Atlas Standards Guide 106

Textiles - Xenon-Arc Weathering and Color Fastness to Light

Summary of Testing Standards

Atlas Material Testing Technology

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Introduction

For most textile applications, such as apparel, sportswear, and garments, color fastness is the most critical material characteristic. Since the 1960s, xenon-arc technology is almost exclusively used in the textile industry for evaluating the color fastness of textiles to light. There are many test methods and standards which describe how to expose textile specimen to xenon-arc radiation. Often these methods have the same purpose: to test the color fastness to light. However, small but critical differences between the different methods exist, which makes it often difficult and complicated for the user to select the right test conditions. This standard guide should therefore help to select the appropriate test conditions for the most important xenon-arc based test methods for light and weather fastness testing of textiles.[1]

In textile testing, the term color fastness to light (often abbreviated as light fastness) is typically related to indoor applications. Apparel, carpets, and other fabrics are in their use environment typically exposed to solar radiation only behind window glass or to even less critical artificial light sources. For light fastness testing xenon-arc instrument must be equipped with optical window glass filters. The term weather fastness on the other hand is relevant for the outdoor application of textiles. Here the materials are exposed to natural solar radiation (Daylight) and to rain and dew. For weathering testing, xenon-arc instruments are equipped with optical daylight filters and typically provide water spray to wet the test specimen periodically.

After the exposure, test specimens are evaluated for their color change by visual inspection or with a colorimeter. The results are often compared to a set of blue wool reference materials to assign lightfastness ratings. For technical applications, such as geotextiles, ropes, seat belts, where the color change is less relevant, often the mechanical properties such as the tensile strength are critical and need to be evaluated.

Xenon-Arc Weathering and Light Fastness Instruments

There are two standard xenon-arc instrument types (**Figure 1**):

1. Xenon-arc rotating rack
2. Xenon-arc flatbed

For many years, rotating rack type instruments have been the only allowed instrument type in most test standards, because of better exposure uniformity and higher test capacity. Flatbed devices use a more basic setup but provide less homogeneous test conditions. Therefore, flatbed devices require repositioning during each test to minimize the effect of variability of irradiance, temperature, and moisture exposure at the static horizontal test area.

For reliable and reproduceable lightfastness testing, xenon-arc devices must control the main test parameters:

- Irradiance (E)
- Black Standard Temperature (BST) or Black Panel Temperature (BPT)
- Chamber air temperature (CAT)
- Relative humidity (RH)

Some textile test methods require light and dark phases. For weathering testing additionally wet and dry phases are required. In most Xenon-arc devices wetting is achieved by water spray.

Figure 1 (left to right): *Xenon-arc rotating rack Ci3000 Fade-Ometer®, Ci4400 Weather-Ometer®, Xenotest® 220, and xenon-arc flatbed Atlas SUNTEST® XXL+.*

Optical Filters

Xenon arc weathering instruments require optical filter systems to adjust the radiation to either outdoor sunlight, so called daylight filters, or indoor environments, so called window glass filters (**Figure 2**). Most lightfastness test methods use window glass filters. However, the requirements for window glass filtered Xenon-arc radiation can vary between standards. ISO 105-B02 defines the color temperature of window glass filtered xenon-arc radiation to be within 5500 - 6500 K. It further requires the transmission of the filter system shall be at least 90 % between 380 nm and 750 nm and falls to zero between 310 nm and 320 nm.

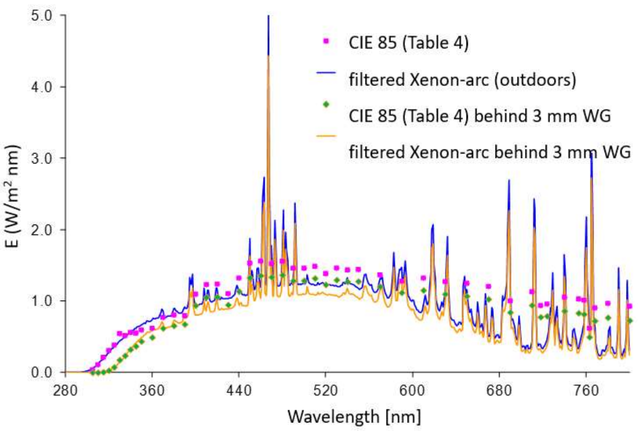

Figure 2: *Comparison CIE85 outdoor and indoor reference sun and Atlas Daylight and Window Glass filtered xenon-arc*

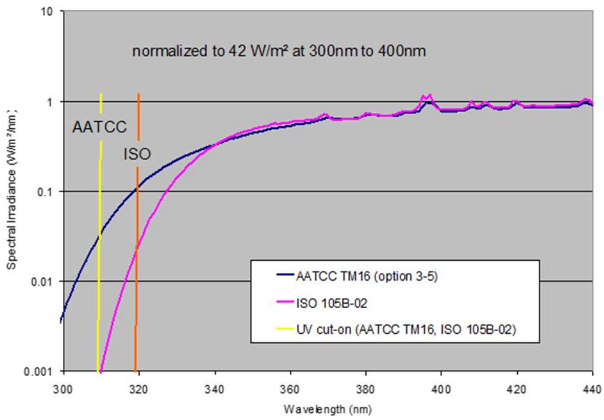

Figure 3: *Window glass filters according to ISO 105-B02 (ISO WG) and AATCC TM 16.3 (AATCC WG).*

On the other hand, AATCC TM16.3 requires window glass filters that reduce irradiance at wavelengths shorter than 310 nm – basically allowing a more aggressive spectral irradiance. Same is true for weathering testing where the definition of daylight filtered radiation can also differ from standard to standard.[2] These differences seem to be small but can have significant effects on the test result and the test duration (**Figure 3**). It is important to use the appropriate filter system for each test method.

Cover Masks

For most lightfastness test methods, it is required to cover parts of the textile specimen to allow direct comparison between the exposed and the covered area after the test. Depending on test method and evaluation procedure different cover masks are required. [3,4,5] Some procedures require masks to be exchanged after intermediate evaluations.

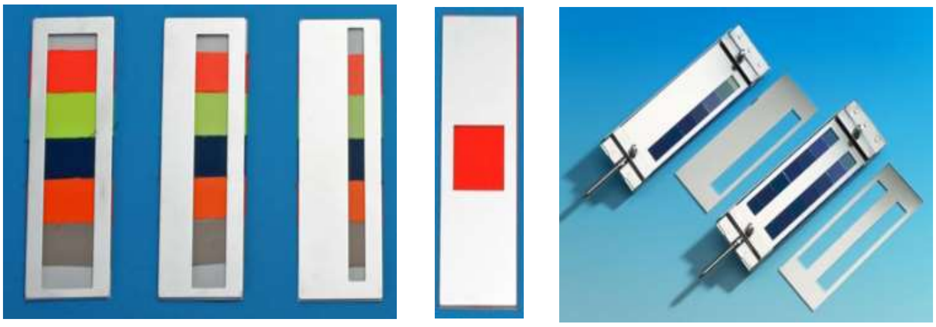

Figure 4 (left to right): *ISO 105-B02 Exposure Method 2 cover masks, AATCC cover mask, ISO 105-B02 Exposure Method 3 (Marks & Spencer) cover masks.*

Blue Wool Reference Materials and Grey Scale

Reference Materials for ISO 105-B02 and their aligned test methods are the ISO Blue Wool Scale #1 to #8. Blue Wool #1 shows the lowest color fastness and #8 the highest. The entire blue wool scale is structured in such a way that each Blue Wool is about twice as lightfast as its previous number.[3] The American test method AATCC TM16.3 use another Blue Wool scale: the AATCC scale L2-L9.[4] Everything worse than Blue Wool **L2** gets a lightfastness rating **L1**.

Note: Only the AATCC L2 blue wool is currently available (at release of this document).

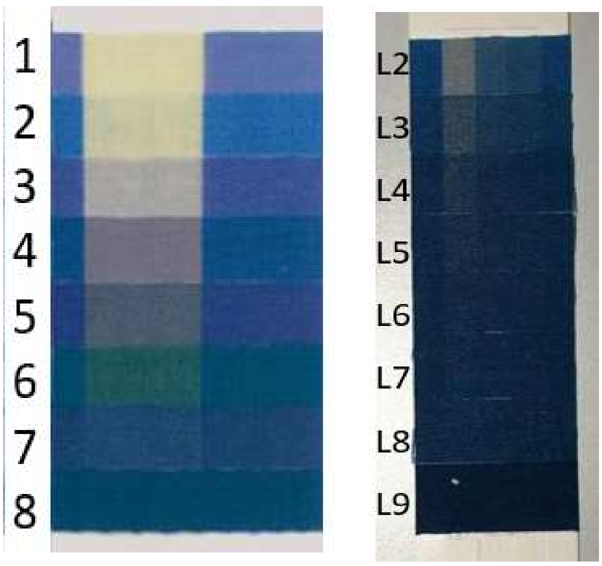

Figure 5: *ISO (left) and AATCC (right). Blue Wool scales faded/unfaded.*

The Grey Scale is used to visually assess color change.[6,7] The Grey Scale has nine levels, each existing of pairs of grey fields with a contrast according to grades 5 (no contrast), 4, 3, 2 to 1 (strong contrast) with intermediate ratings (1/2, 2/3, 3/4 and 4/5). The Grey Scale of a textile corresponds to the grade which is closest to the contrast between the original unfaded and the faded part of the sample. The lightfastness rating corresponds to the number of the blue wool with the same grey scale rating as the evaluated textile sample. For example, if after the exposure the textile sample has a GS 4 rating and BW #7 has a GS 4 rating, the light fastness rating of that textile would be LF 7.

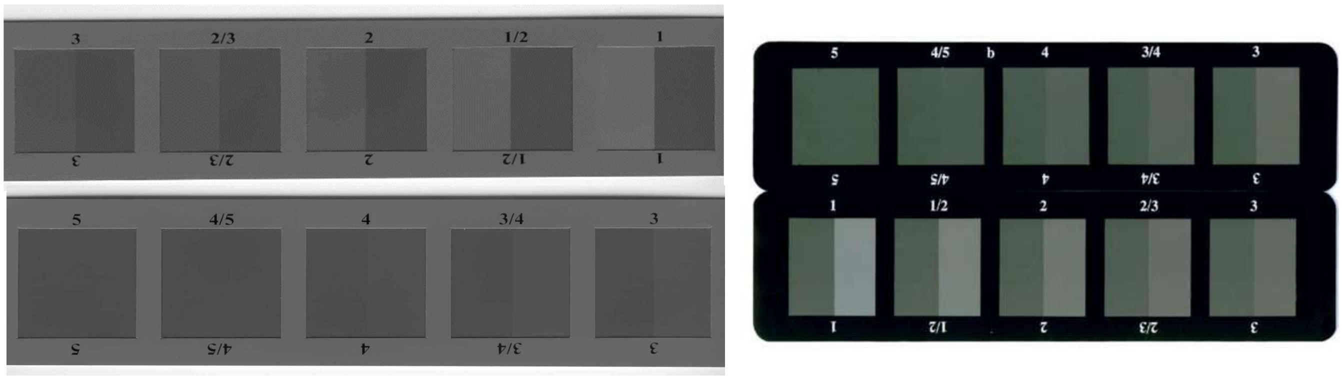

Figure 6: *ISO (left) and AATCC (right). Grey Scale for visual evaluation of color change.*

<u>Note</u>: The grey shades of the ISO and the AATCC grey scale are identical. The ISO grey scale uses a grey backing, while the AATCC grey scale uses a black backing.

Textile Testing Guidelines by Application

a) Color Fastness to Light – Apparel and Home Textiles

- ISO 105-B02
- AATCC TM16-3

As a general guideline for color fastness testing against light, there is the international standard ISO 105-B02 Textiles - Tests for colour fastness - Part B02: Colour fastness to artificial light: Xenon arc fading lamp test. ISO 105-B02 uses window glass filtered Xenon-arc radiation (ISO WG). This standard was originally developed in 1988 and revised several times – last time 2014. It served as a template for other light fastness standards such as the historic Indian standard IS 2454, or the current Chinese GB/T 8427. [8,9] Furthermore, ISO 105-B02 is also often used to test leather, paper, and printing inks.

ISO 105-B02 describes:

- ISO Blue Wool reference materials (#1 to 8)
- Xenon-arc apparatus requirements, control, and calibration
- Spectral irradiance (ISO-WG)
- Preparation of the test specimens
- Cycles A1 (normal), A2 (extreme low RH), A3 (extreme high RH), B (American conditions)
- Procedure
- Exposure Methods 1-5
- Evaluation (Assessment of color fastness)
- Irradiance uniformity requirements in the test area
- Test report

Exposure duration for most light fastness test methods is typically based on the fading behavior of the Blue Wool scale. For example, a test ends when the fading of Blue Wool #4 has reached Grey Scale 4. Or more demanding, an approximately 8x longer test: a test ends when Blue Wool #7 shows Grey Scale 4. Most company specifications for apparel require test durations between Blue Wool #3 and Blue Wool #6 reaching Grey Scale 4.

Note: There are testing philosophies avoiding the use of Blue Wool for test duration and simply base it on a defined test time or radiant exposure.

AATCC TM16.3 has the same purpose as ISO 105-B02 but uses different test parameters and a different test setup, including a different Window Glass filter specification (AATCC WG). AATCC TM16.3 further uses so called *AATCC fading units* (AFUs). Five AFUs are the radiant exposure required to produce a color change equal to Step 4 of the Grey Scale on the L2 Blue Wool Reference. This equals to a radiant exposure of about 21 kJ/m^2 nm at 420 nm or 864 kJ/m^2 total UV from 300 nm to 400 nm. AATCC TM16.3 has three test options, while mostly Option 3 is used in the industry. Textile company specifications refer to ISO 105-B02 or AATCC TM16.3 but typically limit the type of instruments to be used or set specific minimum requirements for specimen fading.

A special type of light fastness testing is perspiration light fastness testing. Here, test specimens are typically soaked in artificial sweat solution prior to exposure. General test procedures are described in ISO 105-B05 and AATCC TM125. The exposure itself follows the light fastness test procedures mentioned above. Perspiration light fastness testing is typically performed for sports apparel.

Test Method	Filter Type	Irradiance (W/m^2)		Surface Temperature (°C)		Chamber Air Temperature (°C)	Relative Humidity (%)
		Broad band (300-400 nm)	Narrow band (at 420 nm)	BST	BPT		
ISO 105-B02 (A1)	ISO-WG	42 (preferred)	1.10	47 (preferred)	45	32	40
ISO 105-B02 (A2)	ISO-WG	42 (preferred)	1.10	62 (preferred)	60	35	15
ISO 105-B02 (A3)	ISO-WG	42 (preferred)	1.10	42 (preferred)	40	-	85
ISO 105-B02 (B)	ISO-WG	42 (preferred)	1.10	65 (preferred)	63	-	30
AATCC TM16-3 (Option 2)	AATCC-WG	65	1.25 (preferred)	60	-	32	30
AATCC TM16-3 (Option 3)	AATCC-WG	48	1.1 (preferred)	-	63	43	30
IS 2454	ISO-WG	42		-	42	-	40
GB/T 8427	ISO-WG	42	-	47	-	32	40

***Table 1**: Light fastness testing.*

b) Weather Fastness – Technical Textiles, Geotextiles, Rope, Functional Wear

- ISO 105-B04 (Functional Apparel)
- ISO 105-B10 (Technical, Functional, Rope)
- AATCC TM169 (General)
- ASTM D4355 (Geotextiles)

All above listed weather fastness test methods use optical Daylight filters to adjust the spectrum to outdoor solar radiation. Most weathering or weather fastness test cycles also use water spray to wet the specimen to simulate the effect of rain and dew. One of the oldest international standards on weathering testing of textiles is ISO 105-B04.[10] ISO 105-B04 originates from textile and apparel testing, suitable for functional wear and similar applications, whenever the textile is not permanently exposed to an outdoor environment. Better suitable for technical textiles which are permanently used outdoors is ISO 105-B10.[11] The basic cycle of ISO 105-B10 is harmonized with weathering test methods for coatings and plastics such as ISO 4892-2 and ISO 16474-2. This basic cycle uses a higher irradiance and a longer wet time compared to ISO 105-B04, providing a harsher test scenario. ISO 105-B10 also describes additional test cycles for more extreme semi-tropical, and semi-arid climates. AATCC TM169 is using the same temperature and water conditions as ISO 105-B10. However, applies a much lower irradiance level.[12] ASTM D4355 is dedicated to geotextiles.[13] It specifically covers the matter of decreasing tensile strength of geotextiles under weather stress of radiation, water, and heat.

Test Method	Filter Type	Irradiance (W/m²)		Surface Temperature (°C)		Chamber Air Temperature (°C)	Relative Humidity (%)	Dry/Wet (min)
		Broad band (300 - 400 nm)	Narrow band (at 340 nm)	BST	BPT			
ISO 105-B04	Daylight	42 (preferred)	1.10	57 (preferred)	45	37	40	29/1
ISO 105-B10 (A) normal	Daylight	60 (preferred)	1.10	65 (preferred)	63	38	50	102/18
ISO 105-B10 (B) no rain	Daylight	60 (preferred)	1.10	65 (preferred)	63	38	50	-
ISO 105-B10 © semi-tropical	Daylight	60 (preferred)	1.10	82 (preferred)	77	47	65	90/30
ISO 105-B10 (D) semi-arid	Daylight	65	1.25 (preferred)	82 (preferred)	77	47	27	-
AATCC TM169 (Normal)	Daylight	40	0.35 (preferred)	-	63	38	50	102/18
ASTM D4355	Daylight	-	0.35 (preferred)	-	65	44	50	90/30

***Table 2**: Weather fastness testing.*

c) Hot Light Fastness – Automotive Interior Textiles

- ISO 105-B06
- SAE J2412
- Automotive OEM specifications

Hot light fastness testing (light fastness testing at high temperatures) has started in the 1980's and was standardized in 1988 as DIN 75202. It has always been a very intensive test method but proven useful for automotive interior textiles, textile laminates, leather, and polymers. Today, international hot light fastness methods are summarized in ISO 105-B06. ISO 105-B06 has five different test conditions, representing global markets and OEM requirements. [14,15] The most important are exposure conditions 3 (based on DIN 75202) and conditions 5 (based on SAE J2412, see below). A test cycle according to conditions 3 is typically based on the time (or radiant exposure) it takes to fade ISO blue wool #6 to a grey scale rating of 3 (or a color change Delta E of 4.3). Typically, two to five cycles are required depending on the requirements of the OEM and the location of the material in the car.

Note: One test cycle typically corresponds to a radiant exposure of H (at 420 nm) = (250 to 300) kJ/(m²·nm) or H (300 nm – 400 nm) = (11 to 13.2) MJ/m², or to a test duration of 60 to 70 hours.

Especially American automotive OEM and their suppliers use another method described in SAE J2412.[16] SAE J2412 (replacement of the withdrawn standard SAE J1881) utilizes extended UV filters instead of Window Glass filters. Extended UV filters allow for shorter wavelength UV than natural sunlight behind window glass and were chosen supporting the thought that shorter wavelength UV would promote further acceleration to save test time.

Note: Short wavelength radiation increases the risk of unrealistic test results.[17,18]

SAE J2412 describes a cyclic exposure with 3.8 hours irradiation, followed by a dark phase of 1.0 hour. As reference material SAE polystyrene chips are available to control the instrument performance.

Test Method	Filter Type	Irradiance (W/m²)		Surface Temperature (°C)		Chamber Air Temperature (°C)	Relative Humidity (%)	Light/Dark (h)
		Broad band (300 - 400 nm)	Narrow band (340 nm / 420 nm)	BST	BPT			
ISO 105-B06 Conditions 3	WG	60	1.10 (at 420 nm)	100	-	65	30	continuous
SAE J2412	Extended UV	-	Light: 0.55 (at 340 nm) Dark: 0	-	Light: 89 (preferred) Dark: 38 (preferred)	Light: 62 Dark: 38	Light: 50 Dark: 95	3.8 1.0

***Table 3**: Hot light fastness testing (automotive interior).*

Summary

The variety of light fastness test methods of textiles is obviously big and can be confusing. Sometimes test methods differ just in one single parameter. Those small differences however may cause different test results. It is therefore important to follow the exact test procedure in accordance with the specific standard.

A major reason for the different test conditions is the attempt to cover different end-use environments. For example, technical textiles, rope, or functional clothing may be tested according to ISO 105-B10 method "C". This test provides a good simulation of a hot and humid end-use environment, such as South Florida. Automotive interior materials, on the other hand, need to be tested to the harsh conditions inside a car according to a hot light fastness test method. Further, there are differences simply exist because of historic reasons.

ISO 105-B02 and AATCC TM16.3 have a similar scope, but a different technical background. Today most weathering instruments are capable to run both methods, but the differences in the test parameters still exist. The exposure durations depend on the specific requirements of the test, the application, and the desired quality. Exposure times can range from 24-48 hours to several thousand hours. For light fastness tests, samples are typically evaluated for color change and fading using a colorimeter or the human eye. For weathering testing of geotextiles, ropes, or for hot light fastness testing of safety belts the focus is often on the physical strength.

Overall, the xenon-arc light fastness and weathering tests are proven tools for assessing the durability of textile dyes and products under outdoor and indoor conditions – one critical element for ensuring expected longevity and quality of textile products.

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