

# Hunter Rd, a, b Color Scale – History and Application



Application Note

No. 1016.01

## ***Abstract***

The Rdab scale is an opponent-color scale, an early version of the Hunter L, a, b scale. Instead of an L, 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 presents the history and form of the Hunter Rd, a, b color scale.

***The Rd, a, b color scale, developed in 1943, was an attempt to develop a better color scale for the communication of color based on CIE X, Y, Z tristimulus values. It was the first version of the better known Hunter L, a, b color scale.***

Keywords: Hunter Rd,  $a_{Rd}$ ,  $b_{Rd}$ , Rd a b, Rdab, opponent color scale

# Hunter Rd, $a_{Rd}$ , $b_{Rd}$

*The higher the reflectance or transmission of an object, the higher the Rd value.*

## History of Hunter Rd, a, b Color Scale

Color science has been a progression in the development of color metrics since the early 1900s with two overall themes – to quantify color as a person perceives it 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, representing additive red, green and blue primaries, does not correspond well to lightness, saturation and hue terms typically used in the human vocabulary 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 transmission 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.

Another key feature of this scale was that being derived by linear mathematical operations from CIE X, Y, Z, the Rd,  $a_{Rd}$ ,  $b_{Rd}$  color scale could be automatically computed by analog devices such as early tristimulus colorimeters of the time.



Formula:  $R_d$ ,  $a_{Rd}$ ,  $b_{Rd}$  was originally developed for C/2 conditions but can be used with other illuminant/observer conditions using the more generalized formula:

$$R_d = Y$$

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

$$b_{Rd} = K_b * f(Y) * \left( \left[ \frac{Y}{Y_n} \right] - \left[ \frac{Z}{Z_n} \right] \right)$$

where:  $X, Y, Z$  are measured CIE tristimulus values for the sample  
 $X_n, Y_n, Z_n$  are the CIE White Point tristimulus values in Tables 1 & 2 below for the chosen measurement illuminant/observer combination

$$f(Y) = \frac{0.51 * (21 + 0.2 * Y)}{1 + 0.21 * Y} \quad (\text{see note \#1})$$

$K_a$  and  $K_b$  coefficients are given in the tables below.

#### Measurement Conditions:

- Instruments: Most HunterLab Instruments
- Illuminant: Any
- Standard Observer: 2 or 10 degree
- Mode: Reflectance or Transmittance

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

Table 1.  
**CIE 1931 2 Degree Observer/Illuminant White Point Values/0 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
D <sub>65</sub>	95.018	100.000	108.824	172.30	67.20
F <sub>2</sub>	98.087	100.000	67.536	175.00	52.90
D <sub>50</sub>	96.384	100.000	82.446	173.51	58.84
D <sub>60</sub>	95.231	100.000	100.861	172.47	64.72
D <sub>75</sub>	94.955	100.000	122.527	172.22	71.29
UL 3000	107.994	100.000	33.908	183.70	37.50
Tl 84	101.401	100.000	65.904	178.00	52.30

Table 2.  
CIE 1964 10 Observer/Illuminant White Point Values/10 nm Band Pass

<b>Illuminant</b>	<b>X<sub>n</sub></b>	<b>Y<sub>n</sub></b>	<b>Z<sub>n</sub></b>	<b>K<sub>a</sub></b>	<b>K<sub>b</sub></b>
<b>A</b>	111.115	100.000	35.194	186.30	38.20
<b>C</b>	97.296	100.000	116.137	174.30	69.40
D <sub>65</sub>	94.825	100.000	107.380	172.10	66.70
F <sub>2</sub>	102.130	100.000	69.369	178.60	53.60
D <sub>50</sub>	96.721	100.000	81.452	173.81	58.13
D <sub>60</sub>	95.210	100.000	99.595	172.45	64.28
D <sub>7</sub>	94.496	100.000	120.697	171.76	70.16
UL 3000	111.115	100.000	35.207	186.30	38.20
Tl 84	103.824	100.000	66.896	180.10	52.70

### Application

The Rd value of this scale used most often as a single-value overall brightness or reflectance for loose, neutral-color limestone-based powders. The Y-value can be used instead as they are identical, 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.

### Further History

Following Rd,  $a_{Rd}$ ,  $b_{Rd}$ , Richard Hunter developed the Hunter L,  $\alpha$ ,  $\beta$  C/2 color scale for lightness, "alpha" redness- greenness and "beta" blueness-yellowness which were different from Rd, a, b and Hunter L, a, b. Unfortunately, this second generation opponent color scale did not find popular industry acceptance and has subsequently disappeared into color science history.

The Hunter L, a, b color scale for C/2 illuminant/observer conditions was developed in 1958 and found popular acceptance to this day as a major breakthrough. In 1967 the Hunter L, a, b color scale was adapted to additional illuminant and observer combinations in 1967 through the use of  $K_a$  and  $K_b$  coefficients for different illuminant and observer combinations.

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.

From this point on to today most of the color scale development has been done in terms of color differences, with a particular focus on elliptical color differences that correlate an equal difference value for a perceived uniform color difference.

### Summary

While still in use in some areas of 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.

***Today, the Hunter Rd, a, b Color Scale is available in most HunterLab software products.***

### References

Hunter, Richard S., and Harold, Richard W; The Measurement of Appearance, 2<sup>nd</sup> ed., John Wiley and Sons, Inc. New York, NY USA 1987.

### About Hunter Lab

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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