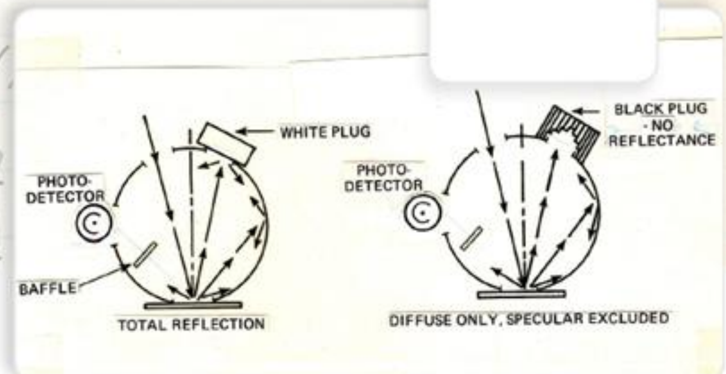
Applications Note

AN 1016



HunterLab Rd, a, b Color Scale History and Application

"The Rd,a,b scale has been in wide use for more than 25 years for the quality evaluation of limestone."

Abstract

The Rd,a,b scale is an industry specific color scale that was developed as early version of the Hunter L, a, b scale. Rd is used to designate lightness and is the same as the CIE Y Brightness/ Luminosity value. Sometimes the Rd, a, b is expressed as L_{Rd}, a_{Rd}, b_{Rd}.

This application note represents the history and calculation of the Hunter Rd, a, b color scale.

The world's true measure of color

HunterLab

History of HunterLab Rd, a, b Color Scale

Color metrics and color science have developed since the early 1900s with two overall themes, to quantify color based on human perception and to represent those color values in a form similar to the words used by humans to communicate color and color differences.

By 1931, the CIE tristimulus values X, Y, Z based on reflectance or transmission spectral data were used to quantify the human perception of color of an object. However X, Y, Z does not correspond well to lightness, saturation and hue typically used by humans to describe color.

Between 1943 and 1967 Richard Hunter made his best attempts to change the CIE X, Y, Z color scale into a form that facilitated better communication while incorporating the human vision concept of opponency. His efforts came in three stages starting with the Rd, a, b scale developed for C/2 conditions in 1943. Rd is identical to Y Brightness/Luminance which corresponds to average reflectance or transmittance of the material. The higher the reflectance or transmission of an object, the higher the Rd value. The “a_{Rd}” and “b_{Rd}” values quantify redness-greenness and blueness-yellowness but are not the same mathematical formula as the current Hunter a and b, or CIE a* and b* color values. The calculations are shown below in Figure 1.

Figure 1. Calculation of Rd, a, b.

$$a_{Rd} = K_a \times f(Y) \times \left\langle \left[\frac{X}{X_n}\right] - \left[\frac{Y}{Y_n}\right] \right\rangle$$

$$b_{Rd} = K_b \times f(Y) \times \left\langle \left[\frac{Y}{Y_n}\right] - \left[\frac{Y}{Y_n}\right] \right\rangle$$

Where:

- X, Y, Z are measured CIE tristimulus values for the sample
- Xn, Yn, Z are the CIE White Point tristimulus values in Tables 1 & 2 below for the chosen measurement illuminant/observer combination
- f(Y) = 0.51à (21 + 0.2 à Y) / (1 + 0.21à Y) (see note #1)
- K_a and K_b coefficients are given in the tables

Note #1 The quantity, f(Y), increases with decreasing values of Rd. Its purpose is to retard an undesirable contraction in size of the a_{Rd} and b_{Rd} scales that otherwise occurs as Rd approaches zero.

Table 1. CIE 1931 2-Degree observer/Illuminant White Point Values/10 nm Band Pass					
Illuminant	**X_n**	**y_n**	**Z_n**	**K_a**	**K_b**
A	109.829	100.000	35.547	185.20	38.40
C	98.043	100.000	118.106	175.00	70.00
D65	95.018	100.000	108.824	172.30	67.20
F_2	98.087	100.000	67.536	175.00	52.90
D50	96.384	100.000	82.446	173.51	58.84
D60	95.231	100.000	100.861	172.47	64.72
D75	94.955	100.000	122.527	172.22	71.29
UL 3000	107.994	100.000	33.908	183.70	37.50
TI 84	101.401	100.000	65.904	178.00	52.30

Table 2 CIE 1964 10-Degree Observer/Illuminant White Point Values/10 nm band Pass					
illuminant	**X_n**	**y_n**	**Z_n**	**K_a**	**K_b**
A	111.115	100.000	35.194	185.30	38.20
C	97.296	100.000	116.137	174.30	69.40
D65	94.825	100.000	107.380	172.10	66.70
F_2	102.130	100.000	69.369	178.60	53.60
D50	96.721	100.000	81.452	173.81	58.13
D60	95.210	100.000	99.595	172.45	64.28
D75	94.496	100.000	120.697	171.76	70.16
UL 3000	111.115	100.000	35.207	186.30	38.20
TI 84	103.824	100.000	66.896	180.10	52.70

Another key feature of this scale was that it could be automatically computed by analog devices such as the tristimulus colorimeters of the time.

The Limestone Application

The Rd value of this scale is used most often as a single-value overall brightness or reflectance for loose, neutral-color limestone-based powders. The Y-value is equivalent to the Rd but some industries become familiar with particular metrics and retain them to report the color quality of their products. In addition, b_{Rd} is sometimes used as a companion metric with Rd to quantify yellowness associated with trace metal contamination of limestone based powders.

In general, a limestone powder of the best color quality is associated with a higher Rd value and b_{Rd} value close to 0.

Limestone is typically prepared for analysis by pressing into a plaque as shown in Figure 2.

Figure 2. Loose Limestone and Pressed Plaque

Further History

The Hunter L, a, b color scale for C/2 illuminant/observer conditions was developed in 1958 and found popular acceptance which continues to this day. In 1967 the Hunter L, a, b color scale was adapted to additional illuminant and observer combinations through the use of Ka and Kb coefficients.

In 1976, the Hunter L, a, b color space was further mathematically optimized by the CIE to become the rectangular CIE L*, a*, b* color scale - lightness, redness- greenness and blueness-yellowness, and its polar equivalent, CIE L*, C*, h color scale - lightness, saturation and hue.

Today most of the color scale development has been done in terms of color differences, with a particular focus on elliptical scales. Elliptical differences correlate well to visual perception meaning that one unit of difference in an elliptical scale equals a visual unit of color change.

Summary

While still in use by the limestone industry, the Hunter Rd, a, b color scale has been supplanted over time by the Hunter L, a, b and CIE L*, a*, b* color scales.

References

Hunter, Richard S., and Harold, Richard W., The Measurement of Appearance, 2nd Ed., John Wiley and Sons, Inc. New York, NY USA 1987.

Ohta, Noboru and Robertson, Alan R., Colorimetry; Fundamentals and Applications, John Wiley and Sons, Inc., New York, NY USA (2005, p. 129).

About HunterLab

HunterLab, the first name in color measurement, provides ruggedly dependable, consistently accurate, and cost effective color measurement solutions. With over 6 decades of experience in more than 65 countries, HunterLab applies leading edge technology to measure and communicate color simply and effectively. The company offers both diffuse/8° and a complete line of true 45°/0° optical geometry instruments in portable, bench-top and production in-line configurations. HunterLab, the world's true measure of color.

 11/2023

The world's true measure of color
HunterLab