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Test Method for Colorfastness to Light: Carbon-Arc

1. Purpose and Scope

1.1 This test method provides the general principles and procedures for determining the colorfastness to light of textiles. The test options described are applicable to textile materials of all kinds and for colorants, finishes and treatments applied to textile materials. Test options included are:

1—Enclosed Carbon-Arc Lamp, Continuous Light

2—Enclosed Carbon-Arc Lamp, Alternate Light and Dark

1.2 The use of these test options does not imply, expressly or otherwise, an accelerated test for a specific application. The relationship between any lightfastness test and the actual exposure in use must be determined and agreed upon by the contractual parties.

2. Principle

2.1 Specimens of the textile material to be tested and the agreed upon comparison standard(s) are exposed simultaneously to a light source under specified conditions. The colorfastness to light of the specimen is evaluated by comparison of the color change of the exposed portion to the masked control portion of the test specimen or unexposed original material using the Gray Scale for Color Change, or by instrumental color measurement. Lightfastness classification is accomplished by evaluation versus a simultaneously exposed series of AATCC Blue Wool Lightfastness Standards.

3. References

3.1 AATCC EP1, Evaluation Procedure for Gray Scale for Color Change (see 30.5).

3.2 AATCC EP6, Evaluation Procedure for Instrumental Color Measurement (see 30.5).

3.3 AATCC EP7, Evaluation Procedure for Instrumental Assessment of the Change in Color of a Test Specimen (see 30.5).

3.4 ASTM D1776/D1776M, Standard Practice for Conditioning and Testing Textiles (see 30.10).

3.5 ASTM G151, Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources (see 30.10).

3.6 ASTM G153, Standard Practice for Operating Enclosed Carbon-Arc Light Apparatus for Exposure of Nonmetallic Materials (see 30.10).

4. Terminology

4.1 **AATCC Blue Wool Lightfastness Standard**, n.—one of a group of dyed wool fabrics distributed by AATCC for use in determining the amount of light exposure of specimens during lightfastness testing (see 30.1).

4.2 **AATCC Fading Unit (AFU)**, n.—a specific amount of exposure made under the conditions specified in various test methods where one AFU is one-twentieth (1/20) of the light-on exposure required to produce a color change equal to Step 4 on the Gray Scale for Color Change or 1.7 ± 0.3 CIELAB units of color difference on AATCC Blue Wool Lightfastness Standard L4.

4.3 **black-panel thermometer**, n.—a temperature measuring device, the sensing unit of which is coated with black paint designed to absorb most of the radiant energy encountered in lightfastness testing (see 30.2).

4.3.1 This device provides an estimation of the maximum temperature a specimen may attain during exposure to artificial light. Any deviation from the geometry of this device described in 30.2 may have an influence on the measured temperature.

4.4 **black standard thermometer**, n.—a temperature measuring device, the sensing unit of which is coated with black material designed to absorb most of the radiant energy encountered in lightfastness testing and is thermally insulated by means of a plastic plate (see 30.2).

4.4.1 This device provides an estimation of the maximum temperature a specimen may attain during exposure to artificial light. Any deviation from the geometry of the device described in 30.2 may have an influence on the measured temperature. The temperature measured by the black standard thermometer will not be the same as that measured by the black-panel thermometer; therefore, they cannot be used interchangeably.

4.5 **broad bandpass radiometer**, n.—a relative term applied to radiometers that have a bandpass width of more than 20 nm and less than 70 nm at 50% of maximum transmittance.

4.6 **color change**, n.—as used in colorfastness testing, a change in color of any kind whether a change in lightness, hue or chroma or any combination of these, discernible by comparing the test specimen with a corresponding untested specimen.

4.7 **colorfastness**, n.—the resistance of a material to change in any of its color

characteristics, to transfer of its colorant(s) to adjacent materials, or both resulting from exposure of the material to any environment that might be encountered during the processing, testing, storage or use of the material.

4.8 **colorfastness to light**, n.—the resistance of a material to a change in its color characteristics resulting from exposure of the material to sunlight or an artificial light source.

4.9 **infrared radiation**, n.—radiant energy for which the wavelengths of the monochromatic components are greater than those for visible radiation and less than about 1 mm.

NOTE: The limits of the spectral range of infrared radiation are not well defined and may vary according to the user. Committee E-2.1.2 of the CIE distinguishes in the spectral range between 780 nm and 1 mm:

IR-A	780-1400 nm
IR-B	1.4-4.0 μ m
IR-C	3 μ m to 1 mm

4.10 **irradiance**, n.—radiant power per unit area incident on a receiver, typically reported in watts per square meter (W/m^2).

4.11 **“L” designation**, n.—the sequence number given each AATCC Blue Wool Lightfastness Standard according to the number of AATCC Fading Units required to produce a color change equal to Step 4 on the Gray Scale for Color Change.

NOTE: See Table I for the numerical relationship between “L” designations of the standards and their colorfastness to light in AFUs. The colorfastness to light of a fabric specimen can be determined by comparing its color change after light exposure with that of the most similar AATCC Blue Wool Lightfastness Standard as shown in Table II.

4.12 **langley**, n.—a unit of total solar radiation equivalent to one gram calorie per square centimeter of irradiated surface.

NOTE: The internationally recommended units are: Joule (J) for quantity of radiant energy, watt (W) for quantity of radiant power, and meter squared (m^2) for area. The following factors are to be used: 1 langley = 1 cal/cm²; 1 cal/cm² = 4.184 J/cm² or 41840 J/m².

4.13 **lightfastness**, n.—the property of a material, usually an assigned number, depicting a ranked change in its color characteristics resulting from exposure of the material to sunlight or an artificial

Table I—AATCC Fading Unit and Light Exposure Equivalents for AATCC Blue Wool Lightfastness Standards (see Section 31)^a

AATCC Blue Wool Lightfastness Standard	AATCC Fading Units	Xenon Only kJ/(m ² nm) @ 420 nm	Xenon Only kJ/(m ² nm) 300-400 nm
L2	5	21	864
L3	10	43	1728
L4	20	85 ^b	3456
L5	40	170	6912
L6	80	340 ^b	13824
L7	160	680	27648
L8	320	1360	55296
L9	640	2720	110592

^a For color change of Step 4 on the Gray Scale for Color Change.

^b Verified by experiment using Daylight Behind Glass and Xenon-Arc, Continuous Light. All other values are calculated (see Section 31).

light source.

4.14 narrow bandpass radiometer, n.—a relative term applied to radiometers that have a bandpass width of 20 nm or less at 50% of maximum transmittance and can be used to measure irradiance at wavelengths such as 340 or 420, ± 0.5 nm.

4.15 photochromism, n.—a qualitative designation for a reversible change in color of any kind (whether a change in hue or chroma) which is immediately noticeable upon termination of light exposures when the exposed area of a specimen is compared to the unexposed area.

NOTE: The reversal of the color change or instability of the hue or chroma upon standing in the dark distinguishes photochromism from fading.

4.16 pyranometer, n.—a radiometer used to measure the global solar irradiance or, if inclined, hemispherical solar irradiance.

4.17 radiant power, n.—energy per unit time emitted, transferred, or received as radiation.

4.18 radiant exposure, n.—time integral of irradiance, typically reported in joules per square meter, J/m².

4.19 radiometer, n.—an instrument used to measure radiant energy.

4.20 total irradiance, n.—radiant power integrated over all wavelengths at a point in time expressed in watts per square meter (W/m²).

4.21 ultraviolet radiation, n.—radiant energy for which the wavelengths of the monochromatic components are smaller than those for visible radiation and more than about 100 nm.

NOTE: The limits of the spectral range of ultraviolet radiation are not well defined and may vary according to the user. Committee E.2.1.2 of the CIE distinguishes in the spectral range between 400 and 100 nm:

UV-A 315-400 nm

UV-B 280-315 nm

UV-C 100-280 nm

4.22 visible radiation, n.—any radiant energy capable of causing a visual sensation.

NOTE: The limits of the spectral range of visible radiation are not well defined and may vary according to the user. The lower limit is generally taken between 380 and 400 nm and the upper limit between 760 and 780 nm (1 nanometer, 1 nm = 10⁻⁹ m).

4.23 wide bandpass radiometer, n.—a relative term applied to radiometers that have a bandpass width of more than 70nm at 50% of maximum transmittance.

NOTE: Wide bandpass radiometers can be used to measure irradiance at wavelengths such as 300-800nm.

4.24 For definitions of other terms relative to lightfastness used in this test method, refer to AATCC M11.

5. Safety Precautions

5.1 The safety precautions specified in the method/procedure are ancillary to the testing procedures and are not intended to be all inclusive.

5.2 It is the user's responsibility to reference applicable safety data sheets, use safe and proper techniques, and wear appropriate personal protective equipment in handling materials in this standard.

5.3 Users MUST consult manufacturers for specific details such as equipment operating instructions and other recommendations. Consult and follow all applicable health and safety regulations (e.g., OSHA standards and rules).

5.4 Do not operate the test equipment until the manufacturer's instructions have been read and understood. It is the operator's responsibility to conform to the manufacturer's directions for safe operation.

5.5 The test equipment contains high intensity light sources. Do not look directly at the light source. The door to the test chamber must be kept closed when the equipment is in operation.

5.6 Before servicing light sources, allow 30 min for cool-down after lamp operation is terminated.

5.7 When servicing the test equipment, shut off both the off switch and the main power disconnect switch. When equipped, ensure that the main power indicator light on the machine goes out.

5.8 Good laboratory practices should be followed.

6. Uses and Limitation

6.1 Not all materials are affected equally by the same light source and environment. Results obtained using any one test option may not be representative

of those of any other test option or any end-use application unless a mathematical correlation for a given material and/or a given application has been established. Enclosed Carbon-Arc, Xenon-Arc and Natural Daylight have been extensively used in the trade for acceptance testing of textile materials. There may be a distinct difference in spectral irradiance, air temperature and humidity sensor locations, and test chamber size between test equipment supplied by different manufacturers that can result in differences in reported test results. Consequently, data obtained from equipment supplied by the different manufacturers, different test chamber size, or different light source and filter combinations cannot be used interchangeably, unless a mathematical correlation has been established. No correlations among differently constructed test apparatus are known to AATCC Committee RA50.

6.2 When using this test method, the test method option selected should incorporate light, humidity, and heat effects based upon historical data and experience. The test method option selected should also reflect expected end-use conditions associated with the material to be tested.

6.3 When using this test method, use a standard of comparison which has a known change in lightfastness after a specific exposure for comparison to the material to be tested. AATCC Blue Wool Lightfastness Standards have been used extensively for this purpose.

7. Apparatus and Materials (see 30.3)

7.1 AATCC Blue Wool Lightfastness Standards L2 through L9 (see 30.1, 30.4 and 30.5).

7.2 L4 AATCC Blue Wool Standard of Fade for 20 AATCC Fading Units (AFU) (see 30.5).

7.3 L2 AATCC Blue Wool (alternate) Standard of Fade for 20 AATCC Fading Units (AFU) (see 30.5).

7.4 Gray Scale for Color Change (AATCC EP1) (see 30.5).

7.5 Card stock: 163 g/m² (90 lb) one ply, White Bristol Index

7.6 Test masks made of material approaching zero light transmittance, and suitable for multiple exposure levels, such as 10, 20, 40, etc. AFU

7.7 Black-Panel Thermometer (see 4.3, 30.2).

NOTE: The Black-Panel Thermometer should not be confused with the Black Standard Thermometer which is used in AATCC TM16.3, Test Method for Colorfastness to Light: Xenon-Arc, Continuous Light, Option 2, and some European test procedures. Temperatures as measured by the two different devices generally will not agree at the same test condi-

tion. The term *Black Thermometer*, as used in this method, refers to either the Black Panel or Black Standard Thermometers.

7.8 Spectrophotometer or Colorimeter (see 3.2).

7.9 Enclosed Carbon-Arc Lamp Fading Apparatus (see Appendix A and 30.6).

8. Comparison Standards

8.1 AATCC Blue Wool Lightfastness

Standards, as defined in AATCC TM16.2, are preferred for all options. However, the rate of fade of any AATCC Blue Wool Lightfastness Standard by one test option may not agree with that of other test options.

8.2 The reference standard can be any suitable textile material where a history of the rate of color change is known. Reference standards for comparison must be determined and agreed upon by the contractual parties. Standards must be ex-

posed simultaneously with the test specimen. The use of the standard assists in determining time-to-time equipment and test procedure variations. If test results of the exposed standards differ by more than 10% from the known standard data, thoroughly review the test equipment operating conditions, and correct any malfunctions or defective parts. Then, repeat the test.

9. Test Specimen Preparation and Mounting

9.1 Number of Specimens—For acceptance testing, use at least three replicate specimens of both the material to be tested and the standard for comparison to ensure accuracy unless otherwise agreed upon between the purchaser and the supplier.

NOTE: It is recognized that in practice one test and one control specimen are used for test purposes. While such a procedure cannot be accepted in cases of dispute, it may be sufficient in routine testing.

9.2 Specimen Cutting and Mounting—Identify each specimen using a label resistant to the environment encountered during the test. Mount in frames such that the surface of the test specimen and the reference specimen are the same distance from the light source. Use covers that avoid specimen surface compression, particularly when testing pile fabrics. The test specimen and the reference standards shall be of equal size and shape. Cut and prepare test specimens for exposure as follows:

9.2.1 Specimen Backing—For all options, if the specimens do not have an integrated backing, mount the specimens and standards on white card stock. The card stock shall be white, non-reflecting cardboard. Consult the *AATCC Buyer's Guide* (www.aatcc.org/bg) for information. When mounted test specimens are masked, use test masks approaching zero light transmittance.

9.2.2 Fabric—Cut swatches of fabric with the long direction parallel to the machine (warp) direction, at least 70.0 × 120.0 mm (2.75 × 4.7 in.) with the exposed area measuring not less than 30.0 × 30.0 mm (1.2 × 1.2 in.). Secure the backed specimens in the frames supplied with the test apparatus. Ensure that front and back covers of the holders make good contact with the specimens and give a sharp line of demarcation between the exposed and unexposed areas without compressing the specimen unnecessarily (see 30.7 and 30.8). When required to prevent raveling, the specimens may be edged by sewing, pinking, or fusing.

9.2.3 Yarns—Wind or fasten yarns on frames of white card stock to a length of approximately 150.0 mm (6.0 in.). Only

Table II—Classification by AATCC Blue Wool Lightfastness Standards^a
Test Specimen Color Change

Less Than Standard	Equal To But Not Greater Than Standard	More Than Standard	Lightfastness Class	AATCC Fading Units (AFU)
—	—	L2	L1	5
—	L2	L3	L2	
L2	—	L3	L2-3	
—	L3	L4	L3	10
L3	—	L4	L3-4	
—	L4	L5	L4	20
L4	—	L5	L4-5	
—	L5	L6	L5	40
L5	—	L6	L5-6	
—	L6	L7	L6	80
L6	—	L7	L6-7	
—	L7	L8	L7	160
L7	—	L8	L7-8	
—	L8	L9	L8	320
L8	—	L9	L8-9	
—	L9	—	L9	640

^a The following are examples for using Table II to assign lightfastness classifications:
The test specimen is exposed simultaneously with standards L4, L5, and L6. After exposure and conditioning, the color change exhibited by the test specimen is less than that exhibited by the standards L4 and L5 but greater than that exhibited by the standard L6. The test specimen would be assigned a Lightfastness Classification of L5-6, or use the following example.
The test specimen is examined after each exposure increment until it exhibits a color change equal to Step 4 on the Gray Scale for Color Change. If this occurs after 40 AFU and before 80 AFU exposure, the test specimen would be assigned a Lightfastness Classification of L5-6.

Table III—Classification by AATCC Blue Wool Lightfastness Standards Above L7

Number of L7 Standards Exposed			Lightfastness Class	Equivalent AATCC Fading Unit (AFU)
Less Than	Equal To But Not Greater Than	More Than		
—	2	—	L8	320
3	—	2	L8-9	—
—	3	—	L8-9	480
4	—	3	L8-9	—
—	4	—	L9	640
5	—	4	L9-10	—
—	5	—	L9-10	800
6	—	5	L9-10	—
—	6	—	L9-10	960
7	—	6	L9-10	—
—	7	—	L9-10	1120
8	—	7	L9-10	—
—	8	—	L10	1280
etc. ^a	etc. ^a	—	etc. ^a	etc. ^a

^a A classification increase of 1 represents the interval when the equivalent AATCC Fading Units are doubled from the previous whole number classification. Any test specimen for which the number of L7 Standards fall between two whole number classifications is assigned both the lower and higher classification defining that interval.