65 for CRI, meaning that a source with CRI near 100 renders object colors nearly as well as D65 does.

Knowing that a lamp has a CRI of 90 only tells us that the lamp renders colors 90% as well as a standard source, but does not tell us whether the standard source is incandescent or daylight. Like color temperature, CRI is an incomplete description of a light source.



For instance, a high pressure sodium lamp may have a CRI of only 15, making the lamp a poor choice for evaluating color. A common light source for office space may have a CRI in the 60s, but industry specifies a CRI of 90 or better for light sources used for color evaluation purposes.

The CRI is a relative index, meaning the lamp performance is relative to a reference light source, which is assigned the highest rating of 100. Since the CRI is not an absolute indicator of lamp performance, it gives an incomplete picture of how colors will appear under light sources that simulate daylight.

	Color Temp	CRI
Cool White Fluorescent	3400	65
Xenon	5920	94
Mercury Vapor	5900	17
100-watt Incandescent	2856	100
Viewing Booth	5000	94
Typical Summer Sky	6500	100

Even lamps having the same CRI may not render colors the same. Two lamps could have the same CRI of 50, but one lamp could be good at showing orange and blue and poor at rendering green and red, while the other may be exactly the opposite.

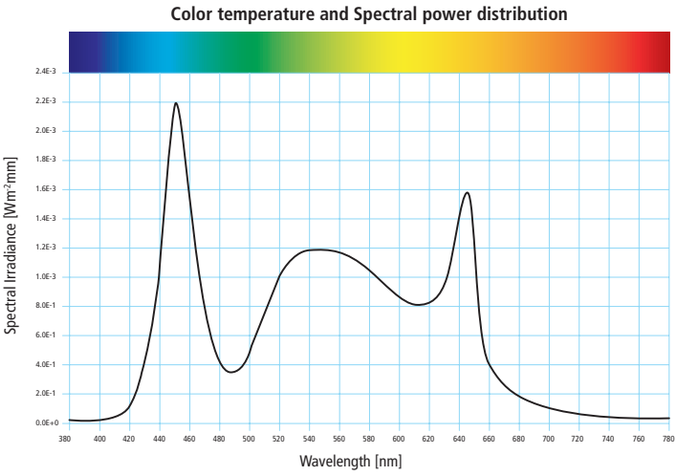
Watch the lux

Companies needing to implement robust visual evaluation also should ask their customers about the quantity of incident light used for visual evaluation of color.

Best practices should address the amount of light used to illuminate light, medium, and dark colored samples for color evaluation. For instance, one standard states that the illumination may be as low as 50 foot-candles or 540 lux for viewing very light materials and as high as 200 foot-candles or 2150 lux for viewing very dark materials.

In most lightbooths, it is not possible to adjust the quantity of light, other than by holding the samples closer or farther away from the source. This practice is useful for some applications, but not for others. (For example, we cannot hold the color sample and standard outside of the standardized light booth in order to reduce the quantity of light without violating every other tenet of Best Practices.)

Both lux and foot-candle are measurements of the intensity of light on a defined area. One lux is defined as one lumen uniformly distributed over an area of one square meter. A typical office may have illuminations in the 320 to 500 lux range, while direct sunlight on a clear day may be measured at more than 100,000 lux. A foot-candle is defined as one lumen uniformly distributed over an area of one square foot, with one foot-candle equaling the power of approximately 10.8 lux.



Companies can use a light meter to determine the lux or foot-candles that are falling on a sample and then adjust test lighting accordingly. X-Rite's SpectraLight QC standardized lighting environment booth allows users to adjust lux settings. **This capability to monitor, adjust and control the quantity of light at the sample surface permits greater standardization of visual color programs in global supply chains between users and locations.**

Tying it all together

Given all the different ways that lamp makers can describe light sources, manufacturers can get somewhat frustrated that there aren't standards to follow that recommend guidelines on the SPD curve, appropriate color temperature, CRI, and other parameters.

Thankfully, there are. ISO 3664:2009(E) and ISO 23603:2005(E), developed by the International Organization for Standardization (ISO) in Geneva, Switzerland, set out generally accepted practices that yield reliable ways to illuminate samples for visual color evaluation. ISO 3664 was developed to assist the photographic and graphics industry, and ISO 23603 was developed largely for manufacturers. Both standards can be used by industry as a solid starting point for reliable illumination.

In general, X-Rite recommends use of a filtered tungsten halogen light source D65 with a CRI rating of more than 90 to achieve a reliable simulation of average daylight. X-Rite also recommends Daylight performance of A/B (visible/UV) to minimum B/B rated daylight according to CIE ISO SO 12 E Metamerism Index rating. To eliminate variations in light emitted from filtered tungsten halogen bulbs that can be caused by variations in line voltages, X-Rite includes precision power regulators with its SpectraLight viewing booths.

Additionally, filtered tungsten halogen technology offers more flexibility for evaluating a wider variety of samples. It provides diffuse illumination, making it better suited for evaluating directional samples such as precious gems and metals; metallic, pearlescent or glossy paint, and plastic samples; and high sheen fabrics or directional textiles.

So, when your customer or vendor tells you about a new source to be used for evaluating color, remember to ask which CIE illuminant or source (defined by SPD) should be used for visual evaluation. Color temperature, color rendering index, and generic lamp name are not sufficient to ensure that both partners are using the same source for color evaluation.

X-RITE WORLD HEADQUARTERS

Grand Rapids, Michigan USA • (800) 248-9748 • +1 616 803 2100
© 2012, X-Rite, Incorporated. All rights reserved.

L10-456 (08/12)

x-rite

PANTONE®