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Spectrophotometric Analysis

Calculating Gardner Color Numbers from Modern Color Software Chromaticity Values

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Although somewhat dated, Gardner color numbers are still very much a part of established analytical procedures used in the US to evaluate the color of a variety of samples. Modern color software can provide more accurate color analysis using color scales such as CIE XYZ, CIE Lab, or chromaticity. However, the Gardner scale is well-established in certain industries and still widely utilized; consequently, it is occasioned that results from a Modern Color Scale be converted to equivalent Gardner numbers.

The Shimadzu Color Software allows the selection of a variety of Color Scales including CIE XYZ, CIE Lab, and Chromaticity (figure 1). In addition, various other parameters such as the dominant wavelength (dWL) can be selected. For Gardner analysis by ASTM D6166, the Chromaticity parameters, x and y, are required for the conversion calculations.

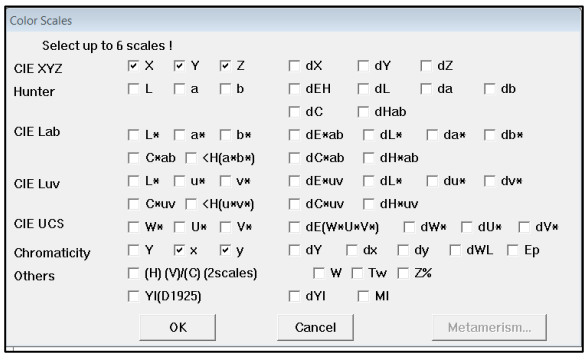

Figure 1: Shimadzu Color Software Color Scale Options

In addition, the Color Software allows the selection of illuminant and standard Observer. For ASTM D6166, the "C" illuminant (average daylight), and a standard observer setting of "2degree" are selected, Figure 2.

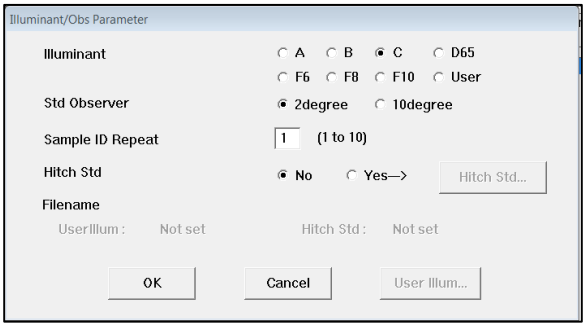

Figure 2: Shimadzu Color Software Parameter Selection

Using a UV-Vis Spectrophotometer, either a Transmittance or Reflectance scan is acquired from the sample whose Gardner number is required. The sample is read into the Color Software and then selected color scale parameters are calculated and displayed, Figure 3. In the case below, the chromaticity values (x and y) for the Sample Y50-1800 were calculated to be x = 0.4576 and y = 0.5205.

	Standard		0.00	0.00	0.00	0.0000	0.0000	
	Seq No.	Sample ID	X	Y	Z	x	y	FileName
	1	2	24.68	10.89	0.01	0.6936	0.3062	R60_1800
	2	3	57.42	39.60	0.08	0.5914	0.4079	O56_1800
*	3	4	71.09	80.87	3.39	0.4576	0.5205	Y50_1800

Figure 3: Chromaticity values x and y, calculated from the Shimadzu Color Software

According to ASTM D6166, the Gardner value (G_{TM}) is the summation of an integer portion (G_1) and a fractional portion (G_F), or:

$G_{TM} = G_1 + G_F$ Equation 1[1]

The integer portion G1, is determined by comparing the x chromaticity value obtained from the software with the x chromaticity values in Table X1.1 of ASTM D6166 and shown below as Table 1. The x value of the sample is 0.4576 and is found to lie between the table x values of 0.4503 (defined as x_{lower}) and 0.4842 (defined as x_{upper}). ASTM D6166[1] specifies that the integer value, G_1 takes the Gardner number of the x value that is lower (x_{lower}) than the measured sample value. For the sample Y-50 1800, this would be that $G_1 = 10$.

Table 1: Gardner number comparison from ASTM D6166[1]

Gardner #	x	y	Y
1	0.3177	0.3303	80
2	0.3233	0.3352	79
3	0.3329	0.3452	76
4	0.3437	0.3644	75
5	0.3558	0.3840	74
6	0.3767	0.4061	71
7	0.4044	0.4352	67
8	0.4207	0.4498	64
9	0.4340	0.4640	61
10	0.4503	0.4760	57
11	0.4842	0.4818	45
12	0.5077	0.4638	36
13	0.5392	0.4458	30
14	0.5646	0.4270	22
15	0.5857	0.4089	16
16	0.6047	0.3921	11
17	0.6290	0.3701	6
18	0.6477	0.3521	4

The fractional value G_F, of the Gardner number is calculated by equation 2[1], which follows:

$$G_F = \frac{[(x_{upper}-x_{lower})(x_{sample}-x_{lower})+(y_{upper}-y_{lower})(y_{sample}-y_{lower})]}{(x_{upper}-x_{lower})+(y_{upper}-y_{lower})}$$

For the Y_50 1800 sample, this equation becomes:

$$G_F = \frac{[(0.4842-0.4503)(0.4576-0.4503)+(0.4818-0.4760)(0.5205-0.4760)]}{(0.4842-0.4503)+(0.4818-0.4760)} = 0.00069$$

From Equation-1 above, the final Gardner number is then calculated to be:

$G_F = 10 + 0.0069 = 10.0069$

■ References

[1]ASTM Standard D6616, 2012, "Standard Test Method for Color of Pine Chemicals and Related Products (Instrumental Determination of Gardner Color," ASTM International, West Conshohocken, PA, 2003, DOI: 10.1520/D6616-12, www.astm.org.

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