White point and color temperature

The color of white

Ask the next person you see, "What's the color of white?" and you'll probably get a look of confusion; white is *white* of course. Most people don't think of white as a color, yet there are many different shades of white. Place sheets of two different kinds of white paper side by side and you'll likely see that they aren't the same color of white. One sheet might look bright and cool (bluish), and the other warmer (yellowish) in comparison. View a single sheet of white paper with nothing else white in your field of vision and its color becomes difficult to define. This is why I wrote about *chromatic adaptation* in last month's column.

The color of white can be defined and measured, and it's often necessary to do so when calibrating a display or any other devices. The color of the brightest white your monitor can display—R255/B255/G255—is its white point. Place two monitors side by side, both emitting the brightest white they can, and one may produce a white that appears cooler or warmer than the other. The white point of the two displays is different. We can measure and describe this white point colorimetrically. We need to define this target value when calibrating a display.

I often read questions on various online photo forums asking what white point is best for display calibration. Ultimately, someone will answer that a display is best calibrated to 6500K or D65, while others will say 5000K (or maybe even D50). What's the difference? Glad you asked. It's important for photographers who use the term *color temperature* to fully understand the differences.

There are several ways to describe the color of white. Photographers commonly use the term "color temperature." For example, tungsten film has a specified color temperature of 3400K, or 3,400 units (Kelvins) as measured in the Kelvin temperature scale. This scale begins at zero(K), which represents absolute zero, the theoretical point at which substances cease to possess thermal energy (minus 459.67 degrees Fahrenheit).

Colors with low Kelvin values appear red; as the Kelvin values get higher, the colors become bluer. Color temperature is really a *range* of colors correlated to

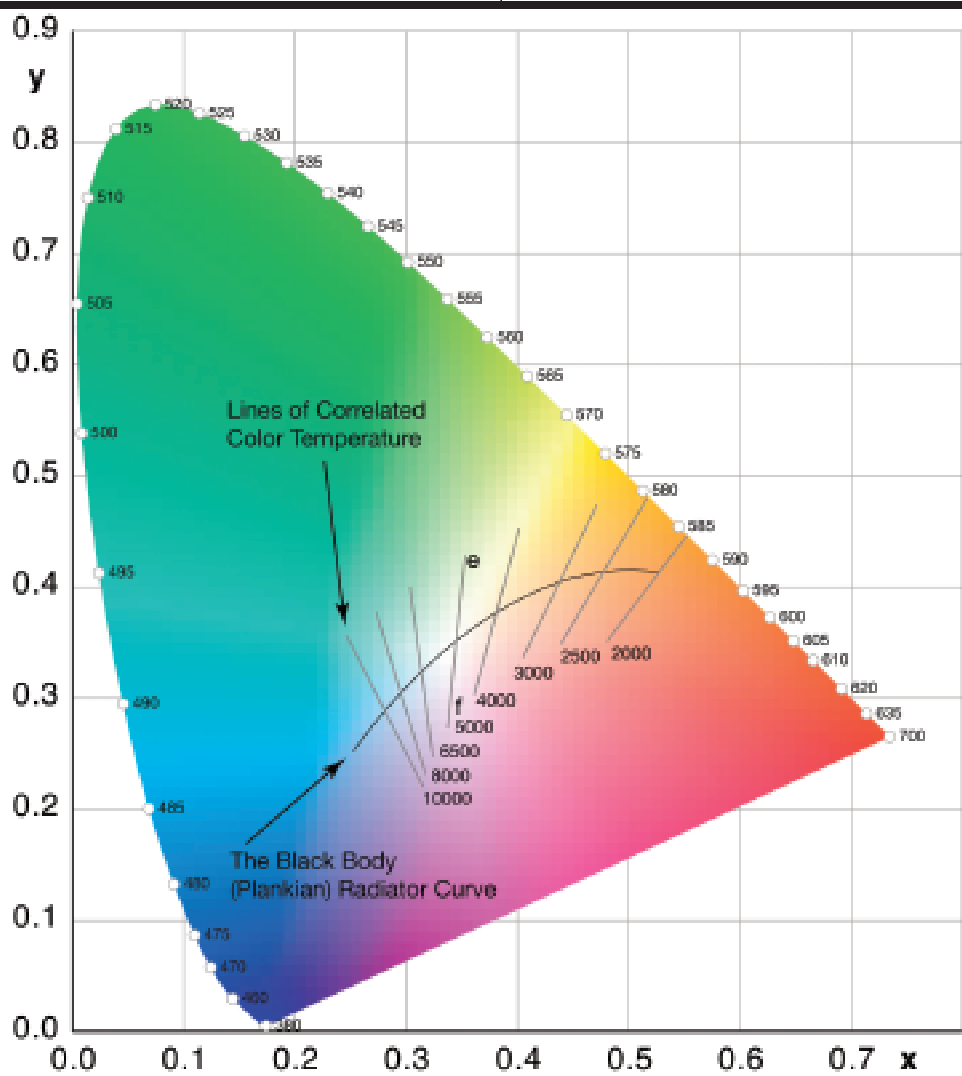

Figure 1: The lines of correlated color temperature and their relationship to the blackbody curve are seen in this illustration. The lines of CCT run roughly perpendicular to the blackbody from green/yellow to orange/violet. Note that all the colors along a line of CCT can be labeled with the same color temperature. The colors marked "e" and "f" in the diagram may both be described as 5000K.

the temperature of a theoretical object known as the *blackbody radiator*. The blackbody reflects no light, and it emits energy in shorter wavelengths as it's being heated. Think of a black cast iron pan on a hot stove. As it's heating up on the burner, the pan begins to glow dark red. As its temperature rises, the wavelengths of light it emits grow shorter, and the pan becomes orange, then yellow-white, then blue-white. In a tungsten light bulb, the filament behaves like a blackbody; because its temperature is so great—about 3200K—it radiates energy in the form of light.

Here's the catch. If all light sources were true blackbodies, a particular color temperature would produce the same color of light, no matter the source. Because natural materials are not theoretical blackbodies, heating them to a specific temperature creates deviations from the theoretical color, on a magenta to green axis (**Figure 1**). This is why you should use the term *correlated color temperature* (CCT)—many different colors of white may correlate to the same blackbody color temperature. If you have a color meter that reports the color temperature of a light source, many light sources that appear different could produce the same CCT value.

An important term to understand in discussions about color is *illuminant*, a light source that is defined spectrally. These real or imaginary illuminants are described in what scientists call a *spectral power distribution* curve (SPD), a graph of intensity for each wavelength in the visible spectrum. Defined this way, illuminants are an absolute, unambiguous measurement of a light source, unlike CCT.

Different illuminants can have the same correlated color temperature. This is one reason why the International Commission on Illumination (or CIE) defined what are known as *standard illuminants*. These illuminants are defined spectrally, meaning a certain amount of energy at each wavelength across the spectrum. An example of standard illuminants is the *D illuminants* (D for daylight), such as D50 or D65. Too often, D65 and 6500K are used interchangeably, but they are not the same. D65 is an exact color, not a range of colors. You see the difference when you examine **Figure 1** and **Figure 2**. Some software products specify D65 and 6500K as choices for white point. When you see this, the 6500K option refers to the exact color of a theoretical blackbody at 6500K.

When calibrating your display, the white point targets most commonly used are the graphic arts standard D50 and the sRGB white point of D65. Many packages offer too many, and often confusing choices. The color science used by the ICC is based on D illuminants; when offered the choice, choose the D illuminant. The default white point of many CRTs is close to a CCT of 9300K. Generally LCDs are closer to CCT 6500K.

It's important to understand the principles of white point and color temperature when we undertake the task of calibrating our displays or decide in what viewing conditions we will view our prints. When discussing color temperature, define whether you're talking about an exact illuminant or a correlated color temperature. ■

For a more in-depth discussion on color temperature and color management, read "Color Management for Photographers," by Andrew Rodney (Focal Press, $44.95).

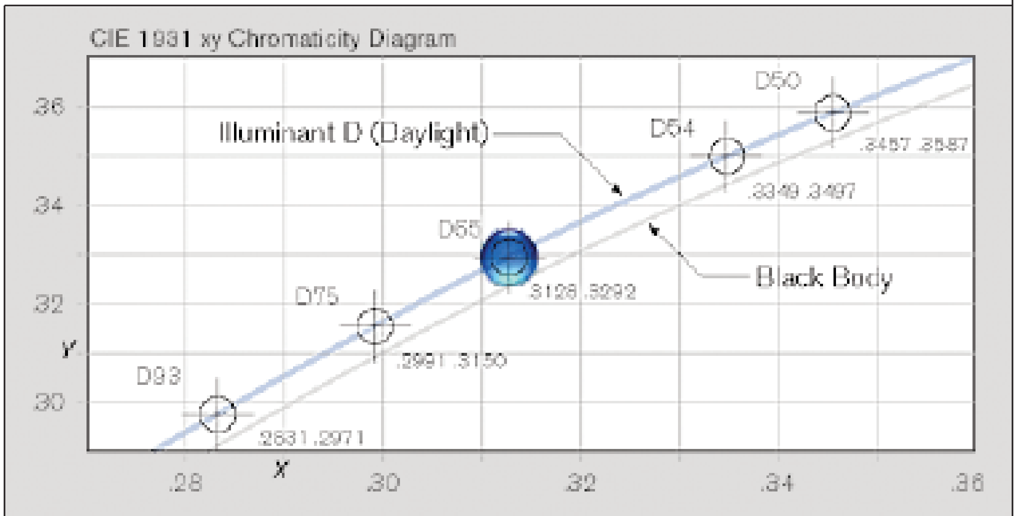

Figure 2: This screen capture from the Sony Artisan display software illustrates a close-up of the blackbody curve and above it, what is known as the daylight curve. They are close but not the same.

Don't miss Andrew Rodney at Imaging USA in Austin, Texas. His presentation, "Color Management from A-Z," explains how Photoshop can be set up to accurately preview digital images and get predictable color output. Monday, January 23, 9:15-10:45 a.m. Register at www.imagingusa.org.