Colorfastness to Light

Developed in 1964 by AATCC Committee RA50; revised 1971, 1974, 1978, 1981, 1982, 1990 (Supersedes AATCC Test Methods 16-1987, 16A-1988, 16C-1988, 16D-1988, 16E-1987, 16F-1988 and 16G-1985), 1993, 2003, 2004; reaffirmed 1977, 1998; editorially revised 1983, 1984, 1986, 1995, 1996. Technically equivalent: Option 6-ISO 105-B01; Related to Option 3-ISO 105-B02.

1. Purpose and Scope

1.1 This test method provides the general principles and procedures which are currently in use for determining the colorfastness to light of textile materials. 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

3—Xenon-Arc Lamp, Continuous Light, Black Panel Option

4—Xenon-Arc Lamp, Alternate Light and Dark

5—Xenon-Arc Lamp, Continuous Light, Black Standard Option

6—Daylight Behind Glass

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.

1.3 This test method contains the following sections that assist in the use and implementation of the various options for determining lightfastness of textile materials.

2. Principle

2.1 Samples 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 AATCC 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. Terminology

3.1 **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 32.1).

3.2 **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.

3.3 **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 32.2).

3.3.1 This device provides an estimation of the maximum temperature a specimen may attain during exposure to natural or artificial light. Any deviation from the geometry of this device described in 32.2 may have an influence on the measured temperature.

3.4 **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 32.2).

3.4.1 This device provides an estimation of the maximum temperature a specimen may attain during exposure to natural or artificial light. Any deviation from the geometry of the device described in 32.2 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.

3.5 **broad bandpass radiometer,** n.—a relative term applied to radiometers that have a bandpass width of more than 20 nm at 50% of maximum transmittance and can be used to measure irradiance at wavelengths such as 300-400 nm or 300-800 nm.

3.6 **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.

3.7 **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 as a result of exposure of the material to any environment that might be encountered during the processing, testing, storage or use of the material.

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

3.9 **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	1.4-3.0 µm
IR-C	3 µm to 1 mm

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

3.11 **"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 AATCC Gray Scale for Color Change.

NOTE: See Table II 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 III.

3.12 **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/cm^2; 1 cal/cm^2 = 4.184 J/cm^2 or 41840 J/m^2.

3.13 **lightfastness,** n.—the property of a material, usually an assigned number, depicting a ranked change in its color characteristics as a result of exposure of the material to sunlight or an artificial light source.

3.14 **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.

3.15 **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 reversion of the color change or instability of the hue or chroma upon standing in the dark distinguishes photochromism from fading.

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

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

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

3.19 **total irradiance,** n.—radiant power integrated over all wavelengths at a point in time expressed in watts per square meter (W/m^2).

3.20 **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

3.21 **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).

3.22 **xenon reference fabric,** n.—a dyed polyester fabric used for verifying xenon-arc equipment test chamber temperature conditions during a lightfastness test cycle (see 32.3, 32.4 and 32.6).

3.23 For definitions of other terms relative to lightfastness used in this test method, refer to the *Glossary of AATCC Standard Terminology.*

4. Safety Precautions

NOTE: These safety precautions are for information purposes only. The 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 on 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 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.

4.2 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.

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

4.4 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.

4.5 Daylight exposure of the skin and eyes for prolonged periods may be hazardous and therefore caution should be employed to protect these areas. Do not look directly at the sun under any circumstances.

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

5. Uses and Limitation

5.1 Not all materials are affected equally by the same light source and environment. Results obtained by the use of 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 Daylight have been extensively used in the trade for acceptance testing of textile materials. There may be a distinct difference in spectral power distribution, 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.

5.2 Results from Xenon-Arc, for all materials should be in good agreement with the results obtained in Daylight Behind Glass (see Table II). Since the spectral distribution of Xenon-Arc, Alternate Light and Dark, equipped with the specified filter glass is very close to that of average or typical daylight behind window glass, it is expected that results should be in good agreement with the results obtained in Daylight, Daylight Behind Glass. The two carbon-arc options, Continuous and Alternating Light and Dark, under the conditions specified, will produce results which correlate with those obtained in the Daylight Behind Glass Method unless the material being tested is adversely affected by the differences in spectral characteristics of Enclosed Carbon-Arc and natural light.

5.3 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.

5.4 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.

6. Apparatus and Materials

6.1 AATCC Blue Wool Lightfastness Standards L2 through L9 (see 32.1 and 32.5).

6.2 Xenon Reference Fabric (see 32.3, 32.4, 32.5 and 32.6).

Table I—Machine Exposure Conditions by Option

Component	Option 1	Option 2	Option 3	Option 4	Option 5
Light Source	Enclosed Carbon[a]	Enclosed Carbon[a]	Xenon[b,c]	Xenon[b]	Xenon[b,c,d]
	Continuous Light	Alternate Light/Dark	Continuous Light	Alternate Light/Dark	Continuous Light
Black Panel Temperature,					
Light Cycle	63 ± 3°C (145 ± 6°F)	63 ± 3°C (145 ± 6°F)	63 ± 1°C (145 ± 2°F)	— —	— —
Black Standard Temperature,					
Light Cycle	— —	— —	— —	70 ± 1°C (158 ± 2°F)	60 ± 3°C (140 ± 8°F)
Chamber Air Temperature,					
Light Cycle	43 ± 2°C (110 ± 4°F)	43 ± 2°C (110 ± 4°F)	43 ± 2°C (110 ± 4°F)	43 ± 2°C (110 ± 4°F)	32 ± 5°C (90 ± 9°F)
Dark Cycle	— —	43 ± 2°C (110 ± 4°F)	— —	43 ± 2°C (110 ± 4°F)	— —
Relative Humidity, %					
Light Cycle	30 ± 5	35 ± 5	30 ± 5	35 ± 5	30 ± 5
Dark Cycle	—	90 ± 5	—	90 ± 5	—
Light Cycle, Hours					
Light–On	Continuous	3.8	Continuous	3.8	Continuous
Light–Off	—	1.0	—	1.0	—
Filter Type	Borosilicate	Borosilicate	see A.3.3	see A.3.3	see A.3.3
Irradiance W/m²/nm (at 420 nm)	Not controlled	Not controlled	1.10 ± 0.03	1.10 ± 0.03	1.25 ± 0.2
Irradiance W/m² (300-400 nm)	Not controlled	Not controlled	48 ± 1	48 ± 1	65 ± 1
Water Requirements (Input)					
Type	demineralized, distilled or reverse osmosis				
Solids–ppm	less than 17 ppm, preferably less than 8				
pH	7 ± 1				
Temperature	Ambient 16 ± 5°C (61 ± 9°F)				

[a] See Appendix C.
[b] See Appendix A.
Be sure that the temperature chosen is appropriate for the type of Black Thermometer to be used.
[c] Options 3 and 5 have different temperature set-points specified because of the differences in the thermal sensing elements between the Black Panel Thermometer and the Black Standard Thermometer.
[d] Option 5 should be used at the recommendation of the equipment manufacturer.

6.3 L4 AATCC Blue Wool Standard of Fade for 20 AATCC Fading Units (AFU) (see 32.5).

6.4 L2 AATCC Blue Wool (alternate) Standard of Fade for 20 AATCC Fading Units (AFU) (see 11.2, 32.5).

6.5 Xenon Reference Fabric Standard of Fade (see 32.5).

6.6 AATCC Gray Scale for Color Change (see 32.5).

6.7 Card stock: 163 g/m² (90 lb) one ply, White Bristol Index (see 32.7).

6.8 Test masks made of material approaching zero light transmittance, and suitable for multiple exposure levels, such as 10, 20, 40, etc. AFU (see 32.8).

6.9 Black-Panel Thermometer (see 3.3, 32.2 and 32.9).

6.10 Black Standard Thermometer (see 3.4, 32.2 and 32.9).

NOTE: The Black-Panel Thermometer should not be confused with the Black Standard Thermometer which is used in Xenon-Arc, Continuous Light, Option 5, and some European test procedures. Temperatures as measured by the two different devices generally will not agree at the same test condition. The term *Black Thermometer*, as used in this method, refers to both the Black Panel and Black Standard Thermometers.

6.11 Spectrophotometer or Colorimeter (see 31.2).

6.12 Xenon-Arc Lamp Fading Apparatus optionally equipped with light monitors and control systems (see 32.9 and Appendix A).

6.13 Daylight Exposure Cabinet (see 32.10 and Appendix B).

6.14 Enclosed Carbon-Arc Lamp Fading Apparatus (see 32.9 and Appendix C).

7. Comparison Standards

7.1 AATCC Blue Wool Lightfastness Standards, as defined in Method 16, 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.

7.2 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 exposed 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.

8. Test Specimen Preparation

8.1 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.

8.2 Specimen Cutting and Mounting—Identify each sample 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:

8.2.1 Specimen Backing—For all options, mount the specimens and standards on white card stock. When mounted test specimens are masked, use test masks approaching zero light transmittance. For Option 6, put the mounted, or mounted and masked, test specimens in frames with backing as directed in an applicable specification: such as open-backed, solid metal, or solid backing (see 32.4, 32.7 and 32.8).

8.2.2 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 32.11 and 32.12). When required to prevent raveling, the samples may be edged by sewing, pinking or fusing.

8.2.3 Yarns—Wind or fasten yarns on frames of white card stock to a length of approximately 150.0 mm (6.0 in.). Only that portion of the yarns directly facing the radiant energy is evaluated for color change. Wind the yarn on the frame closely packed to at least 25.0 mm (1.0 in.) width. The control sample must contain the same number of strands as the sample subjected to exposure. After the exposure has been completed, bind together those yarns facing the light source using 20.0 mm (0.75 in.) masking or other suitable tape to keep the yarns closely packed on the exposure frame for evaluation (see 32.12).

Machine Operating Conditions

9. Preparation of Test Apparatus

9.1 Prior to running the test procedure, verify machine operation by using the following test protocol. To enhance the repeatability of test results, install test apparatus in a room where temperature and relative humidity are controlled in accordance with the manufacturer's recommendations.

9.2 Check to see that the machine has been calibrated and maintained within the manufacturer's recommended calibration schedule interval.

9.3 Turn off all rack and specimen spray units, if applicable.

9.4 Set machine operating conditions according to Table I and the specified option. Be sure that the temperature chosen is appropriate for the type of Black Thermometer to be used (see 32.2). Fill the specimen rack with framed white card stock and the required black thermometer unit. The white card stock is used to simulate air flow in the test chamber during the test exposure and should not include the actual test specimens. Support the black thermometer unit in the specimen drum or rack in the same manner as the test specimen frames. Operate and control the test apparatus as specified in Table I and further defined by the manufacturer. Operate the test apparatus in this mode and adjust the instrumentation to provide the required black panel or black standard temperature, chamber air temperature and relative humidity. When exterior indicators are not available, read the black thermometer unit through the window in the test chamber door.

9.5 Calibrate using AATCC Blue Wool Lightfastness Standards following the guidelines in 11.1-11.2.2. If the fade of the L2 or L4 standards do not meet these requirements follow the instrument manufacturer's instructions for calibration and repeat the 20 AFU exposure with fresh L2 or L4 standards. If the fade does meet the requirements described in Section 11 remove the white card stock from the specimen rack and proceed.

9.6 For additional information to prepare and operate the test apparatus refer to the manufacturer's instructions and the following:

9.6.1 For Both Enclosed Carbon-Arc Options, use Test Standard ASTM G 151 and G 153 (see 31.3 and 31.4).

9.6.2 For Daylight Behind Glass, use Test Standard ASTM G 24 (see 31.5).

9.6.3 For all Xenon Options, use Test Standard ASTM G 151 and G 155 (see 31.3 and 31.6).

9.6.4 For Options as applicable, refer to ISO 105, Part B (see 31.7).

10. Calibration, Verification and AATCC Fading Unit Measurement

10.1 Instrument Calibration—To ensure standardization and accuracy, the instruments associated with the exposure apparatus (that is, light monitor control system, Black Thermometers, chamber air sensor, humidity control system, UV sensors and radiometers) require periodic calibration. Whenever possible, calibration should be traceable to national or international standards. Calibration schedule and procedure should be in accordance with manufacturer's instructions.

10.1.1 The accuracy of machine operation must be verified by exposure of an applicable AATCC Blue Wool Lightfastness Standard and assessment of the Standard after every 80-100 AATCC Fading Units. Always expose reference standards near the center position of the specimen rack adjacent to the black-panel temperature sensing unit.

11. Calibration by AATCC Blue Wool Lightfastness Standards

11.1 Carbon-Arc Options 1 and 2; Xenon-Arc Options 3 and 4, expose the L4 AATCC Blue Wool Lightfastness Standard at the specified temperature, humidity and selected option for 20 ± 2 continuous light-on operating hours (see Table II for the corresponding AATCC Fading Units for xenon lamp options). After exposure, assess the exposed standard specimen, either visually or instrumentally. Increase or decrease the wattage of the lamps, the time of exposure, of both, and expose additional standard specimens until the change in color of the exposed standard meets one of the following criteria.

Table II—AATCC Fading Unit and Light Exposure Equivalents for AATCC Blue Wool Lightfastness Standards (see 32.18)[a]

AATCC Blue Wool Lightfastness Standard	AATCC Fading Units	Xenon Only kJ/(m²nm) @ 420 nm	Xenon Only kJ/(m²nm) 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 1.7 ± 0.3 CIELAB units or Step 4 on the AATCC Gray Scale for Color Change.

[b] Verified by experiment using Daylight Behind Glass and Xenon-Arc, Continuous Light. All other values are calculated (see 32.18).

Table III—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	
—	L2	L3	L2	5
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 III 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 AATCC 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.

11.1.1 Visual Comparison—equals the change in color exhibited by the L4 Standard of Fade applicable to the Lot designation used.

11.1.2 Instrumental Color Measurement—for Lot 5, AATCC Blue Wool Lightfastness Standard, equals 1.7 ± 0.3 CIELAB units of color change as determined by AATCC Evaluation Procedure 6. Other Lot designations of AATCC Blue Wool Lightfastness Standard L4 equals the CIELAB units of color change specified on the calibration certificate supplied with the standard as determined by AATCC Evaluation Procedure 6.

11.2 Alternate for Carbon-Arc Options 1 and 2; Xenon-Arc Options 3 and 4, the L2 AATCC Blue Wool Lightfastness Standard may be exposed at the specified temperature, humidity and selected option for 20 ± 2 continuous light-on operating hours. After exposure, assess the exposed standard specimen, either instrumentally or compare to a L2 Standard of Fade. When required, increase or decrease the wattage of the lamps, or the time of exposure, or both, and expose additional standard specimens until the change in color of the exposed standard meets one of the following criteria.

11.2.1 Visual Comparison—equals the change in color exhibited by the L2 Standard of Fade applicable to the Lot designation used (see 32.5).

11.2.2 Instrumental Color Measurement—for Lot 8, AATCC Blue Wool Lightfastness Standard L2, equals 7.24 ± 0.70 CIELAB units of color change as determined by AATCC Evaluation Procedure 6. Other Lot designations of AATCC Blue Wool Lightfastness Standard L2 equal the CIELAB unit of color change specified on the calibration certificate supplied with the standard as determined by AATCC Evaluation Procedure 6.

NOTE: The Xenon Reference fabric is discontinued for calibration since it is temperature sensitive. It is more appropriately used to monitor test chamber temperature conformance (see Sections 12, 32.3, 32.4 and 32.6).

12. Verification of Test Chamber Temperature by Xenon Reference Fabric, Xenon-Arc Options

12.1 Expose the Xenon Reference Fabric for 20 ± 2 continuous light-on operating hours at the specified temperature, humidity and selected option. Assess the exposed standard specimen, either visually or instrumentally, by one of the following:

12.1.1 Visual Comparison—If the color change of the exposed standard specimen equals the Xenon Reference Fabric Standard of Fade in 20 ± 2 continuous light-on operating hours the test equipment is maintaining the correct temperature.

12.1.2 Instrumental Color Measurement—If the exposed standard specimen equals 20 ± 1.7 CIELAB units of color change in 20 ± 2 continuous light-on operating hours, the test machine is providing the correct temperature.

12.2 If the exposed Xenon Reference Fabric differs visually, or instrumentally, from that specified in 12.1.1 or 12.1.2, as applicable, after 20 ± 2 continuous light-on operating hours, it is an indication that temperature sensing units within the test chamber are not calibrated or responding correctly, or that the test equipment requires maintenance. Verify the accuracy of the temperature sensors and that all machine functions are operating correctly according to the manufacturer's instructions. Replace temperature sensors if they are defective.

13. AATCC Fading Unit Measurement by AATCC Blue Wool Lightfastness Standards

13.1 The use of AATCC Blue Wool Lightfastness Standards and AATCC Fading Units provides a common exposure standard across the various exposure methods: daylight, carbon-arc lamp and xenon-arc lamp. The terms *clock hours* and *machine hours* are not valid reporting methods.

13.2 Table II illustrates the number of AATCC Fading Units to produce a color change equal to Step 4 on the Gray Scale for Color Change on each of the AATCC Blue Wool Lightfastness Standards.

13.3 For instrumental color measurement, the colorimetric data are calculated using CIE 1964 10° observer data for Illuminant D_{65}. Express the color difference in CIELAB units as directed in AATCC Evaluation Procedure 6. NOTE: For Xenon-Arc, Alternating Light and Dark, Option 4, although calibration is conducted using continuous light-on operating hours, it may take more or less operating hours during the actual test cycle due to the inclusion of the dark periods.

14. AATCC Fading Unit Measurement based on Spectral Irradiation, Xenon-Arc, Options 3 and 4 only

14.1 For Options 3 and 4, 20 AATCC Fading Units are produced by an exposure interval of 85 kJ/(m^2nm) measured at 420 nm when xenon-arc machines are operated at the conditions specified in this test method (see Table II).

Machine Exposure Procedures, Options 1-5

15. Machine Exposure, General Conditions

15.1 Specimen Mounting. Mount the framed test material on the specimen rack. Make sure that all materials are adequately supported, both top and bottom, in proper alignment. Any displacement of the material toward or away from the source, even by a small distance, may lead to variation in fading between specimens (see 8.2). The specimen rack must be filled; card stock is used when the number of specimens being tested is insufficient to fill the specimen rack. When alternate light and dark cycles are required, begin exposure at the start of the light cycle.

15.2 In the case of woven, knitted and nonwoven fabrics, unless otherwise specified, ensure that the side normally used as the face is directly exposed to the radiant source.

15.3 Operate the test apparatus on a daily basis until the selected exposure has been completed. Avoid unnecessary delays when interrupting the exposure period to change filters, carbons or lamps, as such delays may contribute to variations in results or lead to errors. When available, monitor exposure test chamber conditions with suitable recorders. If necessary, readjust the controls to maintain the specified test conditions. Verify calibration of the test apparatus during the test cycle (see Sections 10, 11, 12 and 13).

16. Machine Exposure to a Specified Amount of Radiant Energy, Options 1-5

16.1 One-Step Method—Expose the test specimens and applicable standards for 5, 10, 20 or multiples of 20 AATCC Fading Units until the specimen has been exposed to the desired amount of radiant energy defined in terms of AATCC Fading Units measured by simultaneous exposure of the appropriate Blue Wool Standard(s).

16.2 Two-Step Method—Proceed as directed in 16.1, except double the exposure area of the test specimens. After the specimen has been exposed to the first specified level of radiant energy, remove the specimens from the test chamber and mask (cover) one-half of the exposed area and continue the exposure for an additional 20 or multiples of 20 AATCC Fading Units until the specimen has been exposed to the higher desired amount of radiant energy.

16.3 In those machines equipped with irradiation monitors, the AATCC Fading Units of exposure can be determined and controlled by measuring $kJ/(m^2nm)$ at 420 nm (see 14.1 and Table II).

NOTE: The two-step method is preferred for the complete characterization of the lightfastness of a test specimen.

17. Machine Exposure using a Reference Specimen, Options 1-5

17.1 Expose the test specimen(s) and reference specimen(s) simultaneously to the required end point in terms of AATCC Fading Units, kilojoules per square meter of irradiance or reference specimen performance (that is, the reference specimen shows a color change equal to Step 4 on the Gray Scale of Color Change).

18. Machine Exposure for Lightfastness Classification

18.1 One-Step Method—Expose test specimen(s) simultaneously with a series of AATCC Blue Wool Lightfastness Standards or determine the number of AATCC Fading Units required to produce a color change in the test specimen equal to Step 4 on the Gray Scale for Color Change (see 32.22).

18.2 Two-Step Method—Proceed as directed in 18.1, except double the exposure area of the test specimens. After the specimen has been exposed to a color change equal to Step 4 on the Gray Scale for Color Change, remove the specimens from the test chamber and mask (cover) one-half of the exposed area and continue the exposure until the test specimen exhibits a color change equal to Step 3 on the Gray Scale for Color Change (see 32.22).

Daylight Behind Glass

19. Daylight Behind Glass, General Conditions, Option 6

19.1 Mount the AATCC Blue Wool Lightfastness Standard(s) and the test specimen(s) on cardboard with an opaque cover (mask) covering one-half of the standard.

19.2 Expose standards and test specimen(s) simultaneously to the same test conditions behind glass (see 32.14 and Appendix B). Ensure that the face of the exposed standard(s) and test specimen(s) are at least 75.0 mm (3.0 in.) below the inside surface of the plate glass cover and are positioned at least 150.0 mm (6.0 in.) in from the edges of the glass frame. The back of the exposure cabinet may be varied as follows to achieve the desired exposure conditions:

Backing	Exposure Condition
Open	Low Temperature
Expanded Metal	Medium Temperature
Solid	High Temperature

Standard(s) and specimen(s) remain exposed 24 h a day and are removed only for inspection.

19.3 Monitor temperature and relative humidity in the vicinity of the test cabinets (see 32.21).

20. Daylight Behind Glass Exposure to a Specified Amount of Radiant Energy

20.1 Use of AATCC Blue Wool Lightfastness Standards—Mount reference and test specimen(s) to be exposed as directed in 19.1 and expose simultaneously to the same test conditions behind glass as directed in 19.2. Monitor the effect of light by frequently removing the standard(s) from the test frame and evaluating the color change. Continue the exposure until the standard exhibits a difference in color between the exposed and masked portion as described in Section 24. When the test of the specimens is to be terminated after exposure to a specified number of AATCC Fading Units, choose the appropriate standard to achieve the end point. The standards may be used as a set, L2 through L9, or in replicate sets exposed consecutively to total a given end point; that is, singularly expose two L2 standards to reach 10 fading units, or expose one L3 standard to reach 10 fading units.

20.1.1 Remove the samples from exposure when the desire AATCC Fading Units have been achieved and evaluate as specified in Evaluation of Results. For multiple step exposure, that is, 5 fading units and 20 fading units, a single sample may be exposed and portions covered (masked) at intervals measured by the standard. The result will be a sample having an original masked, unexposed section and various sections which have been exposed and subsequently masked. Each section of the specimen, representing a stated exposure interval, can be evaluated versus masked control or an unexposed original portion of the sample.

20.2 Use of Irradiation Monitors—Mount reference and test specimen(s) to be exposed as directed in 19.1 and expose them simultaneously to the same test conditions behind glass as directed in 19.2.

NOTE: The exposure of the AATCC Blue Wool Lightfastness Standards with their known performance can be helpful in determining whether any unusual conditions were present during the test duration (see 32.16).

20.2.1 Record any one, or a combination of global, broad bandpass, or narrow bandpass irradiation with a radiometer, exposed under the same conditions as the specimens (see 32.17).

20.2.2 Remove the reference and test specimens from exposure when the desired radiant energy, as measured by the radiometer, has been achieved. For multiple step exposure, a single sample may be exposed and portions covered (masked) at intervals of measured radiant exposure (see 20.1.1).

21. Daylight Exposure Using a Reference Specimen

21.1 Substitute reference specimen(s) for the AATCC Blue Wool Lightfastness Standards and proceed as directed in 20.1 and 20.2, as applicable.

22. Daylight Exposure for Lightfastness Classification

22.1 One-Step Method—Expose test specimen(s), as detailed in 19.1 and 19.2, simultaneously with a series of AATCC Blue Wool Lightfastness Standards or determine the number of AATCC Fading Units required to produce a color change in the test specimen equal to Step 4 on the Gray Scale for Color Change (see 32.22).

22.2 Two-Step Method—Proceed as directed in 22.1, except double the exposure area of the test specimens. After the specimen has been exposed to a color change equal to Step 4 on the Gray Scale for Color Change, remove the specimens from the test chamber and mask (cover) one-half of the exposed area and continue the exposure until the test specimen exhibits a color change equal to Step 3 on the Gray Scale for Color Change (see 32.22).

Evaluation of Results

23. Conditioning

23.1 After the test exposure is completed, remove the test specimens and comparison standards from exposure. Condition in a dark room at standard conditions for testing textiles, as directed in ASTM D 1776, Standard Practice for Conditioning and Testing Textiles. [65 ± 2% RH and 21 ± 1C (70 ± 2F)] for a minimum of 4 h before evaluation.

24. Assessment of Color Change

24.1 Compare the exposed portion to the masked control or to an unexposed original portion of the specimen, as specified in a material specification or purchase order. Complete characterization of the lightfastness of a test specimen requires evaluation at more than one level of exposure (see 32.15).

24.2 Quantify the color change using either the AATCC Gray Scale for Color Change (preferred), or by colorimetric measurement of color difference at the specified exposure level whether in AATCC Fading Units, kilojoules of radiant energy, or compared to a reference standard (see 32.22).

24.3 Determine total color difference (ΔE_{CIELAB}) and the difference in lightness, chroma, and hue (ΔL^*, ΔC^*, ΔH^*). Use instruments that provide values based on the CIE 1976 equation using illuminant D_{65} and 10° observer data. For instruments with diffuse geometry, include the specular component of reflectance in the measurements (refer to AATCC Evaluation Procedure 6, Instrumental Color Measurement).

25. Acceptance Based on Simultaneous Exposure of a Reference Specimen

25.1 Assess color change of the material as directed in Section 24 in terms of the agreed upon reference specimen.

25.2 Assess the lightfastness of the material as follows:

25.2.1 Satisfactory—If the test specimen exhibits a color change equal to or less than the reference specimen at the exposure level when the reference specimen shows a color change equal to Step 4 on the AATCC Gray Scale for Color Change.

25.2.2 Unsatisfactory—If the test specimen exhibits a color change greater than the reference specimen at the exposure level when the reference specimen shows a color change equal to Step 4 on the AATCC Gray Scale for Color Change.

26. Classification Based on the AATCC Blue Wool Lightfastness Standards

26.1 One Step Exposure—Classify lightfastness of the material by:

(a) comparison of the color change of the test specimen to that of a simultaneously exposed series of AATCC Blue Wool Lightfastness Standards (see Table III), or

(b) determination of the number of AATCC Fading Units required to produce a color change in the test specimen equal to Step 4 of the Gray Scale for Color Change (see Table II).

26.2 Two Step Exposure—Classify lightfastness of the material by:

(c) determination of the number of AATCC Fading Units required to produce color changes in the test specimen equal to both a Step 4 and Step 3 on the AATCC Gray Scale for Color Change (see Table II).

26.2.1 Assign both classifications: the Step 3 level appears first, followed by the Step 4 level in parentheses. For example, a L5(4) classification would illustrate a L5 classification at Step 3 color change and a L4 classification at Step 4 color change. When only one classification number is assigned, it shall represent the number of AATCC Fading Units to produce a Step 4 color change.

27. Classification above L7 AATCC Blue Wool Lightfastness Standard

27.1 Using Table IV, classify lightfastness above the L7 AATCC Blue Wool Lightfastness Standard according to the total number of consecutive L7 standards exposed to Step 4 on the Gray Scale for Color Change during the exposure cycle that is required to produce a Step 4 color change on the test specimen, and Table IV.

28. Report

28.1 Use Table V to report all applicable information.

28.2 Report any deviation from Test Method 16 or the performance of the reference standard.

28.3 Report all information in Table V for the same conditions that the samples and reference materials are exposed.

Precision and Bias

29. Precision

29.1 In 2002 a single laboratory study was performed using a single operator. This study was intended to be a temporary table of variances to give some indication of test variability. A complete interlaboratory study is to be conducted in

Table IV—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.

Table V—Reporting Form

Operator's Name ______________________________ Date______________

Sample Identification ______________________________

Material Exposed: Face ______________________ Back ______________________

Colorfastness to Light Rating______________________ Lightfastness Classification ______________________

Acceptance Compared to Reference Sample (Yes/No)______________________

Test Specimen Compared To: Masked Portion ______________________

Unmasked Portion______________________ Unexposed Original ______________________

Colorfastness to Light Rating determined by:

AATCC Gray Scale for Color Change ______________________

Instrumentally, Name Type ______________________________

Classification Method______________________________

Reference Standard______________________________

Temperature Controlled By: Ambient (Dry Bulb) ______________________ °C

Black Panel ______________________ °C Black Standard ______________________ °C

Exposure Controlled By: AATCC Blue Wool Lightfastness Standards ______________________

Radiant Energy ______________________ Other ______________________

Total Radiant Energy ______________________

Type of Test Apparatus ______________________________ Model No. ______________

Serial No.______________________ Manufacturer's Name______________________________

Specimen Rack: Inclined ______________ 2-Tier ______________ 3-Tier ______________ Horizontal______________

Type of Water Supply______________________________

Option Employed______________________ Elapsed Exposure Time ______________________

Mounting Procedure: Backed______________________ Unbacked______________________

Sample Rotation Schedule ______________________ % Relative Humidity______________________

For Option 6 only report the following:

Geographical Location______________________________

Exposure Dates: From ______________________ To ______________________

Exposure Latitude ______________________ Exposure Angle ______________________

Exposed Behind Window Glass: Yes/No ______________________ If Yes, Specify Type______________________

Daily Ambient Temperature: Minimum __________°C Maximum __________°C Avg. __________°C

Daily Black Panel Temperature: Minimum __________°C Maximum __________°C Avg. __________°C

Test Environment Temperature: Minimum __________°C Maximum __________°C Avg. __________°C

Daily % Relative Humidity: Minimum __________ Maximum __________ Avg. __________

Hours of Wetness: Rain ______________________ Rain and Dew ______________ the near future for the purposes of precision and bias. Table values do not reflect different types of material tested to this standard. *Between-Laboratory* variability is not indicated either. Special care and consideration of the variances reported must be used when examining test variability problems.

29.1.1 Samples tested consisted of four fabrics, with three replicates each. Exposure conditions were those found in Option 3 of this method. Each sample was evaluated instrumentally three times and averages were calculated. The data is found in Table VI.

29.1.2 *Within-laboratory* standard errors and Sample Variance are shown in Table VII. Data is on file at the AATCC Technical Center.

30. Bias

30.1 The colorfastness to natural and artificial light can be defined only in terms of a test method. There is no independent method for determining the true value. As a means of estimating this property, the method has no known bias.

31. References

31.1 AATCC Evaluation Procedure 1, Gray Scale for Color Change (see 32.5).

31.2 AATCC Evaluation Procedure 6, Instrumental Color Measurement (see 32.5).

31.3 ASTM G 151, Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources.

31.4 ASTM G 153, Standard Practice for Operating Enclosed Carbon-Arc Light Apparatus for Exposure of Nonmetallic Materials (see 32.19).

31.5 ASTM G 24, Standard Practice for Conducting Exposures to Daylight Filtered through Glass (see 32.19).

31.6 ASTM G 155, Standard Practice for Operating Xenon-Arc Light Apparatus for Exposure of Nonmetallic Materials (see 32.19).

31.7 ISO 105, Part B, Textiles—Tests for Colorfastness (see 32.20).

32. Notes

32.1 AATCC Blue Wool Lightfastness Standards, except L2, are specially prepared by blending varying proportions of wool dyed with a very fugitive dyestuff, Erio Chrome Azurole B (C.I. 43830) and wool dyed with a fast dyestuff, Indigosol Blue AGG (C.I. 73801). Each resultant higher numbered standard is twice as colorfast as the preceding numbered standard. AATCC Blue Wool Lightfastness Standards and the ISO numbered Blue Wool Lightfastness Standards (as used in ISO 105-B01) produce different ratings and therefore cannot be used interchangeably (see 32.5).

32.2 Black Thermometers are used to control an artificial weathering device and to provide an estimate of the maximum temperature of samples exposed to a radiant energy source. There are two types of Black Thermometers. One type is referred to as a "Black Panel Thermometer" which is uninsulated and is made of metal. The other type is referred to as a "Black Standard Thermometer" which is insulated and is made of metal with a plastic backing. As a point of information, some ISO specifications specify the use of a "Black Standard Thermometer." Typically, Black Standard Thermometers indicate higher temperatures than Black Panel Thermometers under the same exposure conditions.

The Black Thermometer units indicate the absorbed irradiance minus the heat dissipated by conduction and convection. Keep the black face of these thermometer units in good condition. Follow the manufacturer's recommendations for proper care and maintenance of Black Thermometers.

32.2.1 For Black Panel Thermometers: Testing temperature is measured and regulated by a Black Panel Thermometer unit mounted on the specimen rack to permit the face of it to receive the same exposure as the test specimen. Black Panel Thermometers shall consist of a metal panel at least 70 × 150 mm and not less than 45 × 100 mm whose temperature is measured with a thermometer or thermocouple whose sensitive portion is located in the center of and in good contact with the panel. The side of the panel facing the light source shall be black with a reflectance of less than 5% throughout the spectrum of light reaching the specimen; the side of the panel not facing the light source shall be open to the atmosphere within the exposure chamber.

32.2.2 For Black Standard Thermometers: Testing temperature is measured and regulated by a black standard thermometer unit mounted on the specimen rack to permit the face of it to receive the same exposure as the test specimen. The Black Standard Thermometer shall consist of a plane of stainless steel plate measuring 70 × 40 mm with a thickness of about 0.5 mm, whose temperature is measured by a thermal resistor, with good heat-conducting properties, fitted to the reverse side. The metal plate is fixed to a plastic plate so that it is thermally insulated. The side of the panel facing the light source shall be black with a reflectance of less than 5% throughout the spectrum of light reaching the specimen.

32.3 The Xenon Reference Fabric is a knit of 150 denier textured polyester yarn in a double pique stitch, dyed to a purple shade with 1.8% of 2,4-dinitro-6-bromo-2-amino-4—(N,N-diethylamino) azobenzene at 129°C (265°F) for 1 h and then heat set at 179°C (335°F) for 30 s (see 32.6).

32.4 More uniform and reproducible fading of the AATCC Blue Wool Lightfastness Standards, Xenon Reference Fabric, and test specimens is achieved when backed with white cardboard. The color difference values in the initial determination of the end point for both the Xenon Reference Fabric and the AATCC Blue Wool Lightfastness Standards were determined from exposures with such backing. Although tolerances are given for both the AATCC Blue Wool Lightfastness Standards and Xenon Reference Fabric, every effort should be made to achieve the midpoint value given for these standards. For referee purposes, the Xenon Reference Fabric and AATCC Blue Wool Lightfastness Standards will be exposed in multiples of three and the average color difference in the case of the Xenon Reference Fabric will be 20 CIELAB units and in the case of the AATCC Blue Wool Lightfastness Standards will be 1.7 CIELAB units.

32.5 Available from AATCC, P.O. Box 12215, Research Triangle Park NC 27709; tel: 919/549-8141; fax: 919/549-8933; e-mail: orders@aatcc.org.

32.6 The Xenon Reference Fabric Standard of Fade is used as a visual or instrumental reference for test chamber temperature verification. The measured instrumental color difference value will be shown on each standard of fade. The Xenon Reference Fabric is sensitive to temperature as shown in Table VIII.

32.7 Precut white card stock for backing test specimens is available from SDL Atlas

Table VI—ΔE

	Brown #1	Brown #2	Green	Blue
Sample 1	0.61	1.05	2.41	2.04
Sample 2	0.92	1.16	3.18	2.65
Sample 3	0.56	1.79	2.59	2.1
Average	0.697	1.333	2.727	2.263

Table VII—Within-Laboratory Standard Errors and Sample Variance

Sample Identification	Standard Dev.	Standard Error	Sample Variance	95% Confidence
Brown #1	0.195	0.1125956	0.0380333	0.4844603
Brown #2	0.399	0.2305308	0.1594333	0.9918946
Green	0.403	0.2325463	0.1622333	1.0005666
Blue	0.336	0.1941076	0.1130333	0.8351784

*Note: Because the interlaboratory test included less than five laboratories, estimates of standard error and sample variance may be either underestimated or overestimated to a considerable extent and should be used with special caution. The values should be viewed as minimal data with regards to precision. Confidence intervals are not well established.

Table VIII—Temperature vs. Color Change, Xenon Reference Fabric[a]

Black-Panel Temperature	ΔE (CIELAB)
58°C	16.0
63°C	20.0
68°C	23.8

[a] see Note 32.9.

L.L.C., 1813A Associate Lane, Charlotte NC 28217; tel: 704/329-0911; fax: 704/329-0914; e-mail: info@sdlatlas.com. Comparable white card stock (9016 White Bristol Index) is also available from stationery stores and dealers in artist's supplies.

32.8 Test masks made with white paper, 0.005-0.006 inches thick, with a dull black coating that provides zero light transmittance to the specimen are available from SDL Atlas L.L.C., 1813A Associate Lane, Charlotte NC 28217; tel: 704/329-0911; fax: 704/329-0914; e-mail: info@sdlatlas.com.

32.9 One or more of the test apparatus types and materials are available from: SDL Atlas L.L.C., 1813A Associate Lane, Charlotte NC 28217; tel: 704/329-0911; fax: 704/329-0914; e-mail: info@sdlatlas.com; and Suga Test Instrument Co., 4-14 Shinjuku, 5-Chome, Tokyo 160, Japan; tel: +81(3) 3354-5241; fax: +81(3) 3354-5275.

32.10 Available from William Harrison Co., 4595 E. 10th Ct., Hialeah FL 33013; tel: 305/681-8381.

32.11 Pile fabric, such as carpets, which have fibers that may shift position, or texture which may make evaluations in small areas difficult should be tested with an exposed area of not less than approximately 40.0 × 50.0 mm (1.6 × 2.0 in.). Expose sufficient size or multiple specimens to include all colors in the sample.

32.12 Sample frames must be made of stainless steel, aluminum, or suitably coated steel to avoid contaminating the specimens with metallic impurities that might catalyze or inhibit the degradation. When samples are fastened with staples, they should be of the nonferrous type overcoated to avoid contamination of the specimen by corrosion products. Metal frames must have a dull finish and be designed to avoid reflectances that could influence the performance of the material. Frames shall conform to the curvature of the specimen rack. The size of the frame is determined by the type specimens required for individual property requirements.

32.13 In Table C1, the data are for a typical spectral power distribution for an enclosed carbon-arc with a borosilicate glass globe. The daylight data are for global irradiance on a horizontal surface with an air mass of 1.2, column ozone 0.294 atm cm, 30% relative humidity, altitude 2100 m (atmospheric pressure of 787.8 mb), and an aerosol represented by an optical thickness of 0.081 at 300 nm and 0.62 at 400 nm. Data from 701-800 nm is not shown.

The following references provide background information on radiation measurements by Light Control Systems:

32.13.1 *Handbook of Chemistry & Physics*, 61st Edition, 1980, edited by Robert C. Weast; The Chemical Rubber Co., Cleveland OH.

32.13.2 International Commission on Illumination (CIE) Publication No. 20, 1972.

32.13.3 *Atlas Sun Spots*, Vol. 4, No 9, Spring 1975, Atlas Material Testing Technology LLC, Chicago, IL.

32.14 Window glass of the desired quality is available from such dealers as: Libby-Owens-Ford Glass Co., Toledo OH, 2.0 mm flat drawn sheet glass, single strength, quality B; or Pittsburg Plate Glass Co., Pennvernon sheet glass, single strength, quality B, or equivalent.

32.14.1 In order to reduce variability due to changes in UV transmission of glass, all new glass shall be exposed facing the equator, at the site latitude angle, or on an empty under glass exposure cabinet, for at least three months prior to installation in test cabinets.

32.14.2 After the three-month exposure period, it is recommended that the spectral transmittance of representative samples from each lot of glass be measured. Typically "single strength" glass will have a transmittance of 10-20% at 320 nm and at least 85% at wavelengths of 380 nm or higher after the three-month pre-aging procedure. If transmittance of the glass is measured, report the average for at least three pieces of the lot of glass being tested. Follow the instructions for measurement of transmittance of solid samples recommended by the manufacturer of the UV-visible spectrophotometer used. If a spectrophotometer with an integrating sphere is used, the measurements shall be performed in accordance with ASTM E 903, Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres. Additional information on this subject is contained in the following ASTM paper by W. D. Ketola and J. S. Robbins: "UV Transmission of Single Strength Window Glass," *Accelerated and Outdoor Durability Testing of Organic Materials, ASTM STP 1202*, Warren D. Ketola and Douglas Grossman, Eds., American Society for Testing and Materials, Philadelphia, 1993.

32.15 A difference in color between original material and the covered portion of the exposed specimen indicates that the textile has been affected by some agent other than light, such as heat or a reactive gas in the atmosphere. Although the exact cause of this difference in color may not be known, it should be noted in the report when it occurs.

32.16 In some cases high humidity, in combination with atmospheric contaminants, has been found to produce color changes as great as those produced by light. When requested, prepare a duplicate set of test specimens and standards mounted on cardboard, but not masked, and expose simultaneously in another cabinet of the same type used in the light exposures but with the glass covered with an opaque material so that the light is excluded. Since there is a combined effect of light, temperature, humidity and atmospheric contaminants, it cannot be assumed that a comparison between specimens exposed in the covered cabinet and in the uncovered cabinet under glass will permit separating the effects produced by light only. However, a comparison of the two sets of specimens with a piece of the original which has not been in an exposure cabinet will indicate whether a material is sensitive to moisture and atmospheric contaminants. This may also help to explain why different results may be obtained with the same amount of radiant energy in daylight exposures made at different times and in different locations.

32.17 The Eppley PS-P black and white pyranometer has been found suitable for measuring total daylight radiant energy, and the Eppley Broad Band-Pass Ultraviolet Radiometer has been found suitable for measuring the radiant energy from 295-385 nm of daylight. These instruments are available from Eppley Laboratory, 12 Sheffield Ave., Newport RI 02840; tel: 401/847-1020. The Atlas LM-3A narrow band-pass radiometer has been found suitable for measuring radiant energy at 340 or 420 nm of daylight and is available from SDL Atlas L.L.C., 1813A Associate Lane, Charlotte NC 28217; tel: 704/329-0911; fax: 704/329-0914; e-mail: info@sdlatlas.com. The Radialux broad bandpass radiometer has been found suitable for measuring radiant energy from 300-400 nm of daylight and is available from SDL Atlas L.L.C., 1813A Associate Lane, Charlotte NC 28217; tel: 704/329-0911; fax: 704/329-0914; e-mail: info@sdlatlas.com.

32.18 Interlaboratory Test Summary—Committee RA50 has conducted extensive studies to evaluate the use of radiation monitoring devices to terminate exposures in lightfastness testing. Data has been collected in interlaboratory studies using controlled irradiance, xenon-arc equipment and in daylight exposures conducted during a two-year period in both Arizona and Southern Florida. In both studies, one laboratory conducted instrumental measurement of the color change for all exposed specimens.

The interlaboratory studies were undertaken, using eight different lightfastness standard fabrics, to determine the definition of 20 AATCC Fading Units in terms of measured radiation. These studies showed that acceptable agreement between laboratories can be obtained for lightfastness testing providing the following variables are controlled: irradiance level, black-panel temperature, ambient temperature and relative humidity. Overall, there was less than 10% variability in the instrumentally determined color change of specimens exposed in different laboratories. For all specimens tested the standard deviation was equivalent to less than one-half step on the Gray Scale for Color Change. As a result of these tests, 20 AATCC Fading Units was established at 85 KJ/(m^2nm) when measured at 420 nm (approximately 21.5 continuous light–on operating hr) when tested at the conditions specified for Xenon-Arc Lamp, Continuous Light, Option 3

For the daylight studies, 16 different fabrics, in addition to AATCC and ISO Blue Wool Lightfastness standard fabrics, were exposed. An exposure series was begun each quarter year at two locations over a two-year period. Exposures were terminated based on instrumental measurement of radiant energy dosage. A wide variation in climatic conditions was encountered during the test period. The data obtained clearly shows that the color change of individual specimens is affected differently by variations in temperature, humidity, atmospheric contaminants, etc.; however, the single most significant variable is radiation. The variation in color change resulting from exposure during different years, locations, and seasons, averaged ± 30%.

A more detailed summary of these test results was presented to the 14th meeting of ISO, Technical Committee 38, Subcommittee 1 as Document 38/1 N 993, USA Report on Monitoring of Radiation during Lightfastness Testing.

32.19 Available from ASTM, 100 Barr Harbor Dr., West Conshohocken PA 19428; tel: 610/832-9500; fax: 610/832-9555.

32.20 Available from American National Standards Institute, Inc., 11 W. 42nd St., 13th Fl., New York NY 10036; tel: 212/642-4900; fax: 212/302-1286.

32.21 For measuring temperature and relative humidity of the air under the same conditions that the samples and reference materials are exposed and in the vicinity of test cabinets, any suitable indicating or recording instrument may be used. Continuous recording of temperature and relative humidity is preferred.

32.22 An automated electronic grading system may be used as long as the system has been demonstrated to provide results that are equal to and provide equal or better repeatability and reproducibility than an experienced grader performing visual evaluations.

Appendix A

A. Xenon-Arc Lamp Fading Apparatus

A1 Different types of xenon-arc test apparatus may be utilized provided that the test apparatus is capable of automatically controlling irradiance level, humidity level, chamber air temperature, and Black Panel or Black Standard Thermometer temperature.

A2 The design of the test chamber may vary, but it should be constructed from corrosion resistant material.

A3 Xenon-Arc Light Source. The xenon-arc test apparatus utilizes a long-arc quartz-jacketed xenon-arc lamp as the source of irradiance which emits radiation from below 270 nm in the ultraviolet through the visible spectrum and into the infrared.

While all of the xenon-arc lamps are of the same general type, different size lamps operated in different wattage ranges are employed in several sizes and types of apparatus. In each of the various models, the diameter and height of the specimen rack varies according to the lamp size and the wattage at which it is operated to provide an irradiance at the face of the specimen of 1.10 ± 0.03 W/(m^2nm) measured at 420 nm or equivalent when exposed in standard holders.

A3.1 Aging of the xenon burners or filters can result in changes in lamp spectrum. Changes in lamp spectrum may also be caused by accumulation of dirt or other residue in or on the burner envelope.

A3.2 Filter—In order for xenon-arcs to simulate terrestrial daylight, filters must be used to remove short wavelength UV radiation. In addition, filters to remove infrared radiation may be used to prevent unrealistic heating of test specimens that can cause thermal degradation not experienced during outdoor exposures. Filters to reduce irradiance at wavelengths shorter than 310 nm must be used to simulate daylight filtered through window glass.

The instrument manufacturers' recommendations should be used to provide the appropriate spectrum (see A3.4 below). Replace filters when chipped, cracked, or when discoloration or milkiness develops. Discard xenon lamp tubes and filters at the manufacturer's recommended time intervals or sooner, or when 20 AATCC Fading Units can no longer be attained in 20 ± 2 continuous light-on operating (clock) hours.

A3.3 Spectral Irradiance of Filtered Xenon-Arc—Figure A1 shows the desired relative spectral power distribution for filtered xenon-arcs comply with these limits. The acceptable limits for variation of the relative spectral power distribution shown in Fig. A1 are on file at the AATCC Technical Center.

A3.4 Follow the device manufacturer's instructions for recommended maintenance.

Appendix B

B. Daylight Exposure Cabinet and Location

B1 The daylight exposure cabinet shall consist of a glass-covered enclosure of any convenient size constructed of metal, wood or other satisfactory material to protect the specimens from rain and weather, and be well ventilated to allow

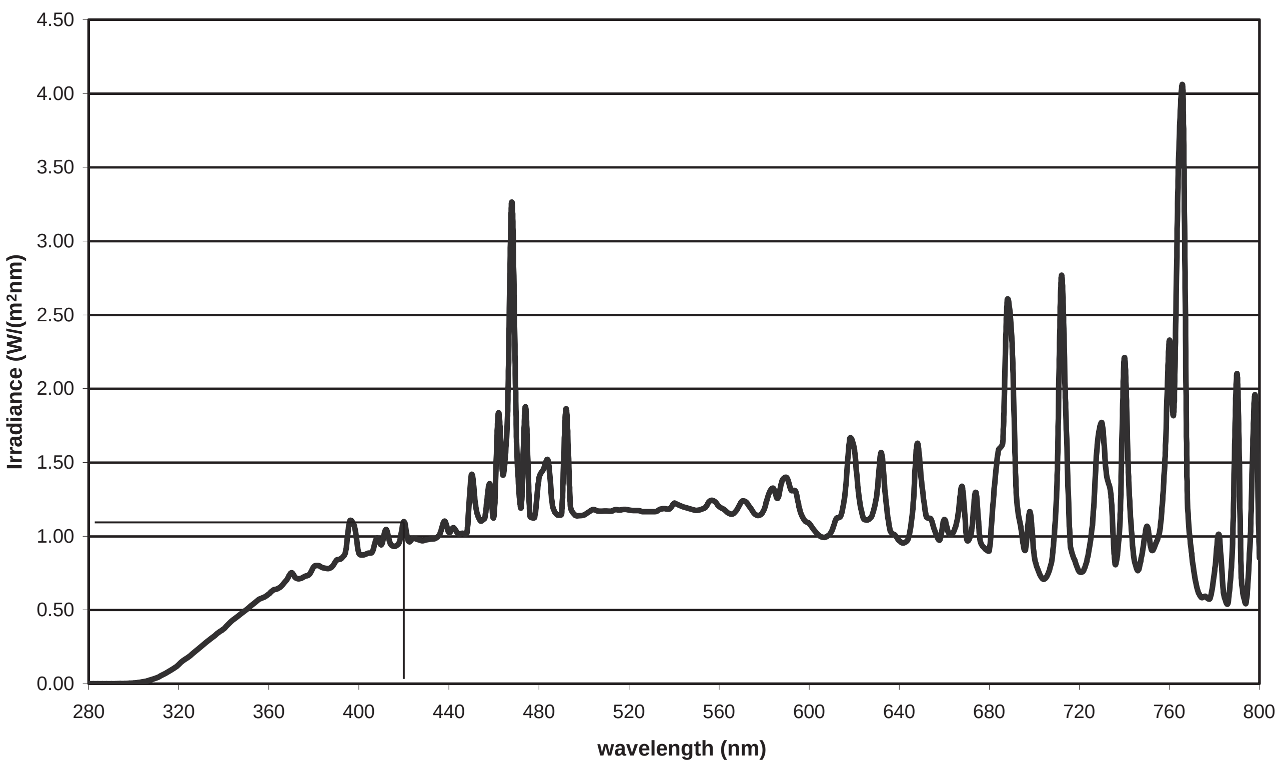

Fig. A1—Filtered Xenon Lamp Spectral Power Distribution Controlled at 1.1 W/(m^2nm) at 420 nm

free flow of air over the specimens. The glass cover shall be a sheet 2.0-2.5 mm thick piece of good grade, clear and flat-drawn. It shall be single strength, free of bubbles or other imperfections.

B2 The enclosure or cabinet shall be equipped with a rack which supports the specimens in a plane parallel to that of the glass cover with the face of the specimen at a distance below it of not less than 75.0 mm (3.0 in.). The specimen mounting rack shall be constructed of a material that is compatible with the test specimens. It may be either the open type providing good ventilation on the back side of the specimen, or of a solid material as required. To minimize shadows from the top and the sides of the cabinet, the usable exposure area under glass shall be limited to that of the glass cover reduced by twice the distance from the cover to the specimens.

B3 The cabinet shall be located where it will receive direct daylight throughout the day and where shadows of objects in the vicinity will not fall upon it. When the cabinet is installed over soil, the distance between the bottom of the cabinet and the plane of the cleared area shall be great enough to prevent any undesirable effects of contact with grass or other plant growth during the period of exposure.

B4 The glass cover and the test specimen shall slope toward the equator at an angle from the horizontal equal in degrees to approximately the latitude of the location at which the tests are being made. Other angles of exposure, such as 45° may be used, but the angle must be reported in the results of test.

B5 Exposure cabinets shall be located in cleared areas, preferably at a suitable number of climatologically different sites representing the various conditions under which the material will be used. Major climatological variations include subtropical, desert, seashore (salt air), industrial atmosphere and areas exhibiting a wide range in percentage of available sunshine. The area beneath and in the vicinity of the cabinets should be characterized by low reflectance and be typical of the ground cover in that climatological area. In desert areas, it should be gravel whereas in most temperature and subtropical areas, it should be low cut grass. The type of ground cover should be indicated in the report.

B6 Instruments for determining climatological data during the exposure period shall be operated in the immediate area of the exposure cabinets. When requested, data obtained shall be reported as part of the results of the test. To characterize the conditions around the test frame, these instruments should be capable of recording: ambient temperature (daily minimum and maximum), relative humidity (daily minimum and maximum), hours of precipitation (rain), and total hours of wetness (rain and dew). To characterize the conditions within the test frame, these instruments should be capable of recording: ambient temperature under glass (daily minimum and maximum), black temperature sensor under glass, total radiant energy and ultraviolet radiant energy (either broad or narrow bandpass) at the same angle of exposure as the test specimens, and relative humidity (daily minimum and maximum) (see 32.17 and 32.21).

Appendix C

C. Enclosed Carbon-Arc Lamp Fading Apparatus

C1. Different types of carbon-arc test apparatus may be utilized. The design of the test chamber may vary, but it should be constructed from corrosion resistant material, and in addition to the radiant source, may provide for means of controlling temperature and relative humidity.

C1.1 Laboratory Light Source—Enclosed carbon-arc light sources typically use carbon rods which contain a mixture of metal salts. An electric current is passed between the carbon rods which burn and give off ultraviolet, visible and infrared radiation. Use carbon rods recommended by the device manufacturer.

C1.2 Filter—The most commonly used filters are borosilicate glass globes which fit around the carbon burners.

C1.3 The emission spectra of the enclosed carbon-arc shows strong emission in the long wavelength ultraviolet region. Emissions in the visible, infrared and short wavelength ultraviolet below 350 nm are generally weaker than in daylight behind window glass (see Table C1). The enclosed carbon-arc does not provide a good match to natural daylight.

C1.3.1 Spectral Irradiance for Enclosed Carbon-Arc with Borosilicate Filters—Table C1 is representative of the spectral irradiance received by a test specimen mounted in the specimen plane.

C1.4 See 32.13 for additional information.

C1.5 Thermometer—A Black Panel or Black Standard Thermometer may be used and shall conform to the descriptions found in 32.2.1 and 32.2.2. The type of thermometer used, the method of mounting on specimen holder, and the exposure temperature shall be stated in the test report.

C1.6 Relative Humidity—The test chamber may be equipped with a means to measure and control the relative humidity. Such instruments shall be shielded from the light source.

C1.7 Apparatus Maintenance—The test apparatus requires periodic maintenance to maintain uniform exposure conditions. Perform required maintenance in accordance with manufacturer's instructions.

Table C1—Typical Spectral Power Distribution for Enclosed Carbon-Arc with Borosilicate Filters. Ultraviolet Wavelength Region Irradiance as a Percentage of Total Irradiance from 300-400 nm

Bandpass (nm)	Enclosed Carbon-Arc with Borosilicate Filters	Sunlight
290-320	0%	5.6%
320-360	20.5%	40.2%
360-400	79.5%	54.2%