Whiteness of Textiles

Developed in 1964 by AATCC Committee RA34; Jurisdiction transferred in 1983 to AATCC Committee RA36; reaffirmed 1968, 1972, 1975, 1979, 2000, 2005; editorially revised 1979, 1980; revised 1989 (title change), 1995; editorially revised and reaffirmed 1994. Technically equivalent to ISO 105-J02.

1. Purpose and Scope

1.1 This test method provides procedures for measuring the whiteness and tint of textiles.

1.2 Whiteness as measured by this test method is an indication of how white the textile appears to an average viewer. Tint, if other than zero, is an indication of a reddish or greenish hue having shifted away from a bluish hue with a dominant wavelength of 466 nm. The formulas for calculation of whiteness and tint are those recommended by the CIE (see 11.1).

1.3 Because reflectance is affected by the nature of the surface of the textile, comparisons can be made only between samples of the same type of textile.

1.4 The application of the formulas is restricted to specimens that are called "white" commercially, that do not differ much in color and fluorescence, and that are measured on the same instrument at nearly the same time. Within these restrictions, the formulas provide relative, but not absolute, evaluations of whiteness that are adequate for commercial use, when employing measuring instruments having suitable modern and commercially available capabilities.

2. Principle

2.1 The CIE tristimulus values are measured using a reflectance spectrophotometer or colorimeter, and the whiteness and tint calculated from formulas based on the CIE chromaticity coordinates.

2.2 Many impurities in textiles absorb short wavelength light, resulting in a yellowish appearance to observers. Therefore, a measurement of whiteness may be an indication of the degree to which a textile is free from impurities.

2.3 The presence of blueing components or fluorescent whitening agents (FWAs) in textiles may also be determined using the whiteness measurement.

3. Terminology

3.1 **CIE chromaticity coordinates,** n.—the ratio of each of the tristimulus values of a psychophysical color to the sum of the tristimulus values (see 11.1) [ASTM E 284].

3.2 **CIE tristimulus values,** n.—amounts of three non-real reference color stimuli required to give a color match with the color stimulus considered, and defined by the CIE for the CIE 1931 standard observer and the CIE 1964 supplementary standard observer and for a particular illumination condition (see 11.1).

3.3 **fluorescent whitening agent (FWA),** n.—colorant that absorbs near ultraviolet (UV) radiation and re-emits visible (violet-blue) radiation. This causes a yellowish material to which it has been applied to appear whiter. [ASTM E 284].

3.4 **perfect reflecting diffuser,** n.—ideal reflecting surface that neither absorbs nor transmits light, but reflects diffusely, with the radiance of the reflecting surface being the same for all reflecting angles, regardless of the angular distribution of the incident light. [ASTM E 284].

NOTE: The perfect reflecting diffuser is the basis of calibration of reflectance measuring instruments. The equations for whiteness and tint are formulated so that the CIE concept of the perfect reflecting diffuser has a whiteness index of 100.0 and a tint value of 0.0.

3.5 **tint,** n.—*in whiteness measurement*, the hue of a white material as influenced by the wavelength of peak emission or reflectance. [CIE 15.2].

3.6 **whiteness,** n.—whiteness is the attribute by which an object color is judged to approach a preferred white. [ASTM E 284].

4. Safety Precautions

NOTE: These safety precautions are for information purposes only. The safety precautions are ancillary to the testing procedures and are not intended to be all inclusive. It is the user's responsibility to use safe and proper techniques in handling materials in this test method. Manufacturers MUST be consulted for specific details such as material safety data sheets and other manufacturer's recommendations. All OSHA standards and rules must also be consulted and followed.

4.1 Good laboratory practices should be followed. Wear safety glasses in all laboratory areas.

4.2 CAUTION: Protect the eyes from UV light. The safety recommendations provided by the UV light manufacturer should be followed.

4.3 Manufacturer's safety recommendations should be followed when operating laboratory testing equipment.

5. Apparatus and Materials

5.1 Color Measuring Instrument. A reflectance spectrophotometer or colorimeter capable of measuring or calculating CIE tristimulus values with at least one of the CIE specified geometries (45/0, 0/45, diffuse/0, 0/diffuse). When integrating spheres are used for measuring fluorescent specimens, the spectral power distribution of the illuminating system is altered by the reflected and emitted power from the specimen. The use of the 45/0 or 0/45 condition is therefore preferable (see 11.1).

5.2 Reference Standard. The primary standard is the perfect reflecting diffuser (see 3.4). Secondary Reference Standards are standards that are calibrated in terms of the perfect reflecting diffuser and are used in the standardization of the instrument.

5.3 UV Lamp. Used for visual determination of presence of FWA on textile specimens.

6. Test Specimen

6.1 Condition each specimen for several hours in an atmosphere of 21 ± 1°C (70 ± 2°F) and 65 ± 2% RH by layering each test specimen separately on a screen or perforated shelf of a conditioning rack (see ASTM D 1776, Standard Practice for Conditioning and Testing Textiles, and 11.5). Keep the samples free of dirt and stains. The exact size necessary will depend on the aperture of the reflectance measuring instrument used and on the translucency of the textile material.

7. Procedure

7.1 Before proceeding with color measurements, determine whether or not a fabric contains FWA by viewing a specimen in a dark room under ultraviolet light. A fabric that contains FWA will fluoresce under the UV light.

7.1.1 If fluorescent whitening agents (FWA) are present on the textile material, the measurement must be made with an instrument that illuminates the specimen with polychromatic light (full spectrum) and has a relative spectral power distribution approximating CIE illuminant D_{65} from 330-700 nm (see 11.3). Consult instrument manufacturers for suitable equipment. The user should also verify the suitability of the instrument if flash il-

lumination is being used.

7.1.2 For the determination of an approximate relative efficiency of an FWA, an instrument which permits the insertion of an ultraviolet cut-off filter into the incident light beam may be used. The difference between the measurements taken before and after the insertion of the ultraviolet cut-off filter can provide an indication of the enhancement of the apparent whiteness due to the addition of an FWA. Because of possible variations in light sources and/or ultraviolet cut-off filters, the user is cautioned to use this procedure only for "relative in-house" determination.

7.2 Operate the color measuring instrument according to the manufacturer's instructions for standardization and measurement, in accordance with AATCC Evaluation Procedure 6, Instrumental Color Measurement.

8. Calculations, Interpretation and Limitations

8.1 Average the measurement values taken for each test sample.

8.2 For each averaged measurement, determine the CIE tristimulus values X_{10}, Y_{10} and Z_{10} for CIE standard illuminant CIE D_{65} and 1964 10° observer (see ASTM Standard Practice E 308 for details on calculation of tristimulus values from reflectance data). Determine the chromaticity coordinates Y_{10}, x_{10}, y_{10}. If the instrument used is not capable of calculating CIE illuminant D_{65} and 1964 10° observer, the user may use CIE illuminant C and 1931 2° observer method as described in 11.3.

8.3 The whiteness index (W_{10}) for any sample shall be calculated by the equation in 8.4 and the tint ($T_{W,10}$) by the equation in 8.5. Due to the limitations of instruments and the linearities of CIE whiteness space, comparisons of whiteness and tint values should only be made when measuring similar samples at nearly the same time and on the same instrument. The degree of difference that will be accepted or rejected is the sole responsibility of the user, as the requirements are extremely dependent on the particular use and material being measured. The higher the value of W_{10}, the greater the whiteness. Equal differences in W_{10} value do not necessarily indicate equal differences in perceived whiteness nor equal concentration differences of FWA. Similarly, equal differences in $T_{W,10}$ value do not always represent equal perceptual differences in greenness or redness of whites.

8.4 Whiteness (see 11.2 and 11.3). (For illuminant D_{65} and 1964 10° observer):

$$W_{10} = Y_{10} + 800\,(0.3138 - x_{10}) + 1700\,(0.3310 - y_{10})$$

where W_{10} is the whiteness value or index; Y_{10}, x_{10}, y_{10} are the chromaticity coordinates of the specimen, and 0.3138 and 0.3310 are, respectively, the x_{10}, y_{10} chromaticity coordinates for the perfect diffuser.

Limited to: $40 < W_{10} < 5Y_{10} - 280$.

8.5 Tint (for illuminant D_{65} and 1964 10° observer):

$$T_{W,10} = 900\,(0.3138 - x_{10}) - 650\,(0.3310 - y_{10})$$

where $T_{W,10}$ is the tint value; x_{10}, y_{10} are the chromaticity coordinates of the sample, and 0.3138 and 0.3310 are, respectively, the x_{10}, y_{10} chromaticity coordinates for the perfect diffuser.

Limited to: $-3 < T_{W,10} < +3$.

Values of $T_{W,10}$, when positive, indicate a greenish hue; when negative, indicate a reddish hue; and when zero, indicate a bluish hue with a dominant wavelength of 466 nm.

9. Report

9.1 Report the numerical whiteness value, the tint value if required, the illuminant and observer used in the calculations, and the instrument used.

10. Precision and Bias

10.1 *Precision.* Precision for this test method has not been established. Until a precision statement is generated for this test method, use standard statistical techniques in making any comparisons of test results for either *within-laboratory* or *between-laboratory* averages.

10.2 *Bias.* The whiteness and tint of textiles can be defined only in terms of a test method. There is no independent method for determining the true values. As a means of estimating these properties, the method has no known bias.

11. Notes and References

11.1 For a description of the CIE colorimetric system, instrument geometry and a complete description of the whiteness and tint formulas used above, see Publication CIE No. 15.2 (1986), *Colorimetry*, *Second Edition*, available from USNC/CIE Publications, Attn: Thomas Lemons, TLA-Lighting Consultants, 7 Pond St., Salem MA 01970-4893.

11.2 The equation used in prior versions of this test method was:

$$W = 4B - 3G \text{ (AATCC Method 110-1979)}$$

where W = Whiteness, B = Blue reflectance and G = Green reflectance for CIE illuminant C and CIE 1931 2° standard observer.

11.3 Tristimulus colorimeters typically do not conform to CIE illuminant D_{65} and the CIE 1964 10° observer. Most produce calculations for CIE illuminant C and the CIE 1931 2° observer. Although the CIE Publication 15.2 recognizes whiteness and tint calculations for the CIE 1931 2° observer, it does not recognize calculations for the CIE illuminant C. Therefore, the following equations are given for those users of tristimulus colorimeters that have no other choice but to perform calculations for illuminant C and the 1931 2° observer. Bear in mind, however, these calculations are to be used only for "relative in-house" measurements and comparisons.

Whiteness (For illuminant C and 1931 2° observer):

$$W_{c,2} = Y + 800\,(0.3101 - x) + 1700\,(0.3161 - y)$$

where $W_{c,2}$ is the whiteness value or index, Y, x, y are the chromaticity coordinates of the specimen and 0.3101 and 0.3161 are, respectively, the x, y chromaticity coordinates for the perfect diffuser.

Limited to: $40 < W_{c,2} < 5Y - 280$.

Tint (For illuminant C and 1931 2° observer):

$$T_{c,2} = 1000\,(0.3101 - x) - 650\,(0.3161 - y)$$

where $T_{c,2}$ is the tint value; x, y are the chromaticity coordinates of the specimen, and 0.3101 and 0.3161 are, respectively, the x, y chromaticity coordinates for the perfect diffuser.

Limited to: $-3 < T_{c,2} < +3$.

Values of $T_{c,2}$, when positive, indicate a greenish hue; when negative, indicate a reddish hue; and when zero, indicate a bluish hue with a dominant wavelength of 466 nm.

11.4 Users who wish to explore the prediction of data under true D_{65} illuminant for samples containing FWAs can refer to the following: F. W. Billmeyer Jr., Metrology, Documentary Standards, and Color Specifications for Fluorescent Materials, *Color Research and Application*, 19, 413-425, (1994), and Publication CIE No. 51, *A Method for Assessing the Quality of Daylight Simulators for Colorimetry.*

11.5 References made to ASTM Standard Test Methods and Practices may be found in *ASTM Standards on Color and Appearance Measurement*, *Fourth Edition*, 1994, ASTM, 100 Barr Harbor Dr., West Conshohocken PA 19428; tel: 610/832-9500; fax: 610/832-9555.

11.6 For a more complete description of the proper procedures in color measurement, refer to AATCC TECHNICAL MANUAL, Evaluation Procedure 6, Instrumental Color Measurement.