T 527 om-02

SUGGESTED METHOD – 1972
CLASSICAL METHOD – 1992
OFFICIAL METHOD – 1994
REVISED – 2002

Color of paper and paperboard (*d*/0, C/2)

1. Scope

1.1 This method specifies a procedure for measuring the color of paper or paperboard with tristimulus filter colorimeters or spectrophotometers incorporating diffuse/0 geometry and CIE (International Commission on Illumination) illuminant *C*.

NOTE 1: TAPPI T 524 "Color of Paper and Paperboard (45/0, C/2)" describes a similar procedure using directional illumination and normal viewing.

1.2 In the method, tristimulus values X (red), Y (green), and Z (blue), appropriate to the CIE-1931 (2°) standard observer, are calculated from reflectance measurements R_x, R_y, and R_z or from R (λ) data. Color can then be expressed in various color space systems:

1. Hunter *L, a, b*
2. CIE L^*, a^*, b^*
3. L^*, C^*, h
4. Dominant wavelength, purity, luminosity
5. Color difference, [ΔE, ΔE^*, ΔE^*94, ΔE (CMC)]

1.3 Instruments equipped with microprocessors which give direct information relating to different color scale systems conform to this method only if the means of measurements and calculation conform to the descriptions herein.

2. Significance

2.1 The color appearance of paper and paperboard is important for its aesthetic value in marketing packaged products, as an aid to distribution of multi-ply forms; to differentiate pages or sections of published literature, in artwork, and in many other applications.

2.2 A numerical definition of color is essential to good quality control and to customer-producer relationships.

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4.4 *Photometric characteristics.* The photometric system must be linear over the entire scale to within 0.2% of full scale. Photometric linearity may be determined by following the procedure described in TAPPI TIP 0804-06 "Photometric Linearity of Optical Properties Instruments." The instrument must be sufficiently stable that the reflectance factor reading will not fluctuate by more than 0.1% of full-scale deflection while the measurement is being made.

5. Standards

5.1 *Primary reflectance standard*[1]. The primary reflectance standard (100%) is an ideal uniform diffuser with a perfectly reflecting and diffusing surface (the perfect reflecting diffuser).

5.2 *Calibration standards*[1]. Calibration standards of ceramic and other materials, used to adjust and check the instrument scale, are available from instrument manufacturers and other sources. Reflectance values assigned to calibration standards shall be traceable to an instrument calibrated in terms of the primary standard and having geometric and spectral characteristics consistent with this method.

5.3 *Specific calibration standards*[1]. Specific calibration standards, colored similar to the paper to be tested, may be used to minimize the effect of spectral and geometric differences between instruments whose results are being compared. The "specific calibration" values for these ceramic standards should be established by first exchanging paper samples of the type of paper to be compared. The paper sample and the ceramic standard must not form a metameric pair.

5.4 *Black standard* – a black cavity with a reflectance factor which does not differ from its nominal value by more than 0.2 reflectance units at all wavelengths.

6. Calibration

6.1 The calibration of photometric scales shall be carefully checked at reasonable time intervals in a manner to insure linearity and accuracy over all ranges. Calibration may be accomplished by placing a series of neutral filters of known transmittance in the incident beam, or by measuring the reflectance factor of calibrated opaque specimens.

NOTE 3: Reference (*1*) describes procedures for use of a set of special test panels in calibration of major photometric, spectral, and geometric characteristics of the instrument.

6.2 Photometric linearity and proper spectral response of the instrument are key factors for determining accurate color measurements. Colored standards should be carefully measured and their results compared to assure color measurement accuracy of the apparatus.

NOTE 4: Ceramic or glass standards may be cleaned, if necessary, using the procedures provided by the supplier of the standards.

6.3 Place the black standard against the specimen aperture and adjust the zero setting of the instrument.

6.4 Replace the black standard with a white calibration standard and set the instrument to the calibrated reflectance value of the standard at each filter position or wavelength, as appropriate.

7. Test specimen

From each test unit of the paper obtained in accordance with TAPPI T 400 "Sampling and Accepting a Single Lot of Paper, Paperboard, Containerboard, or Related Product," cut the sample to be tested into pieces large enough to extend at least 0.25 in. (6.35 mm) beyond all edges of the instrument aperture. Assemble the pieces into a pad which is thick enough so that doubling the pad thickness does not change the test readings. (With creped or other bulky papers care must be taken to avoid pillowing of the pad into the instrument by too much pressure.) Do not touch the test areas of the specimens with the fingers, and protect them from contamination, excessive heat, or intense light.

8. Procedure

8.1 Operate the instrument in accordance with the manufacturer's instructions. Allow adequate warm-up to insure stable results.

8.2 Calibrate the instrument as described in Section 6.

8.3 Place the opaque pad of sample sheets with the side to be measured against the sample aperture and obtain the reflectance values R_x, R_y, and R_z and/or the reflectance spectra.

8.4 Move the uppermost test piece to the bottom of the pad and obtain the reflectances of the newly exposed specimen. Repeat this process until five specimens have been tested.

8.5 Recheck the instrument calibration and retest the sample if any of the calibration reflectances show a drift greater than 0.1% of full scale.

9. Calculations

NOTE 5: The use of the three filter system may result in small to significant differences from the values obtained using the full function for the tristimulus value X depending upon the spectral characteristics of the sample (*4*).

9.1 Calculate the tristimulus values X, Y, and Z for each specimen from:

$$X = 0.78341\ R_x + 0.19732\ R_z$$
$$Y = R_y$$
$$Z = 1.18232\ R_z$$

or by using the integration tables in ASTM E308, "Standard Practice for Computing the Color of Object by Using the CIE System," for a spectrophotometer.

9.2 Calculate color in one of the following color space systems: (most instruments are equipped with microprocessors which do the necessary computational work).

9.2.1 Hunter L, a, b. Calculate Hunter color values from:

$$L = 100\ (Y/Y_0)^{1/2}$$
$$a = K_a\ (X/X_0 - Y/Y_0)/(Y/Y_0)^{1/2}$$
$$b = K_b\ (Y/Y_0 - Z/Z_0)/(Y/Y_0)^{1/2}$$

Constants for the above equations for illuminant $C/2$ are $X_0 = 98.073$, $Y_0 = 100$, $Z_0 = 118.232$, $K_a = 175.0$, and $K_b = 70.0$.

If desired, calculate color difference from:

$$\Delta E = (\Delta L^2\ +\ \Delta a^2\ +\ \Delta b^2)^{1/2}$$

9.2.2 *CIE L^*, a^*, b^* (CIELAB)*. Calculate CIELAB color values from: (preferred)

$$L^* = 116\ (Y/Y_0)^{1/3} - 16$$
$$a^* = 500\ [(X/X_0)^{1/3} - (Y/Y_0)^{1/3}]$$
$$b^* = 200\ [(Y/Y_0)^{1/3} - (Z/Z_0)^{1/3}]$$

where: X/X_0, Y/Y_0 and $Z/Z_0 > 0.01$. The constants X_0, Y_0, and Z_0 are given in paragraph 9.2.1. If desired, calculate color difference from:

$$\Delta E^* = (\Delta L^{*2}\ + \Delta a^{*2}\ + \Delta b^{*2})^{1/2}$$

9.2.3 L^*, C^*, h. Calculate CIELAB color values as in paragraph 9.2.2. Then calculate chroma (C^*) and hue angle (h) from:

$$C^* = (a^{*2} + b^{*2})^{1/2}$$
$$h = \arctan\ (b^*/a^*)$$