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Standard Test Method for Using Reflectance Spectra to Produce an Index of Temperature Rise in Polymeric Siding[1]

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1. Scope

1.1 This test method uses reflectance spectra from the ultraviolet, visible, and near infrared region to produce an index of the temperature rise of polymeric siding above ambient temperature that occurs due to absorption of the sun's energy.

1.2 The test method determines the intensity factor of a sample color. The intensity factor is a function of the sample's reflectance spectra and the energy output of the heat lamp used in the test method Test Method D4803.

1.3 Appendix X1 provides a method for using the intensity factor to determine the maximum temperature rise of a sample under severe solar exposure.

1.3.1 A correlation between intensity factor and heat buildup (temperature rise) as predicted by Test Method D4803 exists.

1.3.2 The heat buildup (temperature rise) for a polymeric building product specimen is determined from its reflectance spectra and the correlation's regression equation.

1.4 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D2244 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates

D4803 Test Method for Predicting Heat Buildup in PVC Building Products

E903 Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres

E1331 Test Method for Reflectance Factor and Color by Spectrophotometry Using Hemispherical Geometry

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *fractional absorptance*—one minus Fractional Reflectance, 1 – R.

3.1.2 *fractional reflectance*—the percentage of energy reflected by a sample at a given wavelength, divided by 100.

3.1.3 *intensity factor*—an indicator of a specimen's heat buildup based on its reflectance spectrum and the energy output of the IR lamp used in Test Method D4803.

3.1.3.1 *Discussion*—The intensity factor is a summation product of the heat lamp's relative intensity and the specimen's fractional absorptance at 20 nm intervals between 200 and 2,500 nm.

3.1.4 *heat buildup*—the temperature rise above that of ambient air due to the amount of energy absorbed from the sun by a specimen.

3.1.5 *relative intensity (of heat lamp)*—the lamp's spectral output across the range of 200 nm to 2500 nm, normalized to a value of 100 at the lamp's maximum output.

4. Summary of Test Method

4.1 The specimen's size must cover the spectrophotometer's measurement port, typically 25.4 mm in diameter. Typical sample dimensions are 102 by 102 by 1.3 mm.

4.2 A black backer card or plaque is used directly behind the specimen to absorb any radiant energy transmitted through the specimen.

4.3 The spectral reflectance curve of the test specimen is measured to determine the amount of energy the specimen absorbs at each wavelength.

4.4 The intensity factor of the test specimen is the result of a series summation for the specimen's spectral absorptance and the relative intensity of the IR lamp used in Test Method D4803. The product of the specimen's spectral absorptance and relative intensity is determined for the spectral region of 200 – 2,500 nm at an interval of 20 nm

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4.5 Appendix X1 provides a method for using the intensity factor to determine the maximum temperature rise of a sample under severe solar exposure.

4.5.1 A correlation of intensity factors and heat buildup (temperature rise) results from Test Method D4803 for a number of specimens was determined to derive an equation expressing a specimen's temperature rise as a function of its reflectance.

4.5.2 A specimen's heat buildup is determined by measuring its reflectance in the UV, VIS, and NIR spectral region and the correlation's regression equation.

5. Significance and Use

5.1 Heat buildup of polymeric building products due to absorption of energy from the sun may lead to distortion problems. Test Method Test Method D4803 was developed to predict a building product's heat buildup (temperature rise). It compares the relative temperature changes of a pigmented PVC product and a PVC panel containing carbon black when exposed to an infrared heat lamp. Based on experimental results that determined the maximum temperature for this black panel under both solar exposure and in the laboratory test, a method for determining the exterior temperature rise and heat buildup for a test panel was developed. This test has shown to be useful and reliable but is time consuming and requires controlled conditions to minimize sources of variation.

5.2 This test method uses a spectrophotometer to measure a specimen's reflectance in the ultraviolet, visible, and near infrared region and uses the spectral power distribution of the heat lamp specified in Test Method D4803 to determine an intensity factor, which is an index of the relative spectral energy absorption by the specimen.

5.2.1 The temperature rise that would occur under an Test Method D4803 test is proportional to this intensity factor. An equation has been derived from the correlation of the intensity factor and temperature rise data obtained from Test Method D4803 testing of samples with a wide range of color and lightness. A total of 99 samples were studied and represent samples with the lowest to highest temperature rise. Linear regression analysis yields a R2 correlation coefficient of 0.98.

5.2.2 The procedure in Appendix X1 allows prediction of temperature rise that would result from testing of the same sample under Test Method D4803.

5.2.3 As this procedure is a correlation to results obtained by Test Method D4803, it is a method that yields a relative temperature rise compared to black under certain defined severe conditions, but does not predict actual field application temperatures of the product. These product temperatures are influenced by incident angle of the sun, clouds, wind speed, insulation, installation behind glass, etc.

5.3 The intensity factor itself is a dimensionless index of the relative energy absorption of the specimen, without conversion to a temperature rise. It can be used to compare the heat buildup characteristics of different colors, or different candidate formulations for the same color. It can also be used to categorize color into ranges of intensity factor, to be used as a basis for testing of full siding products for resistance to thermal distortion.

6. Apparatus

6.1 *UV/VIS/NIR Spectrophotometer*—The spectral reflectance data are obtained using a spectrophotometer equipped with a PTFE-coated integrating sphere detector, capable of reading spectral reflectance across the range of 200 nm to 2500 nm.

7. Sampling and Test Specimens

7.1 Samples shall be representative of the color or pigment system under study.

7.2 Test specimens shall consist of the actual product or material in which the color is used, in a thickness typical of the actual product.

7.3 An opaque black backing material is placed behind the specimen. The backer shall be a card, plaque or other rigid or semi-rigid material. The black color shall cover the entire surface.

7.3.1 Measure the color of the backer in accordance with Test Method E1331. Calculate the CIE 1976 L*a*b* units in accordance with the "CIE 1976 L* a* b* Uniform Color Space and Color-Difference Equation" in Practice D2244.

7.3.2 The backer shall have L* not greater than 30.0, and both a* and b* shall not exceed ±3.0.

7.4 The specimen and backer shall be large enough to cover the instrument's sample port and fit inside the instrument's measurement compartment.

8. Procedure

8.1 Allow the spectrophotometer instrument to warm up and stabilize according to manufacturer's instructions.

8.2 Acquire a baseline correction according to manufacturer's instructions.

8.3 Acquire spectral data between 200 and 2,500 nm.

8.4 Check the spectrophotometer's readiness by testing a known standard.

8.5 Once the instrument's readiness is confirmed, proceed with the analysis.

8.6 Place the test specimen and black backer on the measurement port with the side to be tested facing and covering the instrument's measurement port.

8.7 Acquire the test specimen's spectral reflectance data 200 – 2,500 nm following the procedures in Test Method E903.

9. Calculation

9.1 Determine the test specimen's Intensity Factor:

$$IF = \sum_{n=1}^{116} (1 - R_{\lambda = 20n + 180}) * L_{\lambda = 20n + 180} \qquad (1)$$

where:

IF = Intensity Factor,

R_{λ} = Fractional Reflectance of the test specimen at specified wavelength,

L_{λ} = Relative Intensity of the IR heat lamp used in Test Method D4803 at specified wavelength and reported in Table 1.

TABLE 1 Relative Intensity of IR Heat Lamp Used in Test Method D4803

λ	Lλ	λ	Lλ	λ	Lλ	λ	Lλ	λ	Lλ
200	0	680	41	1160	100	1640	61	2120	33
220	0	700	45	1180	99	1660	59	2140	32
240	0	720	50	1200	99	1680	58	2160	31
260	0	740	56	1220	98	1700	56	2180	30
280	0	760	60	1240	97	1720	55	2200	29
300	0	780	63	1260	96	1740	53	2220	28
320	0	800	67	1280	95	1760	52	2240	27
340	0	820	70	1300	94	1780	51	2260	26
360	0	840	73	1320	94	1800	50	2280	25
380	2	860	77	1340	93	1820	49	2300	24
400	3	880	80	1360	92	1840	48	2320	23
420	4	900	83	1380	90	1860	47	2340	22
440	5	920	85	1400	88	1880	46	2360	21
460	6	940	88	1420	86	1900	45	2380	20
480	8	960	91	1440	84	1920	44	2400	19
500	10	980	94	1460	82	1940	43	2420	18
520	13	1000	95	1480	80	1960	42	2440	17
540	18	1020	96	1500	78	1980	41	2460	16
560	21	1040	97	1520	76	2000	40	2480	15
580	25	1060	98	1540	74	2020	39	2500	14
600	28	1080	99	1560	72	2040	38		
620	32	1100	100	1580	70	2060	37		
640	35	1120	100	1600	68	2080	36		
660	38	1140	100	1620	65	2100	35		

10. Precision and Bias

10.1 The precision and bias of this test method for measuring spectral reflectance are essentially as specified in Test Method E903.

11. Keywords

11.1 heat build; intensity factor; polymeric siding; siding; spectral reflectance; temperature rise

APPENDIX

X1. DETERMINING MAXIMUM TEMPERATURE RISE

(Nonmandatory Information)

X1.1 The intensity factor can be used to calculate an estimated maximum temperature rise for the sample under high-intensity solar exposure. The temperature rise for the sample in a vertical position can be calculated separately from that in a horizontal position.

X1.1.1 The temperature rise predicted by this method has been found to closely match the "heat buildup" temperature rise determined for the same sample using Test Method D4803.[2]

X1.2 Use the specimen's intensity factor, determined in 9.1, in the following equations to calculate the predicted temperature rise, in °C.

X1.2.1 Vertical sample orientation:

$$\Delta T(°\ C) = 0.00501 * IF + 14.2 \qquad (0)$$

X1.2.2 Horizontal sample orientation:

$$\Delta T(°\ C) = 0.00611 * IF + 17.3 \qquad (0)$$

X1.3 The maximum temperature the specimen is likely to reach outdoors due to natural, non-reflected sunlight under the most severe conditions (clear sky, no wind, sun is perpendicular to the specimen) is estimated by adding the predicted temperature rise to the ambient outdoor temperature.

[2] T. Sullivan and G. Peake, *Journal of Vinyl Technology*, "Use of Reflectance Spectra to Predict Heat Buildup of Pigmented PVC Panels," Vol. 15, No. 4, p 232-236, December 1993.