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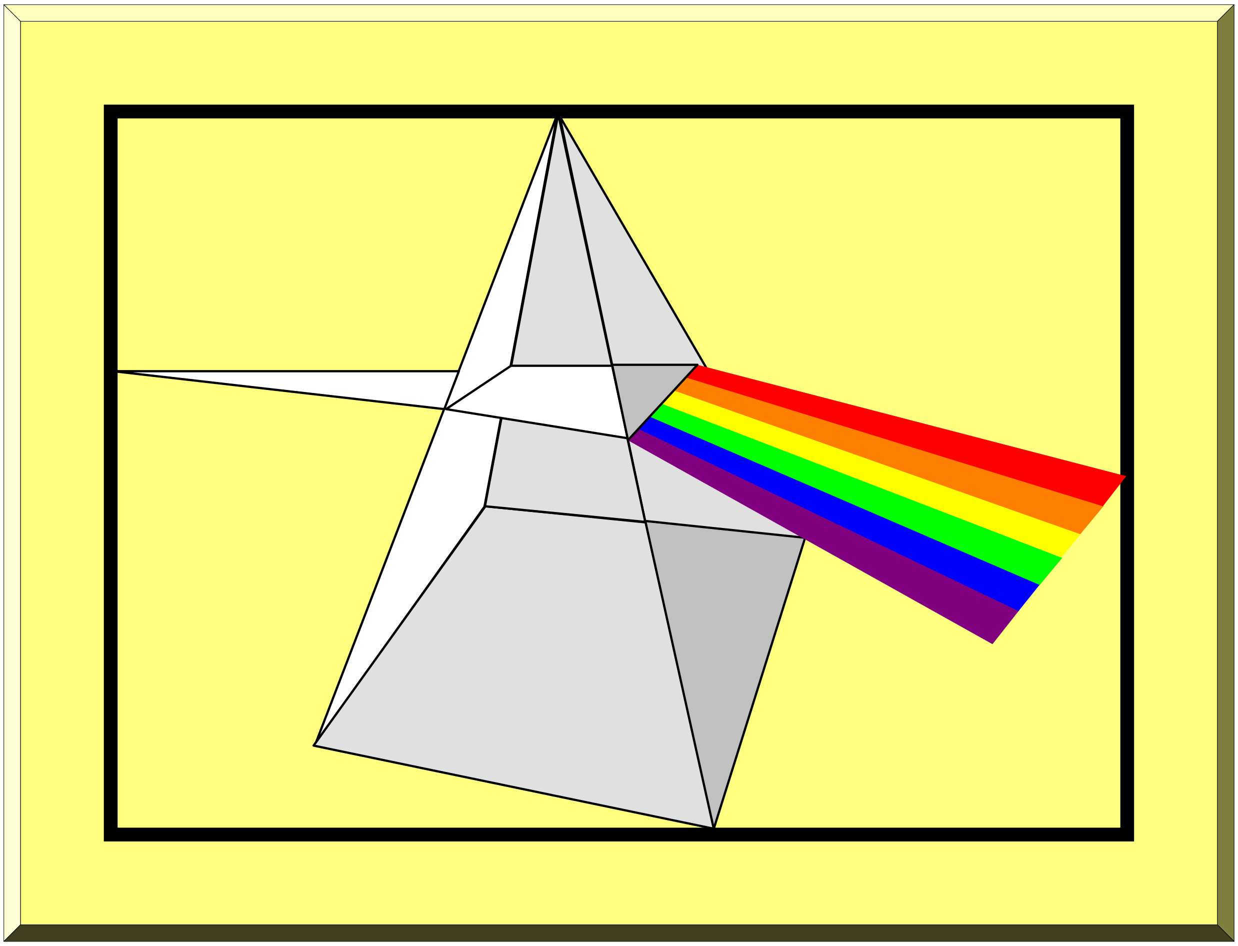
Describing Color



Volume XVI

How does one describe the color attributes of an object? More specifically, how does one communicate color to customers and vendors at different locations in different cities, states, and countries? This article discusses how to describe an ink or a printed substrate by the lightness, chroma, and hue attributes of the printed color.

In 1986, the NAA (Newspaper Association of America) utilized the color spectrophotometer to characterize their AdLitho^7 and AdPro^7 colors. These products adopted a set of specifications, which utilize these components to describe the colors in their color book.

The Components of Color

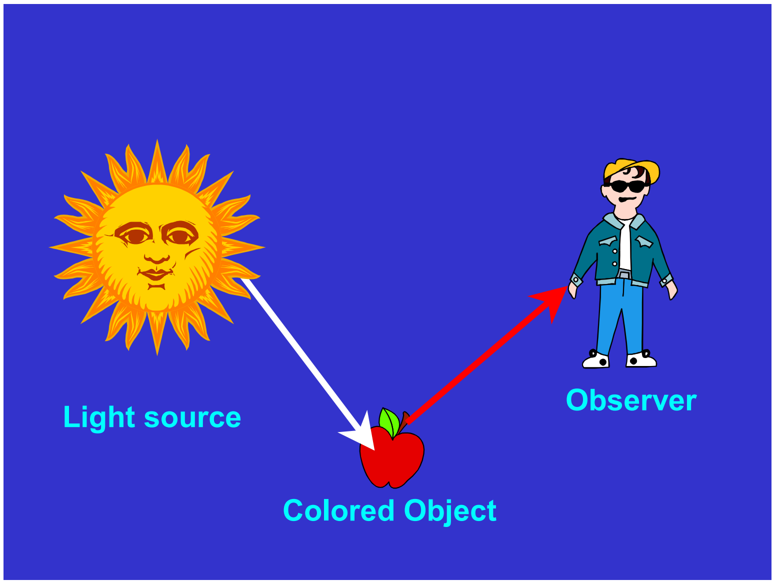


Figure 1

Color is the sensation that is produced when the eye senses visible light (Figure 1). Visible light is an energy known as electromagnetic radiation. Many different types of energy make up the complete electromagnetic spectrum (See Figure 2). Visible light, as well as other types of electromagnetic energy, is measured and described by its wavelength--in nanometers. Visible light (or the visible spectrum) makes up a small portion of this electromagnetic spectrum; the portion from 400 nanometers to 700 nanometers in wavelength. A **nanometer (nm)** is one-billionth (1 X 10^{-9}) of a meter (.0004 mils). When the eye sees color, it sees electromagnetic radiation with wavelengths between 400 nm and 700 nm. In fact, each color has its own particular wavelength in the visible spectrum which makes it unique. The colors can be loosely described as follows: Violet 400-450 nm, Blue 450-500 nm, Green 500-550 nm, Yellow 550-600 nm, Orange

600-650, and Red 650-700 nm (see Figure 3). This means a colored light source emits energy at the specific wavelengths mentioned, and a colored object reflects energy at the specific wavelengths.

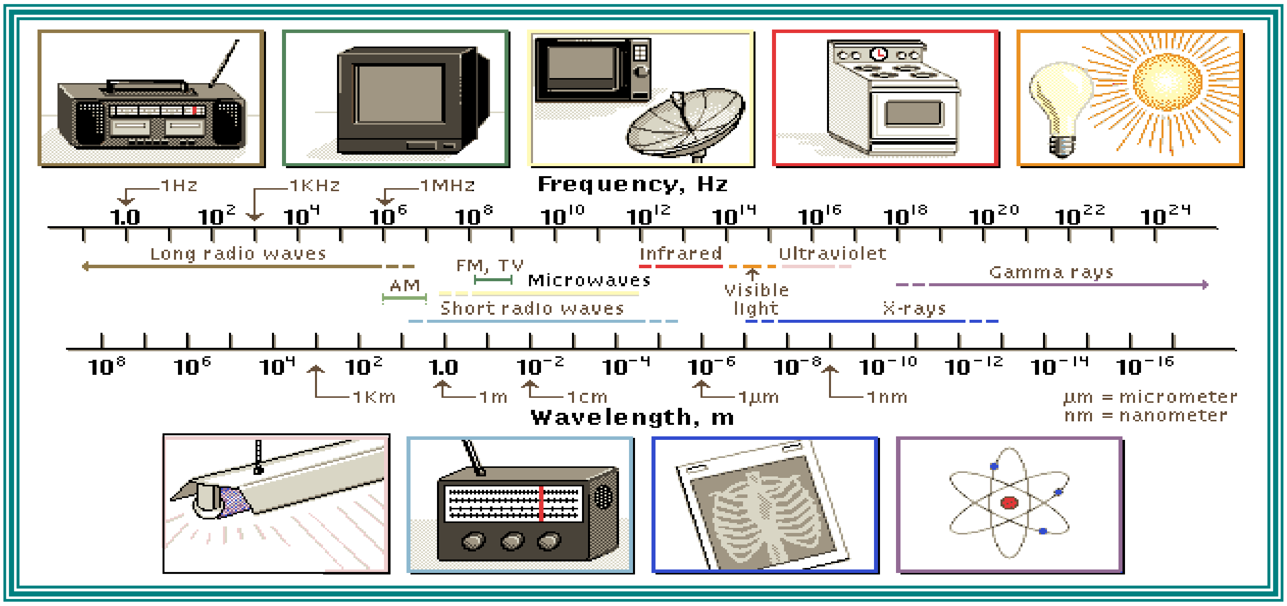


Figure 2

The color of an object is produced by the interaction of that object with the energy from a light source. The object will selectively absorb or reflect all of the energy from the light source that strikes it. When all the energy is reflected, our eye sees white, absorption of all energy yields black, while selective absorption of specific wavelengths results in color. The reflected light is radiated out from the object in all directions and is received by the eye. The eye senses this reflected light and then sends a signal to the brain, which is interpreted as COLOR. Thus, the process of sensing color includes three separate components: a light source,

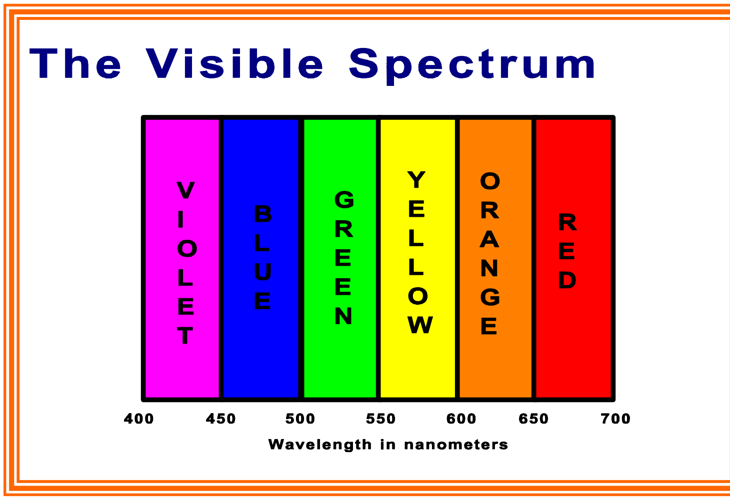


Figure 3

an object, and an observer. The light source provides the energy (known as spectral power or spectral energy) to the object. The object then selectively absorbs or reflects this energy (or light), and the observer then sees (senses) the color. Each of these plays a critical role in the observation of color and each must be numerically characterized in order to be able to describe color precisely.

The Light Source

The light source can be any object that emits energy in the visible spectrum. Three typical light sources are: the sun which produces daylight, fluorescent tubes which produce fluorescent light, and tungsten filament bulbs, which produce incandescent light. Each of these light sources can be described or characterized by the amount of energy they emit at each wavelength in the visible spectrum. This is known as the spectral power distribution (SPD) of that light source. Three common light sources are daylight, fluorescent light, and incandescent light. The SPD for incandescent and Daylight (D65) are illustrated in Figure 4.

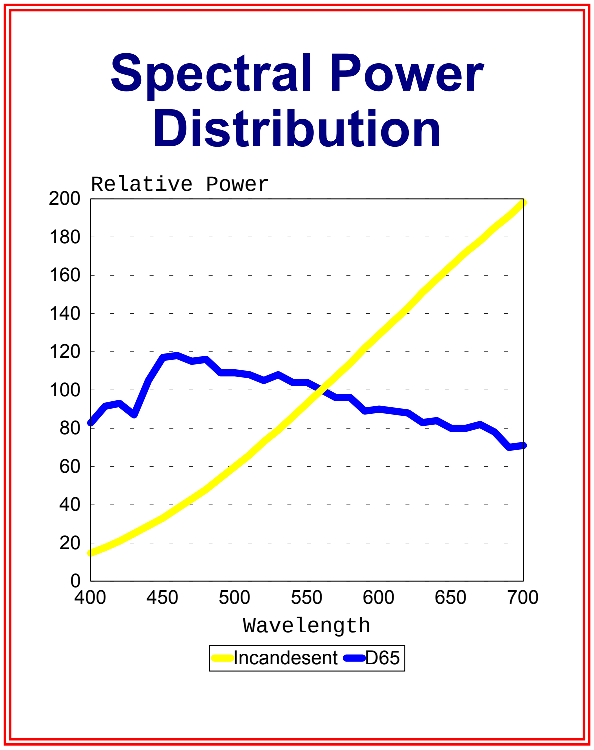


Figure 4

Daylight can be thought of as a white light. It is characterized as having all wavelengths of the visible spectrum in relatively equal amounts. Fluorescent light is a blue-green light because it contains a large amount of energy in the blue and green regions of light, but very little in the yellow and red regions of light. Incandescent light is a yellow-red light because it contains a large amount of energy in the yellow and red regions of light but very little in the blue and green regions of light.

The light sources and their color are described by the International Commission on Illumination

(CIE). A typical daylight is illuminant D6500 or D-65 for short. It approximates an average noonday at a latitude equivalent to Washington, D.C. A typical fluorescent illuminant is CWF, which is Cool White Fluorescent. It is equivalent to a GE Deluxe Cool White Fluorescent tube. The CIE has specified numerous other standard light sources and illuminants; these are among the most commonly used illuminants in the graphic arts industry.

At this point, it is appropriate to discuss the difference between a Alight source and an Ailluminant.@ The two terms are often used interchangeably, but there is a distinction. A light source is a physical object that emits light, such as a fluorescent bulb. An illuminant is a set of numbers that represent a spectral power distribution, such as CWF. Once a light source has been described by a SPD, it becomes a standard light source. An illuminant may be represented by a standard light source, but not necessarily.

The Object

Once energy leaves the light source, it travels until it strikes an object, which will either absorb the energy or reflect the energy away from the printed object. The amount and the wavelengths of energy absorbed or reflected depend on the type and quantities of colorants present in the object.

As light strikes the surface of the object, a small amount of that light is reflected away from the surface and this reflected light is known as **specular reflection** (or commonly referred to as gloss). It comprises about 4% of the incoming light and it leaves the surface at the opposite angle from the incoming light. Specularly reflected light will be the same color as the incoming light.

The remainder of the light then penetrates into the object and either is absorbed by the pigment particles in the ink or is reflected back toward the surface. The reflected light will then interact or strike other pigment particles in the ink film until it is bounced and deflected in all directions. It eventually leaves the surface of the ink film in all directions as **diffuse reflection**. The color of diffuse reflection will be dependent upon the particular characteristics of the pigment present in the ink film. For example, red pigments will absorb all wavelengths of light except red and, therefore, red light is reflected diffusely from the ink film. Blue pigments will absorb all wavelengths except for blue light and, therefore, blue light will be reflected diffusely from the film of the ink. Each color has its own unique wavelengths of light that it absorbs and reflects.

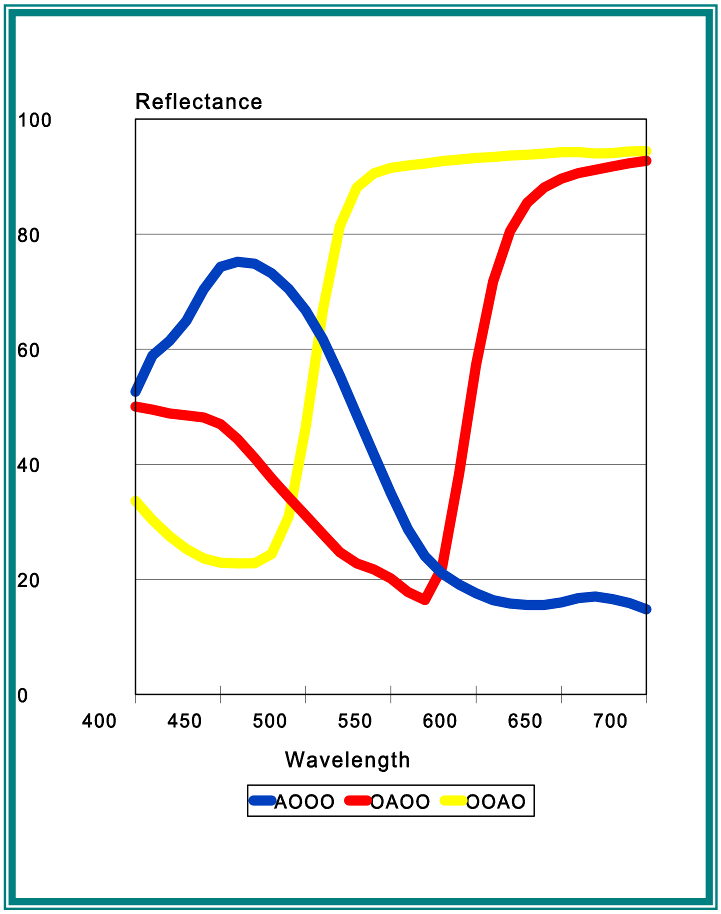


Figure 5

As was discussed earlier, each color has its own unique wavelengths in the visible spectrum, which reflect light. Each color will reflect the light corresponding to the dominant wavelengths that the eye detects and will absorb the remaining wavelengths of light. In these examples, you can see that the blue ink reflects blue light in the region of 450 nm and absorbs light in the other portions of the spectrum. In other words, the ink reflects the blue light back to the observer and absorbs the remaining wavelengths of light. The Process Red reflects red light in the region of 600 - 700 nm and absorbs the remainder of the visible light.

The Yellow reflects light at higher than 540 nm and absorbs light in other regions of the spectrum.

When a spectrophotometer measures a color, it calculates the amount of light reflected from the sample at 10 nm increments from 400 nm to 700 nm. This provides a unique Afingerprint@ for each color. From this fingerprint, color numbers such as color difference, strength, and even color formulation can be derived. These values can be stored on a computer for future reference or transmitted to off-site locations for color standardization.

The Observer

When light strikes the human eye, it is detected by one of three color sensors in the eye: a red, a green, or a blue receptor. These receptors send a signal to the optic nerve, which sends a signal to the brain. However, the optic nerve does not send a red, green and blue signal to the brain but, in fact, sends information in terms of a red/green signal, a yellow/blue signal, or a black/white signal. This particular phenomenon about the way the human eye responds to color is known as the **opponent colors theory**. It describes the way that we see and respond to color by opposites. For

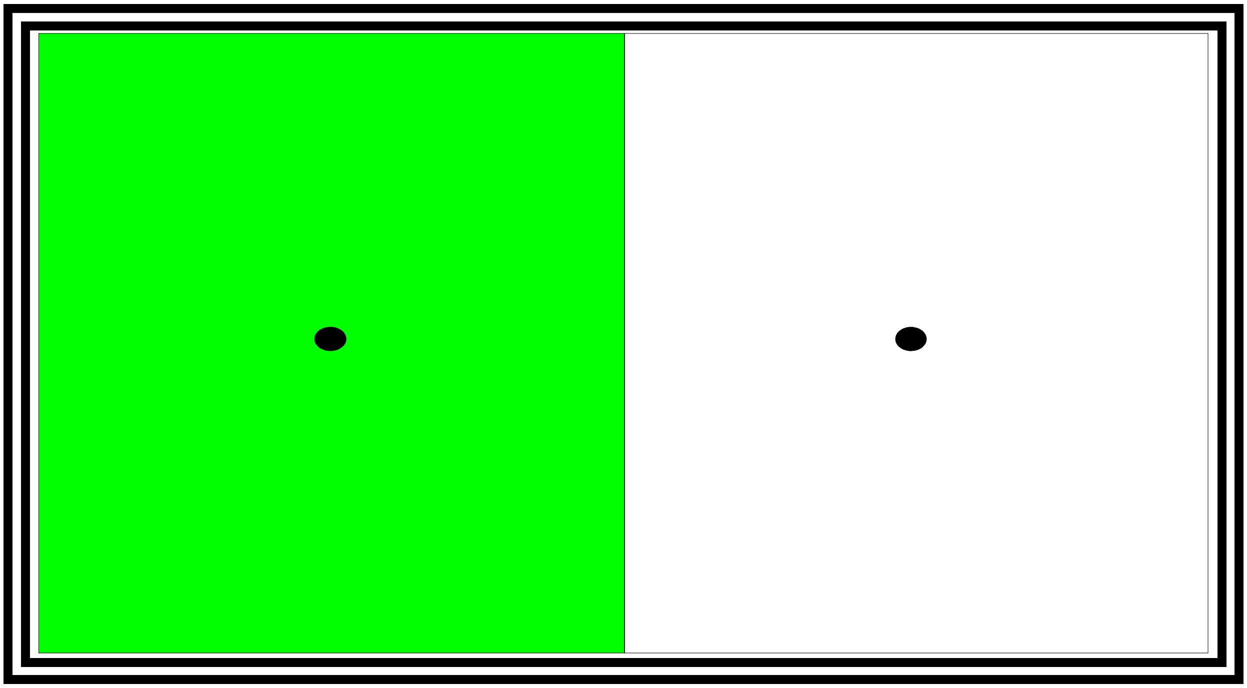


Figure 6

example, yellows or blues can be described as red-shade yellows and red-shade blues as opposed to green-shade yellows and green-shade blues. To demonstrate this effect, stare at the green square in Figure 6 for about 20 seconds. Quickly shift your eyes to the spot in the adjacent white square. You should see a red square, the opponent of green. This response is consistent across the population of normal color vision and has been quantified into a **Standard Observer**.

The Standard Observer was first characterized back in 1931 when scientists showed a group of people colors in all areas of the color spectrum and had them make very subtle, precise judgements on those colors. This information came to be known as the 1931 CIE 2-degree Standard Observer. It is known as the two-degree observer because the people in the test were asked to look at color with a two-degree field of view. These tests were repeated again in 1964 with a larger sampling of people and they looked at color with a larger field of view, a ten-degree opening. This came to be known as the 1964 CIE 10-degree Standard Observer. These two sets of data characterize the way a person with normal color vision would see color. In a practical sense, there are only very small differences between the two observers.

CIE Lab COLOR SPACE

As mentioned previously, the process of sensing color requires the combination of three separate components: a light source, an object, and an observer. We have just examined how each of these components can be quantified: a light source by a standard illuminant, an object by its reflectance curve, and an observer by either the two-degree Standard Observer or the ten-degree Standard Observer. Therefore, it is necessary to include all three components when attempting to describe color. If one of these three components is varied, the resultant color will vary.

All colors can be characterized by **hue**, that is, the dominant shade; by **saturation**, that is, how much color of any hue is present; and by **lightness,** that is, the degree of lightness or darkness of a particular color. Therefore, it is necessary to describe a different hue, saturation and lightness for each unique set of illuminant or observer conditions. By using a standard illuminant and a standard observer, the amount of light reflected from any one object can be converted into the hue, saturation, and lightness descriptions for any color. Additionally, a sample can be compared to any standard with these same three attributes. In 1976 the CIE adopted a standard method of calculating color attributes, known as 1976 CIE L*a*b* (or CIE Lab) Color Space. It uses the designation of Dh to signify a hue difference between a sample and a standard, the designation of DC* to signify a difference in saturation (or chroma) between a sample and a standard, and the designation of DL* to signify a difference in lightness between a sample and a standard.

Thus, by using these three terms, hue, lightness, and saturation, we can describe the attributes of any color, or the difference between a sample and a standard. There are two other terms that are occasionally used to describe color: a red/green color difference and a yellow/blue color difference. CIE Lab Color Space assigns the designation Da* for a difference in red/green value and the designation Db* for a difference in yellow/blue value.

SUMMARY

Most objects reflect visible light. It is that visible light that our eye detects as the color of the object. The color of the object should be characterized with a controlled light source. That means that we want to make sure that the light source we use to view the color under is identical or as close as possible to the light source that the product will be viewed by a customer or an end-user. We can then numerically characterize that light source by selecting the proper standard illuminant. The light from the object itself can be numerically characterized by measuring the amount of reflected light from the object. The observer can be characterized by one of the two standard observers, either the two-degree or the ten-degree observer.

Any color can be described by its hue, lightness, saturation, and total color difference by taking the percentage reflectance of that object using the correct standard observer and the correct illuminants and calculating DL*, Dh*, DC* for that color. This gives anyone the ability to characterize any color by those three attributes: lightness, hue, and saturation. It gives any person the ability to describe a color by those three attributes and communicate that to another location in these common terms. It helps insure that two different locations (or viewers) are discussing and talking about the same color. Thus, we have a common language to describe and communicate color so that both parties can easily understand and agree on color and its attributes.

NAA Tolerances for Shade and Strength of AdLitho[7] Inks

Color	***Strength***	***Lightness***	***Chroma***	***Hue Angle***
AOOO Blue	+/-7%	+/- 0.5	-1.0 to 1.5	-2.0 to 1.0
OAOO Red	+/-7%	+/- 0.6	-2.2 to 1.0	-2.0 to 1.5
OOAO Yellow	+/-7%	+/- 0.6	+/- 2.0	+/- 1.2