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ToolKit

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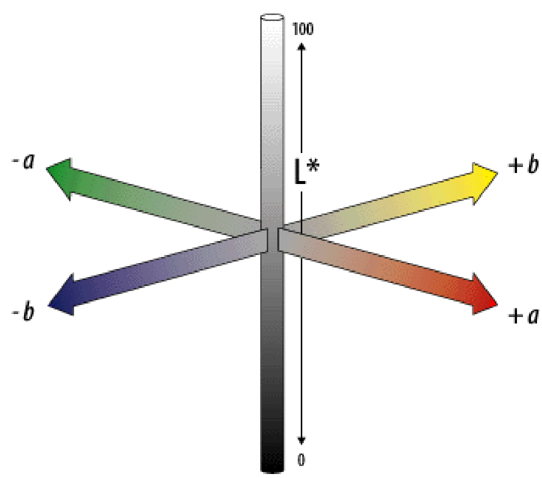
National Coil Coating Association

Color Evaluation in the Coil Coating Industry

Quantifying the color of an object, and then measuring color difference between the object's color and a color standard, is an important factor with regard to color consistency and acceptance. Assembling parts from various lots and production runs requires minimal—or no—color difference, so a typical observer sees nothing objectionable. This tool kit will discuss the details of arriving at color values, while avoiding the complex physics and math behind the readings. The first portion of this toolkit will discuss color and color difference. The second portion will discuss the subtle—but important—difference between color and appearance.

Typically, a color instrument will deliver color values represented by three color coordinates:

- "L" value, which describes the lightness or darkness of a sample
- "a" value, which describes the redness or greenness of a sample
- "b" value, which describes the yellowness or blueness of a sample



Color Difference

In the Coil Coatings industry, the control of color on a coil line is always expressed in terms of delta L (ΔL), delta a (Δa), and delta (Δb). Constituent color coordinates represent color difference as:

ΔL = positive (+) values are lighter than the standard; negative (-) values are darker
Δa = positive (+) values are redder than the standard; negative (-) values are greener
Δb = positive (+) values are yellower than the standard; negative (-) values are bluer

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For example, if the color being produced, compared against the color standard, were:

$$\Delta L = -0.32$$
$$\Delta a = +0.08$$
$$\Delta b = +0.15,$$

then prepainted metal color is slightly dark (negative ΔL), slightly red (positive Δa), and slightly yellow (positive Δb). Experience has shown that maintaining the color vs. the standard to within ± 0.5 ΔL, Δa, and Δb will guarantee color consistency lot-to-lot.

The *total* color difference between a sample and a standard is always expressed in terms of Delta E (ΔE), and there are many methods of measuring and quantifying color difference; however, all methods base the calculations on the difference between two samples in the ΔL, Δa, and Δb color coordinates.

The ΔE color difference between two samples is commonly calculated as follows:

$$\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$$

This use of constituent color coordinates making up DE provides the coil coater with additional capability in producing and maintaining an acceptable color result.

NOTE: There are two color spaces established by color scientists. Explaining color space is beyond the scope of this document. What is important to know, however, is that the color spaces are described as:

- Hunter color space
- CIE color space

Both color spaces are used within the coil coating industry. The L, a and b values in CIE color space are denoted with an asterisk (*i.e.*, L*, a*, and b*), whereas Hunter color space values do not use the asterisk. The above ΔE calculation, however, is exactly the same. ΔE in CIE color space is denoted ΔE^*; in Hunter color space the color difference is ΔE (*i.e.*, no asterisk).

Color vs. Appearance

It is important to understand the fundamental difference between *color* and *appearance*. Color is concerned with the physics of light interacting with pigments, which plays a critical role when using color matching software. Appearance, on the other hand, is how an individual (a human, not a machine) responds to an object's color. For example, a black tire having gone through a car wash looks considerably blacker than before being cleaned. The pigmentation that produces the *color* of the tire has not changed, but its appearance certainly has been affected with the removal of dirt and grime. In common parlance, we may declare the tire's *color* to be blacker, but it is actually the appearance that has changed.

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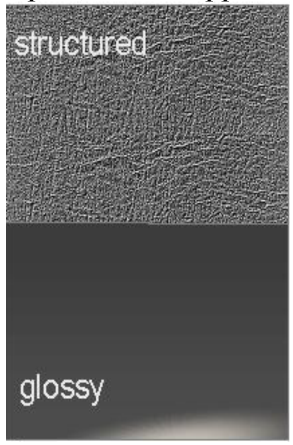
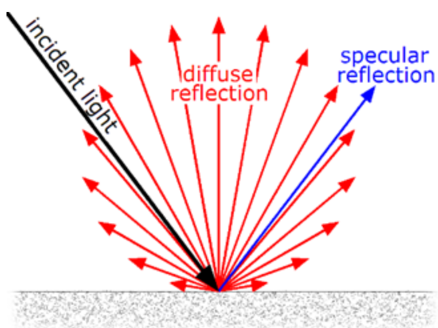
An excellent example of the difference between color and appearance is demonstrated in the figure below, where a glossy, dark gray piece of plastic has had the upper half textured (labeled "structured"). The *color* (the physics of light striking pigments) is the same on both samples, but the appearance shows a notable difference.



Source: BYK Instruments

When light strikes an object, some of that light bounces off the surface at the same angle as the incident light beam. We measure gloss in this fashion. The light strikes the surface at a 60-degree incoming angle, and some of that light bounces off at a 60-degree outgoing angle. This particular reflection angle is defined as specular (mirror-like) reflectance. The percent difference between the amount of light striking the object and the amount of light bouncing off the surface is described as the gloss of object.

In addition to specular reflectance, there is also diffuse reflectance. For a 30-gloss coating, for example, 30% of the incoming light reflects along the specular reflectance angle; the other 70%, however, is reflected into the diffuse region.



When measuring gloss, we do not consider diffuse reflectance, only specular reflectance. While we do not consider diffuse reflectance for gloss, it is critical to understand how the *appearance* of an object is affected by diffuse reflectance. This understanding is important when taking a color reading, because—depending upon the color instrument being used—gloss can impact appearance, but may not affect color readings. The instrument type (discussed below), and the set-up of the instrument, can have a significant influence on the color readings that are generated.

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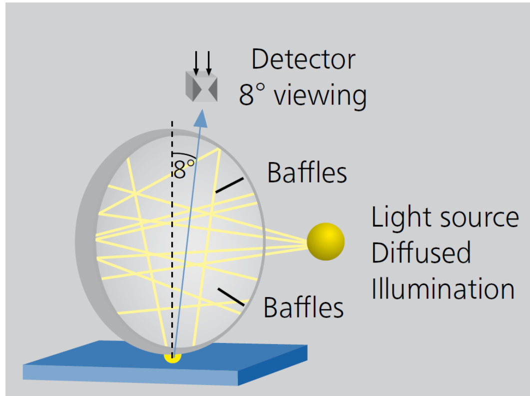
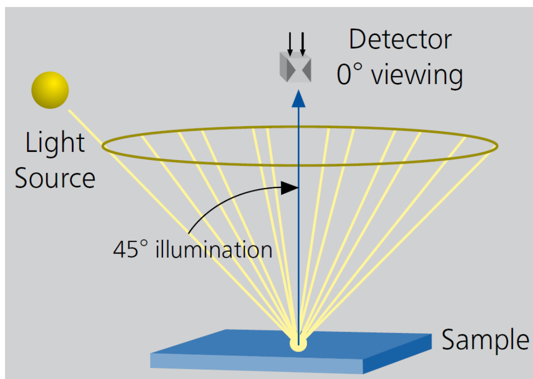
When measuring colors, there are two types of instruments. One type utilizes a sphere to collect *all* the reflected light—both specular and diffuse reflectance—from a sample.



The other type of color instrument is defined as a 45/0 device. In the picture below, the light source illuminates the object as a 45° angle, but only light reflected perpendicular to the surface (the 0° angle) is collected.



When using an instrument that utilizes a sphere, you will have the option to capture all reflections—both the specular and diffuse reflectances. You also have an option to exclude the specular reflectance. When choosing this latter option, the spherical instrument will generate values very similar to a 45/0 instrument.

The way light reflects from a textured surface or a heavily weathered surface influences the appearance of a colored product. In most instances, we are interested in whether the *appearance* has changed. A good example of this is when measuring the color change (fade) of a weathered panel. The pigments used in coil coatings rarely fade when exposed to sunlight, unlike dyes used to color cloth. Upon exposure, a coil coating pigments' color remains constant, but the binder system may degrade, which causes the gloss of the panel to drop. *This gloss drop has the effect of making the color look lighter.* The *appearance* has changed, even though that actual color has not. A building owner, however, only cares about the change in appearance.

The best color instrument set-up to use to match what an observer sees is either a 45/0 instrument or an instrument equipped with a sphere, but using a specular component *excluded* set-up. You can see in the figure below that a 45/0 instrument reads the "color" difference (actually, the *appearance* difference) between the smooth and

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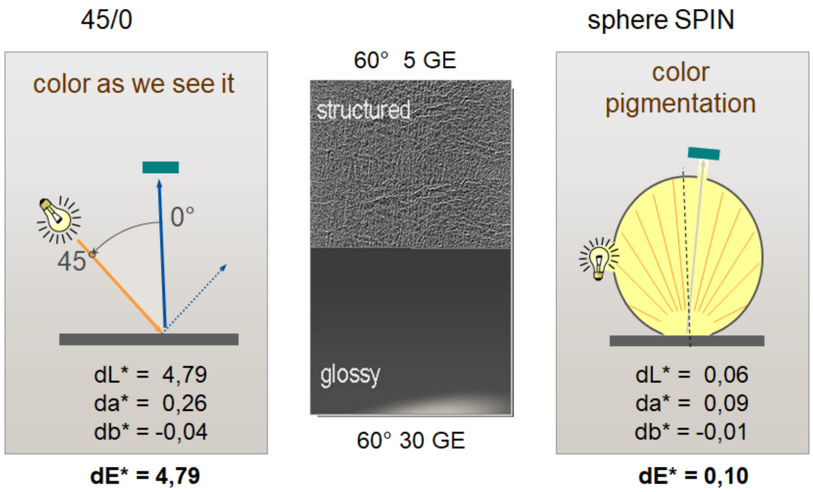
textured piece of plastic at 4.8 ΔE, but using an instrument with a sphere *and including the specular component* (designated as "SPIN" in the figure) yields a ΔE E of 0.1. Clearly the plastic part *looks* significantly different between the glossy and textured sides of the panel.



Source: BYK Instruments

Additional information on the topic of color and gloss can be found in a variety of ASTM methods:

- D523 Standard Test Method for Specular Gloss
- D2244 Standard Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates
- D3134 Standard Practice for Establishing Color and Gloss Tolerances
- D3794 Standard Guide for Testing Coil Coatings
- E284 Standard Terminology of Appearance
- E308 Standard Practice for Computing the Colors of Objects by Using the CIE System

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