CIE whiteness and tint of paper and paperboard (using d/0º, diffuse illumination and normal viewing)

1. Scope

1.1 This method is to be used to determine the CIE whiteness and tint indices \((I)\) of white or near white specimens with or without optical brighteners. Whiteness differs fundamentally from paper brightness in that whiteness includes the entire visible spectrum in its assessment whereas brightness includes only the blue portion of the spectrum.

2. Summary

2.1 The tristimulus values of the specimen are determined under the conditions specified in this method and the CIE whiteness and tint values are then calculated. The ultraviolet (UV) content of different light sources affects the excitation of fluorescent brighteners to a greater or lesser degree and therefore it is necessary to provide a means of adjustment of the ultraviolet energy.

3. Significance

3.1 Paper is bought, sold and used primarily indoors. Therefore it is important to assess the “whiteness” of the paper under similar conditions. When “white” papers are ranked subjectively, it has been shown that people prefer bluish whites to grayish, yellowish, greenish, or pinkish whites. As a consequence, papermakers often add fluorescent whitening agents or optical brightening agents to enhance the appearance of their papers. The CIE whiteness and tint equations have a blue bias to better quantify what people prefer. It has been shown that CIE whiteness values correlate well with visual whiteness assessment when the UV level of the source approximates that of average indoor lighting \((2)\).

3.2 A positive tint value indicates a greenish sample, a negative value indicates a reddish sample. The further the tint value is from zero, the more colored the sample. The perfectly reflecting diffuser has a whiteness value of 100 and a tint value of 0. Whiteness and tint values are not appropriate for strongly colored samples.

4. Definitions

4.1 CIE whiteness index: A measure of whiteness derived from measurements of the CIE tristimulus factors under the conditions specified in this method.

5. Apparatus

5.1 Instrumental components: consisting of a means for fixing the location of the surface of the specimen, a system for proper illumination of the specimen, suitable filters or monochromator for altering the spectral character of the rays reflected from the specimen, photosensitive receptors located to receive the rays reflected by the specimen and a means of transforming the receptor signals to tristimulus functions.
5.2  Spectral characteristics.

5.2.1  Incident light:  The spectral power distribution of the light incident on the specimen is not critical so long as sufficient energy is provided at each wavelength between 340 and 700 nm to achieve the overall spectral response shown in 5.2.2 (3).  The incident UV light energy must be adjustable to allow calibration to the fluorescent standard.

5.2.2  Spectral response:  The overall spectral response of the instrument, as determined by the combination of the spectral distribution of incident light on the specimen, the absorption characteristics of the filters and other light altering optics, and the photosensitive response of the receptors to light reflected from the specimen, shall simulate the CIE color-matching function weighted by the spectral energy distribution of the CIE Illuminant $C/2^\circ$ given in ASTM Standard E 308 (4).

5.2.3  Geometric characteristics:  The specimen shall be illuminated diffusely by means of an integrating sphere meeting the requirements of ISO 2469.  The direction of viewing shall be perpendicular within ± 0.5° to the specimen surface.  Only reflected rays within a solid cone, whose vertex is in the specimen aperture, and of half-angle not greater than 4°, shall fall on the receptor.  To prevent specularly reflected light from reaching the receptor, the receptor aperture shall be surrounded by a black annulus (gloss trap) with external diameter subtending a half-angle of 15.5 ± 0.5° at the center of the specimen aperture.

NOTE 1: Interchange of incident and viewing directions is not provided for within the context of this method.

5.2.4  Photometric characteristics:  The photometric system must be linear over the entire scale to within 0.2% of full scale.  It must be sufficiently stable that the reflectance factor reading will not fluctuate by more than 0.1% of the full scale deflection while the measurement is being made.

6.  Standards

6.1.  Primary reflectance standard:  The primary reflectance standard (100%) is an ideal uniform diffuser with a perfectly reflecting and diffusing surface (the perfect reflecting diffuser).

6.2  Reference standards:  Reference standards, used to adjust and check the instrumental scale on a regular basis, are available from calibrations laboratories, instrument manufacturers and other sources.  Reflectance values assigned to reference standards shall be traceable to an instrument calibrated in terms of the primary standard and having the appropriate geometric and spectral characteristics consistent with the instrument being used.  A stable black standard and at least one stable non-fluorescent white standard must be employed.  If measurements are to be made on optically brightened (fluorescent) specimens, the instrument must also be calibrated to a fluorescent white standard.

7.  Calibration

7.1  Allow the instrument to warm up according to the manufacturer's instructions.

7.2  Using the reference standards described in 6.2, follow the manufacturer's instructions to achieve calibration.

8.  Test specimen

8.1  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 1/4 inch 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.

9.  Procedure

9.1  Calibrate the instrument as described in Section 7.

9.2  Place the opaque pad of sample sheets with the side to be measured against the sample aperture and make a measurement.  If the instrument automatically calculates CIE whiteness, go on to 9.3; otherwise obtain the reflectance values $R_x$, $R_y$ and $R_z$ or tristimulus values, $X$, $Y$ and $Z$.  

NOTE 2:  Interchange of incident and viewing directions is not provided for within the context of this method.
9.3 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 measured.

9.4 Recheck the instrument calibration and retest the sample if any of the calibration values have drifted by more than 0.1% of full scale.

10. Calculations

If the CIE whiteness and tint values are not calculated directly it may be necessary to make the following calculations:

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

and then

\[
x = \frac{X}{X + Y + Z}
\]
\[
y = \frac{Y}{X + Y + Z}
\]

and finally

CIE whiteness = \( Y + 800 (x_n - x) + 1700 (y_n - y) \)
CIE tint = \( 1000 (x_n - x) - 650 (y_n - y) \)

Positive tint indicates greenishness.
Negative tint indicates reddishness.

Where \( x_n \) and \( y_n \) for illuminant \( C/2^\circ \) are:

\( x_n = 0.3100605 \)
\( y_n = 0.3161496 \)

As guidelines, the following limits are recommended:

\( 5Y - 280 > W > 40 \)
\( -3 < T < 3 \)

where

\( W = \text{whiteness} = \text{CIE whiteness} \)
\( T = \text{tint} = \text{CIE tint} \)

11. Report

11.1 Report the average values and standard deviations for the whiteness and tint value.
11.2 Identify the sample type and side (or sides) tested.
11.3 Identify the instrument used by geometry, manufacturer’s name and model number.
11.4 Report any deviations from this method.

12. Precision

The repeatability of CIE Whiteness is better than 1% and the repeatability for CIE Tint is better than 11% in accordance with T 1206 “Precision Statement for Test Methods.” These numbers are based on a study of three different specimens on one instrument with one operator and five replicates.

13. Keywords

Color, whiteness, tinting, brightness

14. Additional information

14.1 Effective date of issue: February 16, 1996.
Literature cited


References


*Your comments and suggestions on this procedure are earnestly requested and should be sent to the TAPPI Technical Divisions Administrator.*