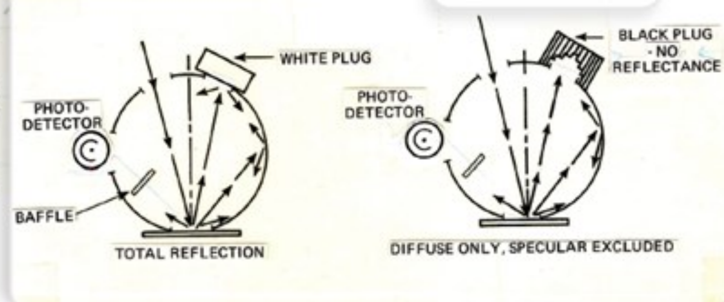
Applications Note

AN 1007



Measuring the Geometric Attributes of Your Products

Consumers have a choice and when all other factors are equal, they buy what looks best.

Abstract

All industries are concerned with the appearance of their products. The overall appearance of any object is a combination of its chromatic attributes (color) and its geometric attributes (like gloss, or, haze). When buyers evaluate a potential purchase, they look at appearance and expect uniformity within any grouping of the same product. If a difference is noted between several of the same product on display, this difference is associated with poor quality. The visual or instrumental assessment of appearance is therefore a critical step in product manufacturing and release.

This application note considers the geometric attributes of samples.

Keywords: Gloss, Haze, geometric attributes, opalescence

The world's true measure of color HunterLab

Geometric attributes are those which describe the interaction of light with an object. For instance, a flat cotton weave fabric is very different geometrically from a corduroy. A glossy photo print looks quite different than a matte one. There are many geometric attributes and this application note considers the following:

Gloss, the property of a surface responsible for shiny or lustrous appearance.
Haze, the scattering of light within the surface of a nearly clear sample that is responsible for a cloudy appearance.
Opalescence, the scattering of light in two colors (dichroism).

Gloss

Gloss measurements quantify the amount of light reflected at the specular angle from an object's surface. The specular direction is the angle equal to but opposite the angle of incidence. This specular light is responsible for the highlights visible on shiny materials. Gloss measurements quantify the amount of shine coming from a surface.

A glossmeter has a configuration similar to that shown below.

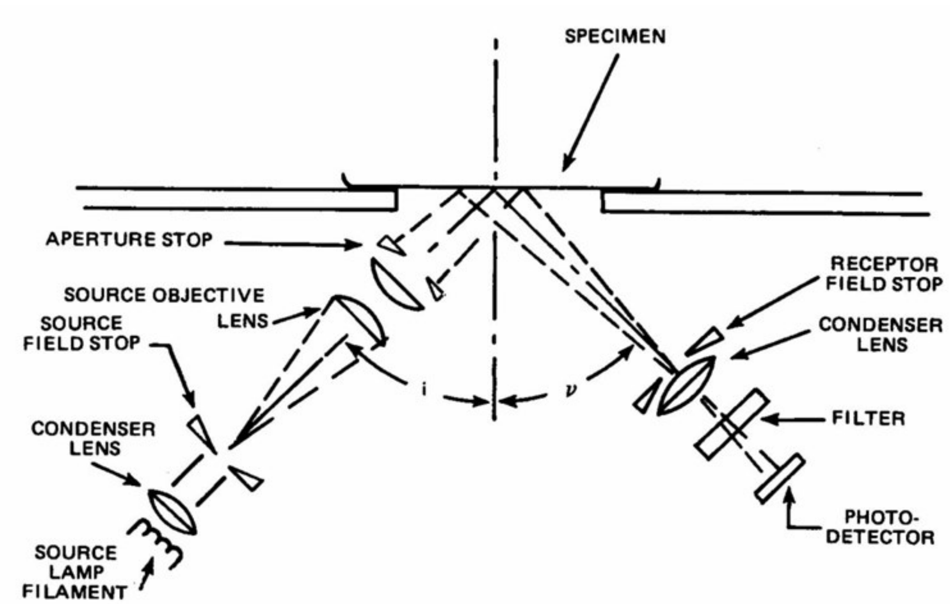


Figure 1. Glossmeter

Glossmeters are configured so that the light generated is incident on the material at a particular angle relative to normal (the perpendicular). The detector is then placed at that same angle on the other side of normal so that only the light reflected at the specular angle is collected. Generally, a green filter corresponding to the CIE Luminosity Function is placed in front of the detector to enable the instrument to better simulate the human visual situation.

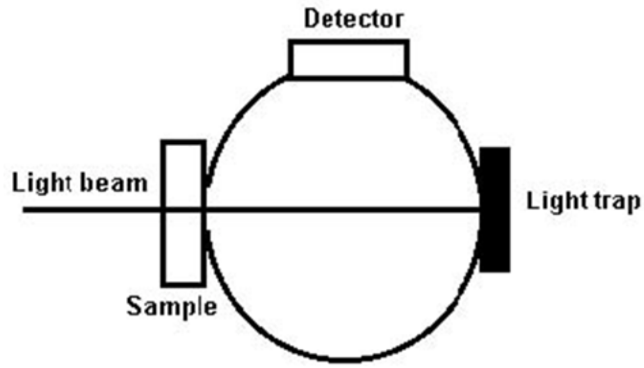


Figure 2. Transmittance Haze Measurement

ASTM Designation D523-89, Standard Test Method for Specular Gloss, specifies how gloss is measured. Glossmeters provide light at one angle or a combination of three angles. The most common angles are 20°, 60°, and 85°. ASTM Designation D523 specifies that a 60° angle may be used for most materials. The test method recommends the use of a 20° angle when the 60° gloss value is greater than 70 (which would be a highly-reflective material). The use of an 85° angle is recommended when the 60° gloss value is less than 10 (which would be a matte material). TAPPI gloss for paper is specified by TAPPI T480 and is measured at a 75° angle.

Conditions for Measurement

Instrumental: HunterLab Agera measures 60° suitable for most materials.

A GU is a measurement used for gloss. A standard GU measurement scale of gloss meters is determined by a reference black glass standard. This black glass is highly polished and features a defined refractive index that, when placed at a specific angle, has a 100GU specular reflectance. GUs are determined through this standard, as 100GU establishes an upper point calibration on a matte surface that can then be used to find how many GUs a product's surface has.

These 100GU gloss meters are appropriate for most non-metallic coatings and materials, such as plastics and paints. For more reflective materials, like mirrors or plated metal parts, companies use gloss meters with a higher upper calibration, regularly going up to 2,000GU.

Typical Applications

Many materials such as car parts, table tops, flooring, paints, and paper are measured to determine the amount of gloss present.

The first step in controlling gloss levels is being able to measure them. The gloss appearance of an object can be affected by several factors, such as the texture of the substrate, the smoothness of the material itself, and even film thickness of coatings applied to an object or surface. With all the factors that can affect gloss's appearance, companies regularly measure gloss to ensure all their products have a consistent look.

Not measuring gloss on a product can lead to several problems. For example, coatings manufacturers typically use gloss additives to achieve specific levels of gloss. Too much or too little can affect not only the coatings appearance when dried but also the coatings flow and leveling, curing times, adhesion, and long-term durability. Gloss levels also change the visual perception of the color of the surface or object. Coating a smooth surface and a textured surface with the same coating will result in the smooth-coated surface appearing much darker than the textured coated surface.

Haze

Haze is the cloudiness of a product that is caused by scattering of light. Haze is an important appearance attribute which can be quantified and then used to assess the quality of objects. Light scattering resulting in haze can be caused by suspended particles, contaminants, or by an imperfect surface.

Haze is instrumentally determined by reflectance or transmittance to mimic the way an object is viewed. A transparent or slightly translucent material is measured by transmitting light through it (transmittance haze). Haze from an opaque material is measured by reflection (reflection haze).

Types of Haze

The type of haze you see when you look at an object is determined primarily by the way in which you view the object. You view a transparent or slightly translucent material by looking at the light which is transmitted through it (transmittance haze). You view an opaque material by looking at the light reflected from it (reflection haze). Hazy appearance is described as either transmittance haze or reflection haze. Both of these terms are described in greater detail below.

Transmittance Haze

Transmittance haze is defined as the scattering of light from the surface of a nearly clear specimen (viewed in transmittance). Light scattered back through the sample is not included. Only light scattered by more than 2.5° from the incident light is considered to contribute to haze. When measuring haze, the percentage of light diffusely scattered compared to the total light transmitted is reported.

ASTM Method D1003-95 describes the type of instrument to be used for measuring transmittance haze. This haze meter uses a pivoting sphere and a single collimated beam of light. The light enters one side of the sphere at an entrance port and is directed to an exit port on the opposite side of the sphere. When the sphere is in the first position, the light leaves the exit port and is absorbed by a light trap placed at that port as shown in Figure 2.

$$\% \text{ Haze} = \frac{T_{\text{diffuse}}}{T_{\text{total}}} \text{ x } 100$$

Where, T = % Transmittance

When using the UltraScan PRO and UltraScan VIS, a white tile is placed at the reflectance port.

When the sphere is pivoted, the beam of light is directed toward the sphere wall and diffused. The detector is filtered to Illuminant C and the y function of the 2° standard observer and the % haze is reported to the nearest 0.1%.

Current HunterLab instruments, UltraScan PRO, UltraScan VIS and Vista both have diffuse light sources that originate from the inside of the sphere rather than a collimated beam light source as described in D1003-95. Also note that the spheres of these instrument types are in a fixed position and cannot be pivoted.

The method used to get similar haze results is to use a white tile at the reflectance port to simulate the pivoted position when light is directed at the sphere wall. There are drawbacks to using this method. The first is that the white standard that is placed at the port to complete the sphere may have a slightly different reflectance than the actual sphere wall and the second is that the reflectivity may vary slightly with each new placement of the standard. To increase accuracy, one can use a standard with reflectivity similar to the material which coats the sphere.

In order to compare results obtained for these various geometries, four samples were measured for haze on a sensor as prescribed in ASTM D1003-05 and then measured on UltraScan PRO and UltraScan VIS. The values obtained are shown in the table below.

Table 1. Comparison of Results between ASTM & Diffuse Geometries

Sample	ASTM D1003-95 Sensor	UltraScan PRO Diffuse Geometry	UltraScan VIS Diffuse Geometry
1	0.64	2.48	0.68
2	3.92	5.80	3.75
3	10.37	11.90	9.66
4	19.49	20.43	18.28
5	33.33	32.91	31.13

Reflectance Haze

ASTM E430-91, defines the measurement of reflection haze as the spread of the specular component of the reflected light from a glossy surface. The specular component is the light that is reflected from an object at an angle equal to but opposite to the angle of the incident light. Most glossmeters measure at the specular angle plus or minus several degrees and therefore cannot report the amount which the specular component spreads. The light that is spread 0.3° from the specular is responsible for distinctness-of-image gloss. The light that is spread 2° is responsible for a quality known as bloom or narrow-angle reflection haze. The light spread 5° is referred to as wide-angle reflection haze.

Opalescence

Opalescence is a type of dichroism seen in highly dispersed systems with little opacity. The material appears yellowish-red in transmitted light and blue in the scatter light perpendicular to the transmitted light. The phenomenon is named after the appearance of opals.

Common examples of opalescence include blue skies in the daytime and the yellowish-red skies at sunset. One can make a quick experiment by adding a few droplets of milk to a glass of water: the milk looks bluish. If one looks through the milk at the light source, it looks yellowish-red. Opalescence is actually related to the degree of scattering of near-transparent liquids. It is not a common colorimetric application in most industries; although one application encountered is the opalescent measurement of bleaching solutions used in dental whitening.

In the European Pharmacopoeia (EP) [www.pheur.org] Section 2.2.1, clarity and degree of opalescence of liquids defines visual clarity and describes a standard for opalescence (haze) relative to water. A primary opalescent liquid suspension of 25 mL hydrazine sulfate solution and 25 mL of hexamethylenetetramine defines four levels of opalescent standards mixed with distilled water and a fifth being 100% distilled water (no opalescence) (Table 2).

Table 2. Opalescence Standards

Opalescence Standards from EP 2.2.1	Opalescent Suspension*	Distilled Water
I	5.0mL	95mL
II	10.0mL	90mL
III	30mL	70mL
IV	50mL	50mL
V	0	100mL

For visual evaluation, the liquid standards and a sample are placed in identical flat-bottomed test tubes (15-25 mm in diameter) to a depth of 40 mm. The evaluator looks down the tubes placed side-by-side against a black background under even daylight lighting. The sample is considered clear if its opalescence is similar to that of distilled water or no more than that of Opalescence Standard I.

If the dichroic color difference in the opalescent sample is of interest, it is possible to measure the color difference based on two measurements, one straight through the sample (regular transmittance) and the other of the diffuse, or scattered transmittance. The measurements would need to be made separately and manually.

It is usually the degree of scattering with the appearance of opalescence that is of interest. Opalescence can be determined instrumentally for liquid samples by using a correlation between the EP Opalescence Liquid Standards and a Transmittance Haze measurement.

The correlation method can be summarized as follows:

1. Select Haze as a read method/procedure for measurement using your software. Note: It will only be available for a bench top sphere instrument such as a UltraScan PRO, UltraScan VIS or Vista.
2. Standardize the instrument in Total Transmittance (TTRAN) mode using a 50-mm transmittance cell filled with distilled water as a blank when setting the top of scale.
3. As an operational qualification (OQ) step, read back the cell of distilled water as a standard or sample. The reading should be very close to:

   L* = 100.0 ±0.05,
   a* = 0.0 ± 0.05,
   b* = 1.0 ± 0.05, and
   Haze % = 0.0

4. If any of the values are more than ±0.05 unit away from these values, stop and determine what the problem is.
5. Measure the four EP Liquid Opalescence Standards in the 50-mm transmittance cell and save the measurements. The Haze % of the standards should increase with the standard number.
6. Using Microsoft Excel or another spreadsheet/graphing program, determine the optimum correlation between the EP Standard Number (0 for distilled water, then 1, 2, 3, and 4) and the Haze % values for your measurements.
7. Implement the formula below in one of your software's custom formula fields in the Color Data Table/Master Color Data view so that EP Opalescence will be automatically calculated and displayed (see below)
8. Refill the 50-mm transmittance cell with a liquid sample and measure it with your instrument.

EP Opalescence = m*(Haze %) + b,

Where, m and b are the correlation coefficients determined

While EP visual Opalescence is reported in a rating system of single digits (corresponding to the standard the sample is most like), instrumental EP Opalescence may be reported to additional decimal places if desired.

Conclusion

The overall appearance of any object must take in to consideration its geometric attributes as well as it's chromatic or color attributes.

References

1. ASTM D1003-95, —Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics"
2. ASTM D4039 Standard Test Method for Reflection Haze of High-Gloss Surfaces
3. ASTM D523 Test Method for Specular Gloss
4. E430 Test Methods for Measurement of Gloss of High-Gloss Surfaces by Abridged Goniophotometer
5. European Pharmacopoeia (EP) Section 2.2.1, Clarity and degree of opalescence of liquids[www.pheur.org]
6. Hunter, Richard S. and Richard W. Harold, *The Measurement of Appearance*, New York: John Wiley and Sons, 1987.

About HunterLab

HunterLab is the technology leader in color measurement solutions, providing instruments, software, knowledge and service to a wide variety of industries.
With over 5 decades of experience in more than 65 countries, HunterLab applies our leading edge technology to your products helping you measure and communicate color simply and effectively.

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